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THE USE OF NEW TECHNOLOGIES IN DIAGNOSING ASYMMETRY IN MUSCLE ACTIVITY AND MOTOR CONTROL ACTIVITIES BASED ON THE EXAMPLE OF YOUNG HURDLERS

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Abstract

Modern technology has created new possibilities for research in the area of regulation and control of movement. The asymmetry of muscle activity and its somatic and functional effects are rarely diagnosed in physical education and the sports activities of children and young people. The authors of this article analyse the problem of asymmetry on the basis of a representative sample of young hurdlers.

Hurdling technique used in 400-m hurdles involves, among others, the necessity of clearing the hurdles with the left and right attacking leg. Differences between the two variants are mainly demonstrated based on analysis of kinematic movement structure focusing on movement of lower limbs.

In this paper, the authors present differences in upper limb movement at the moment of clearing the hurdle in different forms of training.

The application of EMG (electromyography) with image sequence visualisation and registration system was used to analyse the 400 m hurdling technique of eight hurdlers. The hurdlers were first-class and champion-class hurdlers. The electromyograms concerned the work of 5 muscles of the upper limbs, symmetrically on both sides of the body (deltoideus, pectoralis major, biceps brachii, triceps brachii, latissimus dorsi). The analysis concerned three forms of hurdle training related to hurdle clearance first with the right and next with the left leg in three intensities: marching, trotting, and running at maximum speed. Muscle work on the right side of the body was analysed when clearing the hurdle with the left lower limb, and vice versa. All examined hurdlers used the left attacking leg better (regarding the specificity of 400-m hurdling).

The analysis showed significant differences ($p \geq 0.05$) in muscle work of the upper limbs between the right and left side of the body in respective forms of hurdle training. The right upper extremity muscle activity of three repetitions showed high correlation ($r=0.89$) for each performed movement form. Such relationships were not found on the left side of the body when attacking the hurdle with the right leg.

Although asymmetry is inevitable in the process of lateralization of the human body, teachers at the primary stage of education should make every effort to alleviate disorders of muscle activity and dysfunction of the skeletal system. This is particularly significant in the disciplines in which it is possible to use symmetrical exercises, as a stimulus for relaxation and to avoid monotony when training children and adolescents.

Key words: *diagnosing, activity muscle.*

Introduction

Recent development of modern technologies has led to new opportunities for studying regulation and control of movement. Widespread introduction of surface electromyography, in particular the telemetry application, enables precise assessment of teaching and perfecting the technique in the majority of sports disciplines (Snarr and Esco, 2013; Lim et al., 2014).

Teaching hurdling techniques increasingly requires the use of many innovative methods, replacement equipment, and research into new elements that might improve results. Apart from innovations in teaching and training, different solutions of analysing the technique are increasingly looked for. This is done through analysing a sequence of frames of hurdling during competitions, but also in modern research laboratories where the structure of movement is accurately determined at the moment of clearing the hurdle (Li et al., 2011; Iskra and Coh, 2011; Balsalobre-Fernandez, 2013). Hurdling is a sport engaging asymmetrical movements of the upper and lower extremities; however, the movements alternate so they should be symmetrical reflections of one another. An additional difficulty is the necessity of being able to clear the hurdle with the right and left attacking leg (Iskra and Čoh, 2011).

The lateralisation process is regarded as one of the aspects of motor development manifesting, to a greater or lesser extent, as functional asymmetry. The majority of conducted studies have determined a degree of differentiation between organs such as: eyes, ears, hands, and legs as regards the frequency and precision of their movement. Specialists' opinions on the shaping of functional asymmetry can be divided into two groups. Some of them support endogenous factors, seeking lateralisation's etiology in differences between cerebral hemispheres, conditions of foetal development, and the asymmetrical arrangement of internal organs (Castiello and Stelmach, 1993; Annett, 1999). Babu and Roy (2013) indicate that asymmetrical structure of the human body is already visible in about the sixth week of prenatal life and this determines certain postural patterns. The second group of researchers, explaining lateralisation in terms of exogenous factors, is convinced that environmental factors resulting from everyday work and social upraising or from social pressure can be fundamental determinants of this phenomenon (Dirn-berger, 2012; Stöckel and Weigelt, 2012). Ballanger and Boulinguez (2009) have tried to explain lateralisation using surface electromyography on the basis that EMG offers a key tool enabling an explanation of the relationship between the laterality of upper extremities and interactions between cerebral hemispheres.

The electromyogram and the EMG video recording as well as many biomechanical methods aid the analysis of differences in asymmetry; moreover, they correlate with the description of errors in technically complex sports (Illyés and Kiss, 2005; Mastalerz et al., 2012). 400-m hurdling is such a technically complex sport and individual hurdlers' technique is rarely analysed.

Material and Methods

Participants

The analysis included 4 male and 4 female hurdlers with a minimum of five-years training in 400-m hurdling, representing the academic club AZS Politechnika Opolska. The hurdlers have all achieved successes at national level: seven of them were first-class hurdlers and one a champion-class hurdler. On average, the men were 23.30±1.47 years old, their average body weight was 72±4.47 kg, while the average body height was 176.63±3.69 cm. Whereas, women were 22.30±1.55years old, on average, while their average body weight was 58.25±3.03 kg, and the average body height was 168.50±3.35 cm.

Procedures

The hurdlers performed three elements of hurdling training related to clearing the hurdle with a set rhythm of steps and set distances between hurdlers. In the first element (marked I), they marched between hurdles arranged every 150 cm. In the second analysed element (marked II), they trotted at moderate pace between hurdles arranged every 500 cm. In the third element (marked III), they performed the exercise running, and hurdles were arranged every 700 cm. The above exercises (elements) complied with the rules of teaching and training 400-m hurdling (Iskra and Čoh 2006; Adashevskiy et al., 2014; Przednowek et al., 2014). The participants performed the task with three hurdles arranged in a row with the measurement taken at the middle hurdle. In each element (I, II, III), they performed three trials attacking the hurdle starting from the left, dominant leg, and then three trials with the right, alternate leg. In total, each hurdler performed 18 trials (9 for the left leg and 9 for the right leg).

The testing tool was the 16-channel EMG manufactured by NORAXON DTS, registering muscle activity in training with a sampling rate of 1500 Hz. Ten electrodes were placed in accordance to the SENIAM methodology - between the movement spot and the tendons' attachments along the long muscle's midline.

The video material was registered using the high-frequency Point Grey Gazelle camera and the CRI VIST synchronizer. Monochromatic imaging was registered using StreamPix 5 software, with 2048 x 1088 pixel resolution and 250 frames per second speed.

The analysis concerned recordings of five muscles working on both sides of the body (deltoideus, biceps brachii, triceps brachii, pectoralis major, latissimudorsi). The muscle work on the left side of the body was analysed when when attacking the hurdle with the right leg. Next, the participant changed the attacking leg and the upper extremity of the opposite side of the body was analysed. Such arrangement of the analysis (right leg - left hand) results from the natural movement in learning the hurdle clearing technique. Measuring was started when the trailing leg took off the ground and ended when the attacking leg's heel passed the barrier (Fig. 1).

According to the guidelines of the SENIAM project, the NORAXON MR-XP 1.07 Master Edition software was used to process and analyse EMG signals. In surface EMG recordings, the exercise duration was standardised to 100%. The sampling rate was 1000 Hz. The root mean square (RMS) values of EMG signals were calculated for consecutive segments of 50 ms. The average was calculated for signal durations between the start and end of recordings, that is start [1] - stop [2] (Fig. 1). Calculating the average for all the participants might seem an over simplification due to significant individual muscle activity amplitudes, while not using any standardisation might result in little deviations of the values - [mV] shows the average value in individual recordings. Moreover, pilot studies proved a statistically significant correlation between repetitions of each trial. As no logical differences were found between the surface EMG recordings for the examined male and female hurdlers, all of the results were analysed cumulatively. Other authors (Kielnar et al., 2012; Stöckel and Weigelt, 2012) also did not find differences between sexes, despite examining a large group of people.

Purpose of Research

Presenting muscle activity values was not the aim of this research. It aimed at finding a correlation between repeated trials in a certain element of training and the significance of differences between upper extremities in hurdles clearing the hurdle with the left and right leg.

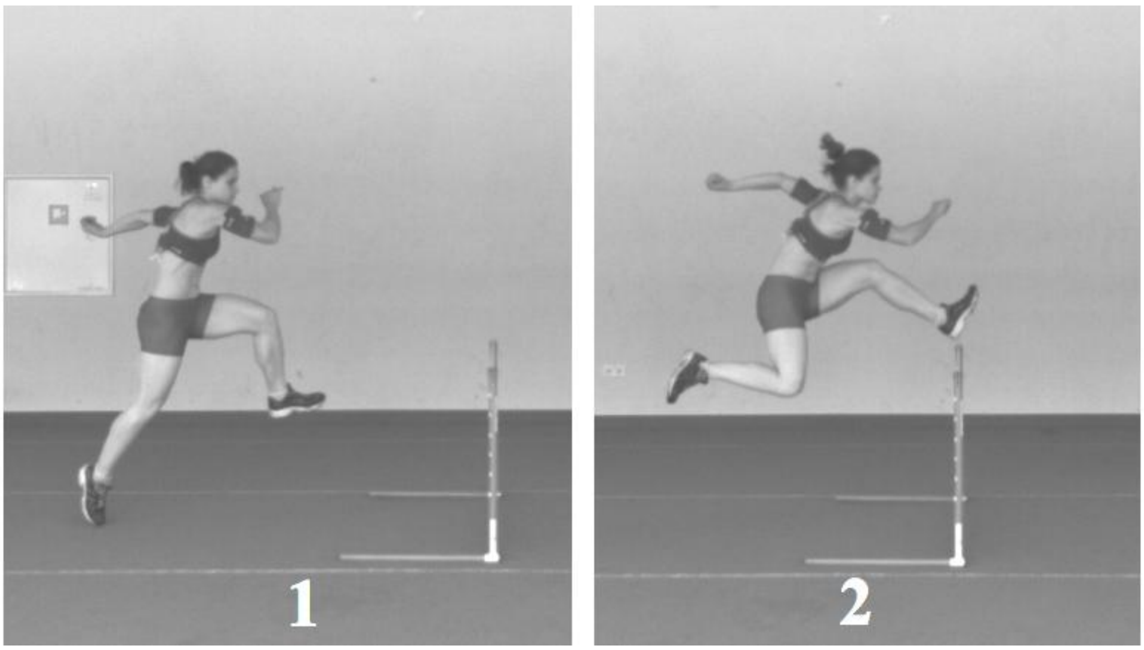

Fig.1. High-frequency camera image: [1] - recording start moment, [2] - recording end moment

Statistical Analysis

Statistical analysis was conducted using the Statistica 12 software (StatSoft). The Spearman's rank correlation coefficient was used to calculate correlation between three trials of each performed movement form (I, II, III). In order to determine the significance of differences between EMG recordings of muscle work of the left and right side of the body, the Wilcoxon signed-rank test was used. Descriptive statistics of the Statistica 12 software (StatSoft) were used to calculate somatic structure parameters.

Results

Regarding the muscle work on the right side of the body, the Spearman's rank correlation coefficient showed high correlation at $p \le 0.05$ between three individual trials of each described element (I, II, III). The lowest correlation coefficient was shown for the element III in which the movement was the most similar to the natural hurdling. Figs. 2-3 present these correlations in graphs.

Muscle work on the left side of the body (right attacking leg) showed sparse and low correlations only in element I - movement performed when marching. With regard to the remaining movement forms, no correlation between the subsequent three trials were found. Graphical analysis of individual movement elements are presented in fig. 2.

Analysis of statistical differences between the right and left side of the body in individual movement elements (I, II, III) revealed significant differences only in elements I and II (Fig. 3). The analysis indicated that muscle activity of the right side of the body has more symmetrical pattern than the left side's muscle activity. Results concerning average muscle activity values [mV] of the selected hurdler and the entire group are shown in tabs. 1 and 2.

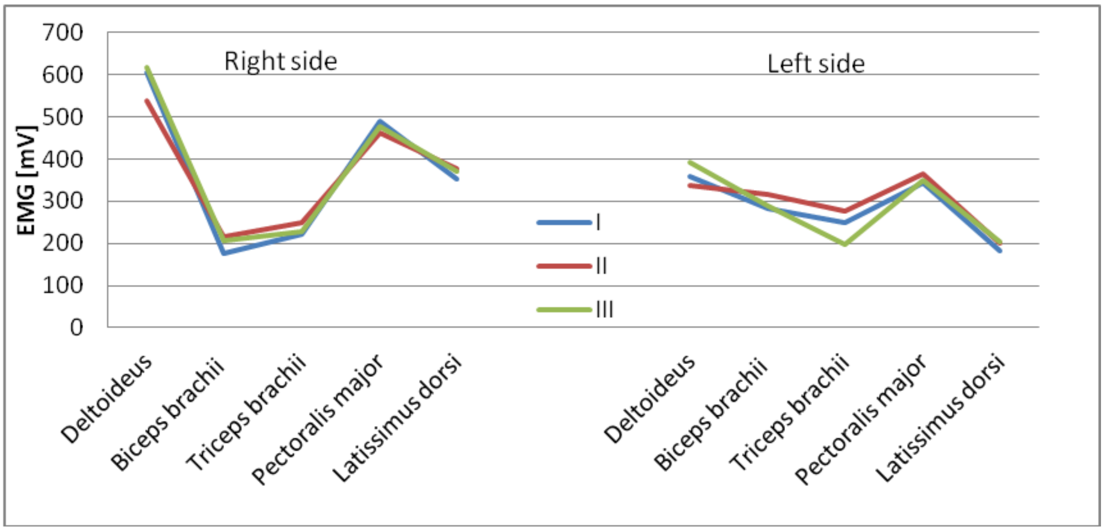

Fig. 2. Differences between EMG recordings of the right and left side of the body in individual movement schemes (I - marching, II - trotting, III - running)

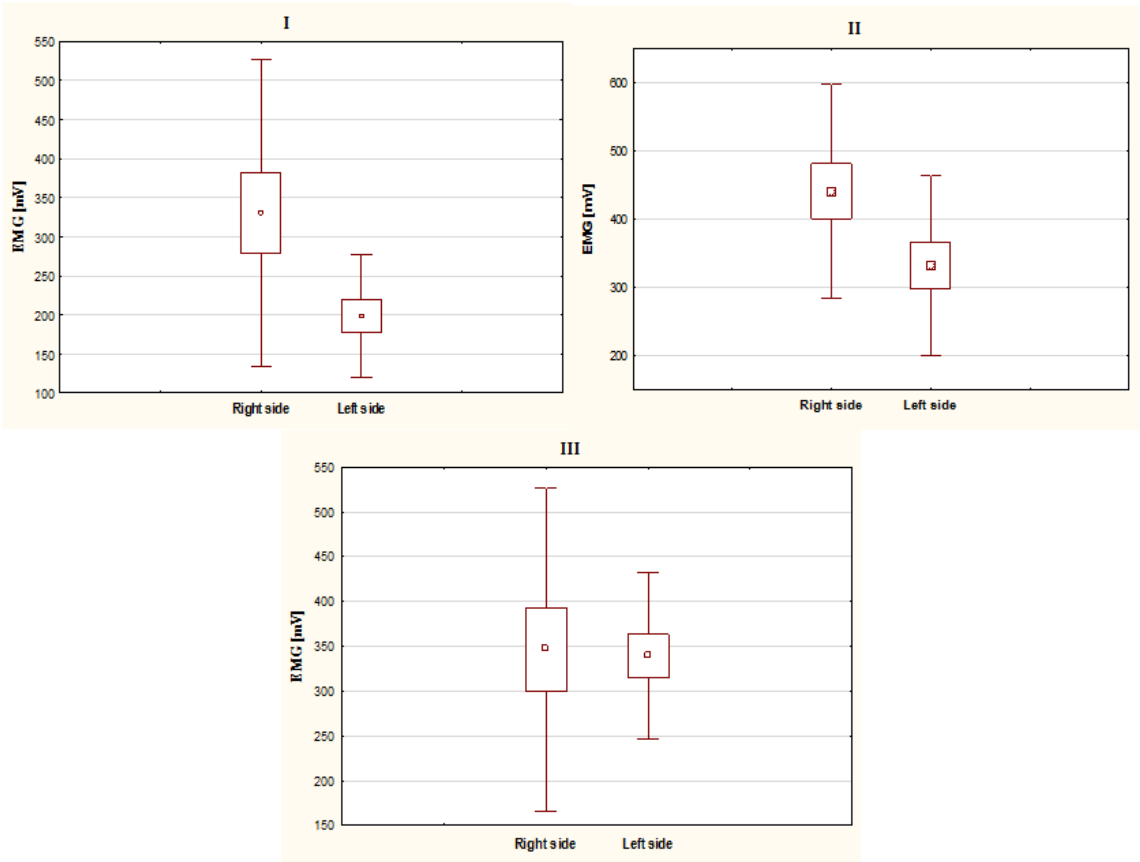

Fig. 3. Wilcoxon signed-rank test results regarding muscle activities of all the tested muscles on the right and left sides of the body in individual movement schemes (I - marching, II - trotting, III - running)

Table 1. Average values for individual muscles of all examined hurdlers in three trials of individual movement schemes [mV]

		Right side					Left side				
		Deltoideus	Biceps brachii	Triceps brachii	Pectoralis major	Latissimus dorsi	Deltoideus	Biceps brachii	Triceps brachii	Pectoralis major	Latissimus dorsi
I	I test	490	117	123	572	285	238	250	165	236	144
	II test	382	124	150	625	384	302	111	99	308	179
	III test	531	89	152	597	333	274	162	97	301	110
II	I test	548	204	297	609	499	323	250	318	489	165
	II test	651	262	327	568	442	337	369	342	562	146
	III test	634	270	253	564	474	434	324	223	535	162
III	I test	774	205	248	292	274	515	350	264	307	239
	II test	583	263	266	192	301	376	464	390	226	280
	III test	691	257	279	266	304	471	377	276	217	335

I - march, II - trot, III - run

Table 2. Average values for individual muscles of the selected hurdler examined in three trials of respective movement schemes [mV]

		Right side					Left side				
		Deltoideus	Biceps brachii	Triceps brachii	Pectoralis major	Latissimus dorsi	Deltoideus	Biceps brachii	Triceps brachii	Pectoralis major	Latissimus dorsi
I	I test	338	78	33	55	105	265	37	15	77	20
	II test	277	58	30	42	79	266	22	13	76	36
	III test	407	70	45	50	91	460	38	15	105	23
II	I test	338	78	33	55	105	265	37	15	77	20
	II test	277	58	30	42	79	266	22	13	76	36
	III test	407	70	45	50	91	460	38	15	105	23
III	I test	565	208	238	45	380	984	611	132	73	186
	II test	648	264	395	40	269	612	1075	394	71	273
	III test	607	236	317	43	324	798	843	263	72	230

I - march, II - trot, III - run

Discussion

Currently, researchers debate whether it is even reasonable to carry out studies on functional asymmetry considering the fact that the scientific world is already aware of the existence of morphological asymmetry of the human body (Niedzielski et. al., 2014). However, the dispute over how the functional asymmetry is shaped has not been settled nor proven yet. Thus, choosing the issue of significant differences in functional asymmetry of the presented complex athletic discipline seems justified. Literature reports a considerable number of studies analysing comparisons of muscle work techniques on the left and right sides of the body in sports activities. This type of studies includes not only individual sports but also team sports and shows significance of asymmetry in the training process and its influence on the playing technique (Parkin et al., 2001; Carpes et al., 2010; Diederichsen et al., 2007; Pakosz et al. 2014).

Studies examining a group of professional and amateur cyclists conducted by Carpes et al. (2010) present muscle activity and differences in asymmetry of surface EMG recordings of lower extremities' movement. In their conclusions, the authors emphasise that differences in muscle work asymmetry in cycling depends on the effort intensity level. Mastalerz et al. (2012), examining lower extremities' fatigue in runners underlines significant differences in fatigue percentage values between the right and left extremity. Studies of Ball and Scurr (2009) compared the relation between asymmetric work of the same muscles during drop jumps from a height of 40 cm. The authors noted statistically significant differences in surface electromyograms between the right and left extremities but only in the drop phase. Konieczny (2014) has shown application of EMG in determining the extent of muscle work asymmetry while throwing a ball with dominant and alternate extremities. Pakosz et al. (2014) while analysing the results of six examined ballers noted that voltages generated by the same muscle of dominant and alternate leg significantly differed as regards the muscle biceps femoris in the value of the EMG signal. Differentiation of the EMG activity concerning shoulder girdle asymmetry were also shown in the studies of Diederichsen et al. (2007). The authors analysed eight muscles of the shoulder girdle in twenty men practising sports during abduction and external rotation of both upper extremities. The results showed significant differences between dominant and alternate extremity, while the size of differences and dominance of a certain side to a large extent depended on the type of performed movement.

However, the authors of this work have not found studies concerning the analysis of upper extremities' muscle activity in hurdlers specialising in a distance of 400 m so it is not possible to compare the results of previously conducted studies. Sprint running is the sport most similar to hurdling; however, so far, EMG analysis of sprint disciplines have been limited to analysing lower extremities' muscle work (Alończyk et al., 2007; Coh et al., 2009). Low start was regarded as the most asymmetric movement structure performed during sprint running. In this type of studies, Wiemann and Tidow (1995), Rand and Ohtsuki (2000) determined the reaction time of individual muscles in certain running phases. The authors also showed differences in muscle activity between extremities.

In the case of hurdling, no studies included the bioelectrical signal created by muscles during running or during hurdle clearance. This was probably caused by the necessity of conducting complicated analysis in a highly dynamic movement form. The probable reason for that is the fact that hurdling is at the same time an asymmetric and acyclic activity. In a paper by Iskra and Coh (2006) hurdling was named a cyclic-acyclic discipline where individual rhythm units, i.e. parts connecting the cleared hurdles and the run to the next obstacle are cyclic. In the case of 400-m hurdling, the situation is more complicated as every next hurdle can be attacked with the right or the left leg. That is why a higher number of studies and analyses of upper and lower extremities during hurdle clearance are worth conducting. Several of the above-mentioned authors have focused their studies on biomechanical analysis of this issue while omitting the muscular apparatus driving this entire system. The conducted studies indicate considerable significant differences in bioelectrical signals generated by muscles and their repetition during hurdle clearance.

Conclusion

Although asymmetry is inevitable in the process of lateralization of the human body, teachers at the primary stage of education should make every effort to alleviate disorders of muscle activity and dysfunction of the skeletal system. This is particularly significant in the disciplines in which it is possible to use symmetrical exercises, as a stimulus to relaxation and avoiding monotony when training children and adolescents.

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