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COMPARISON OF THE ACTIVATION OF SELECTED MUSCLES DURING SPRINT AND SKIPPING[1]

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SUMMARY

The submitted paper discusses surface tension of individual muscles during athletic sprinting and a special running exercise (further only SRE), in this case skipping, measured by the analysis of electromyography record. We have measured sprint and SRE on the distance of 30 metres. At the same time the movement was synchronically video recorded from the side position of a video camera. The aim of this study was to describe the inclusion of individual muscles during sprint, but mainly how muscles participate when realizing skipping. The second aim was to describe to what extent muscles participate similarly during skipping with regard to the final movement – sprint. Furthermore, we can determine and describe how the exercise with its content is drawing on the final movement and if it fulfils at the same time the requirements of a special exercise rather than a generally developing exercise. The presumption is that skipping will fulfil the role of a special developing exercise only in a certain phase of movement, for which it is also preferentially used.

Key words: electromyography, sprint, special running exercise, skipping

INTRODUCTION

Special running exercises (further only SRE) are generally considered as a suitable instrument for training technique in sprint. Experience of trainers and competitors indicate that some SRE are experienced as closer to sprint and some further from sprint from the coordination point of view. SRE are determined for improving technique of a certain phase of running. These exercises play an irreplaceable role during sport training.

In sprint m. rectus abdominis, m. gluteus maximus, and m. quadriceps femoris mainly participate in working – mainly then m. rectus femoris and m. vastus medialis, m. biceps femoris, m. gastrocnemius, m. tibialis anterior, m. soleus and other muscles (Čihák, 2006), which do not take part in the final movement so prominently. In order that individual SRE

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fulfilled their purpose, there should be the highest level of coordination similarity between SRE and sprint; the muscles should be included in a very similar order and intensity like in certain parts of the movement cycle in sprint. These certain parts are understood as critical points (or knot points) of technique, and SRE help to learn and improve the technique.

With the EMG characteristics will be possible to judge timing positions of local maximums of the EMG curve of the observed muscles (Merletti, 2004).

The aim of the study was to describe intra-individual differences in chaining muscle groups and in intensity of individual muscles participation in sprint and skipping.

METHOD

It is a case study of a tested person – an athlete. His specialization is the hurdle sprint 110 metres and 400 metres. The sprinter already has movement habits of SRE fully acquired and uses them to everyday learning of technique in sprint or as a device of warming-up. Exercises were realized with the almost maximal effort on the level of 90% of the maximum to have the measurement the most reliable. A certain deviation from the ideal was not using spiked running shoes, which was with regard to the following SRE complicated due to changing shoes and as SRE are realized always only in training shoes.

Muscle activity was observed with the help of surface electromyography method (further only SEMG). We had 7 channels available for transferring EMG potentials and 1 channel for synchronizing EMG record with the video camera. The device weighed with batteries 1.3 kg and is able to record electrical tension of muscles with the sensitivity in the interval 0.05–6 mV. The time of scanning was 10 seconds, during which the individual realized sprint or SRE on the distance of 30 metres. The sampling frequency was 200 [1/sec], lower filter 29 Hz, upper filter 1200 Hz. The acquired data were transferred from the device into the portable PC, in which they were adjusted by the special software Kaze5, and then the data were exported into the Microsoft Excel software and graphically displaced on the eight-bit scale. We have done together 31 records with the actual setting of the sensitivity of recorded channels and the necessity of occasional sensitivity regulation. We have analyzed 1 sprint section before using SRE, when we did not want to influence the athlete by fatigue after several further sections of SRE. Sprint section was analyzed as the seventh because of the more complicated setting of sensitivity and then sections number 12. In principle we have analysed only sections from the first part of all recorded sections, which ensures us that the fatigue factor will not influence. The whole measuring was realized after the common athletic warming-up. The weather was windless, dry, 23 °C, pre-competition period.

Electrodes were localized on the following muscles, which participate during running:

1. Musculus rectus abdominis dx.
2. Musculus quadriceps femoris dx. – rectus femoris
3. Musculus tibialis anterior dx.
4. Musculus gluteus maximus dx.
5. Musculus gastrocnemius medialis dx.
6. Musculus biceps femoris dx. – caput longum
7. Musculus quadriceps femoris dx. – vastus medialis

The gained data were transferred to real values of electrical tension in individual muscles (more precisely in points of electrode scanning). To evaluate EMG curve, its selected parts respectively, we have used counting the area under the curve of every working cycle. However, this fact is possible to use only as a supportive argument in the evaluation and only in obvious cases (at high numbers or great differences). In this case the working cycle is understood two running cycles, the start and at the same time the end of this cycle was chosen the moment of right foot touchdown during two changes of lower limbs when running. Equally we have determined two working cycles during skipping, whereas the start and the end of this cycle was always chosen the moment of right foot tread. The start and the end of this cycle were possible to read in the video record, from individual pictures. The area under the curve numerically characterizes the intensity of muscle electrical activity, the working unit was set here mV × s. In our case numbers in tables were gained for the mentioned working cycle of running, that is 1.12 s and 0.96 s during skipping. In the EMG curve course we judge the muscle activity, which for guidance refers to muscle work. We have used the datum of maximal value of muscle activation in the set moment to express the level of the intensity of muscle participation in critical moments of sprint and SRE (the moment of tread and take-off). The datum was characterized by the immediate datum of the scanned electrical potential of the muscle. This maximal value was gained from the graph (EMG curve) right at the highest value of the working cycle. All evaluated data were acquired from the almost same time section in all distances, after about 5 second start, which served for starting the run and gaining speed.

In the framework of EMG curves evaluation, there can be a certain time shift. Then we can use cross-correlation (Derrick, 2004). These methods are based on the fact that when we multiply point after point out of the data set, sum of these products will be the quantification of their relation. This correlation will help us to find out how individual muscles mutually cooperate. Values above 0,7 are considered as high, therefore they are marked bolt in tables.

$$r_k\,(x_t,y_t) = \frac{\sum_{t=1}^{N-k}(x_t - \bar{x})(x_{t+k} - \bar{y})}{\sum_{t=1}^{N}(x_t - \bar{x})(y_t - \bar{y})} = \frac{\sum_{t=1}^{N-k}(x_t - \bar{x})(x_{t+k} - \bar{y})}{s_x s_y}$$

Correlation values and the mutual time shift of individual muscles activation as well were gained by evaluation in the Matlab software. Time shift in activation of individual muscles helped us to determine whether individual muscles were activated with the same time delay in skipping and sprint.

Exercise was recorded by a high-speed camera and synchronized with the EMG characteristics in the Dartfish software. This programme is mainly used for biomechanical analyses of sport performances and other movements.

Time sequence of muscle participation can be read from the position of local maximums on the EMG curve in the graph. Differences between muscles are determined according to the localization of their highest values during the muscle contraction.

Furthermore we have evaluated the phase shifts of activation starts. Data were sought in the interval –0,5 to 0,5 of the cycle and were expressed in percents. This interval expresses one working cycle of the each observed locomotion. We have investigated maximal values of cross-correlations of activation starts of individual observed muscles in the interval. Percentage values show phase shifts concretely within the working cycle. M. gluteus maximus dx. was determined as the referential muscle with the value of phase shift 0.

RESULTS AND DISCUSSION

For better orientation in graphs and tables we mention the muscles order in individual lines:

1. Musculus rectus abdominis dx.
2. Musculus quadriceps femoris dx. – rectus femoris
3. Musculus tibialis anterior dx.
4. Musculus gluteus maximus dx.
5. Musculus gastrocnemius medialis dx.
6. Musculus biceps femoris dx. – caput longum
7. Musculus quadriceps femoris dx. – vastus medialis

Lest there was no visual distortion of individual graphs, all graphs are displayed within the same time section of 1.5 second. In tables the value S [mV × pattern] is adjusted, it is always within 2 working cycles. We have added the relative value within 1 second, so we could compare individual exercises.

Table 1. Support time, flight time, and 2 cycle time in individual exercises

	Sprint	Skipping
support time	0.14	0.1
flight time	0.14	0.14
2 cycles	1.12	0.96

Sprint

Figure 1 shows muscle participation in the time of tread. *Musculus rectus abdominis dx.* has one peak of activation before the moment of right foot tread, when the whole leg will be highly stressed and the muscle tries to keep dynamic balance of the whole body with its activation. The highest activation is then when transferring the right swinging leg during the support of the left leg. That is relatively right, as abdominal muscles help us when lifting the swinging knee. The knee lift itself is then finished by inertia, which was gained during folding the leg under the body and during the swing itself by increasing the surface speed of the lower limb. However, it would be better if the muscle was activated a bit later and helped so to lift the swing knee.

Musculus rectus femoris dx. works basically for the whole time of running. There are no visible differences between contraction and relaxation. Activation peaks can be found when tripping up the right leg, when the muscle is in maximal stretching and in the vertical

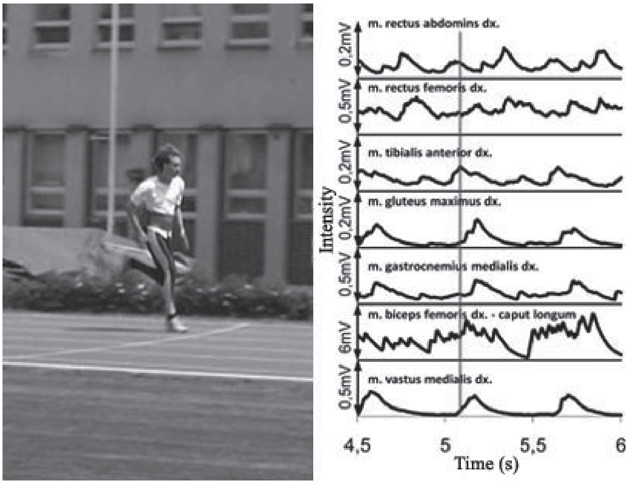

Figure 1. The moment of touchdown

moment (smaller). The both above mentioned muscles have in the moment of tread and take-off the same value of muscle activity. Figures 1 and 2 show clearly that all muscles worked most approximately in the vertical moment, which is logical, because the whole body is also stressed the most in this moment.

Musculus tibialis anterior dx. is most active in the moment of tread (Figure 1). It is why this muscle does so called active work of the foot (dorsal flexion of foot and the following active plantar flexion before the moment of tread). As can be seen in Figure 1 the position of the local maximum is right in the moment of tread, but the muscle realizes high activity also closely before and after the tread (as can also be seen in Figure 2). That is an evidence of athlete readiness for sprint and on the whole good technical realization of tread, when

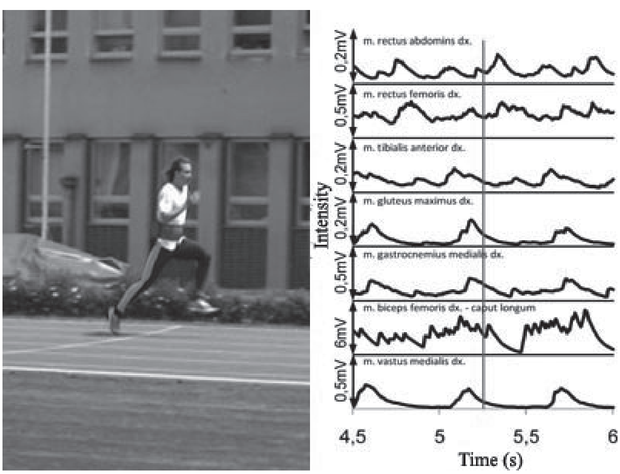

Figure 2. The moment of take-off

it is necessary to reach dorsal flexion, which is later used right for the active tread. The EMG curve has again two peaks; the second is the evidence of *m. tibialis anterior dx.* activity right in the flexion in knee joint (when tripping up) and transferring right leg in the swinging way under the body. The activity is here important for faster transfer of leg, when dorsal flexion makes the leg swing faster. The foot is due to dorsal flexion closer to the centre of turning; the surface speed is higher.

EMG curve clearly shows the changing contractions and relaxations of *musculus gluteus maximus dx.,* when the greatest activity appears closely before the moment of take-off, in the moment of extension in hip joint and starting extension (still slight flexion) in knee joint. This EMG curve and the curve of *musculus vastus medialis dx.* mostly show the changing work of the muscle, when the muscle does not get tired uselessly during another activity.

Musculus gastrocnemius dx. caput medialis are most active closely before the moment of take-off, when full extension in ankle joint gradually appears and the muscle trims.

Figures 1 and 2 show that *musculus biceps femoris dx.* is activated closely before the tread and its activity finishes a while after the take-off. It is obvious that the muscle worked mainly in the support phase, when the horizontal speed is increased by its active work. The strong point is that the muscle is relaxed in the flight phase and knee flexion is realized by swinging way; running can be relaxed so. The local maximum is situated on the EMG curve roughly in the vertical moment; however, it is not very significant. This muscle works very actively for a long time, therefore it gets tired more. That leads to the fact that *musculus biceps femoris* is often hurt in sprint and also because sportsmen often ignore to develop strength of this muscle.

The activity of *musculus vastus medialis dx.* starts to grow during the preparation to tread, it is the highest when stressed most – in the vertical moment and then it decreases again to the moment of take-off. The contraction start and the following muscle relaxation have a constant character.

Skipping

This special running exercise is used to train and develop the phase of knee lift-up and the following active depressing the swing knee towards the surface. It is not only the effort to maximally lift the knee, the exercise together with scissors running serves to practice and develop the pursuit of so called "front drive". That means that the foot should contact the surface more before the median and then the athlete pushes for the active work of lower supporting limb, which we can imagine as the effort to clutching and the effort to drawing up and the following drawing away the surface behind us in the direction of the run. The bad realization means that the foot treads more to the median and the area for active clutching is diminishing and shifts more under us and behind us, which forces us to trip up more with the following longer course for transferring the swing leg. A clear effort for realization can be observed in the exercise high knee skipping with lower leg extension, in skipping the shank of treading leg does not move so much in the direction of running.

Musculus rectus abdominis dx. works in this exercise similarly as in sprint, when the EMG curve has two peaks of muscle activation. The first one is in the moment of right leg tread when transferring the swing leg. In principle we can say the same about the muscle as in sprint (see also Table 2, the values are very similar). Figures 3 and 4 show that the take-off comes earlier, the step is not so long. It can seem as if the athlete “was sitting” during skipping (see Figure 4), the take-off is not entirely finished into the fully stretched leg, which folds itself immediately under buttocks. The whole movement is also realized in slower speed. The datum in the moment of tread is similar; the muscle works with the same intensity, however, the movement is slower. That is caused by the fact that there is a higher vertical lift of the centre of gravity and the followed greater stress.

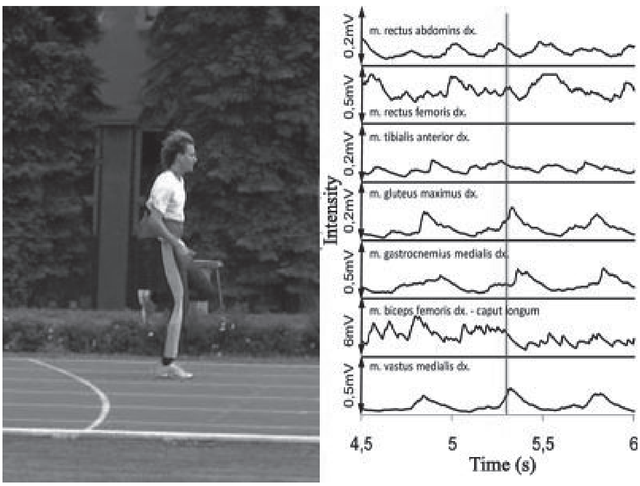

Figure 3. The moment of touchdown

Musculus rectus femoris dx. has its local maximum in the moment of maximal flexion in the knee joint of the right leg. The muscle again worked in certain intensity during the whole movement time. However, interesting is that neither in sprint nor in skipping this muscle was included in such effort in the vertical moment, when the body is stressed the most. This muscle together with *musculus tibialis anterior dx.* did not have clear course of contraction and relaxation.

Musculus tibialis anterior dx. works without a significant mark of activation, same as it is in sprint, even though it works in a similar sequence. We can say the same as in sprint. The course of muscle work is not so differentiated and it is partly chaotic. Table 2 proves the similarity with sprint.

Musculus gluteus maximus dx. also proves with its work here that skipping with its movement content gets the nearest to sprint itself. The local maximum and timing of muscle participation is same as in sprint. The only difference is the area under the curve, which can be explained by the fact that peaks on the EMG curves are not in skipping so sharp, but their bases are wider. The muscle is not activated so fast but it starts working and also finishes slower with activation.

Musculus gastrocnemius medialis dx. again works almost same as in sprint. Figure 4 shows that the local maximum is again in the moment of take-off. The only smaller

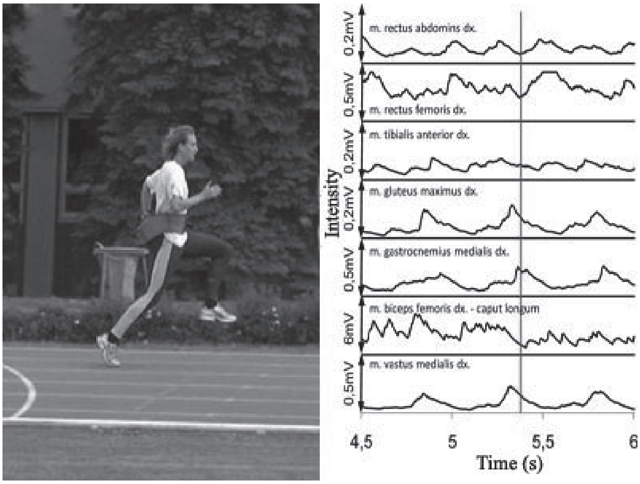

Figure 4. The moment of take-off

difference is in the maximum and at the same time in the area under the curve (Table 2), which can be awarded to the effort of gaining higher vertical speed.

Musculus biceps femoris dx. records the biggest difference out of all measured muscles. The start of muscle activation and work is coincident with sprint, when the muscle starts to activate in the moment when the knee joint goes from flexion to extension of swing right leg, the muscle starts to stretch then. At the same time it starts to work against the inertia and tries to work actively for the preparation to tread and "active clutching" during the contact with surface. It stops to work basically in the moment of vertical, whereas in sprint it works a while after the take-off (Table 3 and 4). Here can be found the difference between the whole realization of sprint and SRE, which can improve a certain phase of running. In skipping it is the "front drive" and mainly the emphasis on the vertical rather than horizontal component of speed. Therefore, this difference is so evident. As it has been mentioned above, in sprint the athlete tries to work actively during the whole time of contact with surface; *musculus biceps femoris* significantly helps to this. The take-off is entirely realized to the stretched lower leg and the muscle work persists a while after the take-off. On the contrary, in skipping the athlete focuses on tread and vertical component of speed, therefore the take-off is "torn off", unfinished, the muscle activity does not carry on to the end of contact with surface. Table 2 shows everything, where both values are about 1/3 lower than in sprint itself.

Table 2. Maximums and areas under the EMG curves of the observed muscles

	m. rectus abdomins dx.		m. rectus femoris dx.	
	S[mV × sample (1 sec)]	max	S[mV × sample (1 sec)]	max
Sprint	28.8	0.31	131.75	0.95
Skipping	31.17	0.24	174.42	1.24

m. tibialis anterior dx.			m. gluteus maximus dx.	
	S[mV × sample (1 sec)]	max	S[mV × sample (1 sec)]	max
Sprint	25.63	0.28	16.27	0.29
Skipping	28.93	0.23	26.25	0.33
m. gastrocnemius medialis dx.			**m. gluteus maximus dx.**	
	S[mV × sample (1 sec)]	max	S[mV × sample (1 sec)]	max
Sprint	60.44	0.6	1502.17	14.5
Skipping	82.65	0.76	1044.72	9.64
m. vastus medialis dx.				
	S[mV × sample (1 sec)]	max		
Sprint	32.97	0.56		
Skipping	52.54	0.67		

On contrary, the last muscle *musculus vastus medialis dx.* has the same course of work as in sprint. Local maximums appear on the same place on the EMG curve. The start and finish of muscle contraction is almost identical. The only difference is in the area under the curve and in the shape of local maximums. In skipping the peaks are sharper and higher (see Table 2); the area under the curve is also greater in Table 2. That can be explained by the fact that this muscle is stressed more during a greater vertical shift of the centre of gravity. This muscle's task is by the way keeping the body upright.

In skipping we can conclude that work of all muscles, except for *musculus biceps femoris dx.*, is very similar as in sprint itself. The difference can be found in the fact that in SRE muscle work is more used for gaining vertical speed rather than horizontal, demonstration is more take-off like, therefore, the overall muscle work does not differ significantly, even though the movement is slower and less dynamic. According to the EMG curve (it proves best the EMG curve of *musculus biceps femoris dx.*) the exercise serves best to train the active work of a leg in the moment of tread and in the first part of the support phase.

Phase Shifts

Table 3 sums up phase shifts of EMG potential starts. Values are stated in % on the axis – 50 to 50%, which means – 0.5 to 0.5 of the cycle.

Table 3. Phase shifts of EMG potential starts in the measured muscles of an average step

	Sprint	Skipping
m. gluteus maximus dx.	0%	0%
m. rectus abdominis dx.	–31%	–31%
m. rectus femoris dx.	–36%	–44%
m. tibialis anterior dx.	13%	13%
m. gastrocnemius medialis dx.	4%	10%
m. bic. fem. caput longum dx.	–19%	–12%
m. vastus medialis dx.	–5%	–1%

The sequence of muscle participation can be clearly read in Figure 5. This figure proves a great coordination relationship between both exercises – sprint and skipping. Muscles in both cases were included in the same sequence. In two cases (if we will not consider the referential muscle of course) muscles were included in the framework of the working cycle with the same delay – *musculus rectus abdominis dx.* and *musculus tibialis anterior dx.* The biggest difference of the phase shift was 8%.

Musculus gluteus maximus dx. has in skipping and sprint one peak, the muscle activity changes clearly with muscle relaxation, EMG curve has phase character. This muscle was chosen as a referential mainly from the reason that activation course was both in sprint and skipping very similar. We come from the fact that a survey about activation of other muscles will be clearer and results are related to a similar initial value.

The phase shift of the decisive muscle activation start in *musculus rectus abdominis dx.* is in sprint and skipping the same. As it has been mentioned above in the article, skipping appears as an exercise, which with its content approximates the sprint itself the most. It is proved in Tables 2 and 3.

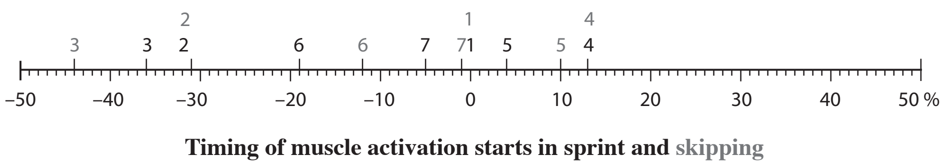

Figure 5. Timing of muscle activation starts in sprint and skipping
1. m. gluteus maximum dx., 2. m. rectus abdominis dx., 3. m. rectus femoris dx., 4. m. tibialis anterior dx., 5. m. gastrocnemius medialis dx., 6. m. biceps femoris dx. – caput longum, 7. m. vastus medialis dx.

The muscle *musculus rectus femoris dx.* embodies similar values in the phase shift also in skipping. Muscles *musculus rectus femoris dx.* and *musculus rectus abdominis dx.* work as functional agonists. This principle is practically used also in training. When running it is good to use the exclamation “clench the belly” rather than “raise knees”. As we can see from the phase shifts values, it has justification. During *musculus rectus abdominis* activation also *musculus rectus femoris* is activated, which function is flexion in hip join; it enables a better knee lift. Strikingly we can mention it in sprint, where the swing leg has higher speed, the centrifugal power is higher, therefore *musculus rectus femoris dx.* activation starts earlier than in skipping, so this power was overcome. Nevertheless, we can state that it would be optimal that both mentioned muscles were included more in cooperation and the knee lift was so more efficient. In skipping and in sprint we can see a shaky course in the described muscle, the muscle works more or less for the whole time of movement, the character of muscle work is postural; it ensures here the upright body.

In the muscle *musculus tibialis anterior dx.* we find again the absolute agreement in the phase shift of the decisive start of muscle activation.

In *musculus gastrocnemius medialis dx.* we can observe the phenomenon of three extension (hip, knee, shin). This statement proves data in Table 3, when muscles *musculus* *vastus medialis dx., musculus gluteus maximus dx.* and *musculus gastrocnemius medialis dx.* participate almost together and cause extension of a leg in all mentioned joints at the same time. *Musculus gastrocnemius medialis dx.* has a slight delay in skipping, which can be caused by incompleting the take-off.

The values of phase shifts of EMG potential starts in *musculus biceps femoris dx.* were influenced most by the shaky course of activation, when the decisive activation start is not significant and it is rather a climax of long-term muscle activation. The mathematical model processes on values of decisive activation starts. This muscle is with its work character the postural muscle. Therefore, values in Table 3 can be misleading; nevertheless, the generally decisive activation start came before the activation of *musculus gluteus maximus dx.*, which is observable from EMG curves.

M*usculus vastus medialis dx.* has again a significantly phase character and in both exercises. It behaves very similarly as *musculus gluteus maximus dx.* Their activation starts are in the same moment. Both muscles participate in keeping body upright, which is the most important in the moment of vertical, when the whole body is stressed the most.

CONCLUSION

The selected exercise was chosen purposely as probably the closest to sprint out of all SRE and it is obviously used in athletic training the most. This statement was proved by the movement content, the EMG curve course and the value of phase shifts. We managed to describe how the muscles start working in sprint and in skipping. Results demonstrate that this exercise is very specific on this intensity level. We can include it without doubts into training units in pre-competition period and competition period not only as a means of warming-up, but also as a part of the main training unit. We can use skipping also in other periods of preparation, but certainly only with a lower intensity of realization.

It is not necessary to fear that inclusion of this exercise into training would disturb the movement stereotype in sprint and subsequently made worse the athlete's performance. It is suitable to include these SRE as a variation of sprint training, when change of means sometimes help to avoid a stereotype very much.

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SROVNÁNÍ AKTIVACE VYBRANÝCH SVALŮ PŘI BĚHU-SPRINTU A PŘI SKIPINKU

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SOUHRN

Uvedený příspěvek se zabývá analýzou elektromyografického záznamu povrchového napětí jednotlivých svalů při atletickém běhu-sprintu a při speciálním běžeckém cvičení (dále jen SBC), v tomto případě skipinku. Měřen byl atletický běh a SBC na trati 30 metrů. Pohyb byl zároveň synchronizovaně zaznamenáván na videozáznam z bočního postavení videokamery. Cílem práce bylo popsat, jak se jednotlivé svaly zapojují při atletickém běhu, ale především, jak se zapojují při provádění skipinku. Druhým cílem bylo popsat, do jaké míry se svaly zapojují podobně při skipinku vzhledem k cílovému pohybu, tedy sprintu. Posléze je pak možné určit a popsat, jak se cvik svým obsahem přibližuje cílovému pohybu a jestli současně splňuje požadavky prvku speciálního a nikoli všeobecně rozvíjejícího. Předpoklad je, že skipink bude splňovat roli speciálně rozvíjejícího prvku pouze v určité fázi pohybu, ke kterému je také prioritně používán.

Klíčová slova: elektromyografie, sprint, speciální běžecké cvičení, skipink

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