ORIGINAL ARTICLE

Time structure and EMG parameters during the sprint start depending on the sprinters' physical preparation

La structure du temps et les paramètres EMG pendant le démarrage du sprint en fonction de la préparation physique des sprinters

K. Piechota*, Z. Borysiuk, M. Konieczny

University of Technology in Opole, Poland Faculty of Physical Education and Physiotherapy, Department of Anthropomotorics, Prószkowska 76/9A, 45-758 Opole, Poland

Summary
Objective. — The primary of the study was to identify relations between motor preparation and speed parameters in the group of experts-sprinters and in the group of novices-students. Interdependence was examined between speed and force factors and indicators of EMG movement structure: bioelectric muscle voltage and muscle activation timing.
Material and methods. — The participants were of 20 1st and 2nd sport class sprinters and a group of 35 students-novices. Force and jumping ability preparation tests were used in the study (standing long jump, standing triple jump and both feet jump with the use of Kistler platform), speed preparation test (30 m run from start block) and EMG signal recording.
Results. — In the post-start phase, the sprinter's group was triggered lower limb muscle groups appropriate for the given sprint start phase (front muscle group: VL: vastus lateralis; RF: rectus femoris; GAS. MED.: gastrocnemius medialis and the back muscle group: STN: semitendinosus and BF: biceps femoris), while the student group demonstrated an advantage in activation of muscles of the upper limbs: BB: biceps brachii and TB: triceps brachii in the same phase.
Conclusions. — On the basis of the present research, a low start motion pattern was created, which enables proper selection of appropriate sprinter technique exercises. It has also been demonstrated that the effectiveness of sprinters' start technique is affected by factors from the area of coordination conditions. But in the group of students — the sprint start depends mainly on physical preparation (force-speed predispositions).
© 2018 Elsevier Masson SAS. All rights reserved.

---

* Corresponding author.
  E-mail address: k.piechota@po.opole.pl (K. Piechota).

MOTS CLÉS
Sprint start ;
Électromyographie ;
Préparation du
moteur ;
Élite sprinters ;
Étudiants-novices

Résumé

Objectif. — Le principal objectif de l'étude était d'identifier les relations entre la préparation motrice et les paramètres de vitesse dans le groupe des experts-sprinters et dans le groupe des novices-étudiants. L'interdépendance a été examinée entre les facteurs de vitesse et de force et les indicateurs de la structure du mouvement EMG: tension du muscle bioélectrique et synchronisation de l'activation musculaire.

Matériel et méthodes. — Les participants étaient de 20 sprinters de 1re et 2e classe sportive et un groupe de 35 élèves-novices. Des tests de préparation de force et de saut ont été utilisés dans l'étude (saut en longueur, triple saut debout et saut de pieds à l'aide de la plate-forme Kistler), test de préparation de vitesse (30 m de départ) et enregistrement EMG.

Résultats. — Dans la phase de post-démarrage, le groupe du sprinter a déclenché des groupes musculaires des membres inférieurs appropriés pour la phase de démarrage du sprint (groupe musculaire avant : VL : vastus lateralis ; RF : rectus femoris ; GAS. MED. :gastrocnemius medialis et le groupe musculature du dos: STN : semitendinosus et BF : biceps femoris), tandis que groupe d'étudiants a démontré un avantage dans l'activation des muscles des membres supérieurs: BB : biceps brachii et TB : triceps brachii dans la même phase.

Conclusions. — Sur la base de la présente recherche, un modèle de mouvement de démarrage faible a été créé, ce qui permet une sélection appropriée des exercices de technique sprinter appropriés. Il a également été démontré que l'efficacité de la technique de démarrage des sprinters est affectée par des facteurs provenant de la zone de coordination. Mais dans le groupe des étudiants — le début du sprint dépend principalement de la préparation physique (prédispositions force-vitesse).

© 2018 Elsevier Masson SAS. Tous droits réservés.

1. Introduction

Motor preparation in sprint running is, along with the motion technique, an integral part of the sprinter training process. In the opinion of researchers, full release of the sportsmen's psychomotor potential is determined by a high level of sport technique, together with the use of the latest technique modelling tools [1]. It is beyond doubt that in sprinter runs we are also dealing with top-level conditions with regard to speed, dynamic force and movement coordination. The aforementioned dispositions affect the level of physical preparation in sportsmen.

Motor preparation model concept in synergy with the level of sport technique components has recently gained importance thanks to technology development. It enables a precise and telemetric diagnosis of adaptation changes with regard to muscle operation and recording of the most complex motion sequences [2,3]. The availability of computer software enables optimization of solutions improving techniques with the use of feedback [4].

Many authors, among others, [5—10], stress that the explosive and dynamic force reflects the initial running speed at the distance of 25—30 meters. Complex preparation of a sprinter involves controlling specific motion habits as well as coordinated exit from start blocks with maximum fast passage to the initial stage of the sprinter run. In addition, neurophysiological dispositions complement the whole in the technical-tactical aspect. Motor preparation of sprinters should be considered as a synergy of fitness (force, power, speed) as well as neuro-muscular conditions [11—13].

Worth emphasising is, as indicated by statistical studies, a strong diversity in motor preparation parameters between the studied groups. This may prove competent selection of the research tools and methods, thanks to which high data parameterization has been made possible. In this case expert opinions were followed of training authorities in light athletics [14,15].

As regards force preparation, following the experts' opinions [5,16], tests expressing force and speed predispositions were selected. It has been decided that vertical and horizontal jumps as dynamic jumping ability improving exercises are valuable tools for evaluation of sprinters' explosive power.

With regard to movement coordination, the optic proposed by Schmidt [17] was adopted. This interpretation treats movement coordination as a complex of control and regulation processes for motion activities. An external expression of the so understood coordination is above all precisions and economics of the activities performed. From this point of view, the application of EMG and analysis of the sequence of activation of particular muscles, including extensors and flexors and the time of their activation, reflect neuropsychiatric bases for particular motion structures [12,18]. In this context, comprehensive recording of EMG signal of the examined muscles during the sprinters' start phase carries important information qualities. Important are bioelectric voltage parameters [µV] and muscle activation timing [ms] in movement sequences as well as muscle voltage before a sound signal. Schmidt and Wrisberg model [19] was adopted as a theoretical premise, concerning the structure of motion patterns in psychomotor reactions.

At present, thanks to progress with regard to innovative technologies diagnosing various aspects of sport technique (EMG), it has become possible to very precisely record data under real training conditions. Owing to the innovative character of the EMG system, it is possible to take measurements in portable mode.

In order to continuously evaluate the development and improvement of technical skills at the initial stage of sports training, the following studies have contributed to showing the differences between the advanced group and the student group. On the basis of the present research, a low start motion pattern was created, which enables proper selection of appropriate sprinter technique exercises in the quality of its support and improvement.

The work presents an innovative approach to the individual predispositions of sports competition. It has also been demonstrated that the effectiveness of sprinters' start technique is affected by factors from the area of coordination conditions. But in the group of students - the sprint start depends mainly on physical preparation (force-speed predispositions).

The primary purpose of the paper was to identify relations between motor preparation and speed parameters in the group of experts-sprinters and in the group of novices-students. Assessment was adopted of interdependencies among motor parameters and motion structure indicators. Identification was made of the most predictive variables determining sprint start effectiveness, depending on the sprinters' sport level.

It was hypothesized that the most predictive indicators determining sprint start effectiveness may be parameters of the area of time conditions (speed) and motion structure (coordination). While, the student group will demonstrate advantage in the motor parameters (force, fitness).

2. Methods

2.1. Subjects

Initial tests involved a group of 20 specialist stage sprinters of 1st and 2nd sport class, Academic Sports Association, Technical University of Opole (age: 21.75 ± 3.03, body weight: 80.63 ± 8.50, body height: 1.86 ± 0.09, BMI: 23.17 ± 0.35) with training seniority 6.40 ± 1.79 and a group of 5 students on their 4th and 5th year of master's study programs (age: 20.80 ± 4.53, body weight: 74.20 ± 11.91, body height: 1.82 ± 0.07, BMI: 22.32 ± 1.87).

The second group was a group of 35 students-novices on second-degree studies in physical education major. In the curriculum of studies, the students had completed 2 semesters of advanced theory and methodology of athletics. The research was conducted upon approval by the Bioethics Commission of the Opole Doctors' Chamber in Opole, which is confirmed by Resolution No. 208 of 05 June 2014.

2.2. Methodology

The tests were preceded by a 20-minute general warm-up along. The tests were conducted in two stages. In the first place, force preparation and jumping ability tests were conducted (standing long jump, standing triple jump and both feet jump on the Kistler platform). In the second run, speed preparation test was conducted (30 m run from start block) with simultaneous recording of the EMG signal. Three attempts were made for each test. On the basis of the results obtained from motor tests and EMG records and cameras, one-best attempt for each participant was subjected to detailed analysis.

Bioelectric voltage was examined from the following muscles: flexors and extensors of the upper both (R and L) limbs: BB and TB as well as flexors and extensors of the lower both (R and L) limbs: RF, VL, BF, STN, GAS MED.

On the other hand, on the basis of video frame records from two cameras, reading was made of the start reaction time the first visible movement on footage started with the activity of the examined arm muscles, then the moment of detaching the back foot and the front foot from the block, the time of the first contact of the both feet with the base, as the time of making the first two steps after start. Running time records were also obtained from photocells for the distances of 5 m, 10 m and 30 m after start. Bioelectric activity timing of selected muscle groups was recorded based on the EMG system. Medium EMG voltages were registered of muscles participating in the start phase, at the moment of exiting the block as well as the first two steps after the start as one continuous recording.

The tests were made with the following equipment: telemetric system configured with two quick cameras, 16-channel surface electromyography system (sEMG), sound signal activation system synchronized with EMG equipment, Kistler platform used for registration of base forces reactions and evaluation of foot pressure forces, electric time measurement system (photocells).

Electrodes were placed in muscles in accordance with the SENIAM project procedures. Surface electrodes (Ag/AgCl) were placed adequately and exactly on a given muscle so that the signal properly reached the middle part of the muscle belly, at the distance of ca. $1-2$ cm, as far as possible from the muscle motor points, as far as possible from the muscle tendons, lengthwise relative to the muscle fibre [4].

2.3. EMG signal processing and the technical specification and software of the system

Processing of EMG signal took place in adequately prepared software (MyoResearch XP Master Edition for DTS Noraxon system). There are many adjustment possibilities, however, initial signal ''processing'' usually consists in filtration, including ''removal'' of the so-called record artefacts [4].

Another way to correct the EMG signal was Data rectification (change of impulses from negative to positive). Concerns ''transfer'' of the lower ranges of amplitude (under zero line) to one-upper data scale. The desirable signal processing method is also Average value data smoothing in order to obtain a clearer EMG curve.

MyoResearch XP Mater Edition software was used in order to determine muscle activation baseline (Onset/Offset). Activation threshold values were estimated on the basis of baseline based on the peak value -5% [4].

Synchronization of signals $-$ video records, EMG and starter shooting sound were connected by means of CRI VIST synchronizer (CRI Jolanta, Poland). The device at the same

time sent the TTL triggering signal with the set frequency to cameras, electromyography device via the TeleMyo 2400 G2 Mini Receiver (Noraxon, Inc, United States), as well as DT9812 analogue module (Date Translation, Inc, United States), and registration was enabled by the following programs: StreamPix 5, MyoResearch XP 1.07 Master Edition and for Mics sound and analogue signals recording software (CRI Jolanta, Poland), which received frames from two cameras, electrical signal from the electromyography device and sound. Synchronization error of camera signals, EMG and sound did not exceed 10ms.

The jumps were recorded by means of a Kistler force platform 9286AA — (Kistler, Switzerland) — and BioWare software 4.0.1.0 (Kistler, Switzerland).

2.4. Statistical analyses

The collected research material was developed using Statistica 13.0. All the hypothesis considered in the paper were verified at significance level $P \leq 0.05$. The assumption about the normal distribution of the analysed statistical features was tested using the Shapiro-Wilk test.

Due to the fact that not all the features have met the assumptions of normal distribution, to test. Interdependence of it nonparametric tool — rank factor Spearman correlation (R) and the nonparametric test — Anova test used to compare the speed and motor parameters of experts-sprinters and novices-students group.

3. Results

Fig. 1 presents both feet jump on the Kistler platform (0.56 m), by the best sprinter among the sprinters group.

Table 1 presents basic statistic and the Anova test of the speed parameters and the motor preparation of the of experts-sprinters and novices-students group.

We can observe the significant differences of the averages of the all tests between the participant of both group. The differences between the average speed parameters of both groups were as follows: in start reaction time in both group were 0.017 [s], in detachment of the back foot 0.043 [s], in detaching the front foot 0.07 [s], in first contact of the back foot 0.04 [s], in first contact of the front foot 0.06 [s], and the run on the 5 m distance 0.70 [s], 10 m 0.75 [s] and 30 m 0.17 [s].

We can also observe the significant statistical differences were shown almost in all the variables. The exception is the maximum value of the both feet rebounding force on the Kistler platform in the case of the sprinters. On the other hand, in the group of students, the significance coefficient value turned out to be higher in all the variables than the usually assumed level ($P \leq 0.05$).

Table 2 presents Spearman rank correlations between motion structure indicators (muscles' bioelectric voltage) and motor preparation parameters in the start phase in the group of experts-sprinters and novices-students.

It can be noted (Table 2) that the statistically significant values are usually demonstrated by explosive — dynamic force tests: standing far jump (0.43), standing triple jump (0.35; 0.42; 0.62) and the maximum value of the both

feet rebounding height (0.36; 0.55; 0.51) and the both feet rebounding force (0.35) on the platform (Tables 3 and 4).

On the basis of subsequent parameters, the relationship of average EMG signal values was examined with time structure indicators (Tables 3 and 4). In the case of both examined groups, significant interdependencies were identified, determining sprint start effectiveness.

In the group of sprinters for muscles: GAS.MED. PR, BF L, STN L, RF and VL several significant values were obtained on a moderate level (0.45; 0.47; 0.53; 0.54; 0.57, 0.61).

A muscle activation model in the pre-start VL and post-start phase was obtained: GAS. MED, RF, BF and STN for the sprinters' sprint start.

This applies in particular to the sequence of activation of muscles of the front limb and the back limb in the post-start phase. It is associated with triggering lower limb muscle groups appropriate for the given sprint start phase (front group: VL, RF, GAS. MED. and the back group: STN and BF) in the case of the sprinters [16,20,21]. On the contrary, the student group demonstrated an advantage in activation of muscles of the upper limbs also in the post-start phase: BB and TB. However, these correlations did not show associations at a high level.

Table 5 presents data concerning correlation of motor preparation variables with time structure indicators in sprinters.

An important fact is that a definitely higher interdependence (in the case of students) is demonstrated by time measured after running the distance of 30 m with motor preparation coefficients (Table 5). It may be concluded that the maximum rebounding power [W/mass] most often shows a significant relation with time of running the distance of 30 m [s].

4. Discussion

The presented research was showed the comparisons of the world experts in sprint start field [18,22—26]. This hypothesis has been confirmed, that the effectiveness of sprinters' start technique expressed by the EMG structure (muscles' bioelectric voltage), is affected by factors from the area of coordination conditions, but in the group of students, the effectiveness of the sprint start depends on force-speed predispositions [16,27—30].

Many trainers and researchers think that the use of electromyography (EMG) is widely recognized as a significant tool for enhancing the development of performance and potential injury risk in sprinting [2,31].

Force and speed parameters play an important role affecting the sprinters' final results. The main goal of a player is to achieve maximum dynamic force expressed by optimal initial speed of the run. Dynamic force was measured using typical force tests of the sprinters' lower limbs. Standing far jump and standing triple jump were used, treated as a measure of lower limbs' power. Jumping tests were performed on the Kistler platform (jump height, maximum force and lower limbs' rebounding power).

In this work, an analysis was conducted of interrelations between the level of motor preparation of sprinters, and motion structure indicators (muscles' bioelectric voltage) determining sprint start effects. With regard to analysis of

Figure 1   Both feet jump on the platform by the chosen sprinter.

Table 1   Statistical tests: basic statistic (averages, SD) and Anova test of the speed parameters and the motor preparation of the of experts-sprinters and novices-students group.

	Anova Test			$P \leq 0.05$		
	Sprinters		Students			
Variable	$\overline{x}$	SD	$\overline{x}$	SD	F	P^*
Start reaction time	0.152	0.021	0.169	0.027	5.940	0.018
Detachment of the back foot	0.357	0.046	0.400	0.046	11.194	0.002
Detaching the front foot	0.54	0.054	0.61	0.048	22.507	0.000
First contact of the back foot	0.62	0.051	0.66	0.049	11.178	0.002
First contact of the front foot	0.87	0.059	0.93	0.066	10.109	0.002
5 m	1.65	0.093	2.35	0.411	54.708	0.000
10 m	2.33	0.112	3.08	0.438	54.569	0.000
30 m	4.18	0.162	4.35	0.203	10.527	0.002
Standing far jump	2.69	0.20	2.45	0.15	21.426	0.0002*
Standing triple jump	8.06	0.67	6.99	0.61	38.091	0.0001*
Both feet jump height	0.54	0.06	0.44	0.07	19.447	0.0001*
Maximum both feet rebounding force	2.74	0.33	2.66	0.35	0.006	0.938
Maximum both feet rebounding force	72.43	8.11	63.83	7.61	17.428	0.0002*

* $P \leq 0.05$.

Table 2 Spearman rank correlations between motion structure indicators (muscles' bioelectric voltage [μV]) and motor preparation parameters in the start phase in the group of sprinters and students.

Variable	Sprinters					Students				
	Standing far jump	Standing triple jump	Both feet jump height	Maximum both feet rebounding force	Maximum both feet rebounding force	Standing far jump	Standing triple jump	Both feet jump height	Maximum both feet rebounding force	Maximum both feet rebounding force
BB R	0.13	0.18	0.24	−0.17	−0.02	0.08	0.10	0.16	−0.14	−0.03
TB R	0.09	0.32	0.18	−0.37	−0.26	−0.05	0.35[a]	0.24	0.17	0.25
BF R	−0.13	−0.09	0.24	−0.15	−0.07	0.20	0.16	0.36[a]	0.32	0.07
STN R	0.01	−0.22	0.15	0.02	0.13	0.17	0.42[a]	0.13	0.02	0.23
GAS.MED R	−0.38	−0.17	−0.03	−0.29	−0.21	0.43[a]	0.15	0.55[a]	0.25	0.20
RF R	0.15	−0.15	0.19	−0.10	0.13	0.06	0.21	0.22	0.27	0.17
VL R	0.24	−0.11	0.05	−0.28	−0.05	−0.08	−0.17	0.03	0.35[a]	0.01
BB L	0.00	−0.01	0.16	−0.4[a]	−0.19	−0.05	0.25	0.13	−0.29	0.01
TB L	0.12	0.16	0.03	−0.18	0.02	0.09	0.62[a]	0.02	−0.01	0.18
BF L	0.28	−0.08	0.24	−0.41	−0.02	−0.12	−0.02	−0.25	−0.01	−0.15
STN L	−0.12	−0.27	0.01	−0.37	−0.03	0.06	0.27	−0.10	−0.31	0.07
GAS.MED L	0.12	−0.11	0.17	−0.36	−0.07	0.05	0.15	0.30	0.16	0.09
RF L	−0.19	−0.35	0.03	−0.16	−0.10	−0.12	0.06	−0.12	−0.28	−0.17
VL L	−0.13	−0.16	−0.11	−0.08	0.05	−0.29	−0.05	−0.5*	0.03	−0.16

[a] Statistical significance (*P*) is at the level ≤ 0.05.

Table 3 Correlations for variables determining average EMG signal values and time structure indicators among sprinters (R: right limb; L: left limb).

Variable	Spearman rank order correlation (Sprinters) $P \leq 0.05$							
	Start reaction time	Detaching the back foot	Detaching the front foot	First contact of the back foot	First contact of the front foot	5 m	10 m	30 m
BB R	−0.10	−0.16	−0.12	−0.23	−0.02	−0.27	−0.30	0.38
TB R	−0.35	−0.23	0.03	−0.06	0.14	−0.07	−0.02	0.32
BF R	−0.09	−0.19	−0.18	−0.28	−0.06	0.11	0.12	0.18
STN R	−0.15	−0.21	0.01	−0.08	−0.03	0.08	0.14	0.22
GAS.MED R	0.24	0.38	0.54[a]	0.53[a]	0.61[a]	0.38	0.38	−0.22
RF R	0.25	−0.03	0.26	0.03	0.10	0.27	0.28	0.32
VL R	0.20	0.07	0.37	0.22	0.16	0.35	0.37	0.37
BB L	0.06	−0.01	0.08	−0.06	0.15	0.16	0.12	0.40
TB L	−0.31	−0.04	−0.01	0.05	0.05	−0.07	−0.05	−0.07
BF L	0.29	0.33	0.45[a]	0.32	0.25	0.57[a]	0.57[a]	0.25
STN L	0.36	0.43	0.57[a]	0.47[a]	0.53[a]	0.47[a]	0.47[a]	0.06
GAS.MED L	0.08	0.07	0.29	0.27	0.16	0.18	0.19	0.07
RF L	0.11	0.29	0.27	0.33	0.16	0.44	0.47[a]	0.29
VL L	0.45[a]	0.38	0.30	0.17	0.12	0.44	0.40	0.20

[a] Statistical significance (P) is at the level ≤ 0.05.

Table 4 Correlations for variables determining average EMG signal values and time structure indicators among the students (R: right leg; L: left leg).

Variable	Spearman rank order correlation (Students) with $P \leq 0.05$							
	Start reaction time	Detaching the back foot	Detaching the front foot	First contact of the back foot	First contact of the front foot	5 m	10 m	30 m
BB R	0.20	0.30	0.45[a]	0.48[a]	0.48[a]	−0.04	−0.01	0.07
TB R	0.27	0.13	0.24	0.14	0.16	0.01	0.02	0.17
BF R	0.19	0.25	0.26	0.18	0.27	−0.05	−0.03	0.16
STN R	−0.19	−0.08	0.13	0.00	0.09	0.05	0.04	0.06
GAS.MED R	0.14	0.32	0.27	0.25	0.31	−0.11	−0.12	0.15
RF R	0.08	0.03	0.12	−0.02	0.01	0.04	0.03	−0.10
VL R	−0.20	−0.19	−0.12	−0.19	−0.14	0.07	0.07	−0.01
BB L	0.33	0.29	0.32	0.21	0.22	−0.13	−0.10	0.12
TB L	0.32	0.30	0.37[a]	0.38[a]	0.35[a]	0.03	0.04	0.24
BF L	0.01	0.01	0.00	−0.03	0.01	−0.17	−0.16	0.18
STN L	−0.02	0.08	0.04	0.00	−0.06	−0.23	−0.23	0.03
GAS.MED L	−0.06	0.03	0.15	0.06	0.13	−0.14	−0.14	0.21
RF L	−0.05	0.01	0.04	−0.02	0.00	0.00	0.00	0.11
VL L	0.26	0.11	−0.04	0.00	0.00	0.07	0.07	0.16

[a] Statistical significance (P) is at the level ≤ 0.05.

Table 5 Spearman rank correlation of motor preparation variables with the time structure indicators among sprinters.

Variable	Sprinters					Students				
	Standing far jump	Standing triple jump	Both feet jump height	Maximum both feet rebounding force	Maximum both feet rebounding force	Standing far jump	Standing triple jump	Both feet jump height	Maximum both feet rebounding force	Maximum both feet rebounding force
Start reaction time	0.04	−0.04	0.12	−0.04	0.13	0.25	0.21	0.20	0.15	0.23
Detachment of the back foot	−0.01	0.01	0.02	−0.16	0.09	−0.07	−0.13	−0.29	0.10	−0.16
Detachment of the front leg	−0.10	−0.01	0.02	−0.35	−0.11	−0.04	−0.10	−0.19	0.11	−0.10
First contact of the back leg	−0.30	−0.17	−0.18	−0.25	−0.19	−0.10	−0.05	−0.28	0.15	−0.12
First contact of the front leg	−0.16	0.02	−0.02	−0.38	−0.13	0.05	−0.05	−0.19	0.19	−0.13
5 m	−0.40	0.38	−0.28	−0.61[a]	−0.40	−0.22	−0.20	0.05	0.02	−0.14
10 m	−0.41	−0.36	−0.27	−0.57[a]	−0.41	−0.23	−0.20	0.04	0.00	−0.14
30 m	−0.12	−0.10	−0.02	−0.17	−0.14	−0.53[a]	−0.55[a]	−0.38[a]	−0.19	−0.48[a]

[a] Statistical significance (P) is at the level ≤ 0.05.

motor preparation parameters in specialist stage sprinters and students-novices of second-degree studies in physical education major, a tendency has been outlined for a greater diversity in the force and speed parameters. In particular, it was concerned with far jump and standing triple jump as well as both feet rebounding height and maximum both feet rebounding force on the platform. This proves the specific nature of the practiced competition, including the application of training accents focused on the development of the group of extensor muscles RF and VL as well as flexors BF and STN of the knee joint.

In the further part of the paper, Spearman rank correlations were conducted between motion structure indicators (EMG signal value) and motor preparation parameters of the analysis, which were focused around group comparisons. In the group of sprinters, they showed statistically significant relations between two variables: activation of muscle BB L [μV] and the maximum both feet rebounding force [N/weight] at the level of $R = -0.47$. On the other hand, in the group of students expressly more statistically significant associations were recorded as compared to specialist stage competitors. Comparison of results of the two groups clearly indicates the principle known from the theory of sport [1] that the effectiveness of technique in specialist stage sportsmen, expressed by EMG, is not substantially affected by physical preparation, but by factors from the area of coordination, neuro-physiological conditions etc. On the contrary, the effectiveness in students having a status of novices depends to a large extent on motor preparation indicators, mostly with regard to force-speed predispositions [32].

Test results of the sprinters [33] do not confirm the above hypothesis. They suggest that physical training capabilities prevail definitely more in the examined sportsmen, and coordination skills and psychomotor skills are significant only to a small extent.

At the further stage of the study dependencies were examined of EMG signal values with time structure indicators of the two groups. It was indicated that in the group of sprinters, the greatest correlations were observed among groups of muscles that mostly affect the effectiveness of the start phase and running speed of the sprinters. These muscles are, among others: GAS. MED, BF, STN RF and VL. On the other hand, in the case of the group of students (novices) statistically significant relations were demonstrated in groups of muscles: BB and TB [21,29,30].

Based on this, the muscle activation model was obtained in the pre-start and post-start phase of sprinters' sprint start. It has been proved that nervous-muscular coordination capabilities in the phase before and after the start have substantial effect on creating the motor program for specialist stage sportsmen [13]. This is definitely related to the factor of activating lower limb muscle groups appropriate for the given sprint start phase. On the contrary, the student group demonstrated advantage in activation of muscles of the upper limbs only in the post-start phase. It should be added that these muscles take part in the whole run step cycle supporting the frequency of movement [14,26,34−37].

An analysis was conducted of Spearman rank correlation between time structure indicators and motor preparation indicators. The received high motor preparation coefficient values associated with jumps [m], maximum values of force [N/weight] as well as rebounding power [W/mass] in the case of competitors-sprinters may be considered as justified and anticipated. Motor preparation in sprinters does not substantially affect the initial run phase, while with reference to the group of students there is a statistically significant effect on subsequent 30 m run stages.

As stated by Mero and Komi [18,38] as well as Čoh et al. [27,28], there are statistically significant relations between force measured on the Kistler platform, EMG indicators and run speed. They stated that the stronger the EMG signal during maximum and supramaximum efforts, the higher the value of generated force expressed by run step speed and length.

On the basis of the obtained results it has been diagnosed that comparison of results from both groups clearly confirms the principle known from the theory of sport that the effectiveness of technique for specialist stage sportsmen, expressed by EMG, is not substantially affected by physical preparation, but by factors from the area of coordination conditions, neurophysiological conditions. On the contrary, the effectiveness of students having the novice status depends to a large extent on motor preparation indicators, mostly with regard to force−speed predispositions ($R = 0.62$ and 0.55). We can claim that better developed predispositions in the field of nervous-muscular coordination in sportsmen at the specialist stage are significantly correlated with the sprint start time structure parameters. On this basis the main hypothesis of this paper was confirmed.

Diverse impact has been proved of motor preparation on the effectiveness of sprint start in the group of specialist stage sportsmen and so has been a significant impact of this factor on the group of students-novices of second degree study programs in physical education major. The results of research have revealed the importance of phases before and after the start in sprinters' sprint start.

5. Conclusions

The specialist stage group activated muscles critical for the movement pattern structure at sprint start: TB, BB, RF and VL (all of the right and left limb).

The effectiveness of sprinters' start technique expressed by the EMG structure (muscles' bioelectric voltage), is affected by by factors from the area of coordination conditions.

In the group of students, the effectiveness of the sprint start depends mainly on force-speed predispositions.

6. Practical applications

From the point of view of coaching practice, the most important EMG applications are:

- constant assessment technical skills development and improvement from the initial stage to master's sport training, taking account of functional symmetry and asymmetry;
- creation of motion patterns of particular techniques along with selection of adequate exercs, fostering their improvement.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Husbands C. Sprinting. In: Training, techniques and improving performance. Ramsbury, Marlborough: The Crowood Press; 2013.

[2] Masso N, Rey F, Romero D, Gual G, Costa L, German A. Surface electromyography applications in the sport. Apunts Med Esport 2010;45(165):121—30.

[3] Starkes JL, Ericsson KA. Expert performance in sports. Hum Kinet Champaign 2003.

[4] De Luca CJ, Gilmore LD, Kuznetsov M, Roy SH. Filtering the surface EMG signal: movement artifact and baseline noise contamination. J Biomech 2010;43(8):1573—9.

[5] Docherty D, Hodgson M. The application of postactivitation potentiation to elite sport. Int J Sports Physiol Perform 2007;2:439—44.

[6] Hafez MA, Roberts EM, Seireg AA. Force and velocity during front foot contact in the sprint start. Human Kinetics, Champaign, IL; 1985. p. 350—5.

[7] Hiserman J. A program design method for sprint and hurdle training. High performance training for track and field 2008.

[8] Jeffreys I. Developing speed. National Strength and Conditioning Association, Human Kinetics, Champion II; 2013.

[9] Reis VM, Fazenda LM. Associations between the placement on the starting blocks and indoor sprint performance. Int J Perform Anal Sport 2004;4:54—60.

[10] Smith M. High performance sprinting. Ramsbury, Marlborough: The Crowood Press; 2005.

[11] Collet C. Strategic aspects of reaction time in world-class sprinters. Percept Mot Skills 1999;88:65—75.

[12] Parry TE, Benson PH, Cooper J. Lateral foot placement analysis of the sprint start. New Studies Athletics 2003;18:13—22.

[13] Ward AJ, Radford PF. Investigation of the kinematics of anaerobic metabolism by analysis of the performance of elite sprinters. J Biomech 2000;33:997—1004.

[14] Maćkała K. Optimisation of performance trough kinematic analysis of the different phases of the 100 metres. New Studies Athletics 2007;2:7—21.

[15] Ozolin E. The technique of the sprint start. Athlete Coach 1988;26(3):38—9.

[16] Mero A, Komi PV, Gregor RJ. Biomechanics of sprint running. Sports Med 1992;6(13):376—92.

[17] Schmidt RA. Motor control and learning. A behavioral emphasis. 2nd ed. Los Angeles: Human Kinetics, Publishers, Inc. University of California; 1988. p. 64—5.

[18] Mero A, Komi PV. Reaction time and electromyographic activity during a sprint start. Eur J Appl Physiol Occup Physiol 1990;61(1—2):73—80.

[19] Schmidt RA, Wrisberg CA. Motor learning and performance: a situation-based learning approach. Hum Kinet 2008.

[20] Mero A. Force-time characteristics and running velocity of male sprinters during the acceleration phase of sprinting. Res Q Exerc Sport 1988;59:94—8.

[21] Simonsen E, Thomsen L, Klausen K. Activity of mono- and biarticular leg muscles during sprint running. Eur J Appl Physiol Occup Physiol 1985;54(5):524—32.

[22] Čoh M, Peharec S, Bačić P, Maćkała K. Biomechanical differences in the sprint start between faster and slower high-level sprinters. J Hum Kinet 2017;56:29—38.

[23] Higashihara A, Nagano Y, Ono T, Fukubayashi T. Differences in hamstring activation characteristics between the acceleration and maximum-speed phases of sprinting. J Sport Sci 2017:1—6.

[24] Ilbegi S, Gheluwe BV. Biomechanical parameters of young elite. Sprinters, LAP Lambert Academic Publishing; 2014.

[25] Ilbegi S, Gheluwe BV. Electromyographic wavelet analysis of lower extremity muscles during sprint start and two subsequent steps. Port J Sport Sci 2011;11(2):739—42.

[26] Tidom G, Wiemann K. Zur Optimierung des Sprintlaufs - bewegungsanalytische Aspekte. To optimise the sprint run - motion analysis aspects. Leistungssport 1994;24(5):14—9.

[27] Čoh M, Peharec S, Bačić P, Kampmiller T. Dynamic factor and elektromyographic activity in a sprint start. Biol Sport 2009;26(2):137—47.

[28] Čoh M, Žvan M, Peharec S, Bačić P. Kinematic, dynamic and elektromyographyc characteristic of a sprint start. OuroPreto—Brazil: XXV ISBS Symposium; 2007. p. 492—9.

[29] Wiemann K, Tidom G. Die Adduktorenbeim Sprint—bishervernachlässigt? (The adductors on the Sprint - so far neglected? The teaching of athletics). Die Lehre der Leichtathletik 1994;10(3):15—9.

[30] Wiemann K, Tidom G. Relative activity of hip and knee extensors in sprinting − implications for training. New Studies Athletics 1995;10(3):29—49.

[31] Howard RM, Conwaya R, Harrison AJ. Muscle activity in sprinting: a review. Sports Biomech 2017:1—17.

[32] Schot PK, Knutzen KM. A biomechanical analysis of four sprint start positions. Res Q Exerc Sport 1992;63:137—214.

[33] Fostiak M, Fostiak D, Domagała Ł. Ocena poziomu koordynacyjnych zdolności motorycznych w lekkiej atletyce i tenisie stołowym (Assessment of the coordination level of motor skills in athletics and table tennis). AWF Gdańsk; 2014.

[34] Atwater AE. Kinematic analysis of sprinting. Indiana, USA: Indiana University; 1980. p. 303—14. Paper presented at the meeting of Biomechanics Symposium, CIC Big 10 Body of Knowledge Conference, At Indiana University.

[35] Čoh M, Tomažin K. Kinematic analysis of the sprint start and acceleration from the blocks. New Studies Athletics 2006;3:23—33.

[36] Čoh M, Jošt B, Škof B, Tomažin K, Dolenec A. Kinematic and kinetic parameters of sprint start and start acceeration model of top sprinters. Gymnica 1998;28:33—42.

[37] Korchemny R. A new concept for sprint start and acceleration training. New Studies Athletics 1992;7:65—72.

[38] Mero A, Komi PV. Force-, EMG-, and elasticity-velocity relationships at submaximal, maximal and supramaximal running speeds in sprinters. Eur J Appl Physiol 1986;55(5):553—61.

Glossary

Legend to the muscles activation: *R:* right limb
L: left limb
BB: biceps brachii
TB: triceps brachii
BF: biceps femoris
STN: semitendinosus
GAS. MED: gastrocnemius medialis
RF: rectus femoris
VL: vastus lateralis

Legend of the sprint start phase:

The pre-start phase: the phase after the signal sound, but before the start

The post-start phase: the phase after the start, since the first visible movement on the film to first two steps after the start