Method of technical training of elite para athletes throwing in sitting position

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Abstract. This study presents a new way to improve technical training in para-athletic disciplines (for athletes with musculoskeletal disorders). The experimental group included 5 men and 1 woman. 5 athletes were preparing to perform in shot put, 2 athletes were preparing to perform in discus throw and 5 athletes were preparing to perform in javelin throw. An algorithm for technical training was developed, comprising three stages. The first stage includes high-speed video recording of the performed exercises in the front plane (from the front, from the back), sagittal plane (from the right, from the left), and transverse plane using a video camera attached to the quadcopter. The second stage includes synchronization of video recordings, recognition of markers, and obtaining 3D biomechanical model of the exercise. The third stage includes the analysis of kinematic characteristics of equipment of competitive exercises with the subsequent interpretation and comparison with the model characteristics revealed earlier by identification of parameters of available motor actions. The recommendations for updating the individual locomotion in the activity and guidance on the selection of major exercises were elaborated. According to the developed algorithm, six measurements were performed in each competitive discipline during the preparatory period of 2 months. After identifying the reserves of equipment, the technique was corrected in each competitive exercise, and the individual recommendations for optimizing the technique were given. At the end of the experiment, the average improvements of athletes were 0.85±0.13 m in discus throw (n=5, $P<0.01$), 3.15±0.69 m in shot put (n=2, $P<0.05$); 2.53±0.41 m in javelin throw (n=5, $P<0.001$). At important competitions at the end of the experiment, the athletes set 10 personal records.

1 Introduction

Throwing performed by disabled athletes in a sitting position is included in the Paralympic games program since the first games of 1960. At the present stage of Paralympic sports development, from 26 to 34 medals are awarded in these disciplines (15-18% of the total amount). These disciplines include shot put, discus throw, javelin throw, and club throw

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[1]. They have no analogues in the Olympic sports and are characterized by a special technique of performing competitive exercises [2].

Technical training is one of the key areas of sports training in the athletics disciplines, especially at the pre-competition stage [3-4]. Without its effective implementation, it is impossible to bring the athlete to the maximum level of sports results. The available scientific literature has no data on the development of methods of technical training in the para-athletics disciplines. Only several experiments studied the individual technique of competitive exercises. These experiments assessed the biomechanical parameters of implementation of different physical actions during the competitive activity of athletes [3-6].

One of the directions of optimization of technical training in various sports is correction of separate motor actions. This correction can be performed after determining the optimal values of individual locomotions (the model characteristics of performing motor actions). In Paralympic sports, such optimization can have a positive effect only if the functional features of the athlete associated with the disability are taken into account. Previously, we have analyzed the technique of throwing various sports equipment by elite Paralympic athletes in the senior World Competitions – Paralympic games, World and European Championships [7-8]. Based on the data obtained, model characteristics of the main ways of shot put, discus throw, javelin throw, club throw in the sitting position were developed. The model characteristics were defined for athletes whose nosological features (amputation of one or two legs, cerebral palsy of the lower extremities, etc.) were almost completely leveled by the use of throwing machines.

This study aims to develop and experimentally justify the technique of technical training of elite para athletes in throwing from a sitting position, considering the characteristics of the athlete associated with disability and features of competitive equipment.

2 Methods

The developed technique of technical training includes the following methods:

- Pedagogical testing. It is used to determine the level of special physical fitness. A week before the beginning of the pedagogical experiment and a week after its completion, 2 pedagogical testing were conducted to evaluate the change in the physical preparation of the athlete during the experiment [9]. The tests highly correlated with the results of the competitive exercises, and made it possible to assess the level of special physical preparedness. The tests included medicinal throw with two hands from behind the head; medicinal throw with two hands from the chest; 150 g ball throw with one hand; bar press lying on the back (bar mass equals 70% of the athlete's weight), 5 presses with time recording; arm flexion and extension in the hanging position, 5 repeats with time recording; bar press lying on the back with recording of maximum weight [10];

- Biomechanical (B/m) analysis. It is used to identify the characteristics of the technique of performing competitive exercises by an athlete (B/m analysis 1). It consists of three stages.

The first stage includes high-speed (100 Hz) video recording of the performed exercises (throwing) using nonsynchronous cameras in front plane (camera 1 is in front, camera 2 is behind), sagittal plane (camera 3 is on the right, camera 4 is on the left), and transverse plane (camera 5). Such arrangement of cameras makes it possible to effectively perform video analysis of the technique of competitive exercises of athletes performing throwing [11-14]. For the possibility of further synchronization of video recording, a temporary calibration is performed using the reference stopwatch, as well as the calibration of the space used by the athlete. When recording video, reflective markers are attached to the

main joints of the athlete. Further processing and analysis of video from each camera is performed using the program "Dartfish 5.5".
The second stage is to synchronize data and obtain 3D biomechanical model of exercises using the program MATLAB 7.10 (R2010a), by combining the spatial and temporal characteristics obtained from shooting with several video cameras.
The third stage is the analysis of kinematic and angular speed characteristics of the technique of competitive exercises with subsequent systematization, generalization of data using the methods of mathematical statistics.

- Biomechanical analysis 2 (B/m analysis 2). It is used to identify the nosological features of the technique of performing competitive exercises. The need to identify the values which are available for athlete's motor actions is associated with the presence of features that affect physical ability. This method consists of three stages.

The first stage includes video recording of individual competition actions in the sitting position without the sports equipment by analogy with the B/m analysis 1. When performing movements in the joint in one plane, imaging is performed with one camera followed by determination of angular amplitude using the "Dartfish 5.5" program, and the second stage is not performed.
The second stage is synchronization of the main parameters of motion, providing a 3D biomechanical model of performing certain motor actions by analogy with the B/m analysis 1 (used in the analysis of motion performed in two projections);
The third stage is to determine the maximum possible amplitude of performing certain locomotions of a competitive exercise involving the affected body link(s).

- Computer simulation. The software was developed to evaluate the throwing efficiency in a competitive exercise depending on the biomechanical characteristics (the sports equipment departure angle, flight speed, flight height), which are determined from biomechanical analysis (B/m analysis 1).

- Formative pedagogical experiment. It is aimed to check the effectiveness of the developed technique.

- Methods of mathematical statistics and analysis. The study uses standard statistical methods for sports pedagogics.

Description of the developed methods of technical training.

For elite para athletes, specializing in throwing from the sitting position, a technique of technical training was developed, consisting of the following components:
- Preliminary pedagogical testing, which comprehensively assesses the level of special physical fitness of the athlete before the cycle of technical training.
- Biomechanical analysis (B/m analysis 2) to identify the functional capabilities of the athlete, limited by the characteristics of the disability and the rules of the competition.
- Formative pedagogical experiment. It is a developmental three-week cycle of multidirectional training at the stage of pre-competition training, conducted during a centralized training camp [15].

The proposed algorithm included in the cycle of technical training makes it possible to identify characteristics of exercises performed by the athlete, compare them with model characteristics and give recommendations for their optimization. The frequency of these classes is determined by rational periodization.

During the pedagogical experiment, the optimality of biomechanical characteristics of the sports equipment flight is checked by computer simulation.

To systematize and generalize the results obtained in the pedagogical experiment, conventional methods of mathematical statistics are used:

- At the end of the experiment, repeated pedagogical testing is carried out to assess the change in the level of special physical fitness during the experiment.

For implementation of the developed technique of technical training of elite Para athletes, specializing in throwing in the sitting position, as well as for solving other training tasks, we, together with the personal coaches of athletes in the experimental group, developed plans of three identical weekly microcycles. (These plans were drawn up on one microcycle, which was repeated three times). The experiment is carried out at the stage of pre-competition preparation.

Thus, the training loads in a week microcycle include three technical training sessions per week. During one of the technical training, the athlete performs training in two disciplines. Further we used this scheme for all its participants during the experiment. It should be noted that there were no cancellation of training sessions, injuries and diseases of athletes. This confirms the optimality of the selected loads.

A video recording with further biomechanical video analysis and comparison of the best (most effective) attempts in the competitive exercise performed with maximum intensity is carried out twice a week during the microcycle of the technical training. The biomechanical characteristics obtained by the B/m analysis 1 are then compared with model characteristics taking into account the nosological features revealed earlier by B/m analysis 2. If the obtained biomechanical values do not correspond to the model characteristics, the recommendations for their correction are developed. For greater visibility of the revealed discrepancies, video recordings are shown to coaches and athletes.

3 Results

To implement and check the efficiency of the developed technique, an experimental group of 6 elite athletes specializing in the athletic throwing performed in sitting position was formed. The group included 5 men and 1 woman. 5 athletes were preparing to perform in shot put, 2 athletes were preparing to perform in discus throw and 5 athletes were preparing to perform in javelin throw. The experiment was conducted during the training camps held from 7 to 28 April 2021. The duration of the experiment was 6 weeks. The first pedagogical testing was conducted two days before the experiment.

Before the beginning of experiment, revealed were the peculiarities of performance of motor actions of the athlete connected with features of disability which could be included in competitive exercises. Biomechanical analysis was carried out to identify the nosological features of the technique of performing competitive exercises (B/m analysis 2). The following features were identified:

- Athlete A.A. is able to perform all the motor actions necessary to effectively perform competitive exercises in which he specializes (shot put, discus throw, javelin throw);
- Athletes K.A. and V.M. cannot perform body movements below the level of the diaphragm, including the leg and pelvic muscles;
- Athlete M.E. has spastic diplegia of the leg muscles, transmitting tightness to the abdominal muscles, as well as to the oblique muscles of the trunk. Spastic manifestations were also detected in the flexor muscles of the right (supporting) hand - elbow joint and wrist. Maximum extension of the right arm at the elbow is possible up to an angle of 164°. Maximum extension of the right arm at the wrist during the pole support grip is possible up to an angle of 172°;
- Athlete X.A. is similar to athlete M.E. in the limitations of the right arm. Maximum extension of the right arm at the elbow is to an angle of 176°. Maximum extension of the right arm during the pole grip is to an angle of 170°;
- Athlete F.B. has cerebral paralysis, tetraparesis. Ataxia, hypotension of all major muscle groups of limbs and muscles of the body were diagnosed. The maximum extension of the right hand in the wrist, when performing grip holding bar is to an angle of 174°.

During the pedagogical experiment, the biomechanical analysis (B/m analysis 1) of the characteristics of the technique of performing competitive exercises by athletes using high-speed video shooting and subsequent obtaining of computer kinematic models was carried out.

In accordance with the developed methodology, the analysis of obtained biomechanical characteristics and their comparison with model characteristics was carried out. Parameters that go beyond the model values were detected. The recommendations for optimization of the athlete's movements were elaborated, emphasis was placed on technology implementation. The recommendations were given on selection of a complex of exercises contributing to bringing biomechanical characteristics to model values. At the same time, computer modeling was carried out to evaluate the effectiveness of the parameters of throwing the sports equipment.

During the experiment, six measurements were made in each profile discipline. A total of 72 tests were performed. The results of several technical training, which athletes performed without biomechanical analysis (B/m 1), were corrected manually. When analyzing the results of testing the athletes from the experimental group (n=6), it was revealed that by optimizing the dynamic characteristics, athletes established 33 results exceeding the best personal achievements: 5 athletes set 11 personal records in shot put; 2 athletes set 9 personal records in discus throw: 5 athletes set 13 personal records in javelin throw. The results are presented in Table 1.

When comparing the results of the first and sixth technical training sessions (beginning and end of the experiment), the average improvement of athletes were 0.85±0.13 m in discus throw (n=5, $P<0.01$), 3.15±0.69 m in shot put (n=2, $P<0.05$); 2.53±0.41 m in javelin throw (n=5, $P<0.001$).

Two days after the experiment, the second pedagogical testing was conducted. Comparison of the results of the first and second pedagogical tests showed no significant differences ($P>0.05$) between them. This indicates an approximately equal level of special physical fitness of participants before and after the experiment.

Table 1. Results of athletes of the experimental group during technical training sessions, meters

Ath-lete	Discipline	Test1 (11.03	Test2 (17.03)	Test3 (24.03)	Test4 (09.04)	Test5 (14.04)	Test6 (21.04)
A.A.	Shot put	12.63	12.95	12.78	13.15*	13.02	13.37*
M.E.	Shot put	11.16	11.41*	11.60*	11.49	12.23*	12.19
F.B.	Shot put	8.78	8.85	8.86	9.03	9.33	9.13
X.A.	Shot put	10.29	10.01	10.81*	11.43*	11.43*	11.55*
B.M.	Shot put	6.70	6.64	6.70	6.77	7.13*	7.49*
A.A.	Discus	38.64*	40.45*	40.23	40.65*	40.85*	41.26*
M.E.	Discus	19.14	19.89*	21.13*	22.49*	22.12	22.82*
A.A.	Javelin	30.86	32.01*	32.76*	33.92*	32.49	33.58
K.A.	Javelin	26.52	26.05	27.67	27.16	27.86	28.36
M.E.	Javelin	19.12	20.27	21.93*	21.32	22.46*	22.18
X.A.	Javelin	20.74	20.53	21.49*	22.56*	23.74*	23.42
B.M.	Javelin	13.48	14.12*	14.18*	14.58*	15.76*	15.83*

Note: * is the result exceeding the best personal achievement of an athlete

In senior competition, the National Championship 2021, athletes of the experimental group set 10 personal records in 12 disciplines. When compared with the personal records before the experiment (Table 2), the following improvements were revealed: 0.77±0.25 m in the shot put (n=5, $P<0.05$), 1.84±0.33 m in the discus throw (n=2, $P<0.05$), 2.75±1.23 m in the javelin throw (n=5, $P>0.05$). At the international start of the season, European

Championships in Para-athletics 2021, the athletes of the experimental group set 3 personal records in 12 disciplines, taking 8 first, 2 second and 1 third place (Table 2).

The obtained results indicated that the performed pedagogical experiment using the developed technique and technical training improved the technical preparedness of elite para athletes in competitive exercises. However, a reliable improvement of special physical readiness wasn't revealed.

The technique of technical training of elite athletes in the world para-athletics based on the algorithm for searching the reserves of equipment in competitive exercise taking into account functional features of athletes was approved and introduced.

The results of the study were used in the preparation of elite athletes in the world para-athletics for international competitions.

Table 2. Sports results of the experimental group of athletes

Name/ Gender/ Class	Discipline	Results, m			
		PB in the beginning of experiment	National champ.	European champ.	
				result	Place
A.A./ M/ F57	Shot put	13.04*	13.47**	13.81**	1
	Discus	38.28*	39.60**	42.11**	1
	Javelin	31.95*	32.25**	34.19**	1
K.A./ M/ F57	Javelin	29.49	27.63	27.03	1
M.E./ M/ F33	Shot put	11.36*	12.98**	11.88	1
	Discus	19.84*	22.20**	21.43	3
	Javelin	20.86*	21.36**	19.65	4
F.B./ M/ F32	Shot put	9.36	9.21	9.02	1
X.A./ M/ F33	Shot put	10.49*	11.68**	11.15	2
	Javelin	21.13*	23.60**	21.66	2
B.M./ F/ F54	Shot put	7.02	7.82**	7.04	1
	Javelin	13.99	15.19**	14.34	1

Note:
* - result for the beginning of 2021, after changing the rules of the competition;
** - personal best (PB) at the competition.

4 Conclusion

Effective technical training in the studied disciplines can be built based on the periodic use of the developed methods of technical training. These methods consider the biomechanical parameters of the competitive exercise with their subsequent comparison with model values, taking into account the nosological factor, with further formation and implementation of recommendations for their improvement. For technical training at the stage of pre-competition preparation, it is necessary to perform at least 3 trainings during a week microcycle.

During the experimental confirmation of the effectiveness of the developed technique, a formative pedagogical experiment was conducted. In the experiment, 6 elite athletes in 12 disciplines showed 33 results exceeding the official personal records. The average improvements of athletes were 0.85±0.13 m in discus throw ($n=5$, $P<0.01$), 3.15±0.69 m in

shot put (n=2, P<0.05); 2.53±0.41 m in javelin throw (n=5, P<0.001). At national Championship, which took place after the pedagogical experiment, athletes set 10 personal records in 12 disciplines. At the event when compared with personal bests of the athletes before the start of the experiment, there were improved results: in the shot put (n=5) and 0.77±0.25 m (P<0.05) in the discus throw (n=2) of 1.84±0.33 m (P<0.05), javelin (n=5) of 2.75±1.23 m (P>0.05). Then, at the European Championship, the athletes of the experimental group set 3 personal records in 12 disciplines, winning 11 medals (8 gold, 2 silver and 1 bronze). For comparison, in the previous season (2019), the athletes in the experimental group won 4 medals at the international start (3 gold, 1 silver).

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