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Complex assessment of athletes' operative status and its correction during competitions, based on the body impedance analysis

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Purpose: The aim of this research was assessment and correction of highly skilled swimmers' operative status during competitions.

Material: The authors carried out complex assessment of 46 high-skilled swimmers during competition period. The body impedance analysis and functional status express diagnosis were conducted before and after competitions.

Results: The components limiting the operational state of swimmers were determined: "component composition of the body" (44.83% of the total load), "functional" (19.97%). Correlation relationships were established between the main indicators that determine the level of the operational state of athletes. The multiple regression equation was calculated, which made it possible to determine the influence of individual significant parameters on the level of the operational state of athletes and the confidence interval. A group of athletes with operational status indicators below the confidence interval received sport supplementation.

Conclusions: The main characteristics of the athletes' operative status are cellular biomarker phase, fat free mass, extracellular water, intracellular water, strength index. These characteristics should be used in assessment of both operative status and complex functional diagnosis of highly-skilled swimmers during competitions.

Keywords: operative status, correction, body impedance analysis, highly skilled swimmers.

Introduction

The duration of competitions and number of competition days directly depends on the kind of sport. Swimming is the second after track and field athletics sport kind by the number of award medals. In the XXXI Olympiad of 2016 athletes participated in 32 kinds of swimming competitions. So, duration of swimming competitions ranges from 7 to 9 days. The winner results differ in centiseconds. Many athletes participate in several swimming distance types, which predisposes for increased requirements to their training, physical working performance and rehabilitation. This is why control and assessment of their operative status during all competitions is important for both timely correction and achieving best sport results. The method of body impedance analysis has recently been widely used in complex examination of athletes, which aids in evaluation of the athlete body composition changes, hydration and energy level during various stages of training. This provides for perfection of the competition trainings, loading intensity, i.e. effectively and timely improve athlete condition before the competitions [1-4]. There have been carried out sufficient number of the body impedance analyses of athlete during training [5-8]. The relation between body impedance characteristics and physical ability to work as

well as preparation level have been revealed. Some studies have been held in cyclic sport types [9-11]. However, none of the studies revealed practice application of the body impedance analysis during competitions. There are still no data on the effect of certain characteristics onto the person's sport performance as well as necessity of timely correction of the athletes' operative status at the start in swimming. *The aim of this research* was assessment and correction of highly skilled swimmers' operative status during competitions.

Materials and methods

Participants

46 athletes of the National swimming team of Ukraine have participated in the study, aged from 17 to 23 years (20±3.2). All participants agreed on their data processing and publication of the study results. In order to assess the operation status of highly-skilled swimmers several tests have been held within the study:

- Multi-factorial express-diagnosis according to Dushanin [17], aimed at estimating functional condition due to the anaerobic metabolism threshold heart rate (ANMT HR), maximum oxygen consumption (MOC), total metabolic capacity (TMC), creatine phosphate (CP).
- Variation pulsometry according to Baievskiy [17], detecting the tension index (TI).

- Body impedance analysis (Bioscan Touch8) of the following characteristics: cellular biomarker phase (CBP), fat free mass (FFM), fat mass (FM), body density (BD), extracellular water (ECW), intracellular water (ICW), Muscle mass (MM), extracellular mass (ECM), intracellular mass (ICM), strength index (SI), health index (HI), fitness score (FS).

Study design

The studies were held during the Licensing Winter Championship of Ukraine in Swimming. The athletes' operative status was assessed during all competition days. The first study was held in the day of athlete arrival, in order to detect the significant characteristics for calculating the multiple linear regression as well as confidence interval (critical data for assessment of the operation status dynamic pattern). The subsequent assessment of operation status was carried out in the morning and evening, before and after preliminary and final races on chosen distance during a day. According to the results of the survey, all athletes were divided into 2 groups. The athletes, whose characteristics exceeded confidence interval (R.L. Neuman [17]) (second group), underwent correction procedures. In order to improve the characteristics, the 2nd group athletes took sport supplementation - Micellar Casein by company Nutrent (45 g Micellar Casein mixed with 300 ml of water) before bedtime. The Micellar Casein basis is represented with milk protein isolate high in micellar casein, enriched with milk serum protein. The milk serum protein provides for enhanced rehabilitation (quick aminoacid balancing), and the level is supported during night by prolonged breakdown of micellar casein. Micellar Casein is also enriched with the probiotic and prebiotic complex LactoWise™. The probiotics (bacterium

strain *Bacillus coagulans*) and prebiotics (bacterium strain Galactomannans) composing the LactoWise™ positively affect gastrointestinal functions.

Statistical Analysis

All obtained data were statistically processed using the STATISTIKA 10.0 software. The data are represented as the mean average \pm standard deviation (SD). The Fisher test was used to check standard distribution of the variables. In case of non-standard distribution, logarithmic transformation was used. The bilateral repeated estimation by STATISTIKA 10.0 was used for comparison of the obtained characteristics before the onset and in the end of the study. The relation between basic characteristics of function status was estimated using the Brave-Pearson correlation coefficient. To make a model of optimum operation status multiple linear regression equation was used, which aided in detecting the most significant parameters, providing for the best sport performance.

Results

To calculate the multiple linear regression in order to detect the most significant characteristics which show the swimmer's condition, factor analysis of the athletes' operation status structure was conducted. The study revealed 4 factors which completely reflect the highly-skilled swimmers operation status, with the first factor reflecting 44.83% of overall load, the second factor – 19.97%, the third factor– 13.7% and the fourth factor 11.2% (table 1). The first and second factors are the main in the dispersion, being the leading ones in detecting operation status of athlete.

The first factor, «body composition», consisted of 9 components - CBP, FFM, ECW, ICW, MM, ECM, ICM,

Table 1. Factor structure of operation status of highly skilled swimmers

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Anaerobic metabolism threshold heart rate	-0.269523	-0.943685	0.081395	-0.018397
Maximum oxygen consumption	-0.204162	-0.952172	0.128614	-0.041784
Detecting the tension index	0.109558	-0.043541	0.944119	-0.072216
Total metabolic capacity	-0.119290	0.217078	0.108833	0.848637
Creatine phosphate	-0.054539	-0.655495	0.742335	-0.079314
Cellular biomarker phase	-0.979173	0.026677	-0.016626	-0.230020
Fat free mass	-0.974103	0.173664	0.125126	-0.212133
Fat mass	0.934969	-0.173232	-0.125654	0.208733
Extracellular water	-0.953013	-0.076487	-0.187605	-0.041514
Intracellular water	0.834177	-0.393846	-0.224038	-0.060263
Muscle mass	-0.840674	0.375749	0.272208	0.055290
Extracellular mass	-0.961170	-0.019385	-0.135626	0.025915
Intracellular mass	-0.845954	-0.219844	-0.341937	0.087828
Strength index	-0.893531	-0.305576	0.027535	0.544199
Operative status	0.047627	0.556781	0.423843	-0.495383
Total %	44.8369	19.9718	13.7490	11.2782

SI. The maximum factor loading (0.97) observed with the FFM and CBP characteristics, which reflect functional condition of active muscular and fat tissue as well as the metabolism rate. The second factor, the «functional» one, joined two components of MOC and ANMT HR, which characterize special working performance of the swimmers. Maximum loading of the factor is observed with ANMT HR (0.95). The third factor joined two components: CP and TI. The maximum factor loading observed with the CP characteristics (0.94). The fourth factor is represented with a single parameter of TMC of 0.84. To choose the most significant characteristic changes, which define the operation status level, the authors detected reliable relation between the obtained parameters (fig.1).

According to the received correlations, multiple linear regression equation was calculated, which provided for detection of certain significant characteristics reflecting the sport performance of the athlete:

$$OS = 1,78X_{10} + 1,49X_7 + 0,932X_{11} + 0,866X_6 + 0,466X_{15} - 178,29 \quad (1)$$

where:

OS – operative status; **X₁₀** – ECW – extracellular water; **X₇** – FFM – fat free mass; **X₁₁** – ICW - intracellular water; **X₆** – CBP – cellular biomarker phase; **X₁₅** – SI – strength index.

According to the results of the primary study, all athletes were characterized with high and “better than average” operation status. To assess the operation status dynamic pattern the authors calculated confidence interval, which equalled 2.67 units. The examination of 46 athletes in the end of the first competition day established two athletes groups. The changes of operation status in first group, represented with 35 athletes (76.09%), didn’t exceed the confidence interval limits. Decreased characteristics of FFM, ECW, ICW, SI and CBP were within tolerance, being closer to the initial ones after the morning and evening start. The operation status criteria in the second group, represented with 11 people (23.91%) were considerably under the confidence interval limits after the morning start and after the final (table 2).

Maximum decrease observed in the FFM characteristics, which evidences about decreased dry muscle mass as well as energy supply SI, which is indicative of decreased power potential of the athletes, CBP, i.e. observed working performance and metabolism intensity. The decrease in these parameters coincides with decreased operation status of the second group athletes. Repeated assessment of the 1st and 2nd group athletes was conducted the next day, before the competitions. An increase in the second group athletes’ operative status was noted, being almost similar with the initial one (Fig.2).

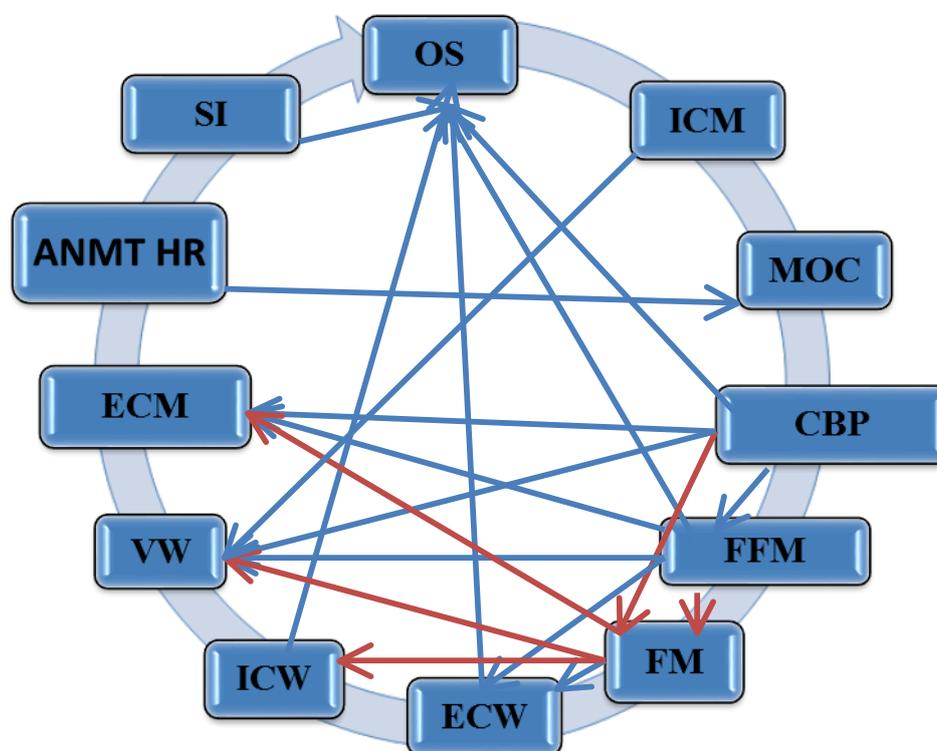


Figure 1. Correlation between the characteristics of sport performance of highly skilled swimmers during competitions.

Note: → positive correlation; → negative correlation; OS – operative status; SI – strength index; ANMT HR - anaerobic metabolism threshold heart rate; ECM - extracellular mass; VW - ; ICW - intracellular water; ECW – extracellular water; FM - fat mass; FFM – fat free mass; CBP – cellular biomarker phase; MOC - maximum oxygen consumption; ICM - intracellular mass.

Table 2. Dynamic pattern of operative status of highly-skilled athletes of second group

Athletes		INDICATORS																			
		OS – operative status (conventional units)			CBP – cellular biomarker phase (conventional units)			FFM– fat free mass (%)			ECW – extracellular water (%)			ICW – intracellular water (%)			SI – strength index (conventional units)				
BC	AMS	AES	BC	AMS	AES	BC	AMS	AES	BC	AMS	AES	BC	AMS	AES	BC	AMS	AES	BC	AMS	AES	
Bohdan D.	95.28	86.03*	82.89*	10.46	9.22	8.47	89.4	84.5	83.2	43.8	42.62	42.4	56.1	58.0	57.9	1.18	1.14	1.11			
Victoria P.	95.54	92.79*	90.56*	10.32	8.73	8.68	91.7	89.19	89.0	41.8	43.62	43.5	58.1	56.37	56.3	1.22	1.07	1.07			
Olga M..	82.73	78.56*	75.93*	8.29	8.12	7.95	82.48	80.0	78.6	43.92	43.52	43.52	56.07	56.47	56.07	1.18	1.15	1.13			
Vadim N.	99.71	96.65*	95.56*	11.21	9.19	8.94	92.79	91.53	90.94	42.79	43.65	43.6	57.2	56.34	56.39	1.22	1.12	1.11			
Mukhalilo R.	89.37	84.51*	76.64*	8.8	8.9	8.22	87.08	86.33	84.09	43.22	42.82	41.88	56.77	57.17	58.11	0.91	0.91	0.91			
Karina S.	92.64	86.02*	82.75*	10.95	9.06	8.39	88.3	83.86	82.84	42.24	44.45	43.19	57.75	55.54	56.8	1.9	1.39	1.31			
Alina T.	70.11	69.2	66.64*	8.55	7.9	7.24	71.79	71.58	70.57	47.9	47.58	47.03	52.0	52.41	52.96	1.03	1.01	1.01			
Daniil T.	99.45	97.92	96.40*	11.34	10.7	9.81	92.89	92.56	91.77	42.05	41.74	42.19	57.95	58.25	57.8	1.2	1.2	1.13			
Evgeniia G.	79.82	77.8	75.94*	8.86	8.14	8.11	80.37	79.66	78.66	43.57	43.23	43.37	56.42	56.76	56.2	1.13	1.13	1.13			
Daria Z.	74.72	75.24	64.68*	8.24	8.13	8.0	76.79	76.57	70.34	44.5	45.4	44.3	55.49	55.56	55.69	1.2	1.14	1.12			
Margo V.	73.51	72.87	69.5*	7.65	7.38	7.23	74.46	74.46	72.22	47.85	47.73	48.04	52.14	51.95	51.26	1.03	1.02	0.98			

Note:

* - operative status of athletes, exceeding the confidence interval limits;
BC – before competition; AMS – after morning session; AES – after evening session.

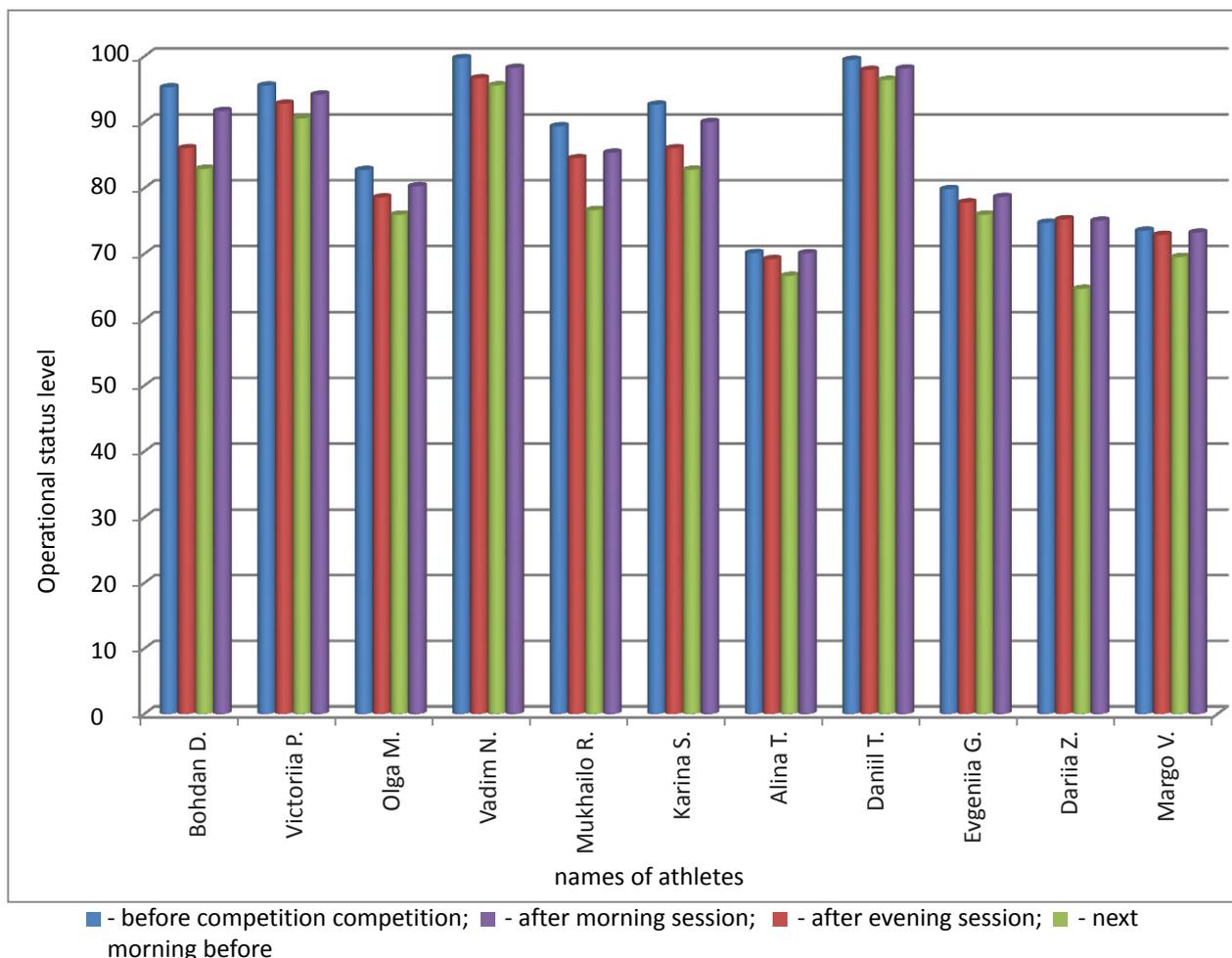


Figure 2. Dynamic pattern of the highly skilled second group swimmers' operation status changes.

Discussion

The importance of the athletes' operation status as a leading factor in high sport performance is doubtless. The offered study includes assessment and correction of the athletes' operation status during the competitions, which was based on the multi-factorial express-diagnosis of functional condition, variation pulsometry and body impedance analysis. According to the received data, the multiple linear regression equation was calculated as well as the most significant characteristics of the body impedance analysis were detected. As far as the authors know, this is the first study, based on the factor, correlation and regression analysis aimed at completing the model of highly skilled swimmers' competition operation status model. Gutiérrez et al. [18] studied the body mass indicators of athletes and determined their role in assessing the preparedness of athletes. Malá et al. [5] conducted a systematic review and identified prospects for the future in the use of bio-impedance analysis in sport and exercise. Campa et al. [19] in his studies established a specific profile of an athlete according to the characteristics of body composition: FFM, EBW, FM, which completely coincides with our studies. Esco et al. [20] determined the accuracy of bioimpedance

analysis to predict body composition in athletes. The significance of FFM was reassessed as one of the main factors in predicting body composition, which is also confirmed by our studies. Koury et al. [21, 22] used the bio-impedance analysis method to assess the functional state of young athletes in conditions of training based on the dynamics of FFM, and a conclusion was made about the need to take into account gender differences. It is proved that FFM can be a marker for determining the level of preparedness. CBP vectors were also determined, as a result of which a significant difference was found in the performance of qualified and unskilled athletes. The results of our studies have confirmed that FFM can be one of the main markers in assessing the operational state, and it was also proved that the FU index depends on the level of the athletes' operational state. Bešlija et al. [23] created a model for classifying athletes according to their level of preparedness based on bio-impedance indicators. Sesbreno et al. [24] monitored body composition and determined its relationship with performance, developed anthropometric models for assessing FFM and ACM, which allows us to determine the workability of athletes based on these indicators. In our studies, these indicators were identified as markers in assessing the performance

of swimmers. Marini et al. [25] developed an individual approach to sports training and determined the main criteria for the effectiveness of the training process of athletes using bio-impedance analysis based on the phase angle index. A high correlation (effects) of FM, FFM, TBW, ICW was obtained, which indicates more accurate indicators of bioimpedance. It was also proven that CBP shows changes in the ratio of ECW and ICW under the influence of physical activity. In our studies, a high correlation relationship between these indicators was also determined. Sukach et al. [16], Veitia et al. [26] investigated the features of the component composition of the body of young athletes in cyclic sports and its impact on the level of performance. Higher CBP values (7.2-7.5) were determined, as well as compliance with the age norm of BMI, FFM indicators. Our studies also confirm the data obtained; higher CBP indicators were noted with an increase in the qualifications of athletes. Tinsley et al. [27] in his studies examined the FFM indicator and conducted a comparative analysis of its effect on the performance of athletes with an atypical physique. In our studies, the FFM indicator was considered as an indicator of improving sportsmanship and the performance of highly qualified athletes. Khafzova et al. [4] in their studies showed the importance of bioimpedance for assessing the adequacy of the applied loads, predicting sports results and the possibility of their use as selection criteria for sports. Our studies confirm the data. Komarova [11] in her studies determined the effect of the FFM, ACM, ECW, ICW indicators on bioimpedance and also confirmed that the indicators of this analysis are markers of a sports form and testify to the effectiveness of building the training process. In our studies, it was determined that FFM, ICW, ICW, SI, CBP are the main brokers in diagnosing the level of operational status of highly qualified swimmers in the conditions of competitive activity, which partially confirms the results of Komarova research. Meleleo et al. [28] evaluated muscle and fat mass, hydration of young athletes. It was determined that the BIA provides reliable information on competitive athletes based on the progression of ECW, ICW, CBP, FFM, FM and the less significant impact of TBW. We confirmed these data in studies with highly qualified swimmers in the conditions of competitive activity. Nickerson et al. [29], the change in VIA indicators was reliably confirmed depending on the level of sportsmanship, which is confirmed by

our research. Silva [7] examined the structural and functional components of the body of athletes in the phenotype of sports health and performance based on the BIA. An integrative model has been proposed that links performance, risk of injury and athletic health. In these studies, it was determined that the performance of FM, FFM, ICW, ECW affect the level of fitness and the performance of athletes. Our results fully confirm these data, but in the conditions of competitive activity of highly qualified swimmers. Sonksen [30] used bio-impedance analysis to evaluate the performance of sports activities. The significance of these studies is confirmed by our data. Segal [6] in his studies showed the importance of the BIA on the basis of the ECW, ICW, FFM indicators in assessing the clinical status of athletes at risk of hydration disorders, indicated the need for certain correction tools. In our studies, these indicators were examined from the point of view of assessing the operational status and performance; on the basis of the identified changes, specific means of correcting these indicators were also proposed, which expands and partially confirms the research of Segal. An important factor for the study is defining significant criteria for the high skilled swimmers' operation status correction during competitions: calculating the confidence interval. Despite the obtained results, it is necessary to note that the importance of physical, technical and tactical readiness for achieving high results in swimming still stays high.

Conclusions

The basic criteria, determining the athletes' operation status, are CBP, FFM, ECW, ICW, SI. According to high reliability of the obtained results, these characteristics must be used for assessment of both operation status and complex functional diagnosis of high-skilled swimmers during competitions.

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Conflicts of interest

Authors have no conflict of interest to declare.

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Blood parameters as a measure for controlling physical performance of young Algerian cyclists (U23 category)

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Abstract

Purpose: The use of blood parameters in monitoring athletes is an essential but an unstandardized component of managing athletic preparation. This study aims to describe and evaluate typical measurements and responses observed while monitoring elite cyclist during a training camp. The reported observations might contribute in constituting a scientific support for other practitioners to employ.

Material: 35 elite cyclists from the Algerian National team aged age 17.5 ± 2.4 years participated in this study. Peripheral fasting blood samples were collected in resting after 24 hrs of physical inactivity and outside competitions. Complete blood count (CBC) and hormonal index values (Cortisol, Testosterone, ProBNP and TnT) were tested twice before and after the training camp. The statistical data were analysed by the SPSS software version 22.0.

Results: The observed rates of change were significant ($p < 0.01$, $p < 0.05$) for most erythrocyte variables, except for leukocyte and platelet distribution levels. Hormonal values recorded for Troponin ($\downarrow 92.78\%$, $p = 0.000$) and Cortisol ($\downarrow 11.85\%$, $p = 0.000$) remained significantly as an anticipatory response to competition. The responses of the ProBNP and testosterone were not statistically significant and experienced a different response with regards to their kinetics.

Conclusions: This study is further support suggesting a viable approach to monitoring physical performance index in elite athletes. The results imply that reducing volume while increasing intensity of training just before competition can enhance performance during short preparation periods.

Keywords: physiological follow-up, physical performance, hematologic indices, hormonal profile, young cyclists.

Introduction

To bring a cyclist at his highest level of performance requires a rational management of the training process. This consists of organizing, controlling, monitoring certain parameters that are decisive for the establishment of high-level performance [1].

The management and organization of training periods and cycles is based on the competition schedule. Short-term "intensified training" (IT) are often used during training cycles over the course of a sporting season to elicit performance gains [2]. These typically short-term IT periods occur in the forms of both training (training camp) and during busy competition schedules (stage races, tournaments) [3].

The process of training camp is commonly used in several endurance sports [4] to enhance training adaptation at specific times in the season [5]. In sport such cycling, the main goal of training camp is to prepare cyclists for the upcoming competition period [6].

For the preparation of the Arab Championships, the Algerian Cycling Federation had, among others, resorted to a short-term training course. The nature of training camp was manipulated to align with certain goals:

improving aerobic capacities, perform high intensity work and preparing for a specific competition. To date, little is known about the hematological and hormonal effects of this kind of training.

Many athletes, coaches, and support staff are taking an increasingly scientific approach to both designing and monitoring training programs [7]. However, highly congested competition calendars in combination with inadequate athletic preparation management could negatively impact athlete performance.

Given the complexity of athletic preparation, some blood markers are typically employed for physiological profiling and monitoring purposes in athletes. During training and competition, hematologic [8], hormonal and immunological [9, 10] markers are routinely used in evaluating the health and performance of professional athletes.

In fact, training induced changes observed in various biochemical variables can be attributed to appropriate load dynamics [11]. Monitoring athletes using blood biomarkers seems to be appropriate tool for making statistical inferences in several key biological systems affected by training.

With the purpose that results can be correctly interpreted and useful in the sport practice, it is crucial to have reference values specific for athletes. So, it is important to establish baseline indices for the main

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variables (cortisol, testosterone, hematocrit) involved in the biological monitoring of cyclists [6]. Physiological baseline values would allow coaches to improve proxies of physical performance.

Although several descriptive and cross-sectional studies have well documented the physiological and / or physical responses of high-level cyclists [12, 13]. The use of blood parameters, as indices of physical performance during short-term IT camp, are not yet justified. Despite the extent of monitoring in elite and professional sport, most of blood tests data remain protected and unpublished.

Given the current literature, this study was undertaken to assess hematologic profile and hormonal indices in younger elite cyclists during a training camp, in anticipation of participation in the Arab Championships in 2018.

Purpose: The objectives of this study are first, a definition of the hematological and hormonal profiles of elite cyclists. Secondly, evaluating the rate of change of these parameters as well as determining the physiological status of cyclists after 4 wks. of training camp.

Materials and Methods

Participants.

35 cyclists from the national team playing in Algeria, France, and Spain, participated in the study. The participants were 15 cadets (15.6 ± 0.6 yrs.), 10 juniors (17.7 ± 0.4 yrs.) and 10 seniors (21.07 ± 1.6 yrs.). In order to be included, they had to meet the criteria of high performance. According to the criteria of Jeukendrup et al. [14], “high-level” or “well-trained” cyclists must answer for their training habits and level of practice. All cyclists had, on average: a seniority of practice (6.6 ± 1.9 yrs.); a training frequency (5 ± 2 times / week); a duration of training (4.2 ± 1.07 h / day); a frequency and level of competitions in the same category (44.5 ± 14.7 race days / yr.) and a UCI Africa- Tour, for U23 only, among the top 200 for at least the last 2 years.

During the training camp, athletes undertook high-intensity intermittent training (3.4 ± 0.5 h / day), with

recovery days. The average weekly training volume was (87.4 ± 11.5 km), mainly at an aerobic rate. The study was conducted in accordance with the declaration of Helsinki and approved by the local ethic committee.

Procedure.

The experiment took place over a period of 4 wks. during the training camp for participation in the Arab championships 2018. Anthropometric measurements were performed at the CNMS (National Center for Medicine and Sport) in Algiers a week advance (Table.1). Blood sample were drawn 24h before and after the training camp in the laboratory of UCH (University Hospital Center) in Mascara. The subjects were asked to refrain from training the day before the sampling.

Diet and Training.

Diet was strictly controlled by team physicians. To maintain circadian rhythms, nutrition, hydration, timing of food intake, and sleep were held constant on the days prior the blood sampling [15]. In addition, the subjects did not administer any supplement or medication during the course of the experiment.

Anthropometric Measurements.

The body surface area was calculated by the method of Izakson [16]. Muscle and bone mass were determined by the method of Mateigka [17]. The fat mass was determined by the equation of Kozlov and Gladisheva [18], taking into account the skin folds tricipital, sub-scapular, supra-iliac and bicipital. Subjects’ anthropometric characteristics are listed in Table 1.

Blood Samples.

Resting blood was drawn from cubital vein in the morning and after a fast of ($9h \pm 1$ hour). For the hormonal status, whole blood was centrifuged to separate the serum. Hematological and Hormonal serum were stored in a sealed box at $4-12$ °C. Controlled temperature was assured during transportation (portable electric refrigerator). Samples were transported by car to the laboratory of the Military University Hospital of Oran (MUHO) for immediate analysis or storage at -20° until analysis. The hematological parameters were analysed

Table 1. Basic descriptive statistics for Anthropometric parameters (N=35).

Variables	Mean	Min	Max	Range	SD	Skew	Kurt
Age (year)	17.58	14	23	9	2.42	0.90	-0.22
W (kg)	64.11	45.0	82.6	37.6	7.20	0.14	0.35
H (cm)	174.53	165	189	24	5.11	0.41	0.27
BSA (m2)	1.77	1.16	2.04	0.88	0.14	-1.50	6.49
FM (kg)	7.52	5.74	17.22	11.47	1.67	4.02	22.04
MM (kg)	28.28	19.88	39.60	19.72	3.85	0.681	1.007
BM (kg)	14.76	11.17	18.18	7.01	1.67	-0.281	-4.15
BI (cm)	80.10	68.26	102.27	34.003	7.85	0.88	0.527
LL (cm)	86.93	79	117	38	6.45	2.68	10.37
LT (cm)	49.37	43	58	15	4.11	0.123	-0.98

W - Weight; SH - Height; BSA - body surface area; FM - Fat mass; MM - Muscular mass; BM - Bone mass; BI - breath index; LL - leg length; LT - length thigh.

approximately after 2 hours from blood drawing. To avoid the effects of the circadian rhythm on hormonal secretion, blood samples were taken at the same time of the day (7h ± 1 hour). The percentage variation in plasma volume ($\Delta PV\%$) was calculated according to Dill and Costill [19] using the equation:

$$\Delta PV\% = 100 \times [(Hb_{pre}/Hb_{post}) \times (1 - H_{tpost}/100) / (1 - H_{tpost}/100)] - 100.$$

Extraction of Reference Values.

The hematological or hormonal values belonging to a cyclist will be referred to as reference value, according to the terminology of the International Federation of Clinical Chemistry [20]. The participants underwent several samples. Subjects, therefore, have more than one reference value for a given parameter. In this case, we selected for each subject the median for the statistical analysis. The hematological profiles are shown in Table 2.

To gain further insight in the physiological adaptation involved, hormonal variables were included in the analysis. The Hormonal profiles studied in our sample (Table 3), relate only to the hormones that were examined as part of endurance training in young cyclists of high level.

Statistical Analysis.

Statistical analyses were performed by using the SPSS software version 22.0. Descriptive statistics comprised: the mean value (mean) with the corresponding standard deviation (SD). Numerical results minimum (Min) and maximum (Max), and range (Range). Rate of change (RoC)

is the increase (↑) or the decrease (↓) as a percentage of a variable. Discriminant measurements were performed by two procedures: Skewness coefficient (SKEW) pointing to the symmetry of the distribution around the arithmetic mean. The Kurtosis coefficient (KURT) denoting the peakedness or flatness of the distribution. Correlational analysis was performed between variables by using Pearson's correlation coefficient (*r*). Paired Student *t* tests were used to determine the differences between the pre- and post-test mean values of the various blood parameters.

Results

Hematological Variables.

We studied in young cyclists the variations of hematological markers spread over two tests: before and after the training camp. The hematological parameters varied differently. The performance of cyclists after the short-term IT task brought about significant changes in the total red line (Table 4). RBC rose by ↑1,75% along with Hb by ↑4.59% and Hct by ↑4,08%. At this time point plasma volume changes (ΔPV) mean was about -6,77%. Regarding the RBC indices, MCV increase by a mean ~ 2,25 fl and MCH by 0.73 pg. These pre-post changes were significant ($P < 0.001$, $P < 0.01$, $P < 0.05$). The MCHC remained unchanged.

Considering the level of performance, analysis revealed no significant difference in the total white line. WBC increase by ↑11,38%, $P = 0,062$. With reference to WBCs subsets, Neutrophil decrease by ↓8,49% and

Table 2. Basic descriptive statistics for hematological parameters (N=35).

Variables	Mean	Min	Max	Range	SD	Skew	Kurt
WBC (10 ⁶ /mm ³)	6.43	3.80	9.60	5.80	1.38	0.30	-0.36
NEUT (%)	46.36	25.9	63.8	37.9	9.0	0.07	-0.20
LYM (%)	40.37	23.4	55.2	31.8	7.32	-0.03	-0.38
RBC (10 ³ /mm ³)	4.92	4.36	6.09	1.73	0.34	0.55	1.44
Hb (g/dL)	14.37	12.6	16.2	3.6	0.84	0.21	-0.79
Hct (%)	41.12	36.6	47.6	11.0	2.47	0.44	-0.39
MCV (fl)	83.79	68.1	93.7	25.6	5.53	-0.83	-0.45
MCH (pg)	29.26	22.9	32.4	9.5	1.97	-1.13	1.32
MCHC (%)	35.84	33.0	65.8	32.8	5.05	5.18	27.92
Plt (10 ³ /mm ³)	216.16	110	343	233	47.47	0.16	0.35

WBC - white blood cells; NEUT - neutrophil, LYM - lymphocyte; RBC - Red blood cells; Hct - hematocrit, Hb - Hemoglobin; MCV - mean corpuscular volume; MCH -Mean corpuscular haemoglobin; MCHC - Mean corpuscular hemoglobin concentration; Plt - Platelets.

Table 3. Basic descriptive statistics for hormonal parameters (N=35).

Variables	Mean	Min	Max	Range	SD	Skew	Kurt
CORT (nmol/l)	397.90	169.00	510.00	341.00	83.73	-1.176	1.331
TESTO (nmol/l)	4.77	1.41	8.11	6.70	1.51	0.279	-0.067
TNT (ng/ml)	6.56	3.27	12.00	8.73	2.23	0.526	-0.518
ProBnp (pg/ml)	320.37	140.00	549.00	409.00	96.46	0.231	-0.529

CORT - steroid hormone; TESTO - Testosterone; TNT - Troponin; ProBnp - prohormone Brain natriuretic peptide.

Lymphocyte by $\downarrow 3,80\%$. The same pattern was observed in platelets count ($\uparrow 5,20\%$; $P = 0,167$). From the pre to post-test, the average values of all the haematological parameters were within the reference range.

Hormonal Variables.

Descriptive analysis of stress hormone in well trained cyclist are presented in Table.5 before. For Cortisol, significant differences were observed between the pre and post-test ($11,85\%$; $p < 0,05$). The Testosterone concentration increased at post-test by $\uparrow 16,49\%$, and this change was statistically non-significant ($p = 0,241$).

According to this study, the measured values of cardiac markers of myocardial stress varied differently. The analysis of pre and post-test hormones revealed a significant ($p < 0,001$) decrease in Troponin level by $\downarrow 92,78\%$. In contrast to Troponine, proBnp was decreased by $\downarrow 19,56\%$ without statistical significance ($p = 0,051$).

Pre-test proBnp-positive (percentage of subjects exceeding the URL= upper reference level: 350 pg/ml) was 31.41% compared with 22,85% at post-test. When age was considered, 17.14% of cyclist aged > 19 yrs. had

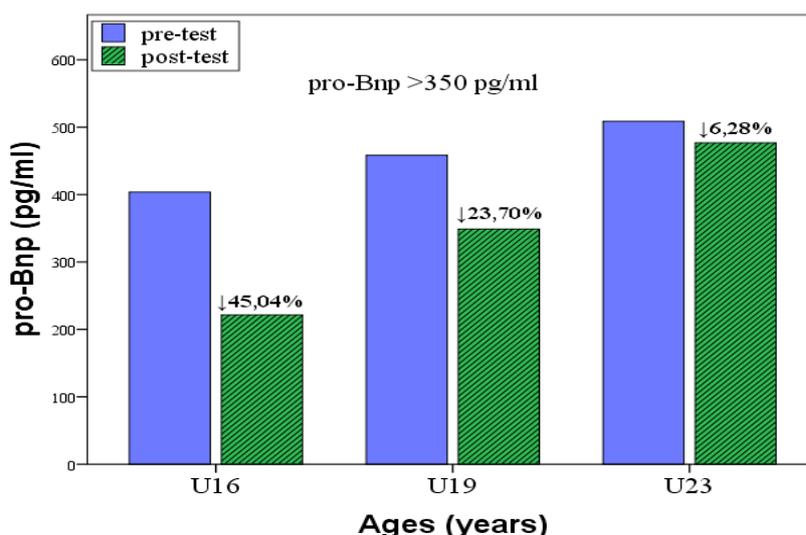


Figure.1. Reduction in proBnp as a function of age and age-adjusted cut-off values in well trained cyclist. $P > 0,05$, no significant different between pre and post- test for proBnp value > 350 pg/ml.

Table 4. Descriptive and analytical Statistics of hematological parameters under study (N=35).

Variables	Pre-test	Post-test	P values	Usual Values
WBC ($10^6/\text{mm}^3$)	6.46 ± 1.47	7.20 ± 1.89	0.062 NS	4.0 – 10.0
NEUT (%)	49.01 ± 8.37	51.85 ± 8.96	0.090 NS	40 - 75
LYM (%)	39.29 ± 6.93	37.80 ± 8.17	0.301 NS	20 - 45
RBC ($10^3/\text{mm}^3$)	4.91 ± 0.34	5.00 ± 0.30	0.042*	4.2 – 5.7
Hb (g/dL)	14.38 ± 0.86	15.04 ± 0.92	0.000**	14 - 17
Hct (%)	41.48 ± 2.56	43.18 ± 2.21	0.000**	40 - 52
MCV (fl)	84.46 ± 5.41	86.71 ± 3.64	0.001**	80 - 95
MCH (pg)	29.37 ± 2.04	30.10 ± 1.81	0.012*	28 - 32
MCHC (%)	35.67 ± 5.45	34.48 ± 0.92	0.224 NS	30 - 35
Plt ($10^3/\text{mm}^3$)	215.52 ± 50.33	226.73 ± 37.32	0.167 NS	150 - 350

Values are expressed as Mean \pm SD; significant difference: $p < 0,05$ *, $p < 0,01$ ** , NS: not significant.

Table 5. Descriptive and analytical Statistics of hormonal parameters (N=35).

Variables	Pre-test	Post-test	P values	Usual Values
CORT (nmol/l)	404.82 ± 120.85	356.48 ± 98.97	0.021*	171 - 536
TESTO (nmol/l)	4.50 ± 2.15	5.24 ± 2.40	0.241 NS	2.8 – 8.0
TNT (ng/ml)	8.33 ± 4.00	4.32 ± 2.58	0.000**	00 - 14
ProBnp (pg/ml)	418.48 ± 188.54	349.98 ± 188.17	0.051NS	≤ 350

Values are expressed as Mean \pm SD; significant difference: $p < 0,05$ *, $p < 0,01$ ** , NS: not significant.

proBnp values >350 pg/ml at post-test; this was reduced to only 6.28% (Fig.1). In contrast, we found a marked reduction in proBnp after short-term IT in the U17 and U19 compared to their pre-test level. The elevation in proBnp values was associated with increasing age ($r=0.594$, $r=0.598$; $p<0.01$).

Discussion

In this paper, the authors attempt to provide an update about the most significant changes of selected blood parameters in response to 4 wks. of training camp. To our knowledge, no previous studies have evaluated both haematological and hormonal response to short-term IT in elite road cyclists of different age (U23).

Hematological Variables.

In endurance sports; the transport of oxygen (O₂) through hemoglobin (Hb) blood is an essential factor for the athlete’s good muscle performance [21]. Parameters required to evaluate O₂ carrying capacity are: Hb, red blood cells (RBC) and Hematocrit (Hct) in the blood [22].

A highly increased RBC and Hb improve performance by facilitating O₂ transport and delivery to metabolically active tissue [23]. Thus, it is a clear advantage for aerobic athletic performance to have a high O₂ carrying capacity [24], particularly in sports such as running and cycling

[21].

Previous cross-sectional and longitudinal studies have investigated the effects of different types of exercise on RBCs variables in various sports. The effects found have been a decrease or increase in RBC, Hb and Hct concentration [25–27]. Nonetheless, regular screening of hematological variables was desirable for the control and the establishment of normal range.

In this study well trained cyclist show, with increasing intensity and decreasing duration of training, the same pattern of elevation in most of RBCs profile. We observed a significant increase ($p<0.05$) in the order of 1.75 to 4.59% in resting RBC, Hct and Hb at post-test. Other investigations also reported similar findings in this regard although employing different exercise protocols [28–30].

The results of this study are not really unexpected. Several mechanisms are discussed as contributing to these adaptations. The primary cause is addressed to a pronounced plasma volume (PV) variation observed after IT [31]. $\Delta PV\%$ changes were calculated from Hct + Hb [19], and gave a mean decrease of 6,77 at rest.

Because during plasma shifts, no blood cells nor Hb leave the vascular system, a part of the increase in Hct value and Hb concentration is due to the 6,77% decrease in PV. Pointing to the same conclusion is a significant

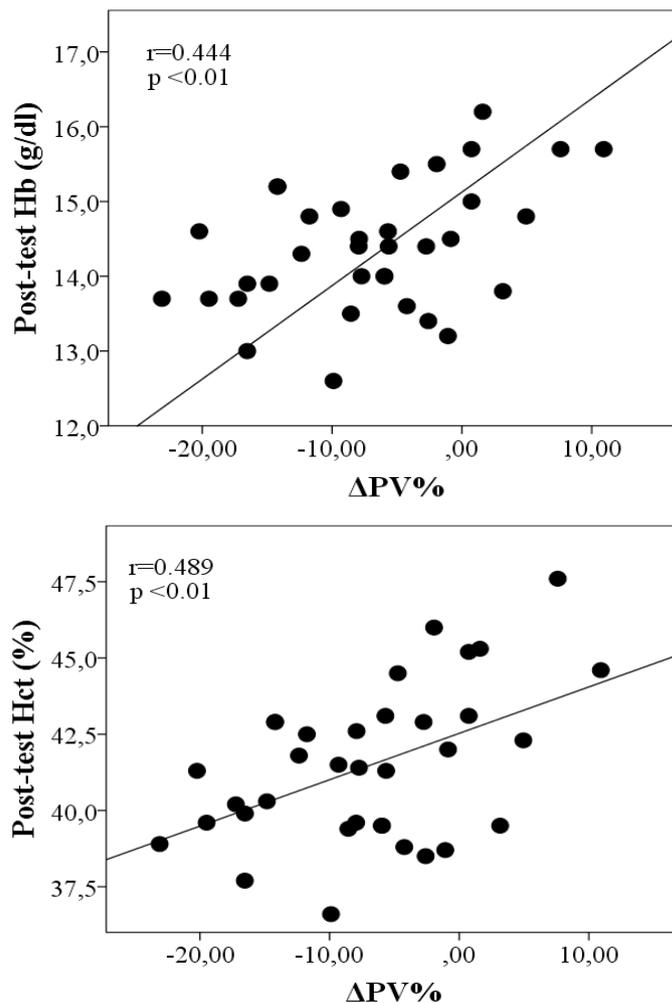


Figure 2. Correlation between plasma volume ($\Delta PV\%$) and individual values combined from post-test Hematocrit (Hct) + Hemoglobin (Hb) in 35 well trained cyclists.

change in Hct and Hb associated with the decrease of PV. Figure.2 gives the association between $\% \Delta PV$ and individual values of Hct + Hb after short-term IT.

Our results add to the evidence that a repeated brief and intensified exercises decreased PV [32, 33], leading to an increase in RBC, Hb, and Hct counts [34]. Thus, short-term IT exercise can induce a 5%–10% decrease in PV of young cyclists.

Furthermore, professional road cyclists are known for performing very high training volumes, up to 30 to 35,000 km/yr. [35]. Nevertheless, training seems to influence the blood system on a seasonal base, as most erythrocyte variable show significant change during IT period [36].

Finally, as cited before [28], 99% of O_2 is carried in combination with Hb in the blood. Elite cyclists are known to possess a height O_2 -uptake capability [37]. Thus, if the need for O_2 in tissues and blood portable O_2 content are not balanced, the body will respond to it through increasing the blood O_2 -carrying capacity, i.e., Hb and RBC [38].

Taken together reports and our results, revealed that IT exercise has no adverse effect on RBCs variables in the short-term. Our finding appears to be consistent with the cyclists' physiological response to maintain and improve highly demanding performances day-after-day [39]. The competition runners (cyclists) reported personal records at the Arab Championships in 2018.

White blood cells (WBCs) or leukocytes are a heterogeneous group of immune cells made up of various subsets with specific function. To date, a vast amount of research has aimed to explain how physical exercise alters the immune system. Increasing attention is being directed to the relationship between exercise (in term of duration and intensity) and immune function [40].

Some researcher addressed decreased or unchanged levels of WBC both during and after exercise [41,42]. Others have suggested that intense exercise can rapidly decrease Lymphocyte counts and that short intense exercise has no effect on Neutrophil function [43, 44]. Evidence is now accumulating that immune response depends on exercise intensity [45], however there is a paucity of data to support these finding.

Anyway, intense exercise may induce perturbations to immune system [46] and homeostasis might not be restored for several hours. Gleeson et al [47] suggest that exercise can cause anti-inflammatory reactions triggered by muscle injury, resulting up to 24 h after exercise. This trend has not been observed in our athletes. The major finding of this study was in the white series which varied inversely to erythrocyte one.

The WBC profile showed non-significant change ($p > 0,05$), despite a rise by $\uparrow 11,38\%$ after 24h of recovery. With reference to WBCs subsets, resting Neutrophil count were 5,81% lower than pre-training values ($49,01 \pm 8,37$ vs $51,85 \pm 8,96$ / %, $p = 0,090$). Short-term IT does not appear to alter significantly WBC counts, including Neutrophils, because the Neutrophils account for 50% to 70% of all circulating leukocytes.

Lymphocytes are involved in the specific immune

response including antigen-antibody reactions [48], and make up 20% to 25% of the peripheral leukocytes. Thus, correct functioning of the lymphatic system identifies the proper physiological state of the immune system. Similarly, to WBC, Lymphocytes remain unchanged ($p > 0,05$), decreasing the possibility that 4-wks of short-term IT acts in an anti-inflammatory fashion that hinder microcirculation.

In general, it was observed that most of the WBCs measures are not altered by short-term IT periods such as 4wks in athletes already training in average ~ 28 h/wk. It is noteworthy; however, that, cyclists habitually high training loads may be associated with some immune regulation to preserve performance and immunity during IT.

Further, possibly the lower number of hours (< 3 h) of exercise training per days may have resulted in less fluctuation in WBCs variables. Post-exercise immune function dysfunction is most pronounced when the exercise is continuous, prolonged (> 1.5 h), of moderate to high intensity [53]. Other studies marked also no significant difference in WBC count [49, 50], Neutrophils number [51] and circulating Lymphocytes [52] after short periods (2–4 wk.) of IT.

Based on our finding, our data strongly suggest that resting immune status was unrelated to exercise intensity, but may depends on training level and exercise duration. The authors concluded that, short-term IT exercises does not affect (or might even enhance) immune function in well trained cyclists.

Platelet (Plt) serves an important role in the physiological process of hemostasis. Exercise and training are known to have multiple effect on blood hemostasis [54]; involving platelet activity [55]. Thus, maintaining platelet homeostasis is important to avoid spontaneous bleeding and organ damage [56].

Like other blood cells, Plt count may not remain constant and vary to different physiological conditions. From the available studies, intensified exercise was found to increase Plt index during recovery [57–59]; although this could not be confirmed in all studies [60, 61].

In our cohort, Plts numbers showed no significant difference ($\uparrow 5,20\%$, $p = 0,167$) at rest, but within the reference range. No coagulopathy was detected in all subjects. Similar observations have been reported by Drygas et al [62] and Scalzi et al [63] on sports participants other than cyclists.

Studies on effect of short-term IT exercise on Plts count in elite cyclists are lacking. Many factors can explain the diverging between our results and the mentioned researches. There is no standardised protocol for defining intensity or duration exercise, uniformity of sampling, and populations studied.

Initially, the sample of these studies used healthy or sedentary subjects, so it is difficult to extrapolate their results to elite athletes. At last, different methods were used to measure Plts function. Studies have varied from laboratory tests based on ergometer or treadmill protocols at a given $VO_{2max}\%$, to field-testing protocols during

competition events.

Thus, a definitive conclusion about effect of short-term IT on Plt counts in competitive cyclists should not be established. The contrasting data, reported in the few published papers, deserve further studies to clarify the importance of our observation.

In conclusion, hematological parameters and its knowledge can be used to assess the performance as well as the physiological status of elite cyclists. In accordance with our hypothesis, the present findings indicate that short-term IT induced significant effects in the erythrocyte measures than leucocytes one. This means a larger significant gain in O₂ allocation / transport capacity with maintaining and / or mild elevation of immune function. Our study documents that reducing volume while increasing intensity of training just before competition was favorable to performance.

Hormonal Variables.

Looking for an effective index to monitor the physical performance in elite athletes has great physiological significance. Many researches have been carried out to identify physiological markers that might be used to monitor training program and to prevent or even to diagnose overtraining.

Two very important hormonal markers of chronic stress and fatigue are Testosterone (as anabolic hormone) and Cortisol (as catabolic hormone). The relationships between these two hormones are thought to reflect the balance between anabolic and catabolic processes [64].

Cortisol the primary stress hormone was used in many studies to evaluate exercise induce-stress. According to Michailidis [65], the release of Cortisol is related to stress and depends positively on the intensity and duration of exercise. In literature, resting levels of Cortisol are generally seen to increase with volume [66,67] and intensity [68] of training.

In the present research, high-intensity, short duration of exercise training showed a significant decrease by 11,85% in resting Cortisol. However, all values of our subject were within the reference limits. Our results align perfectly with other studies including competitive cyclists [69, 70], and the direction of changes was related to the external training load.

An interesting aspect of this study was that the training camp occurred 3 days before the Arabian championships. The training duration, intensity as applied by coaches in this study appears to play an important role. In such instance, there are some considerations when interpreting Cortisol decrease in this study.

First, post-test Cortisol decrease may be due partly to a marked reduction in the training load in the days before the Arab championships. This procedure was undertaken by coaches with the implicit goals of maximizing gained performance and minimizing risk of negative training outcomes. In most case, such reduction in training intensity and/or volume is referred to as tapering.

As defined by Mujika and Padilla [71], tapering is the reduction in training before a major competition. But in contrast to athletes from other sports, the road cyclist

doesn't practise tapering. It was taper-like, training at the usual exercise intensities but with a progressive reduction in duration for the 7-10 days before a race [72].

Interestingly, reduced training periods (2 to 4 wks.) has been observed to improve several physiological and performance measures in cyclists [73, 74]. This possibility is partly supported by our finding and in the study of Chenaoui et al. [69].

Apart from reduction in the training load, other factors may have also influenced the Cortisol response seen in this investigation. Subjects in this study have typically been athletes-exercisers (see methods). In this regard, scientists have shown that Cortisol tend to decrease in response to exercise [75], likely, because of the trained individual being better at preserving blood glucose [76].

Clearly, post-training Cortisol raised in this study was prevented [77] to allow muscle glycogen to become supercompensated in post-exercise [78]. For our cyclists to be prepared for subsequent competition, restoration of muscle glycogen stores is required to sustain the capacity for continued high-intensity activity.

However, the high levels of Cortisol observed at pre-test, may be associated to the stressful condition accumulated during the season [79]. It should be emphasised that the training camp was at the end of the season. Furthermore, for our younger cyclists, it is not uncommon to complete about 25 000 km and 70 competition days after 8 month of cycling season (see methods).

Likewise, in younger age, Skoluda et al [80] found that a higher training volume (measured in kilometers run per wk) was associated with rising Cortisol levels. It appears likely as well trained cyclists exhibit a chronic mild hypercortisolism at pre-test that may be an adaptive response to chronic exercise [81]. But the level of response highly depends on a previous level of training.

In conclusion, our results imply that short-term IT would decrease cortisol in well trained cyclists in post-recovery. Collectively, post-training reduction in cortisol has been reported to be ideal for an athlete to achieve positive adaptations [67]. Finally, our findings lead us to assume that 4 wks. of short-term IT exercise provide the adaptation needed for optimal cycling performance.

Regarding Testosterone the other dependent variable of this investigation, conflicting results have been reported. Some studies involving well trained cyclists reported that, endurance training often reduce serum Testosterone [82, 83], while others have described an increase [84, 85].

In this study as an anabolic profile, Testosterone plasma increases by 16.49% after 4 wks. of short-term IT. But this alteration was no significant ($P>0.05$). Our results are somewhat unexpected in view of previously published papers. Explanations for our observations are lacking, so we will examine a relatively unexplored factor.

The key theme emerging from our findings is that anabolic processes were affected negatively, as indicated by the significant decrease in Cortisol (see Table.5). First evidence for this phenomenon was provided by Cumming et al. [86], discussing the ability of Cortisol to inhibit the

synthesis of testosterone. However, the prevalence of these finding in the case of sports is not yet quite determined.

Whatever the cause, the observed increased Testosterone and decreased Cortisol may have a role in the bioenergetics and metabolic function of skeletal muscles. Physiologically, besides anabolic effects, testosterone may possess anti-catabolic properties [87]. In this regard, Testosterone and Cortisol are through to have opposing effects on muscle metabolism and protein synthesis [75].

Given the latter, it was tempting to conclude that decreased plasma level of Cortisol may result in increased flux of Testosterone in post-recovery. Physiologically, increased Testosterone corresponds to the activation of the anabolic process necessary for the restoration of the body's homeostasis during recovery. In these states, an anabolic internal environment would be present in this study. While the level and direction of activation (i.e., anabolic process) depend on many factors are not easily interpreted (see ref [88, 89] for extensive discussions).

Therefore, despite the Testosterone response did not result in significant increase in this study, but a 16.49% increase may be considered practically significant. In this issue, the anabolic deficit is assumed as an increasing Testosterone counter-regulatory works against the proteolysis effect (i.e., muscle proteins degradation).

Clearly, since Testosterone increases muscle protein synthesis [90], increased plasma Testosterone could also act against the catabolic properties of protein. Consequently, an anabolic response might be initiated while muscle protein synthesis is higher than proteolysis.

Consecutively, because Testosterone increases muscle glycogen synthesis [91], increased plasma Testosterone might reduce the glycogenolysis induced by Cortisol. For our cyclists, this saving of glycogen stores is critical for complete recovery [67], mostly when limited time is between training sessions and competition.

Taken as a whole, there are some take-home messages from this research. First, our findings demonstrate that in well-trained cyclists, a modest increase in Testosterone levels does not need to predict decreased performance. Bermon et al [92] found no correlation between serum Testosterone and performance in elite's athletes.

Second, the observed increased Testosterone and decreased Cortisol would be indicative of enhanced recovery [71], which may express itself in increased performance. Furthermore, short-term IT exercise is desirable for the development of body anabolic processes (i.e. the restoration of the body's homeostasis).

In summary, we could state that short-term IT increases the expression of anabolic process that in turn keep decreasing Cortisol levels. Our findings demonstrate a physiological validation of coach's objective. Therefore, tracking resting Testosterone and Cortisol concentration could be used as stress and recovery state indicators to reflect the training response. However, we are the first to demonstrate that, short-term IT induced Cortisol decreases would perhaps result in subsequent increases in circulating Testosterone.

The study of cardiac-specific biomarkers is crucial

to understanding the physiology of endurance training. Since, the mechanism underlying the release of cardiac biomarkers has become an area of intense scientific investigation. Here, we describe and evaluate change in Troponin and Brain Natriuretic Peptide hormone.

As a cardiac biomarker, Troponin (TnT) is a contractile protein specific to cardiac muscle. In sport medicine, TnT assay is currently widely used in the assessment of myocardial and skeletal muscle injuries. Regarding competitive endurance sports, post-exercise release of TnT have been suggested to be elevated.

The extant literature is replete with observation of significant rise in cTnT after prolonged intense endurance exercise [93–95]. Nevertheless, elevated TnT are considered as indexes of myocardial damage. This theory has been challenged by numerous studies [96, 97], though no definitive explanation has been provided so far [98].

Conversely, other authors demonstrated marked increase in TnT after intense exercise, in absence of clinical symptoms of a myocardial dysfunction [99,100]. Despite many publications, there is, however controversy on the phenomenon of post-exertional TnT elevation, possible explanations have been published [101].

Relatively little is known, however, whether high exercise intensity (with shortened durations) may mediate TnT release [94]. Accurate interpretation of TnT concentrations in this context is challenging. The foremost question being is whether exercise-induced TnT release of physiological or pathological finding.

The key novel finding from this study is that short duration, high intensity cycling training elicit a significant decrease ($p<0,001$) in TnT post-recovery. Since, TnT is the main protein that regulate muscle contraction and relaxation [102], our findings indicate an interesting observation.

Injured skeletal muscle may release proteins that are detected by cTnT assays [101, 103]. Subsequently, the asymptomatic decreased TnT observed in all cyclists may reflect physiologic rather than pathologic substrate [104]. Together, ours finding provides novel insight into the physiologic substrate responsible for the post-exercise release of TnT after short-term IT. The implications of this observation are straightforward.

Based on our observations and the post-exercise TnT observed in other work [105], it is likely that TnT decreased as the training duration decreased. To this end, it is unlikely that a decrease by $\downarrow 92,78\%$ in post-exercise TnT reflect irreversible damage. Actually, the beneficial effect of moderate duration exercise on cardiovascular health is well recognized [106].

Previous identified factors; age and training experience [95, 100, 106] have also been reported to regulate post-exercise TnT but may not be the dominant ones. In this study, subjects were younger ($17,58\pm 2,42$) and athletes-exercisers (see methods). Further, a correlation was found between age and pre-test level of TnT ($r=0,023$, $p<0,05$). Consequently, we cannot rule out a specific role of age and training status in the current study. At present, these possibilities have no substantive evidence to support it but

is worthy of an ongoing investigation.

In conclusion, short-term IT led to significantly low post-recovery levels of TnT in elite cyclist. We propose that exercise duration may influence TnT levels, but the mechanism of release is physiologic. In the absence of cardiac symptoms, we conclude that the myocardium of elite cyclists is more adapted to intensified exercise.

Since the discovery of natriuretic peptide, our knowledge on cardiovascular response to exercise has improved considerably. Cardiac-derived natriuretic peptides, mostly plasma B-type natriuretic peptide (BNP) have become useful markers in diverse aspects of cardiology [107]. Now, BNP and its N-terminal fragment (NT-proBNP) are widely used to appreciate cardiac tolerance of high level athletes undergoing intense training [108].

Previous studies reported that intensified endurance exercise induces significant elevation of NT-proBNP levels [96, 109]. Theoretically, elevated NT-proBNP is often argued as transitory myocardial damage in professional and recreational athletes [110].

Recently, a pro-peptide of BNP (proBnp) has been proposed as potential novel “white count” for earlier cardiac dysfunction [111, 112]. Because proBnp concentration has a longer biological half-life [113], is more stable and has less biological variability [111]. Given the molecular nature of proBnp and its importance as a diagnostic analyte, we have used proBnp assay.

Although the clinical significance of proBnp has been extensively investigated (for review see ref [114]), the biosynthesis of proBnp in the case of sport is strikingly scarce. Until now, no study has assessed concentrations of circulating proBnp on sport performance.

For the first time, this study indicates that, younger cyclists (<23 yr) exhibit both elevated pre and post-test proBnp levels. We found that, post-test proBnp decrease by $\downarrow 19,36\%$ ($P>0.05$). As NT-proBNP represents proBnp [115] and have the same clinical significance, our data coincided with previous results [116, 117].

However, we do not fully understand the cardiac effects of such physiological elevation in proBnp levels. To avoid misinterpretation of elevated values, it is of interest to determine the importance and role of factors that mediate proBnp release.

According to recent research, exercise-induced increase in proBnp depends primarily on exercise duration [118–120]. In the current study exercise duration (<3 hr) may have been insufficient to stimulate a significant proBnp response in spite of intensity.

Exercise duration and intensity alone do not appear to explain clearly the observed proBnp values. The patho-physiology of proBnp modifications is still poorly explained but could be multifactorial. Age [121]; training history [122] and inter-individual variability [123], are factors that can markedly influence proBnp release.

At bivariate correlation, peak pre and post-test plasma of proBnp was evident only with participant age ($r=0.594$, $r=0.598$; $p<0.01$). When age was considered, it is the U17 and U19 who exhibit the largest exercise-induced

increases in proBnp (Fig.3). We suggest that proBnp levels tend to increase with increasing age.

Although only as a trend, similar correlation was also found in the study of König et al [121]. We therefore conclude that the relationship between exercise duration and intensity on the kinetic of proBnp could be influenced by age.

However, analysis between categories found a difference among cyclists over 19 yrs. (U23). 17.14% of cyclist aged >19 yrs. had proBnp values >350 pg/ml (i.e. exceeding the URL) at post-test; this was reduced to only 6.28% (Fig.1). Our findings do not provide a clear explanation for the discrepancy between adolescent and adult.

Anyway, the natriuretic peptides are neurohormones that reflect a condition of increased cardiac stress. As highlighted by Hamazaki [124], even though exercise is performed at high-intensity, if the duration was short, excessive cardiac stress could be preventive.

In turn, it is irrelevant to conclude that an athlete’s cardiac functional state deteriorates from elevated proBnp. Even if proBnp levels exceed the cutoff values, elevated proBnp does not represent myocardial damage [124], resulting in lower athletic performance [163].

Therefore, the observed response here, defined as a decrease in proBnp of >19%, would be suggestive of a physiological reparative or adaptive process [96, 125]. In agreement with earlier investigation [126], we confirm that 4 wks. of short-term exercise decrease proBnp by 20% to 30% and improved myocardial function.

All in all, exercise intensity and age have a regulatory effect on proBnp concentrations, whereas exercise duration significantly influences TnT. The current findings demonstrate that asymptomatic elevated level of proBnp can frequently be found in younger cyclists including adolescents. The lack of in-exercise blood sample in current study is a limitation and warrants further investigation.

Conclusion

Although there were changes in hematologic indices in terms of increase or decrease, it was found that 4wks of short-term IT improved significantly all erythrocyte indices except leukocytes cells. Significant RBCs increases may improve microcirculation and increase the supply of O₂ and essential energy substrates during intensified training exercise. While WBC counts at rest might be lower in elite cyclists, decreasing the possibility that 4-wks of short-term IT acts in an anti-inflammatory fashion.

Moreover, the main findings of this study on the parameters representing the cardiac stress. TnT and Cortisol show that these have remained too significantly diminished as an anticipatory response to the competition. Given the anabolic effects of Testosterone, this can therefore, together with the stable differences in post-test measures of proBnp, render effective the quality of the recovery of the exercise. Our study documents that reducing volume while increasing intensity of training

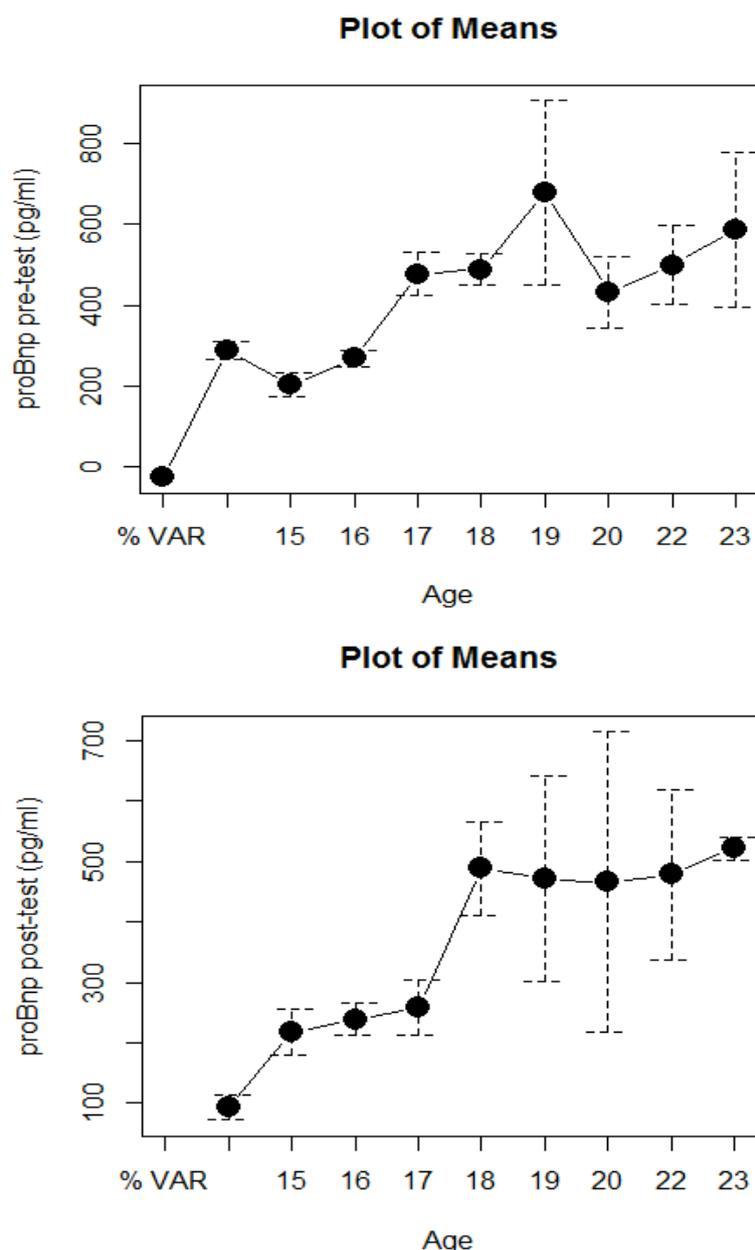


Figure 3. Association between pre and post-test (means \pm SD) plasma concentrations of proBnp and age in professional cyclists (N=35). The correlation coefficient is statistically significant ($p < 0.01$)

just before competition was favorable to performance during short preparation periods.

In contrast, there is great variation in the cardiac hormone as observed between ages. These variations have further underlined the need to establish appropriate reference values for elite athletes. In this context, hematological indices and hormonal profiles and its knowledge can be used to assess as well as monitoring training status and performance of cyclists. With reference to the findings of this study, short-term IT exercise should be applied to specifically induce gains in cycling performance in younger elite athletes.

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Conflict of interests

The author declares no conflict of interests.

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Determination of Anaerobic Threshold by a new approach through the incremental exercise using proportion in heart rate and pulmonary ventilation changes in rowers

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Purpose: The aim of this research is to create a non-invasive and easy to apply in practice approach to determine the anaerobic threshold based only on measurement of the pulmonary ventilation and the heart rate. It uses proportions, with which these variables were changed during a maximal incremental test.

Material: Twenty athletes from the national rowing team of Bulgaria with average age of 17.5 years were tested. Participants performed a one-time graded incremental exercise test to exhaustion on a rowing ergometer. The proposed new approach for determining the anaerobic threshold is related to detecting the power. Thus, one curve (obtained from differences in percentages of heart rate and pulmonary ventilation) crosses the other one (obtained from pulmonary ventilation in percentages). The crossing point corresponds to the anaerobic threshold. This approach was compared with two methods determining the lactate threshold, by blood lactate measurement.

Results: The Shapiro-Wilk test results indicated, that the samples of the heart rate of the compared methods have a normal or close to the normal distribution. The Fisher's F-test demonstrated, that the standard deviations of the samples do not differ significantly two by two at $\alpha=0.05$. The Bland&Altman test presented, that the 95% of all measurement data points lie within the confidence interval limit for each of the comparisons made between the new approach and two methods.

Conclusions: Our proposed approach is non-invasive and can be easily applied in the field conditions, without using gas-analysing devices. In addition, it is reliable, reproducible and comparable to the accepted for "Gold Standard" methods for determination of anaerobic threshold with 95% statistical significance.

Keywords: anaerobic threshold, non-invasive, pulmonary ventilation, heart rate, endurance

Introduction

The management of the training process is important for the effective development of physical performance in endurance sports. For this purpose, objective and informative indicators of the functional state of athletes, are needed. The most commonly used are the following: heart rate (HR); maximal oxygen consumption (VO_{2max}); the maximal working capacity (W_{max}), and anaerobic threshold (AT). Between 1957 and 1963 Holman [1] introduced the concept of onset of anaerobic metabolism to measure the cardiopulmonary and peripheral aerobic performance capacity. Because the changes of the arterial blood lactate and pulmonary ventilation, they defined this point as the "point of optimal ventilatory efficiency", identical with the " O_2 endurance performance limit". A few years later, Wasserman [2] called it the "anaerobic threshold". The term "anaerobic threshold" is defined as an intensity of exercise, involving a large muscle mass, above which measurement of oxygen uptake cannot account for all of the required energy. Stated in other terms, this is the exercise intensity above which there is a net contribution of energy associated with lactate accumulation [3]. In endurance sports, it has been suggested that AT might be a better indicator of aerobic endurance than VO_{2max} , as AT may change without changes in VO_{2max} . VO_{2max} is a less sensitive indicator to changes in training status than either

lactate threshold (LT) or ventilatory anaerobic threshold [4]. Gradually the anaerobic threshold AT (expressed in $\%VO_{2max}$) has become a standard, because it is closely linked to the $\%VO_{2max}$ that can be maintained in long-distance events. However, it does not represent unique mean to assess aerobic endurance [5]. Many models are described for determining the anaerobic threshold. Ten of them use measurement of the ventilatory and gas exchange response or measurement of blood lactate. Two of them use heart rate (HR) and pulmonary ventilation (Ve) [6]. Related to the power of the work performed, they show characteristic changes linked to the determination of AT.

There are two pathways of energy supply of the muscle contraction: aerobic, when the oxygen is enough and anaerobic, when oxygen is in deficit for metabolic processes. In other words, there is a transition of aerobic to aerobic-anaerobic energy supply. The higher the exercise intensity, the greater the part of anaerobically produced energy. Depending on the physiological features of each individual, this aerobic-anaerobic transition may be steeper or smoother. Because of this, studies over the years have shown, that the research and determination of AT is a difficult process. One of the most commonly used methods for determining the AT is to detect the LT [7]. This is a very accurate method for determining AT, but unfortunately it is invasive. In addition, for a more

accurate reading, a larger number of blood samples are needed per one test research. Determination of LT can be done visually by determining the Onset of Blood Lactate Accumulation (OBLA) (4 mmol/L) [8] and by D_{max} method [9]. Lactate threshold tests can be a valid and reliable alternative to VT and MLSS to identify the workloads at the transition from aerobic to anaerobic metabolism in well-trained runners [10].

A group of methods determine AT by finding the ventilatory threshold (VT). They are attractive because they avoid the unpleasant and sometimes dangerous taking blood samples, which is done repeatedly in one test. VT is defined as the exercise intensity at which the increase in ventilation becomes disproportional to the increase in power output or speed of locomotion during an incremental exercise test [6]. With increasing of the workload, the V_e gradually increases, and after a certain exercise intensity it becomes steeper. The curve of minute V_e shows a curvilinear slope pattern with two break points. The first coincides with the 'aerobic threshold', the second with the 'anaerobic threshold'. The first curvilinear rise in V_e is called the '(first) ventilatory threshold' (VT1). It reflects an increasing ventilatory drive because of excess CO_2 , stemming from the buffering of lactic acid by bicarbonate. With increasing of workload beyond 'VT' a second curvilinear rise in V_e may be observed. This second increase in ventilatory drive is also caused by increasing acidosis and by additional CO_2 stemming from lactic acid buffering [6]. Several ventilatory parameters have been utilised in assessing ventilatory threshold, among which are oxygen consumption, V_e , respiratory exchange ratio (RER), exhaled CO_2 , and the ratio of ventilation to oxygen consumption (V_e/VO_2) [11, 4]. Detection of the VT is highly subjective, given the fact that different experts can choose different thresholds from the same data, and that it is dependent on the duration of the stages in an incremental test. The non-invasive determination of the AT from ventilatory data during incremental exercise is not reliable [12].

Beaver et al. [13] utilised a computerised regression analysis of the VCO_2 versus VO_2 slope collected during progressive intensity exercise (V-slope method) to determine AT. Santos and Giannella-Neto [14] compared computerized and visual methods to detect the VT. They found, that the computerized methods for detecting VT are simple to implement and guarantee the reproducibility and repeatability of these measures. The computerized methods showed high reliability when compared to visual inspection. Although the determination of AT by computerized methods for detecting VT is non-invasive, reproducible, and reliable, it requires expensive gas analysis equipment. In most cases, this equipment operated in laboratory conditions with specialized personnel, making it more difficult to apply in daily coaching practice. Nishijima et al. [15] have developed a new objective method of visually estimating VT (by V-slope), assuming that the pre-VT segment is parallel to the respiratory exchange ratio. Thus, determined the VT best agreed with the LT. They have developed a new

objective mathematical method to estimate VT that does not require a computer software program.

Another non-invasive approach to determining AT, is measurement of the HR by incremental exercise. A deflection from linearity of the heart rate versus workload curve may be detected. This is a physiological phenomenon observed in approximately 85% of the healthy adults at the second threshold [6]. It is known as the heart rate deflection point (HRDP). In 1982, Conconi and colleagues suggested that this phenomenon could be used as a non-invasive method to assess the anaerobic threshold. Other authors later failed to find such coincidence between the workload, HRDP, and AT [7, 12]. For example, during an incremental exercise test, in 21 highly trained cyclists, HR response showed a deflection point in 66.7% of subjects, but was linear in 33.3% [16]. Even though Conconi Test seems to offer a certain simplicity in its use, in terms of material equipment, it is important to keep in mind the limitations which the use of Conconi Test also involves. The lack of adherence to the standardization requirements, technical issues, and methodology error could have contributed to the undesirable results, to detect HRDP levels in some attempts. Test stability of CT is very low and there is evidence that DP is not 100% repeated physiology phenomena [17].

Two of the main factors determining oxygen delivery to the muscles are pulmonary ventilation (V_e) and cardiac output (CO). Together they should provide enough amount of oxygenated blood to the muscles. During incremental exercise, they participate in different proportions at different levels of exercise intensity. At lower exercise intensity, the CO rises more due to an enlargement in stroke volume (SV). As the exercise intensity increases, the CO continues to rise, but mostly because of an increase in HR and less because of an enlargement in its SV. After a certain intensity, HR increases less. At the same time, at lower levels of exercise intensity V_e increases less, while at a certain level of exercise intensity it starts to increase exponentially. The proportions in the change can be expressed as a percentage of the maximum reached values of both variables (HR and V_e). The percentage expression of one variable makes it possible to compare the dynamics of physiological variables with different dimensions. The difference in proportions will be greatest at a certain exercise intensity during an incremental test, which is probably related to reaching the AT.

The hypothesis we are testing is whether it is possible to create an approach for determining AT based on the proportions by which HR and V_e change during incremental exercise test.

The aim of the work is to create a non-invasive and easily applicable in practice approach to determine the anaerobic threshold based on the measurement of pulmonary ventilation and heart rate.

Material and Methods

Participants. Twenty athletes from the national rowing team of Bulgaria with average age of 17.5 years were tested. In this experiment, informed consent was

obtained from all participants.

Procedure.

Participants performed a one-time graded incremental exercise test to exhaustion on a rowing ergometer. This represents a control test for the effectiveness of the training process of the competitors from the national rowing team. Of all the parameters recorded standardly, in this test we used the indicators for power (W), heart rate (HR), pulmonary ventilation (Ve) and blood lactate (La). Tests were conducted on rowing ergometer system Concept 2, spirometry system Clark C5, and lactate analyser Arkray LactatePro™. The initial workload was 60 W. Each stage lasted 2 minutes. Each subsequent stage was 40 W higher than the previous. Blood lactate samples were taken at the end of each stage of the earlobe and were measured by a lactate analyser. Thus, we obtained measurements for each participant for HR, Ve, W and La at the end of each stage.

Approach description.

After the end of the test, we used the peak heart rate (HR_{peak}) of each participant to calculate the percentage of HR achieved (%HR) for each stage. Thus, we converted the absolute values for HR into percentages. We used the same procedure for pulmonary ventilation as the peak value (Ve_{peak}) was accepted as 100% of (% Ve). On the Table 1. is an example for one of the participants. The approach we propose is graphical and the determination of AT was done in a specific sequence.

The difference (Diff) between the percentages of %HR and %Ve is compared with %Ve. The %Ve showed larger and more characteristic changes, and a steeper increase after a certain exercise intensity. This is expressed graphically by the intersection between the Diff and % Ve curves (Fig. 1). This intersection point has a relation with the point of AT determined by the LT. When constructing curves, it is important to properly scale the axes in the graph. In the main graph on one ordinate the values for %Ve are plotted, as the minimum is fixed to 1 unit below the smallest percentage of %Ve. This is the measurement from the end of the first stage. We used it for the lower limit of the scale, because Ve at rest is a very variable indicator, and in addition there is no ventilation with a value of

0%. Ventilation at the end of the first stage is already a relatively constant indicator and we can set it at the beginning of the scale. This constancy is due to the neuro-humoral regulatory mechanisms during exercise. We will give examples of scaling the two ordinates. For instance, a ventilation of 21.08 L/min allows us to determine 21 for a minimum scale value for %Ve. Therefore 21 is 0% for the %Ve scale. The upper limit of this scale is also fixed by Ve_{peak} , which is 100% for %Ve. On the other ordinate (at left), the minimum value of the Diff is fixed at 0. The maximum value is fixed up to 1 unit above the maximum value for Diff. For example, if the highest value for Diff is 36.4, we need to set a fixed maximum scale limit of 37. Choosing a higher value than this is not correct, because this indicator is the result of the difference of two 100 percent values. On the abscissa we set the absolute power for each stage. The intersection point between the two curves is very close to the AT determined by LT. Because the intersection point resembles the X sign, we called the approach to determining AT the X-method. In the end we get the exact power (W) in Watt at which the Diff curve intersects with the %Ve curve and determine the AT. We then graphically determine the HR corresponding to the absolute power at which AT is detected.

To determine the applicability of our proposed X-method, we compared the AT obtained by it with the AT obtained at OBLA (4 mmol/L) and the AT obtained by the D_{max} method for determining LT. We compared HR corresponding to each of the three methods for determining AT.

One of the reference methods we focused on is Onset of Blood Lactate Accumulation – OBLA. This approach to determining AT assumes that the anaerobic threshold is the same as the absolute blood lactate concentration of 4 mmol/L, and is described by Mader et al. in [18]. OBLA is usually measured in tests of increasing intensity and subsequent interpolation to determine the intensity of the exercise that is expected to cause 4 mmol/L blood lactate. The advantage of using 4 mmol/L lactate as a criterion for OBLA assessment is that it offers very objective assessment of the lactate threshold. Another advantage is

Table 1. Displays the raw data for one of the participants.

W	La	HR	Ve	%HR _{peak}	%Ve	Diff
60	1.1	102	37.2	53.4	21.1	32.3
100	1.1	115	49.4	60.2	28.0	32.2
140	1.2	125	57.9	65.4	32.8	32.6
180	1.4	143	67.8	74.9	38.4	36.4
220	1.4	158	84.5	82.7	47.9	34.8
260	1.8	174	101.6	91.1	57.6	33.5
300	3.1	181	118.1	94.8	67.0	27.8
340	4.1	188	136.3	98.4	77.3	21.2
380	6.6	176	158.1	92.1	89.6	2.5
420	8.4	191	176.4	100.0	100.0	0.0

NOTE: In the columns La, HR, Ve, W, and derivative values in the columns %HR_{peak}, %Ve, and Diff.

that 4 mmol/L is significantly higher than the resting level, which can be quite variable. This means, that 4 mmol/L will represent a fairly narrow range of intensity during a test with increasing intensity. The problem with the use of absolute concentration of blood lactate is the insensitivity to individual physiological differences [5].

D_{max} is the other reference method for determining AT by LT. First proposed by Cheng [19] LT is defined as the largest perpendicular distance from the line constructed between the first and last lactate measurement (lactate straight line) under increased exercise, and a point on the curve of a 3 degree polynomial that represents the changes in the lactate during the test. This point reflects the change in the tendency of the blood lactate during exercise. The accuracy of the method depends on the location of the

first and last data point from the lactate curve, because of which it shows some variability. To overcome this influence, Bishop et al. [9] proposes a modification of the method. According to him, the lactate straight line starts from the point preceding the first measured difference of 0.4 mmol/L between two consecutive measurements and ends at the last measurement. In order to refine the determination of LT by this modified D_{max} method, we constructed a line, parallel to the lactate straight line, which passes as tangent to the curve of the third degree polynomial (Fig. 2). The position of contact between them determined the point from which a perpendicular is descended to the lactate straight line. For each of the participants, we plotted a graph, with La scaled on the ordinate and the power of each stage on the abscissa

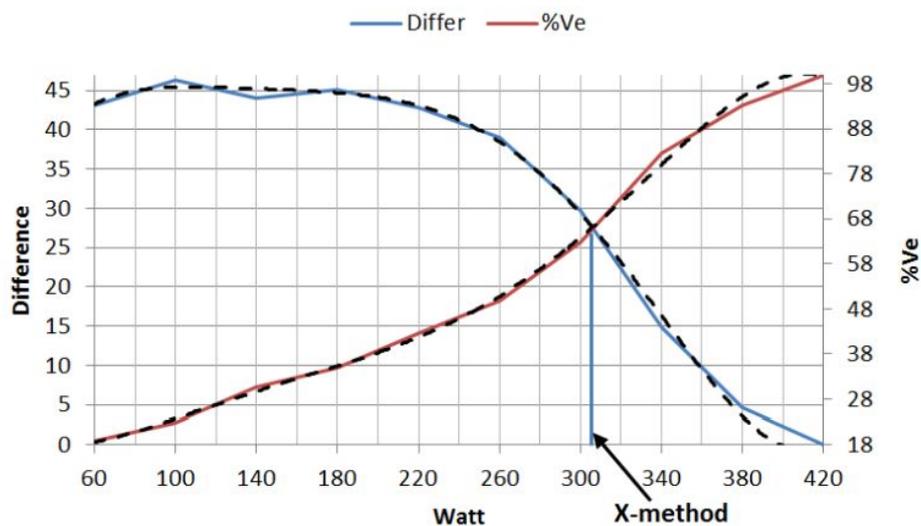


Figure 1. Reflects the relationship between %Ve and the difference between %HR and %Ve. A dotted line shows the 5-degree polynomials of both variables. The intersection point between the curves of the two polynomials determines the AT by the X-method.

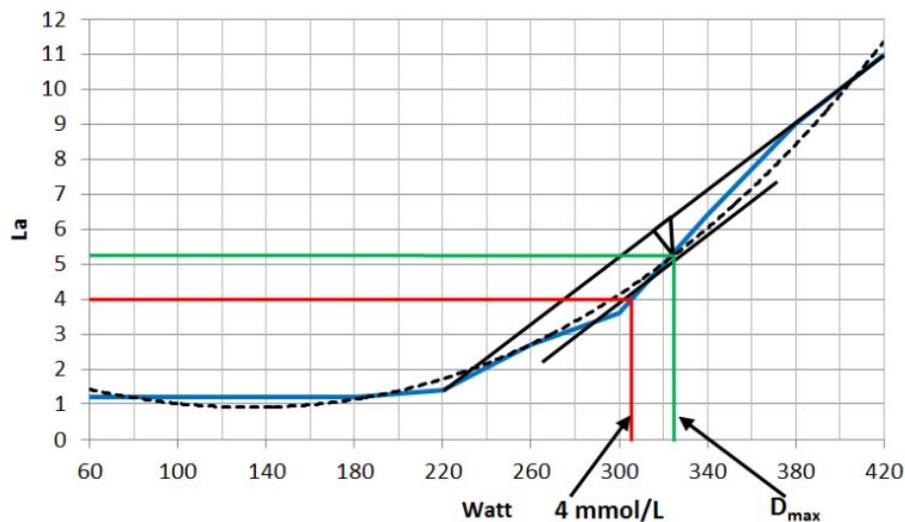


Figure 2. Represents the determination of the power corresponding to the AT determined by the 4 mmol/L method and the AT determined by the modified D_{max} method.

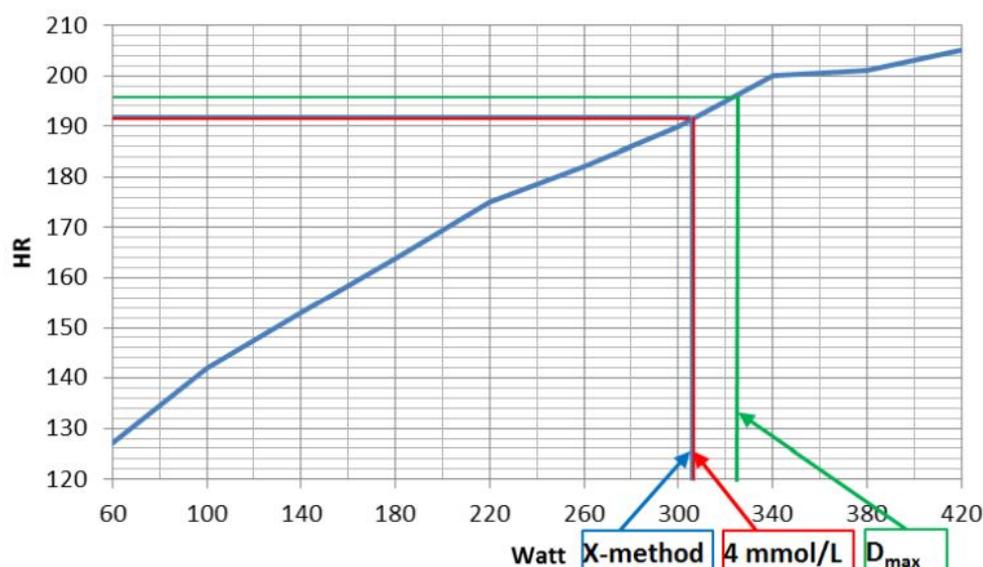


Figure 3. Represents HR corresponding to the power at which AT is detected by each of the three methods.

(Fig. 2). According to this graph, we defined AT as power corresponding to 4 mmol/L and AT by the modified D_{max} method.

To determine the HR versus the power corresponding to the AT determined by each of the three methods, we used a graphical approach (Fig. 3)

Statistical analysis.

To compare the three methods, we arranged the HR corresponding to the AT determined by the respective method for each participant (Table 2). Then we did a test for normality of the distribution of HR for each of the three methods. We used the Shapiro-Wilk test. For comparison of the standard deviations in normally distributed data or close to the normal distribution, we used Two-tailed Fisher's F-test. If the standard deviations of two samples do not differ statistically, it can be assumed that they belong to one general sample. To compare the new approach with the two classic methods, we used the Bland & Altman test, which offers a simple parametric approach based on dispersion analysis and simple graphical methods [20]. The Bland - Altman (B&A) diagram describes the consistency between two quantitative measurements. The area of consistency is calculated by the median and standard deviation of the differences between the two measurements. B&A recommends that 95% of the points lie within limits of $\pm 2s$ from the median difference (s - standard deviation). This way of applying the B&A method is the most common one [21].

For statistical data processing we used EXCEL 10 of Microsoft Office 10 and the application XLSTAT developed for the purpose.

Results

Our proposed X-method was compared with two approved methods for determining AT based on the concentration of blood lactate.

Table 2. Represents the HR measured at AT determined by the respective method.

Subject	D_{max}	X-method	4mmol/L
1	190.00	190.00	190.00
2	180.00	177.00	177.00
3	174.00	173.00	171.00
4	185.00	183.00	185.00
5	201.00	196.00	196.00
6	187.00	185.00	180.00
7	186.00	184.00	185.00
8	179.00	176.00	177.00
9	174.00	170.00	175.00
10	177.00	177.00	179.00
11	192.00	188.00	190.00
12	179.00	176.00	179.00
13	178.00	173.00	176.00
14	173.00	172.00	168.00
15	191.00	191.00	191.00
16	181.00	179.00	181.00
17	190.00	190.00	188.00
18	196.00	191.00	191.00
19	174.00	171.00	168.00
20	186.00	186.00	188.00
STDEV	7.995	7.956	8.097
Aver.	183.65	181.40	181.75

NOTE: In the first column are the consecutive numbers of the participants in the experiment. In the second column are the HR for AT determined by the D_{max} method, in the third are HR for AT determined by the X-method, in the fourth are HR for AT determined at 4 mmol/L.

On the Table 2 are shown the HRs corresponding to AT determined by each of the respective methods. The average HR for each of the three methods differ slightly from each other. Furthermore, the same is observed for the standard deviations, which are also slightly different compared to one another. This indicates that the methods probably have a similar ability to determine AT. From Table 2 can be seen that the standard deviations of the HR of the three methods for determining AT and their averages are very close. Therefore, for the three samples from the table a test for normality of distribution should be performed. The results of the Shapiro-Wilk test are presented in Table 3 and show that all three samples for HR have a normal or close to the normal distribution. This allows us to choose parametric methods to compare the three methods. If the differences between their standard deviations and their average values are not statistically significant, then they can be applied alternatively.

Table 3. Represents p-value for each of the three samples, with statistical significance $\alpha = 0.05$

Variable	Shapiro-Wilk p-value
(D _{max})	0.307
(X-method)	0.199
(4mmol/L)	0.493

Fisher’s F-test showed that the standard deviations of the samples two by two do not differ significantly at $\alpha = 0.05$, and therefore, belong to the same group (Table 4).

Table 4. Represents p-value for Fisher’s F-test for comparing the standard deviations of the three methods for determining AT.

Variable	Fisher p-value
X-method vs. D _{max}	0.983
X-method vs. 4mmol/L	0.940
D _{max} vs. 4mmol/L	0.975

On the Table 5 are presented the results of the analysis of the B&A test for the three methods for determining AT, each compared with the others. Heart rates for AT determined by the three methods are represented graphically by the B&A method in Figure 4. There are compared between each other all three methods for determining the AT.

Table 5. Bias – average of the differences from one compared method – (minus) the other compared method; Standard error; CI Bias - deviation range; Confidence interval of differences.

Statistical parameter	X-method vs. D _{max}	X-method vs. 4mmol/L	D _{max} vs. 4mmol/L
Bias	2.25	0.35	-1.9
Standard error	1.773	2.519	2.634
CI Bias (95%)	1.420 ÷ 3.080	-0.829 ÷ 1.529	-3.133 ÷ -0.667,
Confidence interval (Differences):	-1.226 ÷ 5.726	-4.587 ÷ 5.287	-7.062 ÷ 3.262,

It is seen, that 95% of all measurements lie within the confidence interval, for each comparison of a method with the others. As shown on table 5, the D_{max} method reveals AT at higher HR having 2.25 average heartbeats per minute more, in comparison to the X-method. 4mmol/L method reveals AT at higher HR with 0.35 average heartbeats per minute more, in comparison to the X-method. When we compare the two approved methods, we can also see a difference in the HR in determining AT. This difference shows that the 4mmol/L method reveals AT at lower HR having 1.9 average heartbeats per minute less in comparison to the D_{max} method. The standard error from the three comparisons is the lowest when comparing the X-method with the D_{max}.

Discussion

The comparison between the three methods for determining of AT shows that the differences between them are not statistically significant. The advantage of the proposed from us approach (X-method) is, that it requires only a Heart Rate Monitor, Portable Device for measuring Ve, and Device for measuring Movement Speed or Power of Work. Twelve models are used to determine AT [6], each of which has its advantages and disadvantages. We will mention some of the basic models with their disadvantages, that are avoided with our approach. Using a fixed lactate value as the threshold certainly increases objectivity but denies individuality since the non-linear increase in blood lactate does not always occur at 4 mmol/L [5]. In addition, the procedure is invasive. Moreover, even if we assume that all studies are using the same definition and the same criteria to detect the LT, there is strong evidence to suggest that these thresholds do not occur at the same power output [5]. One of the most accurate methods for determining LT is the modified D_{max} method described above, but unfortunately it is invasive. On the other hand, the level of AT determined with the Dmax method significantly differs in comparison to the level of V-slope method [22], which is not discussed in this article, but is one of the basic non-invasive methods for determining of AT. However, the V-slope method requires expensive laboratory equipment and personnel. It can also be performed in the field conditions by using expensive portable gas analysers, which have less measurement accuracy than laboratory ones.

One non-invasive, easy for use and inexpensive method for determining AT is the detection of the heart

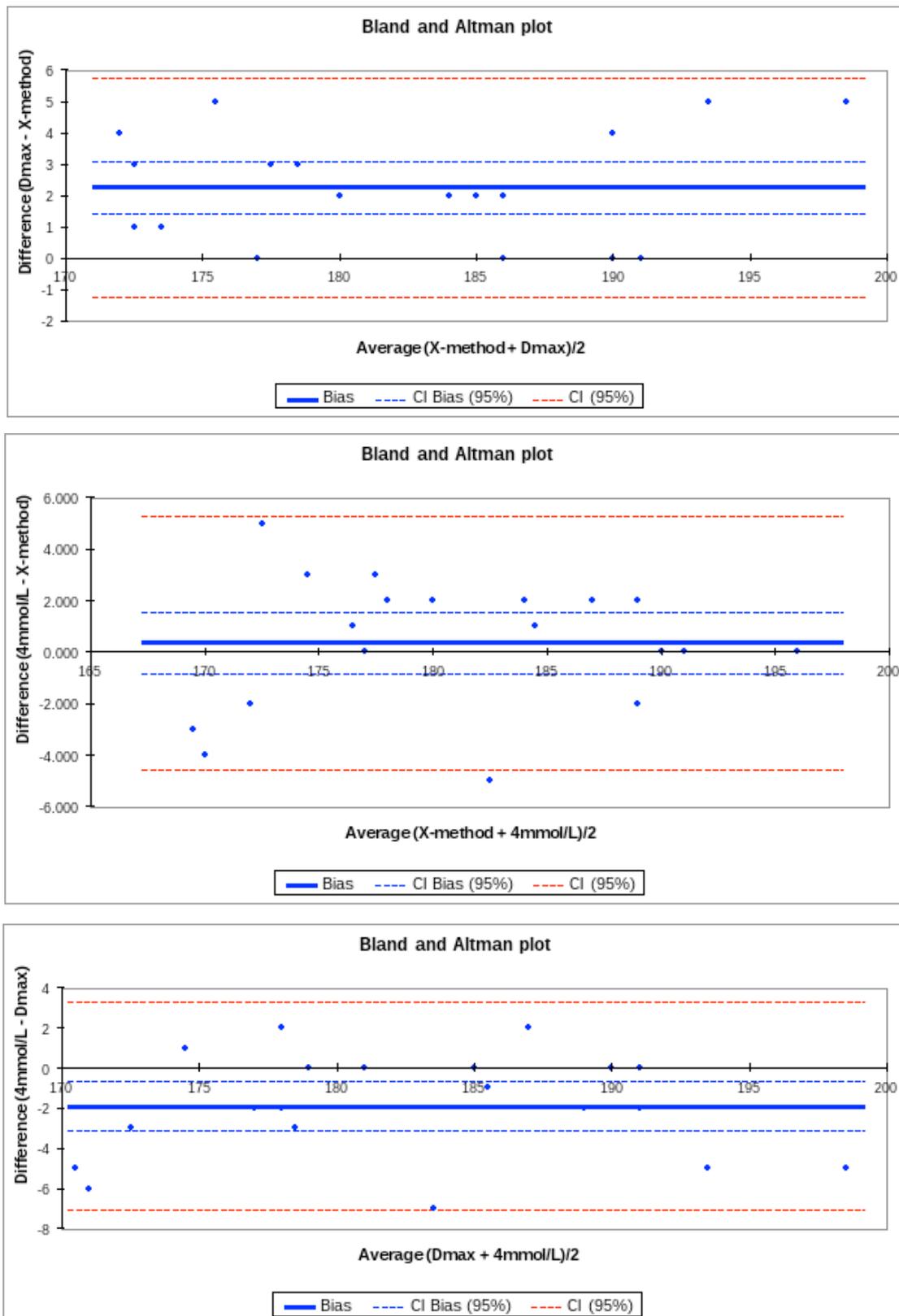


Figure 4. Displays the data points of the compared methods within the confidence interval by the Bland-Altman method.

rate deflection point (HRDP) described by Conconi et al. [23]. Despite the fact that the Conconi test is used by some athletes and coaches, there is serious criticism of the method in the scientific literature. The main difficulty comes from the concept of the deflex point, as

some studies have failed to find it systematically in all investigated subjects. Therefore, a number of authors question the physiological existence of HRDP and suggest that it is a protocol-dependent artefact [24, 5]. Jones and Doust [25] concluded that the failure to determine

repeatable HR deviation in the assessment in 9 of the 15 examined subjects makes the Conconi test unsuitable for reliable assessment of AT. The controversy over the use of HRDP to assess the anaerobic threshold may be related to differences in methodologies. HRDP appears to be associated with LT, but many researches are still needed to link to the maximum lactate steady state (MLSS) [5]. We did not mention MLSS, although it is a very accurate method for determining AT. Unfortunately, it is invasive with a very long and precise procedure. In other hand traditional D_{\max} and OBLA of 4.0 mmol.L⁻¹ methods did not provide valid estimates of the MLSS [26].

There are other attempts to use HR to determine AT. By laboratory trials, the measured HR and power output at the AT, determined either by respiratory gas indices or the HRDP method, give comparable results with AT determined by blood lactate concentrations and could, therefore, be used for guiding the appropriate intensity of rowing training [27].

Conclusions

Our proposed approach is non-invasive and can be easily applied in field conditions, without using gas-analysing devices. In addition, it is reliable, reproducible and comparable to the accepted for “Gold Standard” methods for determination of anaerobic threshold with 95% statistical significance. We have not found similar methods using only heart rate, pulmonary ventilation and speed movement or power of work in the literature available to us, therefore we consider this approach to be new to the sports practice. To be able this approach to be used more widely in sports practice, research in other endurance sports is needed. It could also be used in clinical trials to monitor the physical condition of various contingents of subjects.

Conflict of interest

The authors declare no conflict of interest.

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The efficiency of action of futsal goalkeepers in game situations with varying results of competition

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Abstract

Purpose: The aim of the study was to expand knowledge of the efficiency of actions from top-level futsal teams. Goalkeepers' activity, effectiveness and reliability were estimated with a view to implementing the objectives of the game in offence and defence and depending on the changing match status.

Material: Data about the game were registered on a self-developed observation sheet. 23 goalkeepers participating in 31 matches of the World and the European Championships and the UEFA Futsal Cup played in the years 2012–2015 were observed. In order to estimate statistically significant differences in goalkeepers' activity in situations of neutral, favorable and unfavorable competition scores, the results were averaged by dividing each of the applied actions in a given match by the number of minutes played during a given competition result. The outcome was the average performance of a goalkeeper in one minute of the match during a given score. The results of the activity scale, depending on the result of the match, were compared with the Kruskal-Wallis test and the post hoc Dunn Bonferroni test and the Jonckheere-Terpstra trend test. Statistical analysis was conducted with a use of the statistical package R and STATISTICA 10.

Results: It was found that actions to gain the playfield with the ball and to prevent a loss of a goal dominated in futsal goalkeepers' both when drawing as well as winning and losing game and that game status does not determine the style of play of the goalkeeper. Only in nine of the 60 types of actions examined significant differences in activity were found.

Conclusions: The unequivocal claim that the current score during the competition determines the style of the futsal goalkeeper's game (the frequency of taking actions in the game characteristic of his position), is unauthorized at this stage of research. The obtained significant differences in his activity in nine types of actions constitute only a small percentage (15%) of all his skills in the game.

Keywords: notational analysis, match status, activity of actions

Introduction

In a sport team game, a reliable assessment of a player is possible only through repeated observations of his actions in real-life conditions with an opponent of a similar level of sports proficiency, which is carried out with a use of objective research tools [1]. While assessing players' performance, one should primarily take into account those situational variables that determine the complexity of the game situation. The game situation is determined by the time, the place of the player's action and the tasks he needs to implement, other players' skills and the rules of the game, the place and the current result of competition [2, 3]. The measure of a player's championship lies in his ability to cooperate efficiently and perform various individual actions to achieve a specific goal in the game in increasingly difficult conditions of competition.

For several years, there has been intensive research on futsal players' efficiency of action. A review of the literature [4-7] shows that conceptual eclecticism and a variety of methodological approaches dominate studies of this game. As a rule, research focuses on selected aspects of offensive actions aiming to score goals and position the game (types of attack, ways of scoring goals, set pieces

of the game and their effectiveness) and of defensive actions (types of defence, methods and places of receiving the ball). Comprehensive analyses of various variables are rare, and yet an integrated approach that considers multiple aspects is now recognized as crucial in studying sport team games [8].

The game of futsal still remains unknown in many areas, especially in terms of game analysis [5]. This also applies to the position of the goalkeeper. Most analyses focus on the goalkeeper's participation in offensive actions, in situations of outnumbering when each team uses the 5vs4+GK format [9, 10], on his efficiency in preventing the loss of a goal and ways of saving shots at the goal [11, 12]. Comprehensive assessments of the goalkeeper's efficient performance in the game are rare and rather contributory [13]. Therefore, despite a need for systemic approaches to the assessment of football players' performance skills, as regards futsal, firstly, one must accurately describe and define the variables relevant to effective competition [4], primarily in relation to the players' positions [5], and only then estimate their mutual impact on success in the game.

Szwarc et al. [14] and Oszmaniec & Szwarz [15] already attempted to describe goalkeepers' actions in the game of futsal. They characterized particular actions

and assessed their efficiency* in terms of offensive and defensive objectives pursued by the goalkeeper, namely: keeping the ball, gaining the playfield with the ball, creating goal-scoring situations, scoring goals and preventing such situations. However, the purpose of this research is to broaden knowledge about the efficiency of futsal goalkeepers of teams of the highest level of sport proficiency in the context of different results of the competition. The following research questions have been formulated: (i) what is the activity, efficiency and reliability of futsal goalkeepers in game situations with a neutral, favorable and unfavorable result? (ii) are there any significant differences in the activity of the top-level futsal goalkeepers in game situations with a neutral, favorable and unfavorable match result?

Material and Methods

Participants

23 goalkeepers (age: 27.03 ± 3.86 y, body height: 182 ± 5.64 cm) were examined in 31 matches, rendering 62 game analyses in total (Table 1). The examined group comprised players of the highest level of sports proficiency, competing for the World and the European Championship (all matches of the knockout phase, from the quarter-finals to the finals) and for the *UEFA Futsal Cup* (all matches of the semi-finals and the finals) held in 2012–2015. The study was conducted in a manner that respected the principles established by the Declaration of Helsinki and it was approved by the Ethics Committee of the University.

Measures

This study used the method of observation. The analysis was made with a use of video footage recorded on a DVD, where during a multiple replay of a game situation the tested action was observed. Data about the game were recorded on a special originally developed observation sheet meeting scientific requirements (the ICC test was used, the intra-rater reliability – 1.00 (95% CI 1.00–1.00) and the inter-rater reliability – 0.99 (95% CI 0.99–1.00) [14].

Activity, effectiveness and reliability of goalkeepers' actions in terms of objectives of the game were investigated. In attacking, the efficiency of actions aiming at keeping the ball, gaining the playfield with the ball, creating goal-scoring situations and scoring a goal were estimated, while in defence, the efficiency of actions against losing a goal and against creating a goal-scoring situation was evaluated. Goalkeepers' game was analysed within the regular, 40-minute game time. The analysis excluded the goalkeepers' play time in which they were substituted by players from the field in case of

an unfavorable competition result. Activity in action was examined with regard to all actions occurring in the game (Table 2), taking into account the division of the pitch into 2 sectors and 3 zones (Figure 1). Two zones were distinguished in sector A: A1 – the goal area and A2 – the defence area, from the goal line to the centre line of the pitch, excluding the goal area. In sector B, zone A3 was distinguished - the area of the field of attack, from the centre line of the pitch to the end line of the pitch.

Statistical analysis

In order to estimate statistically significant differences in goalkeepers' activity in situations of neutral, favorable and unfavorable competition scores, the results were averaged by dividing each of the applied actions in a given match by the number of minutes played during a given competition result. The outcome was the average performance of a goalkeeper in one minute of the match during a given score. This procedure was necessary because the examined goalkeepers acted for various lengths of time in situations of neutral, favorable and unfavorable scores. The normality of the distribution of activity results in these situations was analysed with the Shapiro-Wilk test, and after finding significant deviations from the normal distribution, further analyses were carried out with nonparametric methods. The results of the activity scale, depending on the result of the match, were compared with the Kruskal-Wallis test and the *post hoc* Dunn Bonferroni test and the Jonckheere-Terpstra trend test. Statistical analysis was conducted with a use of the statistical package *R* and *STATISTICA 10*.

Results

The data in Table 3 refer to the competition of goalkeepers from the best futsal teams participating in matches of the knockout phase of the World and European Championships and in the *UEFA Futsal Cup* in the years 2012–2015. In situations of neutral, favorable and unfavorable score, dominated the actions of gaining the playfield with the ball (711, 560 and 528 actions, respectively) and of preventing a loss of a goal (459, 424 and 353 actions, respectively). Goalkeepers most rarely executed actions aimed at scoring a goal (17, 31 and 20 actions, respectively). The analysed goalkeepers achieved the highest reliability in situations of neutral, favorable and unfavorable scores in actions aimed at keeping the ball and preventing the creation of scoring situations. They failed the most often while scoring a goal. They played the longest in a neutral competition result (974 minutes). During a favorable result, they played for 753 minutes, and in a situation of an unfavorable result for 586 minutes.

A comparison of the averaged results of the studied players' activity in 12 actions of keeping the ball (Table 2, items 30–41) in the context of three different scores of competition showed that only during keeping the ball by receiving it from a partner in zone A1 (Table 2, item 35) there were significant differences between the frequency of performing this action in game situations with neutral, favorable and unfavorable results. Analysis with a use of the *post-hoc* Dunn Bonferroni test showed (Table 4)

* In praxeological terms [18], efficiency of action is understood as a total of practical qualities of play, which includes: activity (number of actions performed by players of one team during a match), effectiveness (number of positive actions with reference to the game's aims) and reliability (ratio between the number of effective actions and the number of all actions of one type during the game). Other indices of play efficiency encompass rationality (actions cognitively justified), valuableness (value of assessment of action efficiency) and economy (loss-gain ratio).

Table 1. List of the examined futsal goalkeepers from teams of the highest sports level along with their playing time in situations of a neutral, favorable and unfavorable result of the competition.

No.	National team or club (country)	Goalkeeper	Age [years]	Body height [cm]	Number of matches played	Goalkeeper's playing time			
						Actual playing time [min' sec]	Neutral result [min]	Favorable result [min]	Unfavorable result [min' sec]
1.	Italy	Mammarella	28	176	8	269'44	100	112	57'44
2.	Russia	Gustavo	33	184	6	229'51	82	96	85'08
3.	Marca Futsal (Italy)	Higuita	26	181	5	196'01	86	77	33'01
4.	Kairat Almaty (Kazakhstan)	Sedano	33	188	4	151'03	66	54	30'03
5.	Barcelona	Benedito	34	177	4	146'33	79	35	32'33
6.	Sporting CP (Portugal)	Popov	32	185	4	142'42	36	60	46'42
7.	Dinamo Moscow (Russia)	Jukić	26	190	4	137'30	34	12	96'41
8.	Croatia	Tiago	31	173	3	120	62	34	24
9.	Brazil	Juanjo	27	185	3	120	49	64	7
10.	Spain	Amado	36	185	3	115'12	52	62	1'12
11.	Colombia	Lozano	30	180	2	80	34	17	29
12.	Spain	Rafa	34	192	2	78'18	33	35	10'18
13.	Ukraine	Ivanyak	30	180	2	78'08	51	0	27'08
14.	Russia	Zuev	32	186	2	75'45	53	6	16'45
15.	Romania	Lancu	34	180	2	41	14	0	27
16.	Argentina	Elias	29	182	1	40	22	18	0
17.	Colombia	Nanez	28	180	1	40	28	0	12
18.	Sporting Lisbon (Portugal)	Cristiano	36	170	1	40	13	22	5
19.	Serbia	Aksentijević	29	189	1	37;02	30	4	3'02
20.	Ukraine	Lytvynenko	27	175	1	37'10	13	0	24'10
21.	Slovenia	Mordej	24	182	1	35'15	11	0	24'15
22.	Iberia Star (Georgia)	Celio	28	178	1	25'51	12	0	13'51
23.	Moscow (Russia)	Trushkin	21	188	1	35'55	13	5	7'55

Table 2. Types of analysed actions performed in the game by the examined goalkeepers.

No.	Type of action
1.	Gaining the playfield by throwing the ball with an underhand swing in zone A1
2.	Gaining the playfield by throwing the ball overhead single-handedly in zone A1
3.	Gaining the playfield by throwing the ball in "another way" - hip throw, two-handed throw in zone A1
4.	Gaining the playfield by a short pass of the ball with a foot after receiving in zone A1
5.	Gaining the playfield by a short pass of the ball with a foot after receiving in zone A2
6.	Gaining the playfield by a short pass of the ball with a foot after receiving in zone A3
7.	Gaining the playfield by a long pass of the ball with a foot after receiving in zone A1
8.	Gaining the playfield by a long pass of the ball with a foot after receiving in zone A2
9.	Gaining the playfield by a short pass of the ball with a foot without receiving in zone A1
10.	Gaining the playfield by a short pass of the ball with a foot without receiving in zone A2
11.	Gaining the playfield by a short pass of the ball with a foot without receiving in zone A3
12.	Gaining the playfield by a long pass of the ball with a foot without receiving in zone A1

Table 2. Continuation

No.	Type of action
13.	Gaining the playfield by a long pass of the ball with a foot without receiving in zone A2
14.	Gaining the playfield by a long pass of the ball with a foot without a pass in zone A3
15.	Gaining the playfield by passing the ball with a foot in "another way", i.e. after intercepting, after faking and/or dribbling the ball, from a set piece in zone A1
16.	Gaining the playfield by passing the ball with a foot in "another way" - after intercepting, after faking and/or dribbling the ball, from a set piece in zone A2
17.	Gaining the playfield by passing the ball with a foot in "another way" - after intercepting, after faking and/or dribbling the ball, from a set piece in zone A3
18.	Gaining the playfield by faking and/or dribbling the ball in zone A1
19.	Gaining the playfield by faking and/or dribbling the ball in zone A2
20.	Gaining the playfield by faking and/or dribbling the ball in zone A3
21.	Scoring a goal (in contact or without contact with an opponent) by hitting the ball with a foot in zone A1
22.	Scoring a goal (in contact or without contact with an opponent) by hitting the ball with a foot in zone A2
23.	Scoring a goal (in contact or without contact with an opponent) by hitting the ball with a foot in zone A3
24.	Scoring a goal (in contact or without contact with an opponent) by hitting the ball dropped from a hand in zone A1
25.	Creating a goal-scoring situation by throwing the ball overhead single-handedly in zone A1
26.	Creating a goal-scoring situation by throwing the ball with a hand in "another way" - hip throw, two-handed throw in zone A1
27.	Creating a goal-scoring situation by passing the ball with a foot from the ground after receiving in zone A1
28.	Creating a goal-scoring situation by passing the ball with a foot from the ground after receiving in zone A2
29.	Creating a goal-scoring situation by passing the ball with a foot from the ground after receiving in zone A3
30.	Sliding tackle to keep the ball in play in zone A2
31.	Keeping the ball by faking and/or dribbling in zone A1
32.	Keeping the ball by faking and/or dribbling in zone A2
33.	Keeping the ball by catching it after faking and/or dribbling in zone A1
34.	Keeping the ball by catching the ball after partner's playing in zone A1
35.	Keeping the ball by receiving the ball from a partner in zone A1
36.	Keeping the ball by receiving the ball from a partner in zone A2
37.	Keeping the ball by receiving the ball from a partner in zone A3
38.	Keeping the ball by passing the ball backwards in zone A1
39.	Keeping the ball by passing the ball backwards in zone A2
40.	Keeping the ball by passing the ball backwards in zone A3
41.	Keeping the ball by passing the ball from a set-piece in zone A2
42.	Preventing the loss of a goal by catching the ball (in place, in half-kneeling, in kneeling, in jumping, in robinsonade, in the hurdle sit) in zone A1
43.	Preventing the loss of a goal by punching the ball in zone A1
44.	Preventing the loss of a goal by pushing the ball (in place, in half-kneeling, in kneeling, in jumping, in robinsonade, in the hurdle sit) in zone A1
45.	Preventing the loss of a goal through defence with legs in zone A1
46.	Preventing the loss of a goal through situational defence in zone A1
47.	Preventing the loss of a goal through defence in a 1x1 situation in zone A1
48.	Preventing the loss of a goal by defending a set piece (penalty kick, direct and / or indirect free kick, throw-in and corner kick) in zone A1
49.	Preventing the loss of a goal through intervention without contact with the ball in zone A1
50.	Preventing the loss of a goal by consequential doubling (catching the ball, situational defence, defence without contact with the ball) in zone A1
51.	Preventing the creation of a goal-scoring situation by catching the ball (in place, in half-kneeling, in kneeling, in jumping, in robinsonade) in zone A1

Table 2. Continuation

No.	Type of action
52.	Preventing the creation of a goal-scoring situation by punching the ball in zone A1
53.	Preventing the creation of a goal-scoring situation by pushing the ball (in place, in half-kneeling, in kneeling, in jumping, in robinsonade) in zone A1
54.	Preventing the creation of a goal-scoring situation by intercepting / clearing the ball with / without falling to the ground in zone A1
55.	Preventing the creation of a goal-scoring situation by intercepting / clearing the ball with / without falling to the ground in zone A2
56.	Preventing the creation of a goal-scoring situation by intervening without contact with the ball in zone A1
57.	Preventing the creation of a goal-scoring situation by intervening without contact with the ball in zone A2
58.	Preventing the creation of a goal-scoring situation by intervening without contact with the ball in zone A3
59.	Preventing the creation of a goal-scoring situation by consequential doubling (catching the ball, clearing the ball with / without falling to the ground, intervention without contact with the ball) in zone A1
60.	Preventing the creation of a goal-scoring situation by consequential doubling (catching the ball, clearing the ball with / without falling to the ground, intervention without contact with the ball) in zone A2

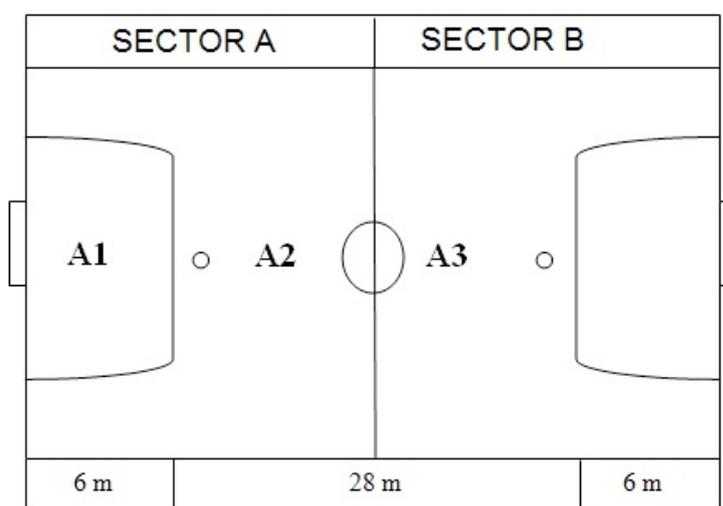


Figure 1. Division of the field into zones and sectors.

Table 3. The efficiency of offensive and defensive actions of the examined goalkeepers in the context of the implemented objectives of the game in situations of different competition results.

Type of actions	Number of actions								
	Neutral score			Favorable score			Unfavorable score		
	A	E	R	A	E	R	A	E	R
Keeping the ball	205	197	96	177	173	98	173	168	97
Gaining the playfield with the ball	711	632	89	560	475	85	528	474	90
Creating goal-scoring situations	52	32	62	42	29	69	33	20	61
Scoring a goal	17	0	0	31	4	13	20	1	5
Preventing the loss of a goal	459	396	86	424	364	86	353	316	90
Preventing the creation of goal-scoring situations	218	209	96	170	166	98	218	205	94
Total playing time of the examined goalkeepers [min]	974			753			586		
Match participation rate [number of full matches]	24.23			18.55			14.65		

A - activity (number of actions), E - efficiency (number of actions), R - reliability (%)

Table 4. List of actions in which the activity of the examined goalkeepers significantly differed depending on the competition result.

No of action ¹	Game status	X	SD	Min	Q ₁	Q ₂	Q ₃	Max	p Kruskal-Wallis test	p (Jonckheere-Terpstra test)	p (post-hoc Dunn Bonferroni test)		
											W	D	L
1	W	.17	.21	.00	.00	.07	.34	1.00				.0023**	.3035
	D	.30	.22	.00	.17	.29	.45	1.00	.0035**	.0846	.0023**		.2543
	L	.33	.62	.00	.00	.17	.48	4.46			.3035	.2543	
22	W	.01	.03	.00	.00	.00	.00	.17				.0406*	.0406
	D	.00	.00	.00	.00	.00	.00	.00	.0172*	.0135*	.0406*		1.00
	L	.00	.00	.00	.00	.00	.00	.00			.0406*	1.00	
24	W	.01	.03	.00	.00	.00	.00	.12				.0005***	.0005
	D	.00	.00	.00	.00	.00	.00	.00	.0001***	.0002**	.0005***		1.00
	L	.00	.00	.00	.00	.00	.00	.00			.0005***	1.00	
35	W	.09	.14	.00	.00	.00	.14	0.50				.0323*	1.00
	D	.16	.27	.00	.00	.12	.20	2.00	.0133*	.9894	.0323*		.0331
	L	.09	.13	.00	.00	.00	.16	.48			1.00	.0331*	
42	W	.07	.12	.00	.00	.00	.11	.50				.7052	.5001
	D	.09	.15	.00	.00	.04	.11	1.00	.0365*	.1683	.7052		.0305
	L	.04	.08	.00	.00	.00	.07	.44			.5001	.0305*	
44	W	.12	.16	.00	.00	.06	.18	.80				.5941	.6620
	D	.14	.19	.00	.01	.09	.18	1.00	.0426*	.2039*	.5941		0.0360
	L	.10	.19	.00	.00	.00	.15	1.00			.6620	.0360*	
45	W	.05	.08	.00	.00	.00	.07	.32				.1951	.8357
	D	.07	.14	.00	.00	.04	.09	1.00	.0125*	.2845*	.1951		.0102
	L	.03	.07	.00	.00	.00	.04	.32			.8357	.0102*	
55	W	.02	.04	.00	.00	.00	.00	.20				.0288*	.1136
	D	.04	.06	.00	.00	.00	.07	.27	.0233*	.0344*	.0288*		1.00
	L	.06	.13	.00	.00	.00	.06	.66			.1136	1.00	
56	W	.02	.05	.00	.00	.00	.00	.25				.1163	1.00
	D	.05	.14	.00	.00	.00	.05	1.00	.0321*	.7454	.1163		.0452
	L	.02	.07	.00	.00	.00	.00	.33			1.00	.0452*	

1 according to Table 2, W- winning, D- drawing, L- losing, p - level of significance, * $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

that the respondents performed this action significantly more often in a game situation with a neutral score than during competition with a favorable or unfavorable score ($p \leq 0.05$). In the remaining 11 actions of keeping the ball, such differences were not found. On average, goalkeepers were active in this action during one minute of the game, playing in situations of a neutral score (0.16), and slightly less during a favorable or an unfavorable competitive result (0.09).

On the other hand, out of 20 actions of gaining the playfield with the ball (Table 2, items 1–20) only in only action – gaining the playfield by throwing the ball with an underhand swing in zone A1 (Table 2, item 1) – did the players' activity significantly vary depending on different scores. The examined goalkeepers significantly more often ($p \leq 0.01$) performed these actions in a game

situation with a neutral result than during competition with a favorable score (Table 4). On average, they performed the most actions during one minute of the game when playing in situations of unfavorable scores (0.33), slightly less during neutral situations (0.3), and the least in game situations with favorable scores (0.17).

Of the four types of goal-scoring actions (Table 2, items 21–24), in two (scoring a goal in contact or without contact with an opponent by hitting the ball with a leg in zone A2 and by hitting the ball dropped from the hand in zone A1), statistically significant differences were found in the activity of actions depending on the score. It follows from statistical analysis (Table 4) that goalkeepers performed these actions significantly more often in a game situation with a favorable result than during competition with a neutral or an unfavorable score

($p \leq 0.05$). On average, the most actions during one minute of the match occurred in situations of a favorable score (0.01); these actions were not used in game situations with neutral and unfavorable scores.

A comparison of the average results of the examined players' activity in 9 actions against the loss of a goal in the context of three different results of competition showed (Table 2, items 42–50) that while preventing the loss of a goal, i.e. while catching the ball – in place, in half-kneeling, in kneeling, in jumping, in robinsonade, in the hurdle sit in zone A1 (Table 2, item 42), while pushing the ball – in place, in half-kneeling, in kneeling, in jumping, in robinsonade, in the hurdle sit in zone A1 (Table 2, item 44) and while defending the ball with legs in zone A1 (Table 2, item 45), there were significant differences between the frequency of performing these actions by the examined players in game situations with neutral, favorable and unfavorable results. According to the data presented in Table 4, goalkeepers performed these three actions significantly more often in game situations with a neutral result than in those with an unfavorable score ($p \leq 0.05$). In the remaining six actions against losing a goal (Table 2, items 43, 46–50), there were no statistically significant differences in the frequency of performing these actions. On average, during one minute of the match, goalkeepers most often caught the ball playing in situations of a neutral score (0.9), slightly less in favorable ones (0.7), and the least in situation of a unfavorable score in the competition (0.4). When pushing the ball, this was respectively: 0.14, 0.12 and 0.1, and when defending the goal with legs: 0.07, 0.05 and 0.03, respectively.

On the other hand, a comparison of the average results of the examined players in 10 actions against creating goal-scoring situations (Table 2, items 51–60) in the context of three different scores showed that when preventing the creation of goal-scoring situations, i.e. while intercepting / clearing the ball with/without falling to the ground in zone A2 (Table 2, item 55) and defence / intervention without contact with the ball in zone A1 (Table 2, item 56) there were significant differences in the frequency of performing these actions in game situations with neutral, favorable and unfavorable scores. Analysis of the data in Table 4 shows that in preventing the creation of goal-scoring situations by intercepting / clearing the ball with/without falling to the ground in zone A2, goalkeepers performed these actions significantly more often in game situations with a neutral score than when playing with a favorable score ($p \leq 0.05$), and in preventing the creation of goal-scoring situations through defence / intervention without contact with the ball in zone A1 significantly more often in game situations with a neutral result than with an unfavorable one ($p \leq 0.05$). In the former case, on average, during one minute of the match, they performed the most actions in situations of an unfavorable score (0.06), slightly less when the score was neutral (0.04), and the least in situations of a favorable competition result (0.02), while in the latter case, they performed the most actions when playing in situations of a neutral result (0.05), and slightly less when the competition result was favorable

or unfavorable (0.02). In the remaining 8 actions against creating goal-scoring situations (Table 2, items 52–54 and 57–60) no statistically significant differences were found in the frequency of these actions depending on the game result.

Discussion

The purpose of this study was to broaden knowledge about the efficiency of futsal goalkeepers from teams of the highest level of sport proficiency in the context of the variable of playing in situations with varying results of the competition and about goalkeepers' activity during competition with neutral, favorable and unfavorable scores.

Our research shows (Table 3) that futsal goalkeepers are more often involved in offensive than defensive actions (58% and 42%, respectively), but slightly more often in game situations with a neutral result (59% and 41%) than while playing with a favorable score (58% and 42%) or an unfavorable one (57% and 43%). These general trends are also confirmed in 11-player soccer, where there are even three times more offensive than defensive actions [16, 17]. When attacking, futsal goalkeepers usually use actions aimed to gain the playfield with the ball and to keep the ball (41% and 13% of all actions performed in the game, respectively) in both neutral, favorable and unfavorable results. They perform these actions with very high reliability (88% and 97%, respectively). In turn, they create scoring situations a lot less often. This offensive action accounted for 3% of all actions performed in the game and was most often performed in game situations with a neutral score. In contrast, scoring goals was performed the least often (1.5% of all actions), and it was the most unreliable (7% reliability) in the game of futsal goalkeepers. In total, in all matches they made only 68 shots at the goal, and the most often they shot at the opponents' goal in game situations with a favorable result (31 actions with 13% reliability), and the least often with a neutral score (17 shots, all ineffective). It is worth adding that our study corresponds with reports by Kunze et al. [12], who also found 40% activity in Brazilian futsal goalkeepers' actions aiming to gain the playfield, by and Paz-Franco et al. [13], who proved that gaining the playfield by a passing the ball with a foot or hand dominates offensive actions of goalkeepers of the best Spanish teams. Szwarc et al. [16] also found a similar structure of the efficiency of offensive actions among goalkeepers of 11-person teams.

In defence, the examined goalkeepers more than twice more often prevented the loss of a goal than they acted against creating a goal-scoring situation (Table 3), respectively, in situations of a neutral, favorable and unfavorable score: 68% and 32%, 71% and 29% and 61% and 39%. They were the most active in the game with a neutral result (459 actions), and the number of their actions when the score of the game was favorable was 16% higher than the number of actions taken when the score was unfavorable (424 and 353 actions, respectively). Our results find confirmation in research on

goalkeepers in 11-player teams. Szwarc et al. [18] noted that goalkeepers' activity in matches concluded in a draw was significantly higher than in won or lost matches, and Taylor et al. [19], Lago-Peñas & Dellal [20], Castellano et al. [21] and Gómez et al. [22] proved that players of teams with an unfavorable score strive to change the status of the result, usually by attacking more often, thus forcing more activity in defensive actions from players and goalkeepers of the team holding the favorable score.

In this study, sixty actions of goalkeepers in the context of a neutral, favorable and unfavorable competition result were statistically analysed (Table 2). It was proved that only in nine of them they achieve statistically significant differences. In attack, the subjects achieved the highest level of statistically significant differences when scoring a goal in contact or without contact with the opponent by hitting the ball dropped from their hand in zone A1 and by hitting the ball from the ground in zone A2, when they performed these actions significantly more often in game situations with a favorable score than during competition with a neutral and unfavorable result ($p \leq 0.001$ and $p \leq 0.05$, respectively). Still, they performed these actions sporadically (Table 4). These situations most often occurred when the "losing" team was building a positional attack using the goalkeeper on the opponent's half or played without him using the 5vs4+GK format [11, 12], and upon taking possession of the ball the goalkeeper of the "winning" team immediately tried to score a goal. In principle, such actions do not occur in the game of goalkeepers from 11-person teams [17, 23, 24].

The examined goalkeepers playing in a situation of a neutral score applied actions to keep the ball by receiving it from a partner in zone A1 significantly more often than during a favorable or an unfavorable score ($p \leq 0.05$). Analysing the game in 11-player soccer, it was proved [25] that the teams tying at the given moment focus on defensive actions on their own half of the pitch, and this causes an increase in their goalkeepers' involvement in positioning the game. Similar behaviors occur in futsal teams in game situations with a neutral score – their goalkeepers also more often receive and play the ball from their own penalty area, without taking excessive risk in the defensive game.

Similar conclusions can be drawn from the analysis of gaining the playfield with the ball. The examined players gained it by throwing the ball with an underhand swing in zone A1 significantly more often in game situations with a neutral result than in those with a favorable result ($p \leq 0.01$). This is due to using a positional attack (game without excessive risk) with the goalkeeper's help more frequently. However, no significant differences were found in positioning the game involving the goalkeeper in zones A2 and A3. This is seemingly surprising, especially as regards the unfavorable outcome of the game. After all, teams in these situations are forced by rivals to attack positionally [9], also with the goalkeeper's participation [10], and this means their significant involvement in the actions of gaining the playfield with the ball. Yet, it should be remembered that in consistence with the methodology

adopted in this research, the analysis excluded the game time in which the goalkeeper was replaced by another player in situations of an unfavorable score. From among the examined goalkeepers only Higuaita (*Marca Futsal, Kairat Almaty*) regularly participated in building a positional attack on the opponent's half in the 5vs4+GK situation, hence this explains the results obtained in this study.

In turn, in three out of nine defensive actions (Table 2), i.e. preventing the loss of a goal in zone A1 by: catching the ball, pushing the ball out and defending the goal with legs, the examined goalkeepers significantly more often used these methods of defending the goal in game situations with a neutral result than during competition with an unfavorable one ($p \leq 0.05$). The obtained results show that the goalkeepers of the "losing" teams significantly less often prevented the loss of a goal. This should be explained by the fact that players of "losing" teams usually strive to change the status of the game, they attack more often, and thus, their goalkeeper's involvement in defence is much smaller. Such a strategy, the so-called "offensive" defensive has been confirmed by many researchers with respect to 11-player soccer [among others, 26, 27, 28].

In two of the ten actions against creating goal-scoring situations, the examined futsal goalkeepers were significantly more active in situations of varying scores (Table 2). In actions preventing scoring a goal by intercepting / clearing the ball with / without falling to the ground in zone A2, they significantly differed in activity in a game situation with a neutral and favorable result ($p \leq 0.05$), and in preventing scoring a goal by defence / intervention without contact with the ball in zone A1 in a game situation with a neutral and unfavorable result ($p \leq 0.05$). In the first case, interpretation of the results for actions against the loss of a goal can also be used to explain the results of this study, but in the second case, unequivocal explanation is difficult to provide. After all, teams playing in situations of an unfavorable score attack more often, and hence their goalkeepers are less often involved in defensive game in their own goal area. This issue requires clarification in subsequent studies.

Conclusion

The unequivocal claim that the current score during the competition determines the style of the futsal goalkeeper's game, i.e. the frequency of taking actions in the game characteristic of his position, is unauthorized at this stage of research, as the obtained significant differences in his activity in nine types of actions constitute only a small percentage (15%) of all his skills in the game. Therefore, research on his activity in game situations with neutral, favorable and unfavorable results should be continued.

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Conflict of interests

No potential conflict of interest was reported by the authors.

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Effects of vertical and horizontal plyometric exercises on explosive capacity and kinetic variables in professional long jump athletes

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Abstract

Purpose: Athletic jumps are specific cyclically-acyclic movements that despite the good performance of the techniques require from competitors a high level of motor, specific-motor and functional abilities. The aim of this study was to examine the response effect of vertical and horizontal plyometric training on explosive capacity and kinetic variables in long jump athletes.

Material: The participants of this study were twenty professional jumpers (22.5 ± 4.2 years; 178.4 ± 9.8 cm; 70.3 ± 7.6 kg) who were divided into two groups: experimental (plyometric training) and control (standard training). They participated in the last track and field championship in country, moreover, three of them participated in the last Asian games, and one athlete participated in the world track and field championship. The experiments were conducted on June-July 2019 in twenty professional athletes. All tests were performed after a standard warm up protocol. The place of camera was always determined wisely around the jumping field to attain best photography. Organizing and controlling the imaging and motor analysis processes were done by a biomechanics expert.

Results: Post training results in experimental group showed more improvement in 30 m sprint, vertical jump, horizontal velocity at take-off, and long jump completion, comparing the control group. Significant between group differences in all variables were detected post training. No significant post training improvements in flight time and take off duration were reported in control group.

Conclusions: Vertical and horizontal plyometric training protocol was shown to be more effective in promoting improvement in explosive capacity than kinetic variables.

Keywords: deep jump, plyometric, long jump, vertical and horizontal exercises

Introduction

Athletic jumps are specific cyclically-acyclic movements that despite the good performance of the techniques require from competitors a high level of motor, specific-motor and functional abilities. Also, all the jumping disciplines contain appropriate morphological profile of athletes (height, weight, BMI, age) that is characteristic for it. It is usually said that the jumpers are of high growth and relatively low weight, with long legs, long and thin muscles, and the muscle structure is dominated by white muscle fibers [1]. The long jump is an athletic discipline of speed-strong character and with triple jump it belongs to a group of remote jumps, in relation to the trajectory of the body center it belongs to the horizontal jumps [2, 3]. The speed of running start is as important as the strength of the lower extremities which give the final impetus bounce, so the result depends on the speed, jumping ability and technique of movement [4]. In top-level long jump athletes, capacity to quickly produce and apply a significant sum of force is plays a basic role [5]. It appears that the capability to arrange the resultant force vector horizontally while accelerating may

be a key determinant of speed [6]. Subsequently, athletes who are able to create enormous amounts of forces onto the ground within the forward course (i.e., horizontal plane) are more likely possible to attain more amounts of speeds while accelerating [7]. In contrast, it has been appeared that the switch from lower to higher speeds attains in shorter support stage term with concomitant increases in vertical peak force [8]. Long jump technique is based on a natural and quite easy movement, where the jumper strives for greater speed (horizontal component-horizontal shot) which will convert the reflection to the greater distance jump (ballistic curve-pitched shot). The ratio of the horizontal component (speed of running start) and vertical component (speed of reflection, flash) is in relation 2:1. The effect of the horizontal and vertical components directs the body so that an elevation angle can be from 18° - 26° . This means that the decreasing of the angle (β) increases a result of movements (R) reducing the elevation angle (α). Bearing all this in mind, a reflection with the long jump should be executed at top speed and to the limit only after the moment of verticals. Research of some authors have confirmed the inverse relationship of horizontal and vertical body centre ascent, ie. with increasing horizontal speed decreases the vertical and

vice versa [9, 10]. Many sports movements depend on the high achievements gained in specific technical stages, then it should be taken care of and developed to the top level and possible level, for example in the jumping movements into track and field sports the approaching stage is the main stage and planned for achievement, while in the running and throwing movements into track and field games the stage of throwing or running is the most important stage in these respects or events [11]. In all jumps there is an unwritten rule that every next stage in the technique of execution is conditioned by the previously performed step (accuracy of movement). Any mistake made has a significant impact on the accuracy of movement in the coming stages and the final result of competitors [1]. The force-vector hypothesis has been proposed to guide coaches and researchers in selecting the most appropriate exercises and drills for each particular stage of running. For case, Contreras et al. confirmed that the horizontally-oriented hip-thrust is predominant to the front squat to extend increasing speed over 20-m after a short-term period (i.e., 6-week), which is possibly related to the anteroposterior constrain vector utilized in this process and can affect even motivation generation [12]. On the other hand, Kale et al. illustrated that, among a few variables collected in vertical and horizontal bounced, the drop hop stature is the most excellent pointer of speed accomplished by a tip top sprinter all through a 100-m sprint race [13]. Comparable comes about were gotten in an arrangement of later examinations executed with sprinters and competitors, affirming that the heading of the resistance constrain vector relative to the body is determinant in intervening adjustments to speed qualities [14]. Be that as it may, in spite of the fact that a few of these considers have been carried out utilizing vertical works out performed at the ideal control zones (i.e., utilizing loads able of maximizing control yield) [8], there's a need of investigating this subject with horizontally-directed works outs (e.g., hip-thrust). The long jump consists of 4 phases: run phase, take-off phase, flight phase, and landing phase [15]. Long jump performance depends on not only a fast horizontal velocity at the end of the run-up but also take-off technique and landing in the sandy area. Successful long jump athletes take a good care of these stages because they affect the distance of long jump, especially, the run phase which is the first phase of the long jump [15]. Each of these phases has its cinematic specificity in terms of performance, which requires full attention and concentration from the competitor. Running start is the first phase in the structure of jumps, which should provide a good starting speed of body flight (V_0), respectively, to achieve the best transition of the maximum speed in the best reflection of jumpers [4]. Precisely in this combination and transition of maximum speed in the final steps and reflection there is a part of the biggest secrets of the success of top jumpers. Many jumpers use their maximal speed of approach combined with technique (optimal technique is used to achieve as bigger speed while sprinting as possible and to bounce off as much as possible) hoping to achieve the longest possible distance

[16]. Most of the speed and strength training exercises that jump trainers recommend through their training programs depend on weight. While some exercises do not match the level of skill capability it seems from previous researches that the use of different deep jump methods (horizontal - vertical) for the purpose of developing the physical capacity and biomechanical characteristics is effective for athletes [17]. The present study provides a period of horizontal and vertical plyometric exercises (Drop Jumps) in the development of explosive capacity and kinetic variables in professional long jump athletes.

Materials and Methods

Participants

The participants of this study were twenty professional jumpers (22.5 ± 4.2 years; 178.4 ± 9.8 cm; 70.3 ± 7.6 kg) who were divided into two groups: experimental (plyometric training) and control (standard training). They participated in the last track and field championship in country, moreover, three of them participated in the last Asian games, and one athlete participated in the world track and field championship. Prior to the experimental phase of study, athletes were briefed on the experimental design and signed an informed consent form.

Study design

In this randomized controlled trial, the long jump athletes in experimental and control groups performed pretest and posttest examinations to determine the effects of vertical and horizontal plyometric exercises on explosive capacity and kinetic variables. The athletes in experimental group were guided to perform plyometric drills as following: Box Jumps, Hurdle hops, Double leg "X" hop, Backward Throw, Ankle jumps, Ankle Hops, Power Skips, Lateral Taps on a Ball, Jump and turn 180° , Standing Jump & Reach, Split squat jump, Single leg zig-zag drill. The participants of control group were training under a standard training protocol same as the experimental group but with different drills. Some of the drills they performed were: Full speed 30-50 meter, Landing drills, Five stride jumps into pit, Take off drills, Long jump approaches 4-8, Conditioning Circuits, Timing and coordination, Pick on additional take off. In table 1 shows is pre training physical characteristics (table 1).

Measurements

Means, tools and devices used for this study are mentioned as follows:

- Electronic stopwatch;
- Computer;
- Metal measurement tape;
- Wooden shutters with different heights;
- Different height barriers and boxes;
- Long jump field;
- Camera and stand.

The researchers prepared explosive capacity and kinetic variables tests as follows:

- 30 m sprint;
- Vertical jump;
- Standing long jump;
- Max vertical height;

- Horizontal velocity at take off;
- Vertical velocity at take off;
- Flight time;
- Take off duration;
- Long jump completion.

Procedure

The experiments were conducted on June-July 2019 in twenty professional athletes. All tests were performed after a standard warm up protocol. The place of camera was always determined wisely around the jumping field to attain best photography. Organizing and controlling the imaging and motor analysis processes were done by a biomechanics expert.

Training protocol

The training program aimed to develop the explosive capacity of the athletes using the various jumps as one of the modern methods used for the development of this capacity. The exercises were performed at full speed, to ensure that the endurance factor does not interfere with the muscular ability. 60% to 80% of the maximum capacity of the athlete were chosen for horizontal and vertical jumps. The number of athletes in each group for warm up and testing were 2-3 and the number of repetitions were from 6 to 12 times with an active rest (3 min between sets and 40-90 seconds between repetitions). The whole program lasted between 50-60 minutes for each athlete.

Statistical Analysis

IBM SPSS statistics version 22.0 package was used to analyse data. The descriptive data is reported as means ± standard deviations and percentage of changes. Physical characteristics before the intervention were tested for

difference between the groups with unpaired t-tests. Test data was examined for normality with Shapiro Wilk test and for homogeneity of variances with Levene's test. If normality of data was present a two way mixed analysis of variance (factors: group, time, and interaction (group vs. time)) was performed. Effect sizes estimates are given in terms of partial eta-squared measures (η^2p). where a significant interaction effect was seen, post-hoc t-tests were applied to decide the source of difference. The level of significance for all measures considered at $p < 0.05$.

Results

At baseline there was no significant difference between two groups in any of the measured variables. Test data was normally distributed in 7 out of the 9 tests table 2. A mixed 2 * 2 multi-factorial ANOVA indicated a significant interaction effect for 30 m sprint ($F = 54, p = .00, \eta^2p = .66$), vertical jump ($F = 12, p = .00, \eta^2p = .31$), standing long jump ($F = 38, p = .00, \eta^2p = .58$), max vertical height (NA), Horizontal velocity at take-off ($F = 70, p = .00, \eta^2p = .72$), flight time ($F = 24, p = .00, \eta^2p = .47$), take-off duration ($F = 15, p = .00, \eta^2p = .34$), long jump completion (NA). No significant interaction effect was found for vertical velocity at take-off ($F = 30, p = .01, \eta^2p = .56$). Further analyses with paired t-tests showed significant within group differences between pre- and post-tests in both groups for all variables. Effects sizes varied from $d = 0.4$ to 6.5 . Changes in the experimental group were significantly greater compared to the control group for 30 m sprint, vertical jump, horizontal velocity at take-off, and long jump completion.

Table 1. Pre training physical characteristics

Basic Variables	Measuring unit	SMA	Standard deviation	Skewness coefficient
Age	Years	22.5	4.2	0.39
Height	Centimetre	178.4	9.8	0.38
Weight	Kg	70.3	7.6	0.42
BMI	Kg.m ²	22.17	5.4	0.75
Experience	Years	5.7	2.3	0.48

Table 2. The results of explosive capacity and kinetic variables examinations

Variables	Experimental group		Control group		P-value (interaction effect)	Value (d)-p	
	pre	post	pre	post		experimental	control
30m sprint	3.74 ± 0.23	3.49 ± 0.18	3.76 ± 0.21	3.62 ± 0.20	0.00 (0.66)	0.00* (2.4)	0.00* (1.5)
Vertical jump	39.21 ± 2.08	51.48 ± 6.12	39.37 ± 2.43	46.75 ± 3.32	0.00 (0.31)	0.00* (2.3)	0.00* (2.6)
Standing long jump	230 ± 5.82	251 ± 9.74	231 ± 4.23	238 ± 5.71	0.00 (0.58)	0.00* (2.3)	0.00* (1.9)
Max vertical height	114 ± 4.56	146 ± 5.35	115 ± 5.12	121 ± 6.38	0.00 (0.63)	0.00* (6.5)	0.00* (1.3)
Horizontal velocity at take off	7.95 ± 0.32	8.89 ± 0.51	7.64 ± 0.39	7.87 ± 0.30	0.00 (0.72)	0.00* (2.1)	0.00* (0.58)
Vertical velocity at take off	2.98 ± 0.50	3.06 ± 0.77	2.94 ± 0.13	2.99 ± 0.34	0.56 (0.01)	0.00* (0.7)	0.00* (0.4)
Flight time	0.65 ± 0.36	0.73 ± 0.03	0.64 ± 0.33	0.66 ± 0.02	0.00 (0.47)	0.00* (1.7)	0.63 (1.2)
Take off duration	0.21 ± 0.02	0.18 ± 0.01	0.20 ± 0.01	0.19 ± 0.02	0.00 (0.34)	0.00* (1.8)	0.61 (1.1)
Long jump completion	5.91 ± 0.10	6.48 ± 0.20	5.86 ± 0.11	6.19 ± 0.15	0.00 (0.48)	0.00* (3.9)	0.00* (2.2)

Discussion

The findings of study in both groups indicated that jump performance had improvements after 8 weeks vertical and horizontal plyometric exercises. The experimental group outperformed in 7 of the 9 parameters when compared to the traditional training program. Our training method (deep jump exercises) which bear a resemblance to the long jump take off, comprise stretch-shortening cycles of different muscles in lower extremity. This method appeared to be favorable for enhancing sprint and jump performance, long jump distance and some other related parameters [18]. This could be due to the fact that deep jump exercises help the athletes to learn the compatibility between arms and legs movement.

The findings of this study in line with previous researches revealed that vertical and horizontal plyometric exercises have a significant effect on long jump performance [19, 20] and also significantly enhances the hip and thigh power which was projected by vertical jump test in this study [21, 22]. Furthermore, our results are in line with the findings of Hewett et al. [23] who indicated an improved hamstring muscle peak power, torque, and hamstring/quadriceps ratio after a period of plyometric jump training.

Plyometric training might have other enhancing effects in addition to performance enhancement, such as knee joint motion stabilization by increasing the lower extremity strength. Simek-Salaj, Milanovic, Jukic [24] determined the changes in agility and explosive strength, the type of jumping ability under the influence of a proprioceptive training program on a sample of physical education students. It was determined that, in the case of untrained participants, changes in vertical jumping ability are possible under the influence of proprioceptive training, and in the case of trained participants, the effects were smaller or not significant.

Markovic et al. [25] studied the results of sprint and plyometric training on the morphological characteristics of young, physically active participants. The research showed that these two methods have a limited effect on the morphological dimensions of younger men. The efficiency of technique depends on the skill of jumper to exercise great pressure on the track in the small protrude of leg, especially in the last step, which provides the necessary height of the jump and the horizontal movement of the body.

Thus excellent jumpers, depending on gender, develop great pressure force (from 300-400kg) on the board, where the stepping leg slightly bents at the knee $\beta = 175^\circ-178^\circ$ or $165-172^\circ$ [9], slightly less at the hip joint ($\gamma = 165^\circ-170^\circ$), and there is also a partially bending at the joints of the spine. It all causes eccentric character of the work. Intentional loosening of the knee joint is done in order to utilize the forces of mm. quadriceps femoris to the extent where leg can withstand the pressure, because it is not possible to avoid the torque of the pressure component in relation to the knee joint. In order to offset the effect of this moment, and to achieve the rebound it is necessary that the product of muscle force (Q) and its

prong (r is constant) is equal to or greater than the product of the pressure force (R) and its prong (k). The current top jumpers at the time of the rebound have less flexion of the knee joint but a stronger force of quadriceps [1]. The deep jump (vertical - horizontal) exercises were beneficial in the development of the explosive power of long jump athletes. These training exercises help to develop the high coordination of the neuro muscular system to respond more strongly and faster during the performance of complicated sport related movements.

Sharkey [26] points out that the various jump exercises increase the explosive capacity of athletes, especially in the jumping competitions. In view of that, the results of our research imply that the deep jump training is a powerful and effective way to improve the strength and speed in long jump athletes, allowing the nervous system to activate the largest number of muscle fibers. Thus, in athletes who need to integrate the maximum strength of muscles with the maximum speed in performing sport movements, especially if the explosive capacity is one of the qualities required, vertical and horizontal plyometric exercises are useful.

Less et al. [9] an attempt was made to identify the mechanism acting during the touchdown to take-off phase which were responsible for generating vertical velocity. It was concluded that there was evidence for mechanical, biomechanical and muscular mechanisms. The former relates to the generation of vertical velocity by the body riding over the base of support; the second is the elastic re-utilization of energy; and the third is the contribution by concentric muscular contraction. The increase in the long jump distance is determined by three basic elements: horizontal velocity, vertical velocity and height of the center of gravity during the flight. the role of muscle strength as a basic variable in jumping is already proven. What is added in this study is the importance of some other physical and kinetic variables such as 30 m sprint, vertical jump, horizontal velocity at take-off, and long jump completion. It seems that the deep jump (vertical - horizontal) exercises are more effective for physical capacity than kinetic variables.

Conclusions

The exercises using varied jumps in the style of deep jump (horizontal - vertical) are effective in the development of muscular capacity of long jump athletes. Furthermore, this training method is helpful in sport performance measures like speed and strength which is resembled in the results of 30 m sprint, vertical jump, horizontal velocity at take-off, and long jump completion tests in the present study. Therefore, vertical and horizontal plyometric exercises are effective alternative to traditional plyometric training.

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Conflicts of Interest

The authors declare no conflict of interest.

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Parents at the sport competition: How they react, feel and cope with the event

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Abstract

Purpose: Researchers rarely focus on documenting parental experiences at sport tournaments. Therefore, our purpose was to document parent cardiovascular, metabolic and emotional responses to watching their child compete while also paying attention to their thoughts before and after the competition, levels of stress, anxiety, depression, and coping strategies.

Material: Parents, a mother and a father of same female adolescent, wore a device made by Firstbeat Technologies which continuously monitored their heart rate from Thursday evening to Monday evening. The competition was on Saturday, and it was the taekwondo Croatian National Championships for cadets. Their child had two fights: she won the first one and lost the second one. Parents completed a number of questionnaires and two open-ended questions regarding their expectations and overall experience.

Results: Before the contest, dad expected his daughter would fight as best she could while giving her best effort. The mother hoped that her daughter would pass the first fight. Parents had a similar pattern of cardiovascular responses to watching their daughter compete but differed in intensity. Emotional profiles of the mother and father changed several times during the measurement period. Overall, parent's experienced low levels of stress, anxiety and depression and used numerous strategies to cope with the event.

Conclusions: Although our research only included one pair of parents it suggests that parents experiences during the sport events are complex and worth investigating in future research on larger samples.

Keywords: stress, emotions, mixed-methods, achievement goal theory, physiology

Introduction

Parents play a significant role in their children's attraction to physical activity and their sport participation [1-3]. However, with their child being involved in sport, parents themselves can experience many behavioral, cognitive, and emotional as well as relationship changes [4]. Additionally, they can experience numerous organisational, competitive and developmental stressors [5, 6]. *Transactional theory of stress* [7] and *Cognitive-motivational-relational theory of stress and emotions* [8-10] are commonly used to investigate stress and coping in sport. Lazarus and Folkman [7] define stress as a relationship between person and environment appraised as reaching or exceeding person's available resources to cope with the demand and therefore represent a threat to its well-being. Coping is defined as investing cognitive and behavioural efforts to deal with the stressors [7]. Research suggested parents use different coping strategies to deal with organizational, competitive and developmental stressors they experience while supporting their child's sport participation [6, 11]. Burgess and colleagues [11] conducted research on parents of elite young gymnasts and concluded that they use four categories of coping strategies: detaching from sport, normalization, desire to learn and managing their emotional reactions.

Furthermore, in their study on parents of young British tennis players, Harwood and colleagues [6] used three categories of coping strategies suggested by Nicholls and colleagues [12] to analyse parent's answers to open-ended question: mastery, internal regulation and goal withdrawal. In their research, mastery and internal regulation were more effective in dealing with sport parent's stressors than goal withdrawal, regardless of type of stressor or their appraisal. These are the only two studies that investigated coping with stress of the sports parents even though there are numerous studies on coping of athletes and coaches [13-15]. Furthermore, using effective coping strategies is recognized as important characteristic of successful sport parent [16]. Therefore, we believe there is a need for further investigating parent's sport experiences.

Reactions to stress are not only psychological but physiological as well, one of them being increased heart rate [17]. Heart rate monitors are commonly used in research on athletes [18, 19], but have only so far been used in one research on sport parents which used AGT theory framework to explain parent's reactions [20]. Achievement Goal Theory (AGT) [21, 22] describes existence of task or mastery and ego or performance individual goal orientations and motivational climates, with ego/performance orientation emphasizing winning and demonstrating superior ability, and task/mastery orientation emphasizing self-comparison and personal

improvement. Research finds that task orientation is connected to positive emotions, while ego orientation is connected to negative emotions [23, 24] and that creating a task-involving climate resulted in higher positive affect while ego-involving climate procured higher levels of salivary cortisol (stress responsive hormone) and negative affect response [25]. It has been suggested that sport parents should provide unconditional love and support to their young athlete with focus being on effort, not on the result [26]. Young athletes also prefer their parents to be positive, supportive and focused on their effort and attitude [27]. Although there are many positive aspects of parents' involvement in their child's sport and their experiences are not just negative, it is obvious that it can be very demanding to provide adequate level and type of support to the young athlete [28]. Thus, research connecting stress, coping and goal orientations of the sport parents could be useful in further understanding their experiences.

Lazarus [8-10] in his CRMT theory of stress suggested that stress, coping and emotions are connected and should be investigated together. In previous research, sport parents reported feeling intense emotions connected to their child's sport participation [4] [29]. Among other, lack of emotional control and inadequate emotional reactions are identified as problematic sport parents' behaviours [26,30]. Therefore, it has been concluded that managing their own emotional reactions is one of the most important skill sport parents should utilize [16]. The Individual Zones of Optimal Functioning (IZOF) model [31] is popular framework for investigating emotions in sport. It suggests there are four global categories of emotion: P+ (pleasant, optimal), P- (pleasant, dysfunctional), N+ (unpleasant, optimal) and N- (unpleasant, dysfunctional). Functionally optimal emotions (P+, N+) are expected to be higher than dysfunctional ones (P-, N-) during successful performances in sport. To our knowledge, this framework has not yet been used in previous research of sport parents' emotions.

Purpose:

The purpose of this study was to document parents' emotional, cardiovascular and metabolic reactions before, during and after their child's sport competition. Additionally, we wanted to examine their expectations, overall experience, levels of stress, anxiety and depression as well as coping strategies they use to deal with the event.

Materials and Methods

Participants

Two parents participated in this study. They were a mother and a father of the same adolescent female athlete. During data collection, mother was 41 years old, 164 cm tall and 65 kg in body weight. Father was 42 years old, 175 cm tall and 75 kg in body weight. Parents self-reported their age, body weight and height.

Instruments

Cardiovascular and metabolic reactions. Parents wore the Firstbeat Technologies Bodyguard 2 device which was continuously monitoring their heart rate. The

device was attached to the participant's skin using two chest electrodes.

Emotions. Parents filled the ESP-40 (*Emotion State Profile*; [32] questionnaire 11 times before, during and after the competition, including before and after each fight. They were given the instruction to think about how they feel regarding their daughter's competition and fill the questionnaire keeping this in mind. The ESP-40 questionnaire consists of 40 items in total, 10 items for each of the IZOF four emotion categories: N- (e.g. tired, sad, upset, distressed, worried), N+ (e.g. tense, dissatisfied, furious, angry, irritated), P+ (e.g. energetic, confident, motivated, certain, enthusiastic), P- (e.g. satisfied, happy, pleased, calm, relaxed). The items are arranged in 10 rows of 4 columns. Participants are asked to rank each item on a four-rank scale within each row, with 4 marking the emotion that describes their experience the best and 1 marking the emotion which describe their experience the least. Total scores are calculated by adding scores within four categories of emotions and can range from 10 to 40. In this research, we used the Croatian translated version of the ESP-40 questionnaire [33].

Stress, depression and anxiety. To measure parent's levels of stress, depression and anxiety connected to the event we used Depression, Anxiety and Stress Scale (DASS-21) [34]. DASS-21 contains 3 subscales, each measured by 7 items. It is designed to measure symptoms of stress, depression and anxiety. Participants give their answer on a 4 point scale (0-did not apply to me at all; 3-applied to me very much, or most of the time) considering how often they experienced described symptoms during the last week. Result on each subscale is obtained by summing the participant's result on all items of each subscale, with higher results indicating greater levels of stress, depression and anxiety. Results can range from 0 to 21. Alpha reliability levels on previous studies were above .70 [35].

Coping strategies. To measure parent's coping strategies which they used to cope with potential stressors connected to their daughter's competition, we used the Coping with Stress Scale (CSS) [36]. The scale measures 11 coping strategies, each measured with 4 items which makes 44 items in total. The coping strategies are: negotiating (active strategies directed to other people who are connected to the problem or situation; seeking advice and confronting), planning (cognitive efforts directed to finding the solution to the problem), active adapting (taking concrete, practical actions to better deal with the situation), reinterpretation (attempts to see the situation differently and give a stressful situation positive meaning), humour (using humour and looking for a funny aspect of situation), social support (turning to other people and seeking emotional support), expressing emotions (expressing emotions openly), wishful thinking (wishful thinking, fantasizing and wishing for a change or disappearance of stressful situation/stressor), avoiding (cognitive and behavioural actions directed to avoiding situation or escape from it), passivization (accepting the situation; giving up from trying to solve the problem and

making peace with destiny), fatalism and religion (turning to religion; hoping for help from God, greater force or luck). Cronbach alpha values as reported by the author of the scale [36] were between .41 and .78. We added two more strategies in the questionnaire for this research: smoking/alcohol and exercising, each measured with one item. The participants answered the questions on a scale from 1 (not at all) to 4 (often) regarding how often they used each coping strategy to cope with stressors connected to their daughter's competition.

Expectations and overall experience. To gain better understanding of parents' expectations before the competition, we asked them to fill one open-ended question in the morning on the competition day, before it started: "Please give a short description of your expectations regarding today's competition". Overall experience was also measured using one open-ended question which parents filled in the evening, after the competition ended: "Please describe your day, give us some thoughts about today's competition, and describe how you felt during today's competition". Both questions were taken from our earlier study on sport parents [20].

Procedure

After obtaining institutional ethical approval, parents were selected by third author based on their active involvement in their child's sport and knowledge that they will be present during the selected competition (Cadet Taekwondo Croatian National Championship). They both were informed about purpose of the study and consented to participate. The competition was selected based on its importance for the athletes. It was held on Saturday and selected competitor had two fights. She won the first one and lost the second one. Duration of the first fight was 7 min, and second fight was 9 min. Data collection started three days before the competition, on Wednesday, and continued until Monday, two days after the competition.

The Firstbeat Technologies device was put on parents at 21:00 Thursday evening and removed at 21:00 Monday evening, so they wore it for 4 consecutive days. Second author gave the instructions and demonstration about how to use the device on Wednesday. After that, parents themselves put the device on Thursday. Second author was travelling with parents to the competition and was present from Friday to Sunday to support and monitor data collection. Parents were asked to fill the ESP-40 questionnaire once on Wednesday (for demonstration purposes), Thursday and Friday regarding their emotional state connected to upcoming competition. On Saturday, at the competition day, parents filled the ESP-40 questionnaire six times: in the morning before competition, immediately before each of the two fights, immediately after each of the two fights, and in the evening after the competition. In addition, parents filled ESP-40 questionnaire once on Sunday and Monday, after the competition. Furthermore, they answered one open-ended question regarding their expectations for the event at the day of the competition, before it started, and the other open-ended question regarding their overall experience in the evening of the competition day, after it was over. They filled the DASS-

21 and CSS on Monday after the competition keeping in mind their overall experience before, during and after the event.

Data analysis

In this research data was collected using mixed-method approach which was previously used in a past sport parents studies [6] [20]. Parent's cardiovascular, metabolic and emotional reactions, levels of stress, anxiety and depression as well as coping strategies were quantitative data. Their expectations for the event as well as their overall experience after the event were qualitative data. All the cardiovascular and metabolic data were analysed using Firstbeat Sport Software. Stress, recovery, cardiovascular and energy expenditure graphs in this study were copied from the reports obtained from Firstbeat Sports Software and Firstbeat Lifestyle Assessment Software.

Results

Expectations

On the open-ended questionnaire about the expectations for the upcoming competition, father answered: "I hope she will fight as best as possible and give her best." His answer suggests him having a task goal orientation toward his daughter's competition, with emphasis put on her giving her best and not on the result or comparison to the other athletes. Regarding her expectations for her daughter's competition, mother wrote: "I'm hoping she will pass further. I just want her to pass the first fight." This answer suggests her having a ego goal orientation towards her daughter's competition because she put an emphasis on the result (winning the first fight and continuing the competition).

Cardiovascular and metabolic reactions

Cardiovascular reactions and energy expenditure of both parents during the competition can be seen in Figure 1 (father), Figure 2 (mother) and Table 1. Parents had similar cardiovascular and energy expenditure patterns during the competition, with the highest values recorded during the second fight (Figure 1 and Figure 2). For the first fight, mother had the strongest reactions at the beginning of the fight and then her HR and energy expenditure dropped towards the end of the fight. Father had the same pattern but his reactions again increased for a short period of time after the fight was over. For the second fight, both parents had almost the same reaction patterns. Their reactions intensified rapidly towards the end of the fight and peaked at the very end, when their daughter was first injured and then lost the fight on golden score. Since they had almost the same minimum resting HR (father 49 bpm; mother 48 bpm), from the Table 1 it is evident that mother had stronger cardiovascular reactions during both fights and the whole event than father did. The Firstbeat device also reported mother having 2 minutes of physical activity and 2 minutes of light physical activity during the first fight, while father experienced 1 minute of physical activity and 6 minutes of light physical activity. During the second fight, device recorded mother having 7 minutes of physical activity and 2 minutes of light

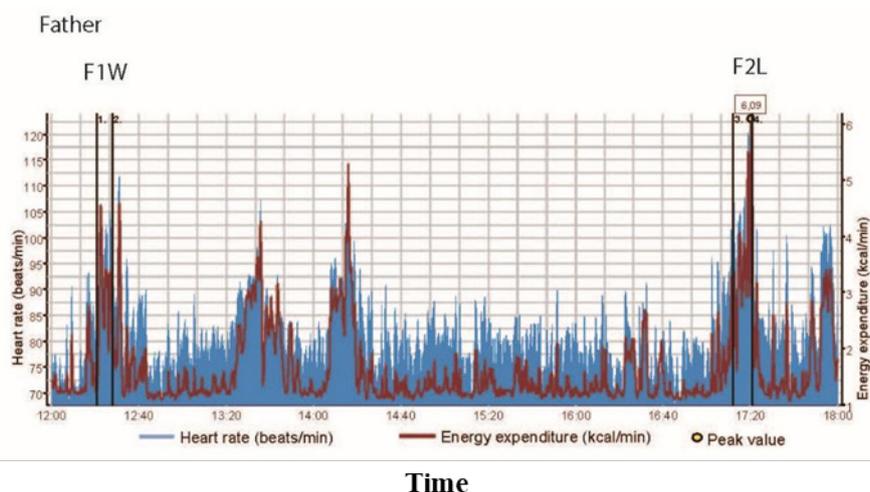


Figure 1. Father’s heart rate and energy expenditure graphs during the competition. Time markers F1W-1st fight, won; F2L- 2nd fight, lost.

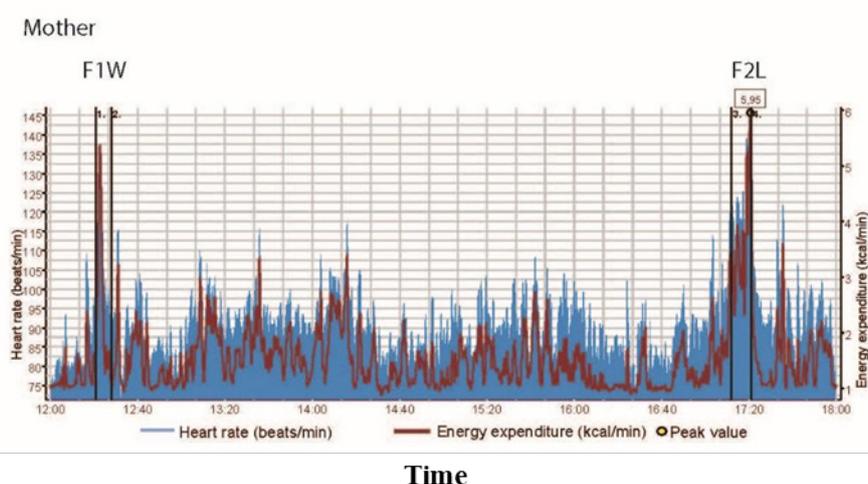


Figure 2. Mother’s heart rate and energy expenditure graphs during the competition. Time markers F1W-1st fight, won; F2L- 2nd fight, lost.

Table 1. Heart rates and energy expenditure of both parents during the competition

Measurements	Father			Mother		
	1 st fight (7 min)	2 nd fight (9 min)	Competition (6 h)	1 st fight (7 min)	2 nd fight (9 min)	Competition (6 h)
Lowest HR (bpm)	82	84	67	90	106	70
Highest HR (bpm)	107	124	124	136	147	147
Average HR (bpm)	96	102	81	106	122	91
Energy expenditure (kcal)	22	36	588	19	36	559
High intensity zone (min)			0			0
Anaerobic threshold (min)			0			0
Aerobic zone 2 (min)			0			3
Aerobic zone 1 (min)			3			13
Training effect (Firstbeat defined)			1.3 (facilitated recovery)			(maintained aerobic fitness)

Note: lowest HR measured father: 49 bpm; lowest HR measured mother: 48 bpm

physical activity while father had 5 minutes of physical activity and 4 minutes of light physical activity. During the whole competition, mother accumulated 9 min of physical activity and 21 minutes of light physical activity while father had 5 min of physical activity and 10 minutes of light physical activity. The device recognizes physical activity as physical activity with intensity over 30% VO2 max, and light physical activity as physical activity below 30% VO2 max. Both parents were standing by the mat, cheering but not moving or walking during both fights. As

for energy expenditure, during the 7 minutes of the first fight father burned 22 and mother 19 calories. During the second fight, which lasted 9 minutes, they both burned 36 calories. In total, father burned 588 calories during the 6-hour event while mother burned 559.

Emotions

Results on the ESP-40 questionnaire are presented in Table 2 as well as Figure 3 and Figure 4. It is evident that the father overall experienced more pleasant than unpleasant emotions before and during the competition,

Table 2. Parents' results on the ESP-40 questionnaire

Day and competition information	Emotions father				Emotions mother			
	N-	N+	P+	P-	N-	N+	P+	P-
Wednesday	14	20	32	34	19	17	37	27
Thursday	12	18	35	35	37	31	19	13
Friday	14	16	33	37	16	15	34	35
Saturday before competition	14	16	33	37	21	17	36	26
Saturday before 1 st fight	12	28	30	30	26	19	33	22
Saturday after 1 st fight (won)	12	19	33	36	16	17	37	30
Saturday before 2 nd fight	16	22	34	28	32	22	28	18
Saturday after 2 nd fight (lost)	35	35	19	11	35	35	19	11
Saturday after competition	35	35	19	11	39	29	17	15
Sunday	20	23	29	28	16	14	33	37
Monday	13	17	37	33	20	11	35	34

N- = unpleasant, dysfunctional emotions; N+ = unpleasant, functionally optimal emotions; P+ = pleasant, functionally optimal emotions; P- = pleasant, dysfunctional emotions

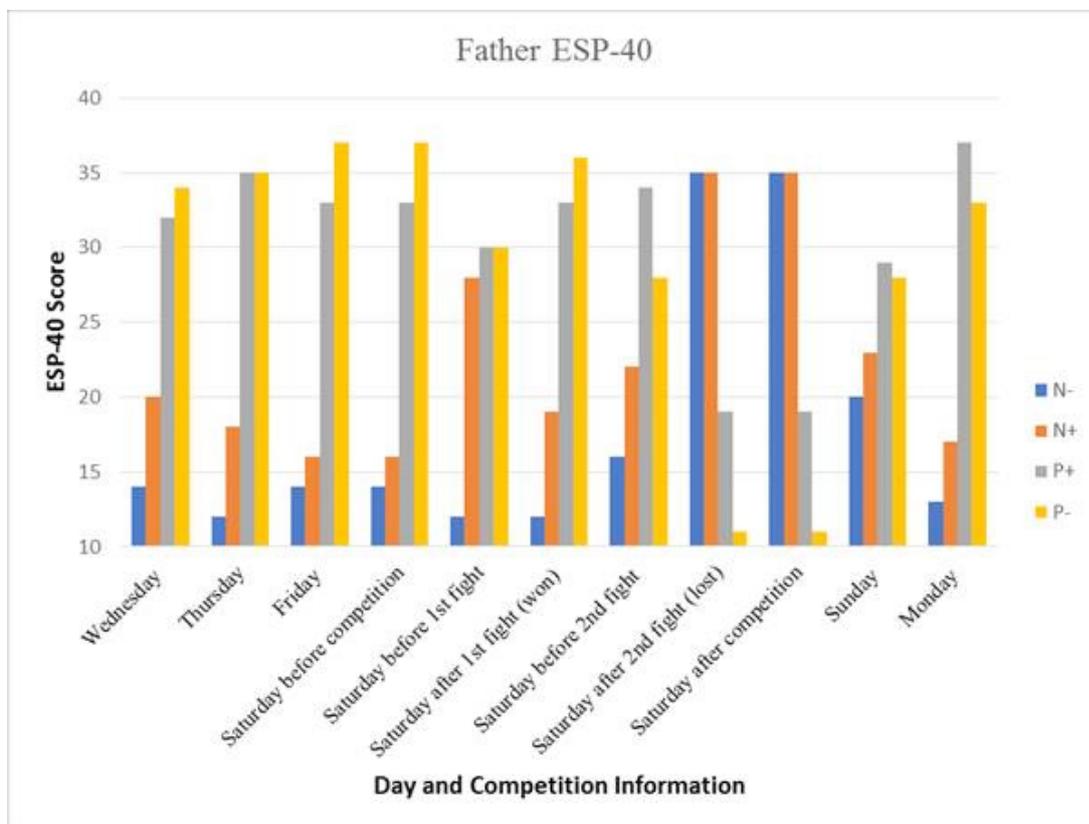


Figure 3. Father's results on the ESP-40 questionnaire. N- = unpleasant, dysfunctional emotions; N+ = unpleasant, functionally optimal emotions; P+ = pleasant, functionally optimal emotions; P- = pleasant, dysfunctional emotions

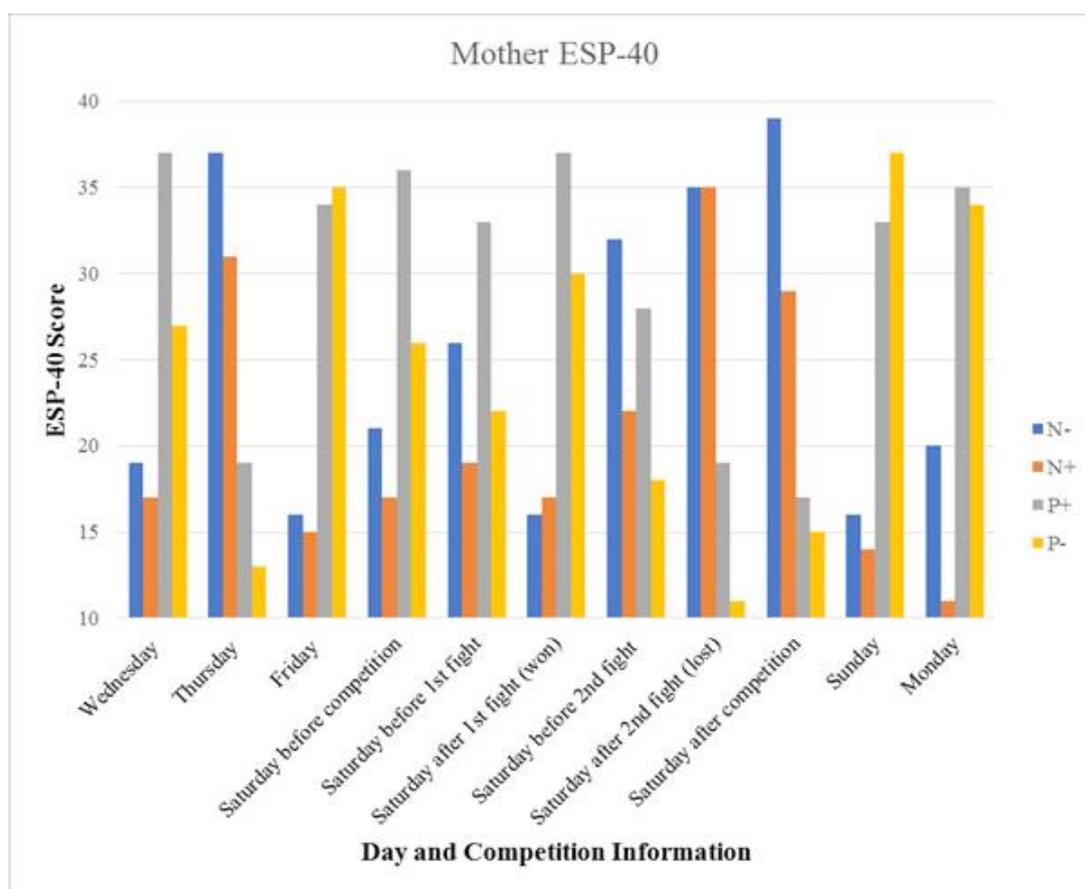


Figure 4. Mother’s results on the ESP-40 questionnaire. N- = unpleasant, dysfunctional emotions; N+ = unpleasant, functionally optimal emotions; P+ = pleasant, functionally optimal emotions; P- = pleasant, dysfunctional emotions

until the end of the second fight which athlete lost and during which she got injured. At this time, father reported experiencing more unpleasant than pleasant emotions and that pattern stayed the same until the end of that day. On Sunday, after the competition, pleasant emotions became again more prominent and continued to be that way on Monday as well. More detailed analysis of the father’s answers indicate that P- emotions were the most prominent on Wednesday, Friday and Saturday before the competition, followed by P+ emotions. On Thursday and on Saturday before the first fight P- and P+ emotions were equally present. However, even though pleasant emotions were still most prominent before the first fight on Saturday, N+ emotions were more present during this time compared to all previous measurements. After athlete won the first fight, father’s emotional profile was again similar to the ones he had before. Furthermore, before the second fight, father for the first time experienced more P+ than P- emotions, and then both pleasant emotions dropped after the fight, with P- being the least prominent and unpleasant emotions (N+ and N-) being the most prominent. This again changed on Sunday and Monday but with P+ emotions being the most prominent, followed by P-, and N- again becoming the least prominent.

The mother’s emotional profile changed more frequently than the father’s emotional profile during the 11 measurements. She reported feeling more pleasant

than unpleasant emotions on Wednesday, 3 days before the competition, with P+ emotions being the most and N- the least prominent. However, this changed two days before the competition, when she reported more unpleasant than pleasant emotions, predominantly N-, with P- being the least prominent. This again changed day before competition with pleasant emotions being higher than unpleasant and this time P- the most prominent. On Saturday, before the competition, this changed again and now P+ emotions were the most prominent, followed by P-. However, just before the first fight the second most prominent emotions were N- following the P+ which was still the most prominent. This again changed after athlete won the first fight. P+ emotions were again the most prominent, followed by P-. However, for the first time N- emotions were the least prominent. Furthermore, before second fight N- emotions became the most prominent, followed by P+ emotions and with P- being the least prominent. Unpleasant emotions were the most prominent after the second fight which athlete lost and got injured. Here, again, P- emotions were the least prominent. The N- emotions continued to rise on Saturday after the competition, followed by N+ emotions and with P- again being the least prominent. Again, mother’s emotional profile changed on Sunday, day after the competition, when pleasant emotions became again more prominent than unpleasant, with P- being the most

and N+ the least prominent. Pleasant emotions stayed higher than unpleasant two days after competition but this time P+ were the most prominent and N+ again the least prominent.

Overall competition experience

On the open-ended questionnaire about the overall experience, which parents filled at the end of the competition day, father answered: *“Today was a day with lots of nervousness and uncertainty about the outcome of each fight. Despite good fights, we were stopped with judge’s decision and with that my daughter showed she didn’t come here on a field trip because she made one of the best competitors in her category struggle until the end. Maybe I could be satisfied at the end, but the whole story was ruined with going to the hospital and doing the RTG of the finger which was injured during the last fight.”*

Mother’s answer was: *“First there was a fear from first fight. After that there was a second fight where opponent was very strong so my daughter lost on golden score. She injured her finger. Overall, I’m sad because of the injury. I know that she can do it, that she gave her best and become a great fighter. I feel a little sad but it will pass.”*

These answers indicate father experiencing nervousness and uncertainty about the outcome of the fights with injury being the most prominent experience which “ruined” the whole experience for him. Mother reported experiencing fear for the first fight and sadness because of the injury. Even though it wasn’t specifically mentioned, from both answers it can be seen that they are proud of their daughter and how she fought.

Stress, anxiety, depression and coping. From the results on the DASS-21 questionnaire (Table 3) it be concluded that mother reported experiencing more stress than father did.

Table 3. Parent results on the DASS-21 and Coping questionnaire

Constructs	Father	Mother
Stress	5	8
Anxiety	1	1
Depression	4	3
<i>Negotiating</i>	3	2.5
Planning	3	4
Active adapting	2.75	3.5
Reinterpretation	2.75	3.25
Humour	2.75	2.75
Social support	3.25	3
Expressing emotions	2.75	2.25
Wishful thinking	3	2.75
Avoiding	2.5	3.25
Passivization	3	2.5
Fatalism/religion	2.5	2.5
Smoking/alcohol	1	1
Exercising	3	3

Father reported feeling slightly more depression than mother but these results were both low. Both reported their anxiety levels as minimal. Figure 5 and Figure 6 shows that father slept less than mother and thus recovered less, especially on Friday and Saturday night, which resulted in his body resources dropping below starting level on Saturday evening and even more on Sunday evening. However, he recovered better on Sunday night and ended up measurement with body resources higher than starting level. Mother’s body resources curve were similar to each other two days before the competition and then started to increase on Sunday evening resulting in them being at the highest point on Sunday morning and overall ending up increased compared to the starting point.

Results on the Coping with stress scale (Table 3) indicate father using social support the most as his coping strategy, followed by negotiating, planning, wishful thinking, passivization and exercising. Mother used planning most to cope with the stressors, followed by active adapting, reinterpretation and avoiding. Mother used more planning, active adapting, reinterpretation and avoiding, as well as less social support, expressing emotions, wishful thinking and passivization than father did.

Discussion

In this study, the goal was to document cardiovascular, metabolic and emotional reactions of sport parents before, during and after their child’s competition taking into consideration their expectations for the event. The mixed-methods approach was used, similar to the one used in our previous pilot study on sport parents [20]. To further expand the existing research base in this area, we quantitatively measured parent’s cardiovascular, metabolic and emotional reactions, levels of stress, anxiety and depression as well as coping strategies they used to cope with stress before, during and after their daughter’s National Championship in taekwondo. In addition, we qualitatively investigated their expectations for the event as well as asked them about their overall experience after the event. Previous research indicates that parents have vital and complex roles before, during and after their child’s sport competition [37-39]. In this research we wanted to expand the existing literature by investigating their thoughts, reactions, level of stress and ways of coping with their child’s competition.

Cardiovascular reactions and thus energy expenditure of mother and father was somewhat similar in pattern but differed in intensity with mother experiencing stronger reactions. Both parents were the most physiologically engaged during the fights. Father’s answers to the open-ended question about his expectations suggest him having task-goal orientation while mother put more emphasis on winning the fights thus showing ego-goal orientation. In our previous study [20], task-oriented mother had the cardiovascular reactions similar to both parents in this study since she was the most physiologically engaged during the fights. Although in this study we didn’t confirm the same pattern of ego-goal orientation parent

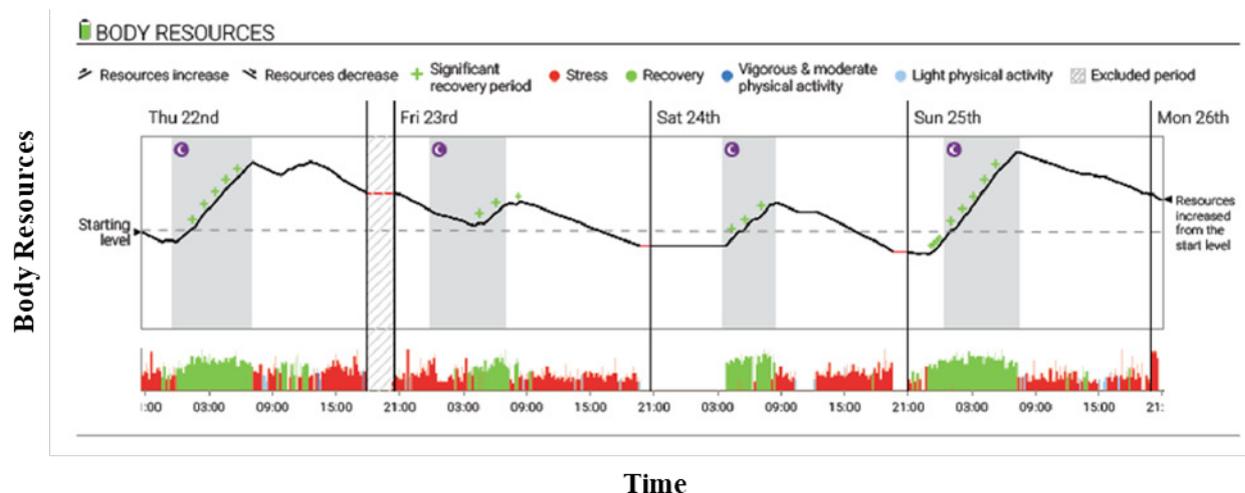


Figure 5. Overview of father's stress measurements during all measurement days

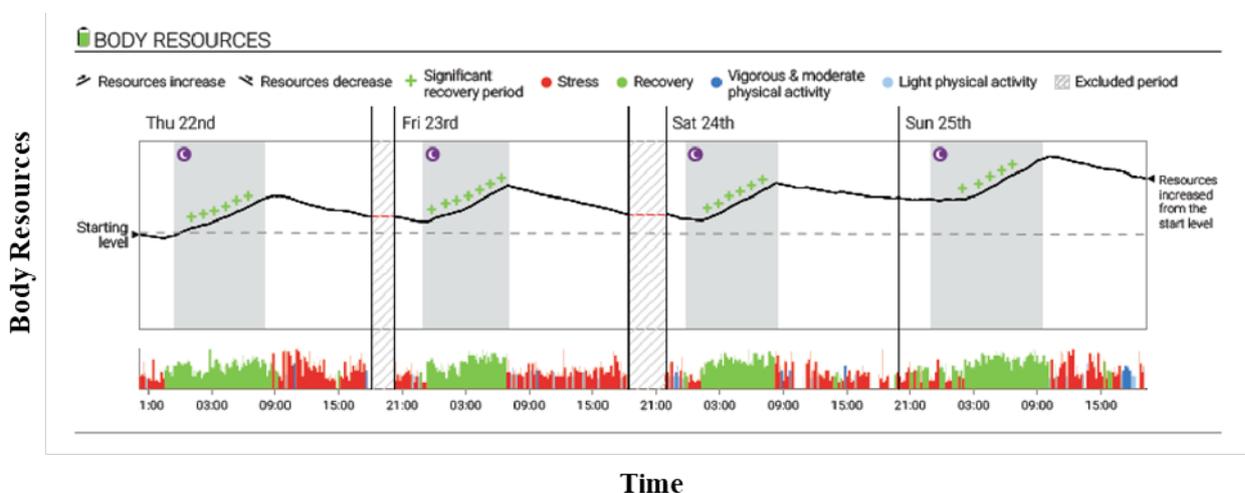


Figure 6. Overview of mothers' stress measurements during all measurement days

reacting clearly to the outcome of the fights like we did in our previous study, mother's stronger reaction at the beginning of the first fight and decline in reaction towards the end of that fight, which her daughter was winning, suggests her reactions also depending on the outcome. Furthermore, during the second fight both parents in this study had almost the same reaction pattern, with the highest physiological activity recorded toward the end of very close fight where winner wasn't decided up until the very end. Also, their daughter got injured during the second fight which influenced parent's experience of the whole event as they both mentioned it in their overall reflection question answered at the end of the competition day. It is impossible to distinguish their cardiovascular and metabolic reactions for the fight from their reaction on the injury from the data we have collected so more research is needed to clarify these findings.

To further clarify the cardiovascular and metabolic data, in this study we collected parent's emotional reactions 11 times before, during and after the competition including before and after each fight. Results suggest father experiencing overall more pleasant than unpleasant emotions with only exception being after the second fight and at the end of the competition day, when it was

vice versa. This shift of emotions could be due to the injury but also the negative outcome of the fight which was lost. Mother's emotional profile changed 8 times during 11 times measurement. She reported feeling unpleasant emotions more frequently than father did although her experience was also overall more pleasant than unpleasant. She experienced three big increases in N- emotions, one two days before the competition, second one just before the second fight and the third one after the competition was over when these emotions become the most prominent. Same shift as with father's emotions happened after the second fight was lost and her daughter got injured. At that time, she also reported feeling more unpleasant than pleasant emotions and that pattern also continued until the end of the competition day with an increase in N- emotions on Saturday evening compared both to all of her previous measurements and father's N- emotions at the same measurement point. Furthermore, mother reported experiencing greater level of stress than father. Keegan and colleagues [40] found that parents emotional reactions and behaviours before their child's sport competition can have a great influence on young athlete. Management of their own emotional reactions is recognized as important skill sport parents

should develop to successfully support their child's sport participation [16]. Investigating their emotional reactions before, during and after the competition can help further expand the knowledge from the few existing research studies on parents' emotions in sport [6, 29]. Previous research on parents in sport suggests that their involvement is influenced by numerous factors, including their expectations as well as goals for their child's sport participation [41]. The results in our study are in line with finding that task-orientation is positively correlated with positive emotions and ego-orientation with negative emotions [23, 24]. This indicates parent's goals as well as their goal orientation is important area for further investigation.

This is the first research that investigated sport's parents experiences few days before, during and few days after the competitions and also the first one which used technology to monitor their stress and recovery. Results in this study showed that father had less sleep and recovered more poorly compared to the mother which resulted in his Firstbeat reported body resources dropping below the starting level on the evening of the competition day and even more the day after. On the contrary, mother's body resources never dropped below the starting point. He also reported feeling slightly more depressed than mother although both of their results were low. These findings suggest there is a need to include more variables into investigating and explaining sport parent's experiences before, during and after their child's sport competition, one of them being the amount and quality of sleep. Only more in detail research focusing on these variables can clarify their potential importance.

Finally, results of this study suggest both parents using numerous coping strategies to cope with this experience. This is in line with findings from study conducted by Burgess and colleagues [11] who suggested that sport parents often use multiple coping strategies

in combination. In our study, father predominantly used social support while mother mostly used planning. This is in line with study conducted by Harwood and colleagues [6] who reported tennis players parents using mostly mastery coping strategies (e.g. communicating with a child, information seeking, time management) followed by internal regulation (e.g. cognitive reappraisal, seeking emotional support, behavioural avoidance) to deal with competitive stressors. It was previously suggested that people rarely cope with stress isolated from others and that coping should be investigated as social phenomenon [42]. Thus, we suggest including dyadic coping research into investigating sport parents' experiences since authors in dyadic coping area often put the emphasis on close relationships [43-45].

We suggest future studies on more parents are worth conducting. If the measurements are held during the number of days before and after the competition, we suggest that giving the parents some kind of diary with open-ended questions to answer every day would help better understand their experiences. Diaries are often used in stress research on coaches and athletes [46, 47] and could provide valuable information we missed in this study.

Conclusion

It is important to document and understand parent's experiences during the sport events of their children to enhance their well-being but also help them provide adequate support to their child. Sport competitions can be very demanding for the parents and this research provides an insight into their physiological and psychological reactions to the event. Future studies with more participants are necessary to put these results into perspective.

Conflicts of Interest

The authors declare no conflict of interest.

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Criteria for assessing the level of physical fitness and physical state of football players with cerebral paralysis, taking into account their sports classes

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Purpose: The article is devoted to finding ways to optimize the training of players with cerebral palsy (CP). It is determined that testing and elaboration of criteria for assessing the level of physical fitness of football players with cerebral palsy can be used as a mean of evaluation the sportsmanship of football players of this nosology in training and competitive activities. The purpose of the study is to determine the level of physical and functional preparedness of football players with cerebral paralysis and to develop criteria for their evaluation during the intensive training period, taking into account the functional classes of athletes.

Material: 25 football players with cerebral palsy, candidates and members of the national team of Ukraine, three-time Paralympic champions, multiple world and European champions took part in the study voluntarily. Athletes of the selected group have 5-8 classes of the adapted classification of the International Association of Cerebral Palsy (CP-ISRA) for CP-Football. Biochemical parameters were studied before and after training work of different focus. The value of maximum oxygen consumption (MOC) was determined by means of bicycle ergometric testing. The physical state and level of physical fitness of football players were monitored during the study. The research was conducted on the basis of the research laboratory of Prydniprovsk State Academy of Physical Culture and Sport and on the basis of the Municipal Institution "Dnipropetrovsk Medical and Physical Dispensary" of the Dnipropetrovsk Regional Council.

Results: It was found that athletes with cerebral paralysis are able to adequately tolerate heavy physical loads. Football players with disabilities had biochemical parameters of blood sampling and registration of recovery processes of the cardiovascular system after training activities of different focus within the permissible norm for both healthy athletes. Obtaining such data became the basis for the intensification of training process, which promoted the development of motor skills of football players.

Conclusions: Obtained data were the basis for creation the criteria for assessing the level of physical fitness of football players depending on their sports classes. In future, this will allow coaches to determine the effectiveness of the training period, obtain information about the condition of players in training, in the recovery process. On this basis it will help to individualize the workload of players and adjust the training process. The analysis of a direction of preparation and decision-making about educational process correction for football players with disabilities can be realized according to the received data in various structural formations of an annual macrocycle.

Keywords: cerebral palsy, physical fitness, testing, international classification, sports classes.

Introduction

Sports movement of people with disabilities is a part of the modern Olympic movement. This creates a powerful stimulus to mobilize the body's reserve capacity and gives hope to people with severe disabilities to overcome their diseases [1, 2]. This approach takes place in fundamental sources and research of specialists [3 – 5]. Ensuring the activities of Ukrainian national teams of athletes with disabilities, their training and participation in international competitions is one of the priorities of the Ministry of Youth and Sports of Ukraine and Ukrainian center "Invasport" [6]. Athletes with disabilities in Ukraine include 4 nosologies [7, 8]: with cerebral palsy (CP), with mental and physical disabilities, with vision impairments, with hearing impairments. Football for people with cerebral palsy is played by athletes with © Serhii Ovcharenko, Artem Yakovenko, Tetiana Sydorчук, Iryna Stepanova, Oleksandr Pikiner, 2021
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minimal criteria for ataxia, hypertension or athetosis (i.e., three types of disease that are most often associated with people with neurological disorders). Athletes with motor control disorders (brain injuries) have recently been allowed to compete in this sport [9, 10]. Scientists have proven that it can be the result of cerebral paralysis, apoplexy or traumatic injury. This impairs the function of the lower limbs and limits the performance of specific skills, for instance, jumping, running, changing directions or dribbling skills [11 – 13].

The International Paralympic Committee (IPC) applies a functional system to all athletes participating in official events. It includes eight functional classes: the first four groups (grades 1 – 4) correspond to athletes who need a wheelchair to engage in any sport. The last four groups (grades 5 – 8) correspond to athletes who do not need a wheelchair. The classification developed by the International Federation of Cerebral Palsy Football

(IFCPF) was used for CP football. It is defined as the grouping of players into sports classes according to the extent to which their defects affect their motor activity (10, 14). Classification groups assign classes to athletes by collectively reviewing the results of functional and motor tests, which are constantly modified and improved [15 – 18]. After the 2016 Paralympic Games, the classification of football CP has undergone very significant changes [9]. Reina et al. [18] have developed four classes (FT) for CP-football:

1) Class FT5 includes impairments of two legs, impairments of both legs and arms, meanwhile the lower limbs are more impaired than the upper ones; or athletes with dystonia, whose lower limbs are more impaired than the upper ones.

2) Class FT6 includes moderate impairments of all four limbs. Athetosis, dystonia, or ataxia are usually the most common factors.

3) Class FT7 includes the degree of spasticity of body half. Athletes walk, run with a clearly visible limping due to spasticity in the lower limb.

4) Class FT8 includes hemiplegia, monoplegia in the lower limbs; athetosis, dystonia, ataxia, mixed cerebral palsy or other neurological conditions.

Scientists have discovered relations between impairments and limitations of motor activity in this sport [19]. Studies by Anastasiadis et al. [20] showed that players with CP have the basic elements of movement technique, as in classic football, which requires players to use strength, speed, agility, flexibility and endurance. Davids [21] determined that CP-football is characterized by intermittent motor actions of short duration and high intensity. Bangsbo [22] investigated the motor activity of players during a football match. Ovcharenko et al. [23] found that the most backward part in the structure of physical fitness of most football players with cerebral palsy is speed and strength preparedness, which is associated with the peculiarities of the disease. Person with hemiparesis (form of cerebral paralysis) couldn't do symmetrical movements; jumps and jumps off require compensatory movements of the healthy half of the body. In this regard, the development of jumping in players with lesions of one or both legs are a long and continuous process. As soon as the level of motor activity decreases, and this usually happens in the transition period, muscle atrophy occurs. This significantly negatively affects the speed and strength capabilities of athletes [23].

Considering the complex structure of sports training in team games, experts offer a comprehensive approach to assessing the preparedness of athletes [24, 25]. Reina et al. have developed tests used in the classification of players with CP [26]. Meanwhile, there are serious problems with the interpretation of the data obtained during the classification and their use in the training of athletes with disabilities. The reasons are the lack of criteria to assess the level of physical state and physical fitness of players of this nosology during the long training process and, based on this, the inability to compare the initial state of the athlete, his condition against training loads and the

required target condition.

The *hypothesis* of the study is to scientifically predict the possibility of controlling the level of physical fitness of football players with cerebral palsy to improve the quality of their long-term sports training.

The *purpose* of the study is to determine the level of physical and functional preparedness of football players with CP and to develop criteria for their evaluation during the intensive training period, taking into account the functional classes of athletes.

Material and methods

Participants: 25 football players with cerebral palsy, candidates and members of the national team of Ukraine aged 20 to 34 took part in the study voluntarily. Athletes of the selected group have 5-8 classes of the adapted classification of the International Association of Cerebral Palsy (CP-ISRA) for CP-Football. All athletes gave informed consent to participate in the research.

Procedure: Anthropometric researches on the basic rules and principles connected with selection of means of measuring equipment and methods of measurement were carried out [27]. The following anthropometric parameters were measured: body length, body weight, chest circumference (CC), vital capacity of the lungs (VLC). Bicycle ergometric testing was used to determine the value of maximum oxygen consumption (MOC). During the dispensary examination after warming up (3-4 minutes) and rest, the athletes performed a single physical activity for 5 minutes. Pedaling speed – 60 rotations per minute. The load power increases to the range of heart rate – 120 – 170 heartbeats per minute. After cycling ergometric testing, the values of MOC were determined using a special nomogram [28].

The biochemical method allows determining some biochemical indicators of athletes' condition: the state of training, the state of overtraining, recovery, etc. Strength load on the trainers included exercises for developing maximum leg muscle strength using weights 70% or more of the maximum with full range of motion. It was measured the amount of creatinine, creatine and lactic acid in blood, creatinine and creatine in urine, urea in blood serum before and after strength load performed by players on the trainers.

A running test (cross-country running 9000 meters with an average speed of 3.5 – 4.0 meters per second) was used in aerobic mode. The power of work is such that the energy supply of the working muscles can occur (mainly or exclusively) due to aerobic processes associated with sufficient oxygen consumption. Therefore, the power in these exercises can be estimated by the level (speed) of remote oxygen consumption [29]. It was measured the concentration of non-esterified fatty acids (NEFA) and urea in blood serum, lactic and pyruvic acid, glucose and hemoglobin in blood taken from athletes before and after running. Heart rate and blood pressure (BP) were measured to assess post-cross recovery processes. Measurement of blood pressure allows identifying the dynamics of indicators that well reflect the body's preparedness

for exercise [30]. Heart rate and blood pressure were registered at rest, immediately after exercise and during recovery.

To diagnose the level of players' special physical training, a minimized set of informational and reliable pedagogical tests was used. It included an assessment of the starting speed for the running time of 10 meters from the spot. Distance speed was measured by the running time of 50 meters from the spot. Speed and strength abilities were registered by the height of jump up from the place with using of a contact platform and an electronic stopwatch. Special endurance was determined according to the integrated time of shuttle run 7 x 50 meters. The informativeness and reliability of these tests have been proven by previous studies [31, 32].

Statistical analysis. Data were processed by descriptive and comparative statistical procedures. Mathematical statistics were conducted by the method of calculating quantitative indicators. We calculated the arithmetic mean (\bar{x}), standard deviation (S). The reliability of the obtained data was determined by Student's t-test and

was considered statistically significant at $p < 0.05$ and $p < 0.001$.

Results

Studies of biochemical parameters of football players with disabilities before and after training load with different focus provide an opportunity to find out how training loads affect the physical condition of football players. Running and strength work were offered to football players with cerebral palsy as control exercises. An average speed of football players was $3.5 - 4 \text{ m}\cdot\text{s}^{-1}$ during the running. Strength load on the trainers included exercises for developing maximum leg muscle strength using weights 70% or more of the maximum with full range of motion. Obtained results show that biochemical parameters of athletes before and after exercise were within the allowable norm for healthy athletes (Table 1).

Test subjects adequately tolerated to proposed large physical load: rapidity of recovery (according to heart rate registration) after running was also quite fast (Table 2). I.e. we can confirm that proposed load corresponded to

Table 1. Biochemical parameters of football players with CP before and after training load of different focus (n = 25)

Focus of training	Indicators	Before load		After load		t	p
		\bar{x}	S	\bar{x}	S		
1. Strength load	Creatinine in blood, $\text{mkmol}\cdot\text{l}^{-1}$	101.9	1.64	102.8	2.03	1.71	.093
	Creatine in blood, $\text{mmol}\cdot\text{l}^{-1}$	186.9	10.4	292.1	14.0	30.16	.000*
	Creatinine in urine, $\text{mmol}\cdot\text{l}^{-1}$	35.2	1.9	32.3	2.3	4.86	.000*
	Creatine in urine, $\text{mmol}\cdot\text{l}^{-1}$	6.4	1.0	10.6	1.5	11.66	.000*
	Urea, $\text{mmol}\cdot\text{l}^{-1}$	6.8	0.3	7.1	0.2	4.16	.000*
	Lactic acid, $\text{mmol}\cdot\text{l}^{-1}$	2.0	0.1	4.5	0.2	56.81	.000*
2. Cross-country running 9000 m	Hemoglobin, $\text{g}\cdot\text{l}^{-1}$	149.4	1.71	163.2	1.32	32.09	.000*
	NEFA, m-equivalent $\cdot\text{l}^{-1}$	0.59	0.01	0.61	0.02	5.0	.000*
	Urea, $\text{mmol}\cdot\text{l}^{-1}$	7.52	0.34	8.75	0.41	12.05	.000*
	Lactic acid, $\text{mmol}\cdot\text{l}^{-1}$	1.99	0.12	5.07	0.21	70.0	.000*

* $p < 0.001$.

Table 2. Physiological parameters of football players with CP before and after cross-country running (n=25)

Indicators	Before load		After load		Recovery after 5 min.		Recovery after 10 min.		% increase / p (before running and 10-minutes recovery)
	\bar{x}	S	\bar{x}	S	\bar{x}	S	\bar{x}	S	
Heart rate, beats per min.	74.0	2.7	152.8	5.6	96.0	2.5	79.9	3.4	
% increase			+69.48		-45.65		-18.30		+7.66
p			.000*		.000*		.000*		.000*
Systolic blood pressure, mmHg	117.5	1.4	135.9	3.8	119.1	2.7	112.0	2.1	
% increase			+14.52		-13.17		-6.14		-4.79
p			.000*		.000*		.000*		.000*
Diastolic blood pressure, mmHg	73.0	1.5	79.0	2.4	77.3	1.9	75.0	1.8	
% increase			+7.89		-2.17		-3.02		+2.7
p			.000*		.007**		.000*		.000*

* $p < 0.001$; ** $p < 0.05$.

the functional capabilities of athletes with cerebral palsy. The positive dynamics of the concentration of lactic acid and urea, the decrease of NEFA after exercise indicate a high level of functional preparedness of football players at the time of diagnosis. The cardiovascular system of football players responded with a combined increase of heart rate, increased systolic blood pressure and pulse pressure. It indicates that athletes' level of preparedness match to performed load.

To assess the impact of the level of players' physical fitness on their game activity, a correlation analysis was calculated between the level of motor skills development and technical and tactical actions during games (Table 3). The nature of the statistical relationship between the volume of technical and tactical actions and special endurance deserves attention. If we take into account the fact that according to the rules of football CP field's size is 55×75 meters without fixing the position "out" and each team involves only 7 players, the leading quality in the structure of physical fitness of football players, in our opinion, is special endurance. This assumption was confirmed by the results of correlation analysis.

The increase of special endurance is associated with the number of short and medium passes in games ($r = - 0.81, p < 0.05$), long passes ($r = - 0.77, p < 0.05$), dribbling ($r = - 0.82, p < 0.05$), head play ($r = - 0.71, p < 0.05$), shots on goal ($r = - 0.80, p < 0.05$).

According to the study design we significantly increased the means of anaerobic (lactate and glycolytic) orientation, rationally combined the loads with different focus at the stages of the annual cycle. This contributed to the development of motor skills (especially speed and strength qualities and special endurance) [33].

Based on the data obtained during the control and analysis of indicators, we developed criteria for assessing the preparedness of football players with cerebral palsy, taking into account the motor abilities of athletes (their sports classes) (Table 4).

The presented criteria have three levels. The first level determines the lower limit of physical fitness indicators and physical development of football players with cerebral palsy, who have the highest degree of musculoskeletal disorders (classes FT5 and FT6 of international classification). The second level corresponds

Table 3. Correlation matrix of the relationship of physical fitness of football players with CP and their technical and tactical actions in competitions

Indicators	Run 12 min.	Run 10 m	Run 50 m	Jump up	Shuttle run 7× 50 m
Short and medium passes	-.18	-.01	.02	.35	-.81*
Long passes	.07	-.90*	-.33	.69*	-.77*
Dribbling	.19	.33	-.24	-.20	-.82*
Interseption	-.24	-.41	.15	.75*	.51
Bypass	-.18	-.11	-.05	.72*	.01
Ball tackle	-.16	.01	.14	-.40	.61
Head play	-.09	.04	-.14	.12	-.71*
Shots on goal	-.01	.30	-.13	.01	-.80*
Total amount of technical and tactical actions	.01	.03	-.01	-.08	-.49*

* $p < 0.05$.

Table 4. Criteria for assessing the morphofunctional condition and physical preparedness of football players with CP, taking into account the degree of musculoskeletal system impairments (their sports classes)

Indicators	Functional class FT5, FT6 (level 1)	Functional class FT7 (level 2)	Functional class FT8 (level 3)
Body mass, kg	66.6	69.5	72.4
Body length, cm	174.6	176.7	178.7
CC, cm	91.6	93.8	96.1
VLC, ml	4222	4525	4828
MOC, ml·min·kg ⁻¹	44.9	48.8	52.6
Run 12 min., m	2600	2800	3000
Run 10 m, sec.	1.88	1.85	1.80
Run 50 m, sec	6.80	6.60	6.50
Jump up, cm	42.4	45.7	47.9
Shuttle run 7×50 m, sec.	70.6	66.6	60.7

to the indicators of footballers with an average degree of musculoskeletal system impairment (class FT7 of international classification). The third level shows physical state of football players with the lowest degree of musculoskeletal disorders (according to class FT8 of international sports classification).

Achieving such results allows coaches to select for the national team, as well as to determine the effectiveness of the training process at the stages of the annual training cycle and, in particular, at the stage of preparation for international competitions.

Discussion

The analysis of literature sources on the problem of training football players allowed to establish the importance of the control system during the training process. The obtained results of complex control should be used for planning and correction of training plans. The content of programs and plans depends on their authenticity, reliability and informativeness, and the coach receives objective information about the health and mental state of each player, the impact of physical activity and changes in the functional systems of the body. A lot of experimental material has been accumulated on the problems of long-term training and control in football [24, 25]. The authors of these studies thoroughly and in detail considered the issue of pedagogical control of football players' training both in the process of long-term training and in various structural formations of the annual training cycle. Many studies have been aimed to improve the training process of athletes with disabilities in team [34-36] and individual sports [37-39]. We have developed a program of the training process in the annual cycle for football players with CP [33]. The advantage of our research is the possibility of applying a control system for football players with cerebral palsy. A comparative analysis of the test results of the control and experimental groups, which were trained in different programs and methods, showed the effectiveness of the proposed program. The implementation of this program contributed to the realization of the individual capabilities of the athletes of the experimental groups. Analysis of the results of retesting the level of physical fitness revealed that football players with CP of the experimental group compared to the previous testing had a significant ($p < 0.05$) increase in all indicators. Athletes of the control group had significant improvement ($p < 0.05$) only in indicators of speed.

Athletes with cerebral palsy can adequately tolerate heavy training loads. Results obtained for the first time in the testing process indicate that the medical and biological indicators of football players with CP before and after exercise were within the permissible norm for healthy athletes. In previous studies, we found certain patterns of influence of physical fitness on the playing activity of football players. A correlation analysis was conducted between the average indicators of the level of motor skills development and technical and tactical actions during official international competitions. This allowed

to determine that the leading quality in the structure of physical fitness of players with CP is special endurance. Thus, the higher level of special endurance in players with CP, the greater amount of load they can perform on the field during the game [40]. The results of our studies were supplemented by data from Yanci and co-authors [41] to determine the external load that players perform during games. We supplemented the data of Lukovska with co-authors [42] about a significant reduction in functional and motor abilities of athletes with cerebral palsy during a long break in training, which related to lack of self-movement.

Reina et al. [43] found that the lagging link in the structure of physical preparedness of football players with CP is speed and strength training, which related with the features of the disease. Differences in jumps between active functional classes (FT5 – FT8) were analyzed and it was determined that only players of class FT8 (less serious lesions) had significantly higher results in all jumping tests than players of lower classes ($p < 0.01$). We supplemented the data obtained by Reina [44] during the classification process about the difference in the level of motor skills between players of sports classes FT5, FT6, FT7 and FT8. FT5 and FT6 players had the worst scores in the tests. Athletes of the FT7 class had limited activity in walking and running on the injured side. Although the athlete usually moves with noticeable limping, it can almost completely disappear while running.

Based on the data obtained during the control and analysis of indicators, we have for the first time developed criteria for assessing the preparedness of football players with CP, taking into account their motor abilities (sports classes). This approach in CP-football is the most correct, because it is justified by the degree of impairment to the musculoskeletal system. This, in turn, in different ways limits the motor abilities of athletes of this nosology. Testing was conducted at the final stage of preparation for international competitions, when players were in the state of greatest training. Quantitative characteristics of the level of physical fitness and functional state can be classified as "regulatory requirements". Their achievement is ensured by the optimal functioning of bodies' basic systems. They are optimal and reflect the real state of the training process on this level of team development.

Conclusions

Literary analysis on the problem of research and generalization of training of football players with CP at the stage of preparation for higher achievements revealed problematic issues. These issues are the lack of comprehensive assessment and the lack of criteria to assess the level of various aspects of preparedness of athletes with special needs. The obtained data of control of physical fitness and functional condition of football players with CP made it possible to develop criteria for assessing the level of players' preparedness. This allows coaches to determine the effectiveness of the training period, to obtain information about players' condition and on this basis to individualize the workload for players and

adjust the training process. The analysis of the direction of training process is carried out based on the obtained data. Also decisions about the correction of the educational and training process of football players with disabilities may be made in various structural formations of the annual macrocycle.

Prospects for further research are the creation of criteria for assessing the technical and tactical readiness of football players with cerebral palsy, taking into account the functional classes of athletes.

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Conflict of interest

The authors declare no conflict of interest.

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The prediction of repeated sprint and speed endurance performance by parameters of critical velocity models in soccer

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Abstract

Purpose: The prediction of running anaerobic sprint test and 800 m performance by parameters of critical velocity was examined in this study.

Material: The participants of study were consisted of thirteen amateur soccer players (n=13, age=22.69±5.29 years, weight=72.46±6.32 kg, height=176.92±6.73 cm). The 800 and 2400 m running tests were performed for determination of critical velocity and anaerobic distance capacity. The critical velocity and anaerobic distance capacity were determined by three mathematical models (linear total distance, linear velocity, non-linear two parameter model). The repeated sprint and sprint endurance ability was determined by running anaerobic sprint test and 800 m running test. The simple and multiple linear regression analysis was used for prediction of dependent variables (running anaerobic sprint test and 800 m running performance) by independent variables (critical velocity and anaerobic distance capacity) of study. The correlation between variables was determined by Pearson correlation coefficient.

Results: It was found that anaerobic distance capacity was a significant predictor of running anaerobic sprint test and 800 m running performance (p<0.05). However, it was determined that critical velocity predicted significantly only time parameters of running anaerobic sprint test and 800 m test (p<0.05). Also, the parameters of 800 m test (except for average velocity) were significantly predicted by running anaerobic sprint test parameters (p<0.05).

Conclusions: It may be concluded that anaerobic distance capacity is an indicator of repeated sprint and speed endurance ability in soccer and may be used in improvement of sprint endurance performance.

Keywords: soccer, critical velocity, repeated sprint, speed endurance, sprint tests.

Introduction

The oxygen uptake of muscles may be accepted as important determinant of aerobic exercise performance and critical velocity (CV) or critical power parameter is closely related to it. It is indicated that the critical power is an important indicator of oxygen uptake ability during exercise [1]. The CV was originated from critical power concept. The critical power concept was firstly defined by Monod and Scherrer [2]. The critical power tests were consisted of a series of exhausting exercises on small muscle groups with different exercise intensities [2]. The critical power (slope of linear regression graph) and anaerobic work capacity (y-intercept of linear regression graph) parameters were yielded by the linear relationship between work (parameter determined by multiplied of power and time) and exhaustion time of test [4-6]. Then, test procedure was performed on cycle ergometer with different power values [3]. The CV and anaerobic distance capacity (ADC) were determined by a series tests performed on treadmill [7, 8]. The CV and ADC parameters corresponded to critical power and anaerobic work capacity parameters in critical power test [9, 10]. The CV is maximum running velocity sustained without fatigue and ADC is distance covered with anaerobic energy sources in muscles [9-11]. The aerobic fitness level of

athletes may be evaluated with CV and ADC parameters. The CV tests have various advantages at determination of aerobic fitness. The procedure of CV tests is simple and easy for aerobic performance measurement of athletes. The CV parameter was determined with distance, velocity and time parameters of two or more runnings. Also, the CV test protocol may be performed on treadmill or field.

The aerobic exercises such as walking, runnings with low intensity are frequently performed during soccer game frequently. On the other hand, it was indicated that the explosive power activities, explosive runnings, jumps, repeated sprints are important decisive of match performance [12-15]. The repeated sprint ability may relate to performance at last parts of soccer match observed fatigue. The anaerobic activities such as sprint may have high importance on critical moments of soccer match [16]. The anaerobic activities such as repeated sprints may be related to various performance parameters as CV and ADC. If the probable effects on anaerobic activities (repeated sprint and 800 m) of CV and ADC parameters is determined, the anaerobic activities of soccer players may be organized in the light of CV and ADC parameters. Many studies are available in literature about anaerobic activities such as repeated sprint and 800 m running. However, it has been seen that few studies in literature have focused on relationship between CV test parameters and anaerobic activities such as repeated sprint and 800

m. The aim of this study was to predict repeated sprint and 800 m performances by CV and ADC parameters.

Material and Methods

Participants

The thirteen amateur soccer players (n=13, age=22.69±5.29 years, weight=72.46±6.32 kg, height=176.92±6.73 cm) participated in the study. The participants consisted of players playing in a soccer team competing regional amateur league of Turkey and performing soccer trainings 1.5 hours for five days of a week regularly. The participants were informed about study and they signed informed voluntary consent form. The study was performed according to principles of Helsinki Declaration.

Research Design

Data Collection

800 m and 2400 m Running Tests

The 800 and 2400 m running tests were performed in order to determine CV and ADC [17]. The tests were performed on synthetic grass soccer pitch at same hour of day to eliminate effects of circadian rhythm. The high intensity exercises were not performed within 24 hours before the tests. The measurements were performed at pre-season preparation term. The distance of tests was marked with training cones. The 800 m test was firstly performed firstly. The players performed ten minutes warm-up and stretching exercises before the test. Each player entered the test individually. The players tried to run 800 m distance in shortest time with maximum effort (with 100% exercise intensity). The verbal encouragement was given to players by researchers during test. The test was finished when 800 m distance was covered by players. The test time was measured by wireless photocell system (Witty, Microgate, Bolzano, Italy). The test time was recorded in second unit with 0.01 precision. After three days from 800 m test, 2400 m test was performed by players. The procedure of 2400 m test was similar to the 800 m test. The test time of players was measured similarly. After the tests, the players performed warm-down exercises.

Running Anaerobic Sprint Test (RAST)

RAST was a test used for determination of repeated sprint ability [18, 19]. The RAST was consisted of six 35 m sprints performed with 10 seconds rest interval. The test was carried out on synthetic grass soccer pitch at same hour of day after three days from 2400 m running test. The 35 m test track was set on soccer pitch. The gates of wireless photocell system (Witty, Microgate, Bolzano, Italy) were placed at start and finish point of 35 m test track. The players performed warm-up and stretching exercises before test. The players performed six 35 m sprints with 10 seconds recovery interval between each sprint. The verbal motivation was given to players during test. The time of six sprints was recorded in second unit with 0.01 precision. The test parameters were determined as follow:

- Power (watt)= Weight (kg) x Distance (m)² ÷ Time³(sec) [20],
- Minimum power (watt): The lowest power value of

six sprints,

- Peak power (watt): The highest power value of six sprints,
- Average power (watt): The mean power value of six sprints,
- Fatigue index (watt/sec) = (Maximum power (watt)- Minimum power (watt)) ÷ Total time of 6 sprints (sec) [18],
- Average test time (sec): Mean of six sprint times,
- Total test time (sec): Sum of six sprints times,
- Velocity (km/h)= Sprint distance (km) ÷ Sprint time (h),
- Average velocity (km/h): Mean velocity of six sprints,
- Maximum velocity (km/h): The highest velocity of six sprints.

800 m Running Test

The 800 m test was carried out in order to determine relationship between 800 m performance and RAST, CV and ADC parameters. After three days from RAST, 800 m test was performed at same hour of day on synthetic grass soccer pitch. Test track was prepared on soccer pitch. After warm-up and stretching exercises, players started the test. Each player performed the test individually. The players ran with maximum effort and covered 800 m distance at shortest time. Test time was determined by wireless photocell system (Witty, Microgate, Bolzano, Italy). The 800 m test time was recorded in sec unit with 0.01 precision.

Determination of Critical Velocity (CV) and Anaerobic Distance Capacity (ADC)

The three mathematical models were used for determination of CV and ADC. These mathematical models consisted of linear and non-linear regression models. The time (t), distance (D) and velocity (V) at 800 and 2400 m tests were used in three mathematical models. The first mathematical model was linear total distance (Lin-TD) model. The Lin-TD model was derived from linear regression analysis between D and t parameters of 800 and 2400 m tests for each participant [20-27]:

$$D = ADC + CV \times t$$

In Lin-TD model, the regression slope was CV and y-intercept of distance-time relationship (y-intercept of regression line) was ADC.

The second mathematical model was linear velocity (Lin-V) model. The Lin-V model was consisted of regression analysis between V and inverse of time (1/t) of 800 and 2400 m tests and the 1/t value were used in model to be converted to linear of hyperbolic relationship between V and t [23-25, 27-31]:

$$V = ADC \times (1/t) + CV$$

In Lin-V model, the regression slope was ADC and y-intercept of V – 1/t relationship (y-intercept of regression line) was CV.

The third mathematical model was known as non-linear model with 2-parameter (Non-2). The equation

of Lin-V model was solved for t parameter and the hyperbolic relationship between V and t was indicated by Non-2 model [27-30, 32-34]:

$$t = \text{ADC} / (V - \text{CV})$$

Statistical Analysis

The descriptive statistics of study were presented as mean ± standard deviation and range (minimum-maximum) values (table 1). The CV and ADC parameters of each player were determined by linear and nonlinear regression analysis. The Shapiro Wilk test was utilised to examine normality of data. The simple scatter graphs were examined for determination of linearity between dependent and independent variables at regression models. The multicollinearity between independent variables of regression models was examined by VIF (variance inflation factor). The regression models were designed in accordance with ideal VIF. The simple and multiple linear regression analysis was used for prediction of dependent variables (RAST and 800 m test parameters) by independent variables of study (CV and ADC). All data were analysed in the SPSS package program (IBM SPSS 22.0. Armonk, NY: IBM Corp.). The significance level at statistical analysis was performed as p<0.05.

Results

Table 1. The Descriptive Statistics of Test Parameters

Tests	Parameters	Mean ± SD	Range	
CV Test (n=13)	Lin-TD Model	CV (km/h)	12.93 ± 0.61	11.95 – 14.00
		ADC (km)	0.22 ± 0.03	0.15 – 0.28
	Lin-V Model	CV (km/h)	12.96 ± 0.61	11.93 – 14.01
		ADC (km)	0.22 ± 0.03	0.16 - 0.28
	Non-2 Model	CV (km/h)	12.96 ± 0.62	11.98 – 14.01
		ADC (km)	0.22 ± 0.03	0.15 – 0.28
RAST Test (n=13)		t _(average) (sec)	5.23 ± 0.27	4.87 – 5.81
		t _(total) (sec)	31.40 ± 1.64	29.20 – 34.85
		V _(average) (km/h)	24.20 ± 1.22	21.75 – 25.95
		V _(max) (km/h)	26.08 ± 1.35	23.38 – 27.88
		Min. power _(relative) (watt/kg)	7.04 ± 1.06	5.27 – 8.92
		Min. power (watt)	509.89 ± 92.50	393.57 – 713.31
		Max. power _(relative) (watt/kg)	10.94 ± 1.66	7.82 – 13.27
		Max. power (watt)	791.76 ± 135.62	589.85 – 1061.23
		Mean power _(relative) (watt/kg)	8.82 ± 1.29	6.36 – 10.78
		Mean power (watt)	638.38 ± 108.38	479.26 – 862.42
800 m running test (n=13)		Fatigue index (watt/sec)	9.05 ± 2.42	5.53 – 14.12
		t (sec)	155.00 ± 9.35	145.00 – 179.00
		V _(average) (km/h)	18.30 ± 1.43	15.00 – 20.00
		V _(max) (km/h)	24.50 ± 2.33	19.60 – 27.70

Note. Lin-TD: Linear Total Distance Model, Lin-V: Linear Velocity Model, Non-2: Nonlinear 2-parameter Model, CV: Critical velocity, ADC: Anaerobic Distance Capacity, RAST: Repeated Anaerobic Sprint Test, t: test time, t_(average) = average test time, t_(total) = total test time, V: velocity, V_(average) = average velocity, V_(max) = maximum velocity, min. power_(relative) = relative minimum power of six 35 m. runnings, min.power=salt minimum power of six 35 m. runnings, max.power_(relative) = relative maximum power of six 35 m. runnings, max. power=salt maximum power of six 35 m. runnings, mean power_(relative) = relative mean power of six 35 m. runnings, mean power=salt mean power of six 35 m. runnings, fatigue index=fatigue index of six 35 m. runnings.

There was no significant correlation between CV values and RAST parameters in Table 2 (p>0.05). On the other hand, it was found that the ADC values correlated significantly with RAST parameters (p<0.05).

According to analysis results in Table 3, it was seen that CV and ADC parameters correlated significantly with time and maximum velocity at 800 m test (p<0.05). It was found no significant correlation between average velocity at 800 m test and CV, ADC parameters (p>0.05).

According to results of correlation analysis between RAST and 800 m test parameters in Table 4, there was a significant correlation between RAST parameters and time and maximum velocity at 800 m test (p<0.05). It was found that there was no significant correlation between average velocity at 800 m test and RAST parameters (p>0.05).

In Table 5, the analysis result indicated prediction of the RAST parameters by CV and ADC parameters. The both CV and ADC predicted significantly time parameters of RAST (t_{verage} and t_{total}) (p<0.05). The velocity and power parameters of RAST (V_{average}, V_{max}, minimum, maximum and mean power) were significantly predicted by ADC merely (p<0.05). Also, it was found that the ADC of Lin-TD and Non-2 model was a significant predictor of fatigue index value of RAST (p<0.05).

According to results in Table 6, the parameters of time and maximum velocity at 800 m test were significantly

Table 2. Pearson Correlation Analysis Results Between CV, ADC and RAST Parameters

Model	Parameters	Correlation	RAST						Fatigue index (watt/sec)	
			t _(average) (sec)	t _(total) (sec)	V _(average) (km/h)	V _(max) (km/h)	Min. power _(relative) (watt)	Max. power _(relative) (watt)		Mean power _(relative) (watt)
Lin-TD	CV (km/h)	r	-0.500	-0.501	0.480	0.411	0.438	0.384	0.457	0.135
		p	0.082	0.081	0.097	0.163	0.135	0.195	0.116	0.661
	ADC (km)	r	-0.635	-0.637	0.629	0.671	0.594	0.666	0.621	0.593
		p	0.020*	0.019*	0.021*	0.012*	0.032*	0.013*	0.024*	0.033*
Lin-V	CV (km/h)	r	-0.504	-0.505	0.485	0.433	0.424	0.407	0.463	0.199
		p	0.079	0.078	0.093	0.140	0.149	0.167	0.111	0.515
	ADC (km)	r	-0.696	-0.697	0.693	0.679	0.721	0.675	0.688	0.506
		p	0.008*	0.008*	0.009*	0.011*	0.005*	0.011*	0.009*	0.078
Non-2	CV (km/h)	r	-0.504	-0.505	0.485	0.414	0.446	0.388	0.462	0.137
		p	0.079	0.078	0.093	0.160	0.127	0.191	0.112	0.656
	ADC (km)	r	-0.633	-0.635	0.626	0.668	0.596	0.662	0.618	0.596
		p	0.020*	0.020*	0.022*	0.013*	0.032*	0.014*	0.024*	0.031*

Note. * p<0.05

Table 3. Pearson Correlation Analysis Results Between CV, ADC and 800 m Test Parameters

Model	Parameters	Correlation	800 m test		
			t (sec)	V _(average) (km/h)	V _(max) (km/h)
Lin-TD	CV (km/h)	r	-0.452	-0.064	0.555
		p	0.121	0.837	0.049*
	ADC (km)	r	-0.770	0.510	0.681
		p	0.002*	0.075	0.010*
Lin-V	CV (km/h)	r	-0.475	-0.071	0.565
		p	0.101	0.817	0.044*
	ADC (km)	r	-0.782	0.499	0.726
		p	0.002*	0.082	0.005*
Non-2	CV (km/h)	r	-0.451	-0.074	0.560
		p	0.122	0.810	0.047*
	ADC (km)	r	-0.762	0.493	0.686
		p	0.002*	0.087	0.010*

Note. *p<0.05

predicted by both CV and ADC (p<0.05). Also, it was seen that CV and ADC were not significant predictors of average velocity at 800 m test (p>0.05).

The results in Table 7 indicated that the RAST parameters were significant predictors of time and maximum velocity at 800 m test (p<0.05). The average velocity at 800 m test was not significantly predicted by RAST parameters (p>0.05). On the other hand, it was found that the fatigue index parameter of RAST predicted significantly time of 800 m test merely (p<0.05).

Discussion

The CV and ADC parameters are products of linear relationship between distance and time of exercise. Also, these parameters are determined from linear relationship between velocity and time⁻¹ or other non-linear mathematical models. The CV and ADC were frequently investigated in various studies. It was found that CV correlated with maximal aerobic velocity and maximum oxygen uptake [35, 36]. The significant and high correlation (r = 0.80-0.93 range, p<0.01) between CV of five mathematical models and one hour running performance indicated relationship between CV and

Table 4. Pearson Correlation Analysis Results Between RAST and 800 m Test Parameters

RAST Parameters	Correlation	800 m test		
		t (sec)	V _(average) (km/h)	V _(max) (km/h)
t _(average) (sec)	r	0.806	-0.341	-0.746
	p	0.001*	0.254	0.003*
t _(total) (sec)	r	0.807	-0.342	-0.745
	p	0.001*	0.253	0.003*
V _(average) (km/h)	r	-0.799	0.335	0.725
	p	0.001*	0.263	0.005*
V _(max) (km/h)	r	-0.815	0.438	0.698
	p	0.001*	0.135	0.008*
Min. power _(relative) (watt)	r	-0.698	0.197	0.762
	p	0.008*	0.519	0.002*
Max. power _(relative) (watt)	r	-0.804	0.434	0.678
	p	0.001*	0.139	0.011*
Mean power _(relative) (watt)	r	-0.790	0.330	0.705
	p	0.001*	0.271	0.007*
Fatigue index (watt/sec)	r	-0.661	0.420	0.387
	p	0.014*	0.153	0.191

Note. *p<0.05

Table 5. The Regression Analysis of Effect on RAST Parameters of CV and ADC as Predictor Variables

Dependent Variable	Model	Predictor Variables	B	Standard Error	β	t	p	R	R ²	Standard Error of Estimate
t _(average) (sec)	Model-1	Constant	8.895	1.146		7.764	0.000*			
		Lin-TD-CV	-0.205	0.086	-0.464	-2.371	0.039*	0.786	0.618	0.184
		Lin-TD-ADC	-4.543	1.462	-0.608	-3.107	0.011*			
	Model-2	Constant	8.904	1.062		8.385	0.000*			
		Lin-V-CV	-0.192	0.081	-0.435	-2.386	0.038*	0.819	0.671	0.171
		Lin-V-ADC	-5.328	1.496	-0.649	-3.561	0.005*			
Model-3	Constant	8.918	1.145		7.787	0.000*				
	Non-2-CV	-0.205	0.086	-0.467	-2.384	0.038*	0.786	0.618	0.184	
	Non-2-ADC	-4.611	1.494	-0.604	-3.086	0.012*				
t _(total) (sec)	Model-1	Constant	53.472	6.869		7.785	0.000*			
		Lin-TD-CV	-1.235	0.518	-0.465	-2.385	0.038*	0.788	0.621	1.107
		Lin-TD-ADC	-27.414	8.765	-0.610	-3.128	0.011*			
	Model-2	Constant	53.527	6.360		8.417	0.000*			
		Lin-V-CV	-1.160	0.483	-0.436	-2.403	0.037*	0.821	0.674	1.027
		Lin-V-ADC	-32.149	8.961	-0.651	-3.588	0.005*			
Model-3	Constant	53.607	6.867		7.807	0.000*				
	Non-2-CV	-1.237	0.516	-0.468	-2.397	0.037*	0.788	0.621	1.108	
	Non-2-ADC	-27.818	8.961	-0.606	-3.104	0.011*				
V _(average) (km/h)	Model-1	Constant	8.308	5.315		1.563	0.149			
		Lin-TD-CV	0.881	0.400	0.445	2.201	0.052	0.770	0.592	0.857
		Lin-TD-ADC	20.204	6.783	0.602	2.979	0.014*			
	Model-2	Constant	8.232	4.911		1.676	0.125			
		Lin-V-CV	0.826	0.373	0.416	2.216	0.051	0.807	0.651	0.793
		Lin-V-ADC	23.880	6.920	0.648	3.451	0.006*			
Model-3	Constant	8.200	5.313		1.543	0.154				
	Non-2-CV	0.884	0.399	0.448	2.214	0.051	0.769	0.592	0.857	
	Non-2-ADC	20.494	6.934	0.598	2.956	0.014*				
V _(max) (km/h)	Model-1	Constant	10.150	5.918		1.715	0.117			
		Lin-TD-CV	0.817	0.446	0.372	1.832	0.097	0.767	0.588	0.954
		Lin-TD-ADC	24.112	7.551	0.649	3.193	0.010*			
	Model-2	Constant	9.934	5.879		1.690	0.122			
		Lin-V-CV	0.801	0.446	0.365	1.796	0.103	0.770	0.593	0.949
		Lin-V-ADC	26.126	8.283	0.640	3.154	0.010*			
Model-3	Constant	10.060	5.932		1.696	0.121				
	Non-2-CV	0.818	0.446	0.374	1.834	0.096	0.765	0.585	0.957	
	Non-2-ADC	24.464	7.741	0.645	3.160	0.010*				

Table 5 (continued)

Dependent Variable	Model	Predictor Variables	B	Standard Error	β	t	p	R	R ²	Standard Error of Estimate
Min. power _(relative) (watt/kg)	Model-1	Constant	-5.692	5.047		-1.128	0.286			
		Lin-TD-CV	0.698	0.380	0.404	1.835	0.096	0.718	0.516	0.813
		Lin-TD-ADC	16.677	6.440	0.571	2.590	0.027*			
	Model-2	Constant	-5.662	4.335		-1.306	0.221			
		Lin-V-CV	0.606	0.329	0.351	1.843	0.095	0.801	0.642	0.700
		Lin-V-ADC	21.951	6.109	0.684	3.593	0.005*			
	Model-3	Constant	-5.885	5.006		-1.176	0.267			
		Non-2-CV	0.706	0.376	0.411	1.877	0.090	0.723	0.523	0.808
		Non-2-ADC	17.022	6.533	0.570	2.606	0.026*			
Max. power _(relative) (watt/kg)	Model-1	Constant	-7.583	7.459		-1.017	0.333			
		Lin-TD-CV	0.928	0.562	0.346	1.652	0.130	0.750	0.562	1.202
		Lin-TD-ADC	29.310	9.518	0.645	3.080	0.012*			
	Model-2	Constant	-7.904	7.383		-1.071	0.310			
		Lin-V-CV	0.911	0.560	0.339	1.627	0.135	0.755	0.570	1.192
		Lin-V-ADC	31.895	10.403	0.639	3.066	0.012*			
	Model-3	Constant	-7.706	7.473		-1.031	0.327			
		Non-2-CV	0.931	0.562	0.348	1.657	0.129	0.748	0.560	1.206
		Non-2-ADC	29.740	9.753	0.641	3.049	0.012*			
Mean power _(relative) (watt/kg)	Model-1	Constant	-7.291	5.811		-1.255	0.238			
		Lin-TD-CV	0.883	0.438	0.422	2.016	0.071	0.750	0.563	0.937
		Lin-TD-ADC	21.101	7.416	0.596	2.845	0.017*			
	Model-2	Constant	-7.413	5.362		-1.383	0.197			
		Lin-V-CV	0.825	0.407	0.394	2.027	0.070	0.792	0.627	0.866
		Lin-V-ADC	25.131	7.555	0.646	3.326	0.008*			
	Model-3	Constant	-7.414	5.809		-1.276	0.231			
		Non-2-CV	0.887	0.437	0.426	2.031	0.070	0.750	0.562	0.938
		Non-2-ADC	21.396	7.581	0.592	2.822	0.018*			
Fatigue index (watt/ sec)	Model-1	Constant	-4.682	13.152		-0.356	0.729			
		Lin-TD-CV	0.392	0.991	0.100	0.396	0.701	0.602	0.362	2.121
		Lin-TD-ADC	38.975	16.783	0.588	2.322	0.043*			
	Model-2	Constant	-6.274	13.978		-0.449	0.663			
		Lin-V-CV	0.574	1.061	0.146	0.542	0.600	0.527	0.277	2.257
		Lin-V-ADC	35.738	19.695	0.491	1.815	0.100			
	Model-3	Constant	-4.883	13.100		-0.373	0.717			
		Non-2-CV	0.392	0.985	0.101	0.398	0.699	0.605	0.366	2.115
		Non-2-ADC	39.983	17.096	0.590	2.339	0.041*			

Note. *p<0.05

aerobic exercise performance [37]. It was reported that CV was significantly correlated with both maximal lactate steady state and onset of blood lactate [38]. Also, performance at 3000 m running was closely related to CV parameter [39]. These findings support that CV is an aerobic performance indicator. In our study, it was determined that CV parameter of three models correlated with maximum velocity at 800 m test ($p<0.05$) (table 3). However, it was seen that the significance level of correlation was not high (0.44-0.49 range of p value). In this context, it may be said that the 800 m test is an anaerobic test dominantly and the contribution on test performance of aerobic fitness is low. Simões et al. [40] found a significant correlation between CV and 500 m,

3 and 10 km running velocity and this result showed parallelism to correlation between CV and maximum velocity at 800 m test in our study. Particularly, the findings of our study were similar to correlation between CV and 500 m running velocity in mentioned study. This relationship in mentioned study is remarkable although the anaerobic contribution to 500 m performance is higher than 800 m test. Similarly, Bosquet et al. [41] reported that the 40-62 % of variance in velocity at 800 m running was explained by CV estimates of five mathematical models. The CV and ADC estimates of three models used in our study predicted significantly maximum velocity at 800 m test and both parameters explained 73-76.8 % of total variance in mentioned variable (table 6). It was seen that

Table 6. The Regression Analysis of Effect on 800 m Test Parameters of CV and ADC as Predictor Variables

Dependent Variable	Model	Predictor Variables	B	Standart Error	β	t	p	R	R ²	Standard Error of Estimate
t (sec)	Model-1	Constant	277.148	31.199		8.883	0.000*	0.871	0.759	5.032
		Lin-TD-CV	-6.160	2.351	-0.408	-2.621	0.026*			
		Lin-TD-ADC	-190.976	39.813	-0.746	-4.797	0.001*			
	Model-2	Constant	278.619	30.667		9.085	0.000*			
		Lin-V-CV	-6.000	2.327	-0.396	-2.579	0.027*			
		Lin-V-ADC	-207.828	43.209	-0.739	-4.810	0.001*			
	Model-3	Constant	276.729	32.118		8.616	0.000*			
		Non-2-CV	-6.101	2.414	-0.405	-2.527	0.030*			
		Non-2-ADC	-192.589	41.915	-0.737	-4.595	0.001*			
V _(average) (km/h)	Model-1	Constant	16.620	8.354		1.990	0.075	0.519	0.269	1.347
		Lin-TD-CV	-0.218	0.629	-0.094	-0.347	0.736			
		Lin-TD-ADC	20.290	10.660	0.516	1.903	0.086			
	Model-2	Constant	17.214	8.363		2.058	0.067			
		Lin-V-CV	-0.293	0.635	-0.126	-0.462	0.654			
		Lin-V-ADC	22.165	11.783	0.513	1.881	0.089			
	Model-3	Constant	16.997	8.426		2.017	0.071			
		Non-2-CV	-0.242	0.633	-0.105	-0.383	0.710			
		Non-2-ADC	20.093	10.996	0.500	1.827	0.098			
V _(max) (km/h)	Model-1	Constant	-9.908	8.228		-1.204	0.256	0.854	0.730	1.327
		Lin-TD-CV	1.947	0.620	0.517	3.141	0.011*			
		Lin-TD-ADC	41.474	10.500	0.650	3.950	0.003*			
	Model-2	Constant	-10.023	7.615		-1.316	0.217			
		Lin-V-CV	1.861	0.578	0.493	3.221	0.009*			
		Lin-V-ADC	47.182	10.729	0.674	4.398	0.001*			
	Model-3	Constant	-10.215	8.060		-1.267	0.234			
		Non-2-CV	1.950	0.606	0.520	3.219	0.009*			
		Non-2-ADC	42.619	10.519	0.654	4.052	0.002*			

Note. *p<0.05

the finding of our study was similar to results of Bosquet et al. [41].

It was found that the time and distance values of test performed with 120 % of maximal oxygen uptake velocity were correlated with curvature constant (W' parameter corresponded to ADC) of Lin-TD and Lin-V models in professional young soccer players [42]. The ADC parameter was a significant predictor of the most parameters of RAST (table 5) and 800 m tests (table 6) in our study and this finding was in agreement with results of mentioned study. These findings show that the effect of ADC is too distinct in anaerobic exercises. Beck et al. [43] found high and significant correlation ($r = 0.68-0.83$ range, $p < 0.05$) between RAST power and maximum velocity parameters and times of short distance anaerobic running (50, m running) [43]. Also, the related study reported a significant correlation between mean power at RAST and time of 300 m running. However, it was determined that the correlation between ADC (constant curvature (W') in related study) and times of 50, 100 and 300 m runnings was not significant in mentioned study. It was found a significant relationship between 800 m performance and ADC in our study (table 3). The discrepancy of findings may be arisen from difference of

running distances (800 m v 50, 100 and 300 m) in these studies. It may be indicated that 800 m performance may be highly affected by ADC.

Chatzakis et al. [44] reported that there was a significant correlation between RAST minimum and mean power parameters and 300 and 1000 m running time in children and young adolescents. In mentioned study, it was reported that maximum power parameters of RAST were only correlated with 300 m running time. It was found that RAST parameters were significant predictors of time and maximum velocity at 800 m test in our study (table 7). The 800 m running test is dominantly anaerobic test. The parameters of RAST involving repeated explosive sprints are indicators of anaerobic exercises such as 800 and 1000 m running. However, maximum power parameter of RAST is the highest power in exercise. Therefore, it may be said that maximum power parameter of RAST may be more dominant in exercises requiring high contribution of anaerobic energy system such as 300 m running. Zagatto et al. [45] researched relationship RAST parameters and results of Hoff test (a soccer-specific test developed by Hoff et al. [46] for anaerobic fitness level in soccer players) in professional soccer players and found no significant correlation between test results. It was

Table 7. The Regression Analysis of Effect on 800 m Test Parameters of RAST Parameters as Predictor Variables

Dependent Variable	Model	Predictor Variables	B	Standard Error	β	t	p	R ²	Standard Error of Estimate
t (sec)	Model-1	Constant	10.394	32.047		0.324	0.752	0.650	5.781
		t(average)	27.613	6.112	0.806	4.518	0.001*		
	Model-2	Constant	10.753	31.875		0.337	0.742	0.651	5.770
		t(total)	4.593	1.014	0.807	4.531	0.001*		
	Model-3	Constant	302.458	33.557		9.013	0.000*	0.638	5.881
		V _(average)	-6.093	1.385	-0.799	-4.400	0.001*		
	Model-4	Constant	301.431	31.417		9.594	0.000*	0.664	5.659
		V(max)	-5.615	1.203	-0.815	-4.667	0.001*		
Model-5	Constant	198.001	13.460		14.711	0.000*	0.487	7.000	
	Min. power _(relative)	-6.108	1.892	-0.698	-3.229	0.008*			
Model-6	Constant	204.570	11.171		18.312	0.000*	0.646	5.809	
	Max. power _(relative)	-4.530	1.010	-0.804	-4.484	0.001*			
Model-7	Constant	205.360	11.902		17.254	0.000*	0.624	5.990	
	Mean power _(relative)	-5.709	1.336	-0.790	-4.273	0.001*			
Model-8	Constant	178.091	8.165		21.811	0.000*	0.437	7.332	
	Fatigue index	-2.549	0.873	-0.661	-2.920	0.014*			
V _(average) (km/h)	Model-1	Constant	27.722	7.828		3.542	0.005*	0.116	1.412
		t(average)	-1.798	1.493	-0.341	-1.204	0.254		
	Model-2	Constant	27.710	7.798		3.553	0.005*	0.117	1.411
		t(total)	-0.299	0.248	-0.342	-1.207	0.253		
	Model-3	Constant	8.790	8.076		1.088	0.300	0.112	1.415
		V _(average)	0.393	0.333	0.335	1.180	0.263		
	Model-4	Constant	6.220	7.499		0.829	0.425	0.191	1.350
		V(max)	0.464	0.287	0.438	1.614	0.135		
Model-5	Constant	16.439	2.832		5.805	0.000*	0.039	1.472	
	Min. power _(relative)	0.265	0.398	0.197	0.667	0.519			
Model-6	Constant	14.195	2.603		5.453	0.000*	0.188	1.353	
	Max. power _(relative)	0.376	0.235	0.434	1.597	0.139			
Model-7	Constant	15.074	2.818		5.349	0.000*	0.109	1.418	
	Mean power _(relative)	0.367	0.316	0.330	1.159	0.271			
Model-8	Constant	16.049	1.518		10.573	0.000*	0.177	1.363	
	Fatigue index	0.249	0.162	0.420	1.537	0.153			
V _(max) (km/h)	Model-1	Constant	57.869	8.979		6.445	0.000*	0.557	1.619
		t(average)	-6.372	1.712	-0.746	-3.721	0.003*		
	Model-2	Constant	57.696	8.967		6.434	0.000*	0.555	1.623
		t(total)	-1.057	0.285	-0.745	-3.707	0.003*		
	Model-3	Constant	-8.873	9.564		-0.928	0.373	0.526	1.676
		V _(average)	1.379	0.395	0.725	3.494	0.005*		
	Model-4	Constant	-6.765	9.672		-0.699	0.499	0.488	1.742
		V(max)	1.199	0.370	0.698	3.237	0.008*		
Model-5	Constant	12.801	3.033		4.220	0.001*	0.580	1.577	
	Min. power _(relative)	1.662	0.426	0.762	3.898	0.002*			
Model-6	Constant	14.077	3.439		4.093	0.002*	0.460	1.788	
	Max. power _(relative)	0.952	0.311	0.678	3.063	0.011*			
Model-7	Constant	13.304	3.431		3.877	0.003*	0.497	1.727	
	Mean power _(relative)	1.269	0.385	0.705	3.295	0.007*			
Model-8	Constant	21.130	2.500		8.453	0.000*	0.150	2.244	
	Fatigue index	0.372	0.267	0.387	1.392	0.191			

Note. *p<0.05

indicated that the Hoff test was used for measurement of aerobic fitness level with soccer specific exercises (dribbling and activities with ball) [46]. The RAST power parameters were not significantly correlated with CV in our study (table 2) and this finding sustained the results of Zagatto et al. [45].

It was indicated that 20 m sprint time was a powerful predictor of total time and sprint decrement score at RAST test in national level soccer players [47]. Similarly, the ADC parameter was a significant predictor of RAST parameters in our study (table 5). The sprint time decrement index (score developed by Glaister et al. [48]) of RAST had significant correlation with maximum oxygen uptake (VO_{2max}) in low and high level VO_{2max} groups (positive correlation for low level VO_{2max} group, negative correlation for high level VO_{2max} group) but no significant correlation was found for medium level VO_{2max} group [49]. There was no correlation between CV and fatigue index of RAST in our study (table 2) and this finding drew parallelism with the correlation result of medium level VO_{2max} group in mentioned study. The decrement index used in study of Alizadeh et al. [49] was different from fatigue index in our study and this difference might cause discrepancy in results of two studies. Keir et al. [50] indicated that contribution of aerobic metabolism in RAST was higher than Wingate test although there was no significant difference between VO_{2max} values of two tests. There was no comparison between tests in our study and it was not seen a significant correlation between CV and RAST parameters (table 2). The mentioned study has focused on comparison of RAST and Wingate tests and interpreted aerobic metabolism effects on tests by VO_{2max} graphs. Our study was based on prediction of RAST parameters by CV and ADC and it was seen that the CV predicted significantly time parameters ($t_{(average)}$ and $t_{(total)}$) of RAST (table 5). The only CV effect on time parameters of RAST has sustained findings of Keir et al. [50] emphasizing aerobic contribution in RAST.

In study performed on professional soccer players, it was found that the correlation between RAST parameters and soccer match performance (total distance, maximum speed, high intensity and sprint count during soccer match) was not significant statistically [51]. Although the parameters determined in mentioned study were anaerobic activities except for total distance, the relationship between RAST and match parameters was not found by Redkva et al. [51]. Loures et al. [52] reported

that the anaerobic work capacity (equivalent of ADC) of soccer players under seventeen age did not correlate with power and fatigue index parameters of RAST but velocity parameters (mean and maximum velocity) had significant correlation with ADC. Similarly, it was determined a non-significant correlation between RAST and anaerobic running capacity (equivalent of ADC) in male futsal players [53]. Unlike finding of mentioned study, there was a significant correlation between all the RAST parameters and ADC (as an anaerobic parameter) in our study (table 2).

Conclusion

The CV and ADC parameters are yielded by linear and non-linear mathematical models. The CV is defined as aerobic fitness indices although ADC is an indicator of distance covered with anaerobic energy sources. The repeated sprint and sprint endurance ability is critical for performance in soccer involving repeated sprints. Therefore, RAST and 800 m performance that are indirect indicators of anaerobic performance is tried to predict by CV and ADC parameters in this study. It was found that ADC was a strong indicator of RAST performance. Also, it was seen that 800 m performance might be predicted by ADC and RAST parameters. CV parameter was not a significant predictor of RAST and 800 m performance except for time parameters of tests. It may be concluded that ADC may be used as an indicator of repeated sprint and sprint endurance performance while CV is a determinant of aerobic endurance performance. The CV and ADC parameters may be easily determined by simple methods without expensive measurement equipment and the performance of soccer players may be tracked by these parameters.

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