ACTA UNIVERSITATIS CAROLINAE
KINANTHROPOLOGICA Vol. 47, 1 – 2011 Pag. 139–147

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A CASE STUDY OF THE SIMILARITY OF KICK-BIKING AND RUNNING IN TERMS OF KINESIOLOGY

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SUMMARY

Kick-biking and running at above average intensity were examined in terms of muscle activation. Surface electromyography was used to evaluate the timing of muscle activity. The electric potentials of seven lower limb muscles were detected by unique KaZe05 mobile apparatus during both activities. Cross-correlation analysis was introduced to compute the similarity in muscle behavior as well as the timing of muscle activation.

Similar mechanisms in terms of timing and motor control were identified for lower limb extensors. The kick-bike seems to be efficient tool in teaching partial running skills.

Key words: electromyography, kinesiology, time-series, cross-correlation, pre-activation, co-contraction

INTRODUCTION

Running technique is the object of research in many recent studies (Hottenrott, Neumann, 2002; Wessinhage, 1996). In contrast the technique of kick-biking is a rare topic in articles (Žďárek, 2005). The kinematic analysis of kick-bike running showed similarities in certain stages of the movement cycle. The residual (or follow-through) phase can be identified immediately after take-off termination. The residual phase is ended at the instant of zero rotation in the hip joint of the recently support limb. The main purpose of remaining in the residual phase is the advantageous position of body leading to minimizing air resistance.

The transition phase's main goal in sprinting is to reach maximum knee-lift on front of the runner's body in the shortest possible time. Similarly, the purpose of the transition in kick bike running is to enable maximum knee lift in the shortest time (in the case of sprinting) or minimize energy cost (in moderate pace riding), which means giving muscles enough time to relax. Second approach is usually applied by the pendulum-like limb forward swing, while the first is more similar to the sprinter swing movement. Two sub-phases are identified in the pendulum-like swing transition of the standing limb: downward und upward. The standing leg also helps the whole body rise, during the final stage of transition.

The ground preparation phase begins with a negative hip joint acceleration in front of the body. The leg leads downward and backward with the heel striking the ground. The standing leg is bent at its joint to achieve lower centre of mass position in order to lengthen the following support phase. Recent studies of running (Lowering et al., 2005; Seyfarth, 2001; Seyfarth et al., 2002) found the pre-activation of the main extensors of lower limbs in sprinting or jumping movements. Our hypothesis expects similar pre-activation of the same muscles before first ground contact in kick-biking. Secondary co-contraction of antagonists in both activities are expected according to the study of Jinha et al. (2006) in the ground preparation phase.

The ground contact (support) phase is usually divided into braking and propulsion phases. While longer air resistance force application kick-biker needs to produce a sufficiently high amount of forward momentum to avoid slowing down. This is the reason for the touch-down being adjusted not much in front of the vertical projection of center of mass, in order to minimize braking and maximize propulsion forces. A similar principle is presented in acceleration running (Kugler, Janshen, 2010; Hunter et al., 2005).

PROCEDURES

A male participant (1.79 m height, 69 kg weight) was measured and video-taped during running at 70% intensity while running and kick-biking. The participant was an experienced athlete with running and kick-biking, performing both activities at least twice a week, so his performance was visually stable.

The surface electromyography method (EMG) was used, in order to evaluate the similarity in muscle activation timing in running and kick-biking. A unique 8-channel apparatus KaZe05 was used for measurement of electric potentials of seven muscles. The 8th channel was used for coordination with a digital camera (CANON HDV 1080i) with sample rate of 50 frames per second. Muscle activation was detected in the following muscles: m. tibialis anterior (TA), m. soleus (SOL), m gastrocnemius med. (GAM), m. rectus femoris (RF), m. gluteus maximus (GLM), vastus medialis (VM) a m. biceps femoris long head (BF). Ag-electrodes of a circular shape (5 mm diameter) were placed on muscle bellies. Muscles were palpated by a physiotherapist and each electrode location was marked before placement. Skin was shaved-off, old skin was removed with abrasive paper. Skin on the muscle belly was cleaned with ethanol and finally a conductive gel was applied before electrode placement. The inter-electrode distance was 2 cm between centers of circles. Electrodes were connected to the apparatus with cables. Cables were taped to the skin in order to avoid electrode displacement. The apparatus was placed in a belted bag, which was fixed to the athlete's body with low-back belt. Signal from the muscles was filtered (high-pass filter 20 Hz and low-pass filter 1000 Hz), full-wave rectified and enveloped with time constant of 25 ms. The processed analog signal was digitized by an 8-bit A/D converter at the frequency of 200 Hz and was stored on a hard disc in the apparatus. Every single measurement was checked and the amplifier's setting was changed to maximize the range of scaling used. The weight of the machine was 1.4 kg with the belt-bag.

A script made in the Matlab R14 editor was used to evaluate the multi-channel signal. A cross-correlation function was introduced and defined by the formula:

$$r_k = \frac{\sum_{t=1}^{N}(x_t - \bar{x})(x_{t+k} - \bar{y})}{\sigma_x \sigma_{y+k}}$$

Where is the correlation of two signals *x(t)* and *y(t)* delayed by *k* samples. In contrast with traditionally defined cross-correlation, our formula does not tend to zero values with increasing value of shifted samples *k* close to the sequence length *N*. Time-shift of pair muscle activation is defined as time of the local maximum of cross-correlation function, which is closest to the zero sample shift. The period of movement was computed from seven auto-correlation functions of signals as a median of their first local maximum appearance in a positive time-shift. Phase-shift of pair of muscle's activity was computed as a ratio of time-shift to period of movement:

$$\varphi(x,y) = \frac{t_x(x,y)}{T}$$

wheredenotes the phaseshift of the electric activity of muscles x and y, T denotes the period of movement and ts is the expression for time shift of muscle activation computed from cross-correlation function.

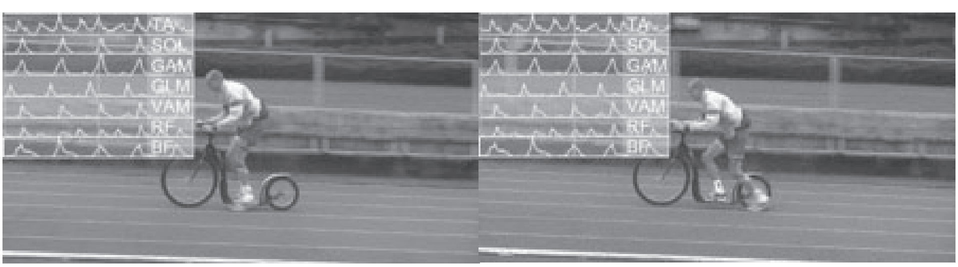
The software Dartfish allowed us to visualize the results of our study. A Dartfish CSV Reader was used to link data from the EMG with video.

RESULTS

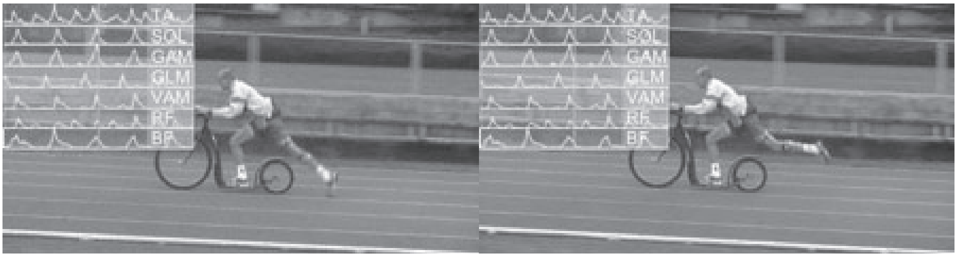
The muscle activity of examined actuators is shown in Figures 1 (kick-biking) and 2 (running) during various phases of the movement cycle.

Figure 1. The muscle activation during various phases of a movement cycle in the kick-biking

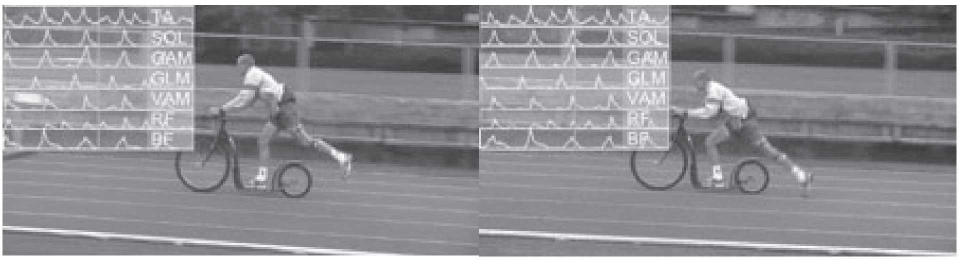
1A. The highest knee position of take-off leg (left); the ground preparation phase (right) leading to the active heel strike against the ground.



1B. The instant of touch-down (left) performed very close below the centre of mass; the take-off phase in progression (right)

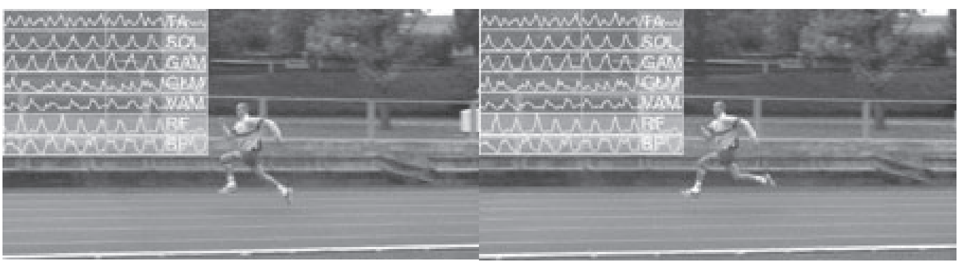


1C. Take-off termination (left); follow-through termination (right)

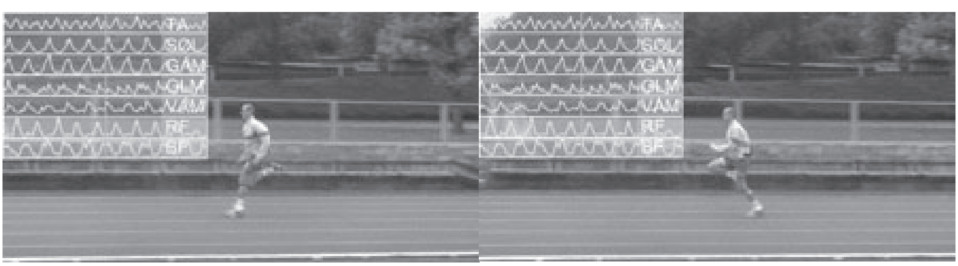


1D. Front swing downward phase beginning (left); front swing in progression – instant of the upward phase beginning (right)

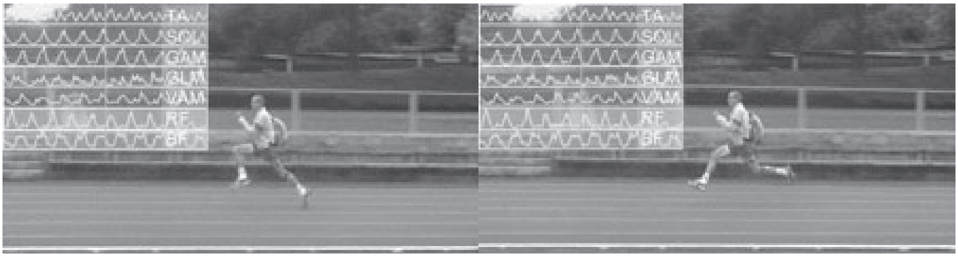
Figure 2. The muscle activation of seven actuators in various stages of working cycle in running



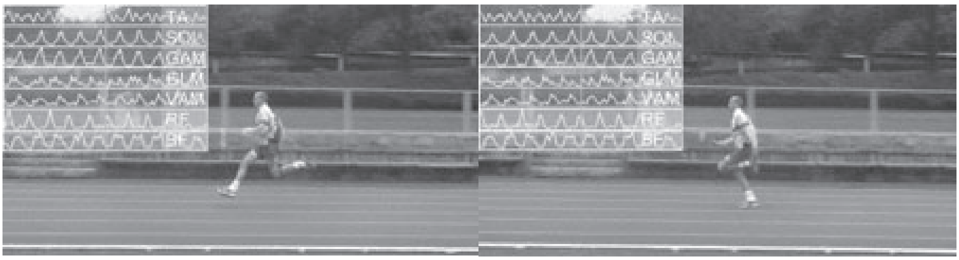
2A. The highest knee position – transition phase termination (left); active heel strike against the ground in progression – the ground preparation phase



2B. The instant of touch-down (left), the propulsion phase in progression (right)



2C. The propulsion phase termination (left); the residual phase termination (right)



2D. The transition phase – swing heel to buttock distance lowered (left); transition phase in progression – beginning of active upswing of knee (right)

The degree of muscle activation similarity is expressed in Table 1A (kick-bike) and 1B (running). The maximum values of cross-correlation function are displayed for each pair of muscles on time interval ± 1 period. Only values in the upper triangle of the matrix are displayed, due to matrix symmetry. High values (more than 0.7) show a similar function in the muscle. Lower values are corresponding to one-peak, to two-peak activity during movement cycle (according to studies of Hojka et al., 2010; Mehta et al., 2009).

Tab. 1.a. Maximum cross-correlation – kick-bike

	1 TA	**2 SOL**	**3 GAM**	**4 GLM**	**5 VAM**	**6 RF**	**7 BF**
1 TA	1.00	0.67	0.72	0.73	0.69	0.74	0.46
2 SOL		1.00	0.94	0.78	0.91	0.96	0.76
3 GAM			1.00	0.79	0.92	0.95	0.84
4 GLM				1.00	0.64	0.65	0.55
5 VAM					1.00	0.94	0.70
6 RF						1.00	0.76
7 BF							1.00

Tab. 1.b. Maximum cross-correlation – running

	1 TA	2 SOL	3 GAM	4 GLM	5 VAM	6 RF	7 BF
1 TA	1.00	0.61	0.65	0.60	0.67	0.82	0.52
2 SOL		1.00	0.97	0.95	0.93	0.69	0.95
3 GAM			1.00	0.91	0.88	0.67	0.95
4 GLM				1.00	0.88	0.71	0.92
5 VAM					1.00	0.71	0.90
6 RF						1.00	0.56
7 BF							1.00

Maximum cross-correlation values alone do not describe precisely the character of muscle co-operation controlled by the central nervous system. Time-shift or phase-shift values need to be introduced for muscle timing evaluation. Relative timing of muscle activation at a percentage of the movement cycle is displayed in tables 2A (kick-bike) and 2B (running). Values at every slope display what percentage of the stride is delayed activation of the muscle behind the muscle in the corresponding row.

Tab. 2.a. Relative timing of muscle activation – kick-bike

	1 TA	2 SOL	3 GAM	4 GLM	5 VAM	6 RF	7 BF
1 TA	0%	8%	7%	– 22%	10%	– 48%	7%
2 SOL		0%	– 4%	– 30%	0%	3%	– 2%
3 GAM			0%	– 29%	3%	4%	– 3%
4 GLM				0%	31%	34%	23%
5 VAM					0%	2%	– 8%
6 RF						0%	– 48%
7 BF							0%

Tab. 2.b. Relative timing of muscle activation – running

	1 TA	2 SOL	3 GAM	4 GLM	5 VAM	6 RF	7 BF
1 TA	0%	–39%	–43%	21%	–34%	10%	–36%
2 SOL		0%	–5%	–35%	–3%	41%	–17%
3 GAM			0%	–28%	5%	–50%	–5%
4 GLM				0%	42%	–16%	11%
5 VAM					0%	42%	–15%
6 RF						0%	48%
7 BF							0%

Both activities show double TA muscle activation during a movement cycle: the first during recovery from the residual phase, where the swing heel is approaching the buttock; second during the ground preparation phase, when the toe of the foot is lifted and held in a static position against the shank. Three muscles (SOL, GAM and VAM) are activated almost simultaneously, even before the instant of touch-down. A different role of RF is presented in both: tables and figures. RF was activated during the transition phase in running, but while kick-biking it was also active during take-off, so it showed a double activation similar to TA.

Specific cooperation of BF and GLM shows differences during both activities. GLM was active during the braking upswing and the beginning ground preparation phase, while riding kick-bike. BF behaved as a helping take-off muscle. GLM and BF showed a more similar performance in the case of running. Both muscles are activated at the beginning of the ground preparation phase and in the propulsion phase of the support phase.

DISCUSSION

The main extensors of ankle and knee joint manifested simultaneous co-activation even before the instant of touch-down (see Figures 1A and 2A). According to the theory of movement control (Latash, 2008; Véle, 2006) this phenomenon is arising from learned fixed motor programs stored in the memory in the cortex. Cavanagh and Komi (1979) presented that electromechanical delay varies from 30–100 ms. Pre-activation time in our study was estimated at about 80–100 ms, which may be explained as a result of the high accuracy of touch-down prediction from the central nervous system.

Differences in phase-shift values at TA with other muscles arose from the change of main peak voltage in both activities: peak in the transition phase was determined as the main one while kick-biking, whereas the peak preceding the ground phase was considered as the main one in running. A high cross-correlation value of TA and RF in running corresponds with double peak activity during a working cycle.

Both activities showed SOL activation to be a little delayed behind GAM. VAM activity was rising almost simultaneously with SOL. The standard error of phase-shift determination was estimated as a standard deviation of 20 stable movement cycles and was 2.6%. The accuracy of the maximum cross-correlation value was estimated at 0.05 by the same procedure. This inaccuracy might explain some values over 0.7 for cooperation TA with other muscles.

GLM and BF act in similar ways in running. The gluteus muscle was activated earlier to slow-down hip flexion during transition, while BF followed during the beginning of the ground preparation phase. The role of both muscles during the support phase may be explained as a role of pelvis stabilizers. Stability in kick-biking is provided by the kick-bike machine, so the cinematic chain of a kick-biker is more stable than the cinematic chain of a runner. This may explain the longer contraction of BF and GLM during the support phase. GLM acted as a more complex muscle (pelvis stabilizer and producer of torque) than in recent findings of Vystrčilová, Hojka (2009), where its role was only as a torque generator in running. Otherwise BF performed the other role. These findings may lead to the idea, that role of both muscles should be balanced.

Very important in terms of motor control was an observed presence of co-contraction of antagonists in the ankle joint and knee joint. Recent studies report, that co-contraction's role is at first damage prevention (Latash, 2008), and increase of joint stiffness, leading to conserving elastic energy as a second function (Jinha et al., 2006). More advanced methods (such as dynamometry) should be used to evaluate the true role of co-contraction.

Recommendations for practice may be summarized with two points. First, the kick-bike may be used as an instrument in motor learning of take-off activities (especially running). Its contribution is resulting from the similar timing of muscle activation of the main flexor/extensors of the support limb due to improved stability. Length of support phase was estimated to be similar in both activities.

Second, kick-bike might help to learn the mechanisms necessary to perform high-intensity exercises such as plyometrics, because of antagonist co-contraction, performed when impact is anticipated. In contrast with plyometrics, the kick-bike is more "user-friendly" method for learning fast high-force production activities.

ACKNOWLEDGEMENTS

Research was financially supported by Grant-Agency of the Charles University GAUK 300411/2011 "Myodynamics of support phase in human take-off movements".

Authors thank to Dr. William Crossan for the help with language and grammar corrections.

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KINESIOLOGICKÁ PODOBNOST BĚHU A KOLOBĚHU – PŘÍPADOVÁ STUDIE

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SOUHRN

Úkolem případové studie bylo porovnat timing svalové aktivace při jízdě na koloběžce a u běhu. Byla použita metoda povrchové elektromyografie pro detekci svalové aktivity. Mobilní aparát KaZe05 umožňoval snímání elektrických potenciálů sedmi svalů na dolní končetině. pro určení podobnosti zapojování jednotlivých svalů jsme využili metodu cross-korelační analýzy. Podobné mechanismy v otázkách svalové kokontrakce antagonistů a svalové preaktivace byly nalezeny u obou činností. Jízda na koloběžce může tedy tvořit alternativní postup při učení správného zapojování svalů při odrazu.

Klíčová slova: elektromyografie, kinesiologie, časování, kros-korelační analýza, před-aktivace, svalová kokontrakce

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