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CONTENTS

Original research papers

Review papers

Short communication

p-ISSN: 1691-7669/e-ISSN: 1691-9912/ISO 3297

ORIGINAL RESEARCH PAPER

PEDALLING TECHNIQUE AND POSTURAL STABILITY DURING INCREMENTAL CYCLING EXERCISE – RELATIONSHIP WITH CYCLIST FMS™ SCORE

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Abstract

Purpose of the present study was to examine the changes in the pedalling kinetics and in the ground reaction forces as a measure of the cycling stability during an incremental cycling exercise. Furthermore, we compared the effectiveness of the pedalling technique and postural stability between the high and low Functional Movement Screen score (FMS™) cyclists and analysed the relationships between the cycling specific postural stability, pedalling kinetics and cyclists FMS™ test scores. 31 competitive cyclists (18.5±2.1y; 1.81±0.06m; 73.7±7.5kg) were categorized based on the (FMS™) test results in a low (LS, n=19; FMS≤14) and a high (HS, n=12; FMS>14) score group. The pedalling effectiveness and absolute symmetry indexes, as well the ground reaction force (GRF) were measured during incremental cycling exercise. Cycling specific postural stability was expressed as the body mass corrected standard deviation of 3 linear and 3 angular GRF components during a 30sec cycling at four power levels. We found that during incremental cycling exercise the pedalling effectiveness, smoothness and cyclist's swaying in all three planes increased according to the combined effect of the workload and fatigue. Cyclists with high FMS™ score showed a lower bilateral pedalling asymmetry and a greater cycling specific postural stability, but showed no differences in the pedalling effectiveness and smoothness compared with the LS cyclists. Cyclist's FMS™ score were moderately related with the stability components acting along the horizontal plane. The pedalling effectiveness, smoothness and bilateral asymmetry were inversely related to the components acting perpendicularly to the horizontal plane.

Key words: *Core stability, Pedalling effectiveness, Bilateral Asymmetry, Ground Reaction Force*

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Introduction

Road cycling is a time and energy consuming sport where the training and competitions last up to 7 hours (Jeukendrup, Craig & Hawley, 2000), vary largely in the intensity levels (Ebert, Martin, Stephens & Withers, 2006) and the effective use of strength and energy are important factors for the successful performance (Lucía, Hoyos, & Chicharro, 2001) and injury preventation (Holmes, Pruitt & Whalen, 1994). The metabolic cost (Broker & Gregor, 1994; Ettema & Lorås, 2009), muscle activity (Duc, Bertucci, Pernin, & Grappe, 2008) and biomechanical effectiveness (Gonzales & Hull, 1989; Coyle, et al., 1991) are indicators that quantity the economy of cycling. No direct relationships between those parameters have been found (Castronovo, Conforto, Schmid, Bibbo, & D'Alessio, 2013), but they are all sensitive to bicycle set up according to cyclists, and to pedalling cadence, workload, road incline, cyclist experience, riding position and fatigue (Fonda & Sarabon 2010). The biomechanical rationality in cycling is mainly measured as a torque delivery effectiveness from the legs to the pedals using specially designed pedals (Gonzales & Hull, 1989; Coyle, et al., 1991) or commercially available equipment (Bini & Hume 2014). But these methods account mainly the work of the lower limbs and less of the upper body motion. It is known that with the increase in workload not only the amount of the force delivery, direction and efficiency on the pedals are changing, but also the application of the force to the saddle and handlebars (Stone & Hull, 1995). In other words, when the reaction forces on the pedals increase, then the body weight is less supported by the saddle. Furthermore, accelerations of the trunk center of mass, hips and shoulders will increase (Costes, Turpin, Villeger, Moretto & Watier, 2015). In line with this it has been found that stabilisation of the upper body (McDaniel, Subudhi, & Martin, 2005) and balancing of the bicycle (Miller, Heath, Bressel & Smith, 2013) bear additional metabolic cost.

Stability of the cycling is also associated with the overuse injuries. Neck and back injuries are described as the most common overuse injuries associated with the long distance road cycling (Weiss, 1985; Wilber, Holland, Madison, & Loy, 1995; Dannenberg, Needle, Mullady & Kolodner, 1996). Increased lumbar flexion and rotation with an associated loss of stabilization of the lumbar spine have been show to be related to the lower back pain (Burnett, Cornelius, Dankaerts, et al., 2004). It has been also shown that after strenuous cycling exercises during a test of closed-eyed standing there is a significant increase in the instability of the antero-posterior, but not in the medio-lateral direction (Wiest, Diefenthaeler, Mota

& Carpes, 2011), that indicates to the fatigue in the postural stabilisation muscles after an intensive cycling.

Overuse problems in cycling can be attributed to a high number of pedalling repetitions produced by more or less asymmetric human body that is fixed as closed kinetic chain on the symmetrically designed bicycle (Holmes, Pruitt & Whalen, 1994). Existence of the asymmetry in the cycling kinematics (Edeline, et al., 2004), kinetics (Daly & Cavanagh 1976; Sanderson, 1990; Smak, Neptune & Hull, 1999; Carpes, et al., 2008) and muscle activation (Carpes, et al., 2011; Rannama & Port 2015) is well known. It seems that an increased effort improves the symmetry of pedalling kinetics and is also influenced by the pedalling rate (Carpes, Mota & Faria, 2010). At the same time the relationships between the pedalling symmetry and the cycling performance or the injury risk are not frequently discussed. The asymmetry in the strength of the bilateral knee extensors and the difference in the trunk motion kinematical between the left and right side during the pushing phases have been found to be negatively related with a short term sprint cycling performance (Rannama, Port, Bazanov, & Pedak, 2015), but there is also an opposite evidence that cyclists with a higher effectiveness in the bilaterally asymmetrical force delivery had better results in a 4 km time trial (Bini & Hume 2015). It has been proposed that the inclusion of the core stability training could have a beneficial effect in the terms of overuse injuries, and may also help to reduce the asymmetry of the movements, improve bike handling and stability (Fordham, Garbutt & Lopes, 2004; Asplund & Ross 2010). But there is a lack of empirical evidence of the relationships between the state of the core muscles and the variables of cycling performance and the injury incidence rate. Abt et al (2007) found that after fatiguing muscles of the torso the pedalling kinetics remained unchanged, but there was an alteration in the movement kinematics. Authors suggested that the training of the core strength for the greater torso stability within the saddle helps to maintain the alignment of the lower extremity for the greater force transmission to the pedals (Abt, et al., 2007).

In a last decade the Functional Movement Screen (FMS™) has become popular as a measurement method for the core stability and for the fundamental movement abilities in the monitoring of the training and in the scientific research (Kraus, Schütz, Taylor & Doyscher, 2014). The FMS™ test includes 7 fundamental movement exercises that are evaluated in the terms of the quality of movement patterns, bilateral asymmetry and existence of the compensatory movements in a scale from 0 to 3 with a maximal overall score of 21 points (Cook, Burton, Hoogenboom & Voight

2014a and 2014b). This test complex is shown to have a good intra- and interrater reliability (Minick, et al., 2010; Teyhen, et al., 2012) and validity as a predictor of injury risk (Kiesel, Plisky, & Voight, 2007; Hotta, et al., 2015). Research is showing that the FMS^{TM} score equal to or lower than 14 is associated with a bigger injury risk in the professional football players (Kiesel, Plisky, & Voight, 2007) and among the competitive male runners (Hotta, et al., 2015). Validity of the FMS to predict sport performance is not as clear as demonstrated with the risk of injuries (Kraus, Schütz, Taylor, & Doyscher, 2014). Some suggest that the core stability and FMS^{TM} are not strong predictors of exercise performance (Okada, Huxel & Nesser, 2011), but there is evidence that high FMS^{TM} scored track and field athletes have better results in a longer time perspective, as less injuries disturb the training process (Chapman, Laymon & Arnold, 2014). Authors of the present study have not found empirical evidence relating the FMS^{TM} test results to the competitive road cyclist’s pedalling technique and cycling specific postural stability. We believe that current study is the first attempt to analyse the cycling specific stability by measuring the changes in the ground reaction force components during the various work intensity levels in the cycling.

Purpose of the present study was to examine the changes in pedalling kinetics and ground reaction forces as a measure of the cycling stability during incremental cycling exercise, to compare the effectiveness of the pedalling technique and postural stability between high and low FMS^{TM} score cyclists and to analyse the relationships between cycling specific postural stability, pedalling kinetics and cyclists FMS^{TM} test scores.

Material and methods

Participants

Participants of current study were 31 competitive junior (n=9) and U23 (n=22) class male road cyclists (18.5±2.1 years, 181.1±6.0cm, 73.7±7.5 kg, Vo2max – 64.6±4.6ml/min/kg). All athletes had had at least 4 years of focused endurance cycling training and competition experience and had annual cycling distance above 12000km during the last season. 30 cyclists were right and 1 left leg dominant, assessed as ball kicking preference.

Study was performed after the end of a competitive season and before the start of a new preparation period. All participants were free of injuries and were informed of the research procedures and risks before the testing. All participants were told to avoid heavy or intensive trainings at least two days before the experiment.

Procedures

All experimental procedures for one person were made at same day. After arrival the cyclists performed following steps in the named order:

answered the questionnaire about training and health history of the past season; passed basic anthropometric measurement; performed Functional Movement Screen (FMS^{TM}) tests and completed incremental cycling exercise.

The FMS^{TM} consisted of the following sub-tests (Fig. 1): deep squat, hurdle step, in-line lunge, shoulder mobility test, active straight leg raise, trunk stability push-up and a rotary stability test, that assessing hip flexion, external and internal rotation strength and mobility, core stability and the mobility of shoulder joints (Cook, Burton, Hoogenboom & Voight, 2014a and 2014b) . All the sub-tests were performed at least three times and were registered from the different views, while the best trials were scored. All performed tests were captured by HD video camera (frame rate 60Hz).

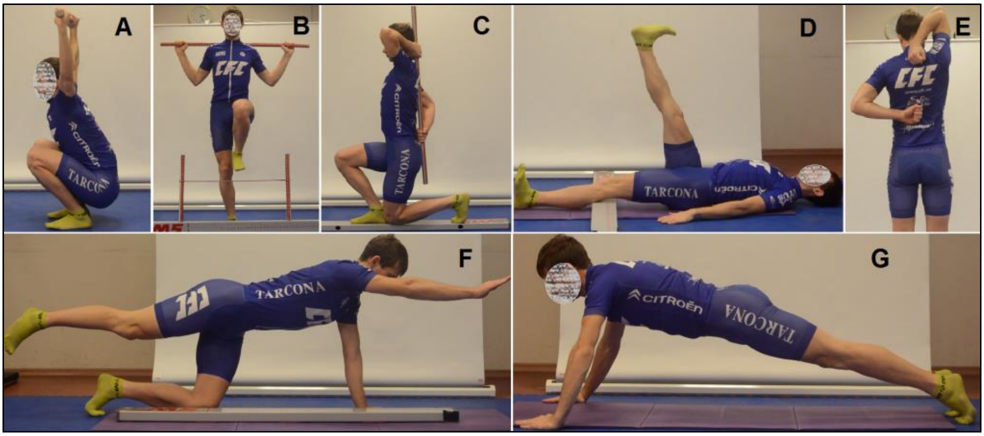


Figure 1. The *FMS^{TM}* tests (A – deep squat, B – hurdle step, C – in-line lunge, D – active straight leg raise, E – shoulder mobility test, F – trunk stability push-up, G – rotary stability test)

Experimental cycling exercise was performed using the personal racing bikes, which were mounted on the cycling ergometer Cyclus 2 (Avantronic, Cyclus 2, and Leipzig, Germany) that allows lateral inclination of the bike to matches the real life cycling. Exercise protocol consisted of a 10 minutes warm-up of steady ride at the power level of 100W and was followed by the incremental cycling exercise: target cadence 90±5 revolution/min (rpm), initial workload of 100W and the workload increased by 25W after every 2 minute until exhaustion. Exhaustion was defined as the point when the participant was no longer capable of maintaining a cadence of 70rpm. The cycling tests were conducted in sitting position hands on the drops (Fig. 2A).

During and after 3 minute of the cycling exercise the heart rate and breath by breath pulmonary O_2 (VO_2), CO_2 production ($\dot{V}CO_2$), and expired minute ventilation ($\dot{V}E$) were measured continuously with the Cosmed Quark CPET metabolic analyser (Rome, Italy). Prior to each test, system was calibrated according to the manufacturer's instructions.

To measure the *pedalling kinetics* each participants bicycle was equipped with a pair of Garmin Vector power meter pedals (Garmin Vector™). Same Vector pedals were used throughout and were calibrated before the each testing session according to manufacturer's guidelines.

Cycling specific postural stability was measured with two six component Kistler 9286B force plates (virtually combined surface of 0.6x1.4m plate) connected rigidly with Cyclus2 ergometer supports (Fig. 2) – one plate was under the bicycle front fork support (fixed with double side tape) and the other plate was under the ergometer load unit, connected with bicycle rear fork (fixed with special plate). The ergometer weight was set to zero before the cyclist sat on the bicycle, therefore only riders mass was counted. During the incremental test 6 GRF components were captured with frequency of 200Hz: 3 linear components along medio-lateral (Fx), anterior-posterior (Fy) and vertical axis (Fz) relative to bicycle direction and 3 rotational moments (Mx, My, Mz) around those axis (Fig. 2A).

All data from Cyclus2 ergometer, Cosmed Quark CPET metabolic cart, Garmin Vector pedals and Kistler Force plates were synchronized in time and captured continuously. Data from the test was analysed after the test.

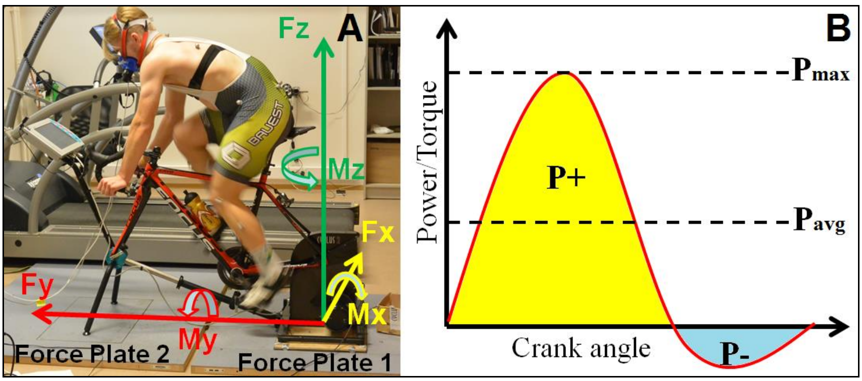


Figure 2. The placement of force plates and GRF components (Figure A); computational parameters for Torque Effectiveness (TE) and Pedalling Smoothness (PS) (Figure B)

Measures

Captured video of FMS™ tests were analysed with the video analysis software Kinovea 0.8.24 by an experienced (22 years of practice) physical therapist with 6 years of experience with the FMS. The movement quality of all 7 FMS™ were evaluated in four point ranking system: „3“ – the correct performance of the movement pattern, „2“ – the subject needs compensatory movements to solve the sub-test, „1“ – the individual is not able to perform the movement pattern at all, „0“ – subjects feel pain while performing a exercise. Five of the seven FMS™ items (hurdle step, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability test) are performed independently on the right and left sides of the body and the lowest score of the two sides were accounted. All of the seven sub-test scores were summed to a total FMS™ score, resulting in a maximum of possible 21 points. (Cook, Burton, Hoogenboom & Voight, 2014a and 2014b)

According to a previous study cyclists were divided into low FMS score (LS – 4 or less point) and high FMS score (HS – over the 14 points) group (Kiesel, Plisky & Voight, 2007; Hotta, et al., 2015).

The maximal aerobic power (VO_2max) and ventilatory threshold levels assessment were performed using Cosmed PFT Ergo software independently by two experienced researchers. The first (aerobic level – AeL) and second ventilatory thresholds level (Anaerobic level – AnL) were estimated by methods described and validated by Weston and Gabbett (2001). The indicators for AeL were: the first nonlinear increases in the VE curve; the first increase VE/VO_2 curve while the VE/VCO_2 slope remains constant; the inflexion point between VO_2 and VCO_2. The AnL was determined by the second nonlinear increase in VE and the second nonlinear increase in VE/VO_2 slope with simultaneous increase in VE/VCO_2. The maximal aerobic oxygen uptake (VO_2max) was determined as the highest 30sec average during the exercise. For the future analyses the AeL, AnL and VO_2max power levels were determined as increments where the level moment was achieved. When the certain intensity level was achieved during first 30sec of the incremental step the previous increment was chosen.

The kinetics of the pedalling were described by the pedalling power (POW), pedalling Torque Effectiveness (TE=(P+)/[(P+)+|P-|]*100(%)) and pedalling smoothness (PS=Pavg/Pmax*100(%)) collected from Garmin Vector pedals with 1sec interval, independently for the left and right sides throughout the experimental exercise(Fig. 2B). Also the absolute symmetry index (ASI (%)=100*|DO-ND|/0.5*(DO+ND)) was calculated (Robinson, Herzog & Nigg, 1987) for POW, TE and PS. Average values of the period of 30 seconds during the middle of the second minute of a 150W workload, as well as for AeL, AnL and for the VO_2max levels were used for the analysis. The TE and PS values were expressed as a mean of dominant and nondominant leg.

The drift of force plates were corrected by reference values and the force and moment values from force plates were filtered with 20Hz zero lag 4^{th} order Butterworth low pass filter to remove high frequency noise. The standard deviation (SD) of each GRF component over the 30sec period in 150W, AeL, AnL VO_2max levels were computed to measure the direction specific linear and angular force dispersion from average (or zero) value according to all 3 plane of space (Duarte & Freitas 2010). The SD values were normalised with cyclists body weight (Fx/BW, Fy/BW, Fz/BW, Mx/BW, My/BW, Mz/BW) in percent's (%).

Analysis

Data analyses were performed by using the IBM SPSS Statistics version 21.0 for Windows. Descriptive statistics were computed for all variables and for every test phase and expressed as a mean±SD. All the data were tested for their normal distribution (Kolmogorov-Smirnov test). The significance of differences in anthropometric variables between HS and LS group were controlled by student t test for independent data. A multivariate ANOVA was applied to assess differences between intensity levels and between LS and HS groups in pedalling kinetics, GRF components and VO_2 values. Pearson (for normally distributed parameters) and Spearman (for not normally distributed and FMS™ test and sub tests data) tests were used for correlation analysis between FMS test values, pedaling kinetics, ASI(%) and body mass corrected GRF components were measured at the AeL and AnL. Significance level was set at $p<0.05$.

Results

FMS™ test results

The descriptive statistics of FMS™ tests and it sub-tests score are presented in table 1. The lower scores for cyclists associated with Rotary Stability test, where only one person was able to perform exercise correctly and 13 persons performed the simplified version of the exercise with compensatory movements. The highest average score had Deep Squad test, because there was no cyclists who scored "1" or "0", but most athletes (n=22) performed this exercise also with compensatory movements, as well as in the other 6 tests. Most cyclists (n=19) had total FMS™ test score equal or lower than 14 points (LS group), 12 persons had score over to this critical line (HS group).

Table 1

The descriptive statistics of FMS^{TM} test and it sub-tests score values

n=31	FMS score	Deep Squat	Hurdle Step	In-line Lunge	Active SLR	Shoulder Mobility	Rotary Stability	Pushup
Minimum	12 (n=6)	2 (n=22)	2 (n=28)	1 (n=3)	1 (n=3)	1 (n=5)	1 (n=13)	1 (n=1)
Maximum	20 (n=1)	3 (n=9)	3 (n=3)	3 (n=6)	3 (n=7)	3 (n=7)	3 (n=1)	3 (n=4)
Mode	13 (n=7)	2	2	2 (n=22)	2 (n=21)	2 (n=19)	2 (n=17)	2 (n=26)
Mean	14.13	2.29	2.10	2.10	2.13	2.06	1.61	1.97
SD	1.80	0.46	0.30	0.54	0.56	0.63	0.56	0.55

The comparison of incremental cycling exercise results in high and low FMS scored cyclist groups

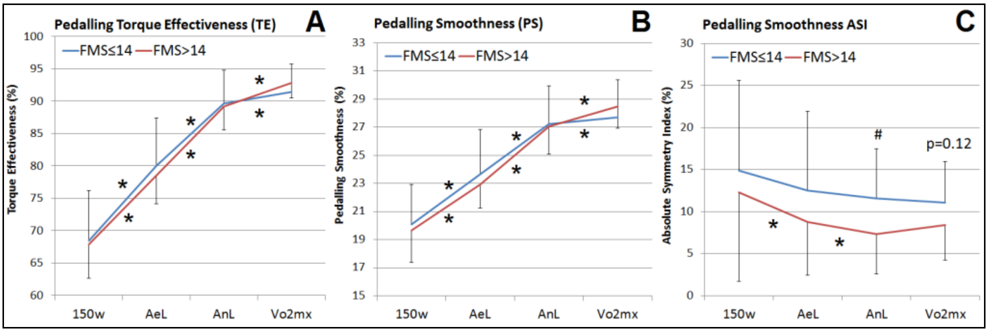
The LS and HS groups did not differed between anthropometric parameters (age 18.6 2.0± and 18.3±2.3y, height 181.7±6.5 and 180.1±5.3cm, body mass 73.5±8.6 and 74.3±5.5kg respectively). Also there was no significant differences in cadence, power and VO_2 values in any intensity level (Table 2).

Table 2

The descriptive statistics of intensity level cadence, power and body mass corrected VO_2 values in low and high FMS scored cyclist groups

	Group	n	AeL			AnL			VO_2max		
			Mean	SD	p	Mean	SD	p	Mean	SD	p
Cad (RPM)	FMS≤14	19	90.2	3.9	.81	91.6	4.8	.49	91.2	6.0	.18
	FMS>14	12	90.5	3.0		90.5	2.9		89.4	2.7	
Power (W)	FMS≤14	19	211.6	29.1	.95	303.4	37.9	.76	340.0	37.7	.97
	FMS>14	12	211.0	22.7		299.6	25.2		339.5	26.7	
Power/BW (W/kg)	FMS≤14	19	2.9	0.3	.71	4.1	0.3	.39	4.7	0.4	.61
	FMS>14	12	2.8	0.3		4.0	0.3		4.6	0.4	
VO_2 (ml/kg/min)	FMS≤14	19	45.4	4.0	.79	59.1	4.4	.24	65.2	4.5	.33
	FMS>14	12	45.0	4.3		57.2	4.2		63.6	4.7	

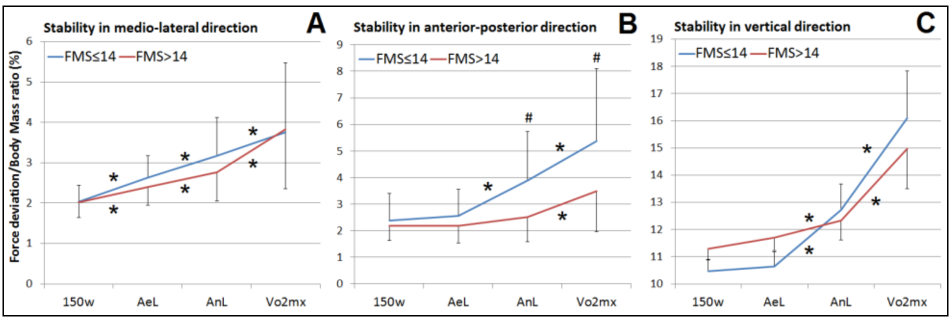
In figure 3 are presented dynamics of pedalling TE, PS and PS asymmetry in LS and HS group. During the incremental exercise in both groups the TE and PS values significantly increased, but there was no significance between FMS^{TM} scores groups' differences in pedalling efficiency values (Fig. 3A and B). At the same time the bilateral asymmetry in PS was notably higher in LS group in AnL and same tendency (p=0.12) existed in VO_2max level (Fig. 3C). No differences between groups were found in POW and TE ASI in any workload.



(*- significant difference between intensity levels; #- significant difference between groups p<0.05)

Figure 3. Dynamics of average (+/-SD) Torque Effectiveness (TE) (Fig. 3A) and Pedalling Smoothness (PS) (Fig. 3B) and bilateral PS symmetry values (Fig. 3C) during incremental cycling exercise in low (FMS≤14; n=19) and high (FMS>14; n=12) FMS™ score cyclist's group

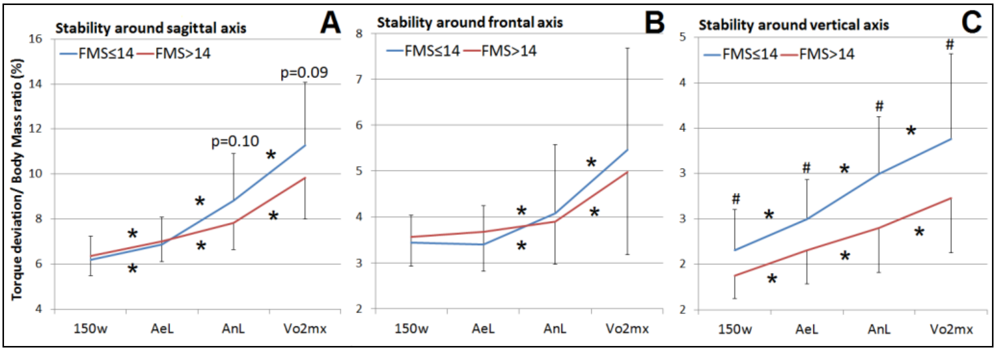
The comparison of linear GRF components deviations (Fig. 4) referred to a significantly ($p<0.05$) higher anterior-posterior direction force (Fy/BW) deviations in LS group at higher intensity levels (Fig. 4A) no differences were found in the force deviations in the other two direction. During the incremental test the medio-lateral (Fx/BW) deviation increased with every intensity level, but in anterior-posterior (Fy/BW) and vertical direction (Fz/BW) the force deviation increased significantly after AeL (Figure 4 B and C).



(*- significant difference between intensity levels; #- significant difference between groups p<0.05)

Figure 4. Dynamics of average (+/-SD) body mass normalised GRF linear components deviation along medio-lateral/Fx (Fig. 4A), anterior-posterior/Fy (Fig. 4B) and vertical/Fz direction (Fig. 4C) during incremental cycling exercise in low and high FMS™ score cyclist's group

The rotational GRF components increased significantly along the workload increase, except My/BW, where there was no differences between the values at two lower intensity level in both FMS™ score group. The cyclists from LS group had a significantly higher rotational torque deviation around vertical axis in all of the intensity levels (Fig. 5C). Same tendency existed in the higher intensity levels deviation of the momentum around the sagittal (Mx/BW) axis (Fig. 5A). No differences between the groups were found in the deviations around the frontal axis moment (Fig. 5B).



(*- significant difference between intensity levels; #- significant difference between groups p<0.05)

Figure 5. Dynamics of average (+/-SD) body mass normalised GRF rotational components deviation around sagittal/Mx (Figure 4A), frontal/My (Figure 4B) and vertical/Fz (Figure 4C) axis during incremental cycling exercise in low and high FMS™ score cyclist's group

Relationship between FMS™ test score, pedalling kinetics and GRF components deviation

The correlation analysis results are given in Tables 3, 4 and 5. There were no significant correlations between the FMS™ test composite score and the pedalling kinetic variables or the bilateral pedalling asymmetry values (Table 3).

Table 3

The Correlations between FMS™ score and pedalling kinetics variables

n=31	AeL					AnL				
	FMS score	TE	PS	Pow ASI	TE ASI	FMS score	TE	PS	Pow ASI	TE ASI
TE	-.30	1				-.27	1			
PS	-.23	*.90***	1			-.14	*.83***	1		
Pow ASI	.19	-.11	.02	1		.07	-.24	-.20	1	
TE ASI	.15	*-.54***	*-.39**	*.62***	1	.02	*-.55***	*-.44**	*.63***	1
PS ASI	-.04	*-.50***	*-.39**	.26	*.75***	-.16	*-.42**	-.27	.17	*.49***

* Correlation is significant at the p<0.05 level (2-tailed); ** Correlation is significant at the p<0.01 level (2-tailed)

Significant moderately strong negative correlations were found between the composite FMS score and body mass corrected GRF deviation components – higher FMS^{TM} score was related with lower deviation values of Mz/BW in AeL and AnL and Fy/BW in AnL. The higher value in Deep Squad sub-test associated with smaller deviations of GRF component associated with the sagittal direction lineary (Fx/BW) and around the vertical axis rotational (Mz/BW) motions. Also in-line Lung test correlated negatively with the Fy/BW deviation in AnL and Rotary Stability test score with Mz/BW in AeL. All GRF components, which were correlated with FMS test results, were related with the force actions in the horizontal plane and no correlation were found with GRF components acting perpendicular to horizontal plane (Table 4).

Table 4

The Correlations between FMS tests scores and body weight corrected GRF components deviation values

	AeL						AnL					
n=31	Fx/ BW	Fy/ BW	Fz/ BW	Mx/ BW	My/ BW	Mz/ BW	Fx/ BW	Fy/ BW	Fz/ BW	Mx/ BW	My/ BW	Mz/ BW
FMS score	-.22	-.26	.27	.03	.12		-.09	*-.39**	.03	-.21	.01	*-.46**
Deep Squat	*-.40**	-.26	.07	-.01	.00	*-.45**	*-.49***	-.30	.02	-.14	-.06	*-.41**
Hurdle Step	.18	-.07	.32	.26	.18	-.02	.26	-.27	.13	.15	.10	.12
In-line Lunge	-.08	-.30	.14	-.09	.01	-.25	.03	*-.36**	.01	-.15	-.04	-.29
Active SLR	.02	.05	.09	-.07	.10	.07	.28	.10	-.17	-.19	-.08	.21
Shoulder Mobility	-.20	-.30	-.09	-.32	-.12	-.18	-.02	-.09	-.19	-.31	-.13	-.25
Rotary Stability	-.15	-.13	.32	.21	.23	*-.40**	-.13	-.28	.23	.00	.18	-.32
Pushup	.13	-.09	-.02	.04	-.15	-.01	-.07	-.17	.01	.05	-.09	-.27

* Correlation is significant at the p<0.05 level (2-tailed); ** Correlation is significant at the p<0.01 level (2-tailed)

The TE, PE and asymmetry was mostly related with GRF components associated with the movements perpendicular to the horizontal plane (Fz, My and Mx) and had almost no significant correlations with the GRF components acting in the horizontal plane (Fx, Fy and Mz). The higher TE and PS associated moderately with the lower rotational moment deviation around the sagittal axis during AeL and AnL cycling. Also the ASI of TE and PS associated with named GRF component deviation, but in the opposite direction.

Table 5

The Correlations between pedalling kinetics, bilateral asymmetry and body weight corrected GRF components deviation values

n=31	AeL						AnL					
	Fx/ BW	Fy/ BW	Fz/ BW	Mx/ BW	My/ BW	Mz/ BW	Fx/ BW	Fy/ BW	Fz/ BW	Mx/ BW	My/ BW	Mz/ BW
TE	.00	-.32	*-.48***	*-.61***	*-.40**	-.31	-.04	-.15	*-.43**	*-.46***	-.33	-.24
PS	-.08	-.28	-.35	*-.56***	-.26	-.34	.07	-.08	-.26	*-.37**	-.16	-.24
Pow ASI	-.03	.08	*.37**	.27	.29	-.03	.01	-.09	.11	.06	.06	.02
TE ASI	-.03	.22	*.47***	*.59***	*.44**	.32	-.01	.15	.19	.24	.17	.21
PS ASI	-.19	.26	.24	*.43**	.26	.31	.02	*.38**	.14	.29	.16	.28

* Correlation is significant at the p<0.05 level (2-tailed); ** Correlation is significant at the p<0.01 level (2-tailed)

Discussion

The aim of the present study was to evaluate the young road cyclist's core stability and ability to perform fundamental movements. The results of FMS^{TM} test showed that more than a half of (n=19) cyclists achieved the score 14 points or less and were in raising injury risk group after the competition period (Kiesel, Plisky, & Voight, 2007; Hotta, et al., 2015). At the same time the mean FMS^{TM} score for the road cyclist's in the current study was 14.1±1.8, which is similar to results of same aged competitive male runners (14.1±2.3) (Hotta, et al., 2015). The less scored sub-test's for cyclists were Rotary Stability (1.61±0.56) and Pushup (1.97±0.55), this points to the problems with trunk and hip region muscles stability (Cook, Burton, Hoogenboom & Voight, 2014a and 2014b). The poor results in Rotational stability test were related with higher horizontal plane rotational movements in cycling. Similar to our findings the poorest sub-test results for male runner's population were also in the Rotary Stability test (1.5±0.51 to 1.6±0.6) (Agresta, Slobodinsky & Tucker, 2014; Hotta et al, 2015). But different from runners (Agresta, Slobodinsky & Tucker, 2014; Hotta, et al., 2015) (scores between 1.3±0.7 to 2.0±0.47) the cyclists had relatively higher Deep Squad scores (2.29± 0.46). At the same time the Deep Squad performance with compensatory movements associated with lower cycling specific postural stability in medio-lateral direction and around vertical axis, for the runners this sub-test results were the most sensitive for injury prediction (Hotta, et al., 2015).

During the incremental cycling the postural stability decreased and this is in line with findings of Costes et al. (2015) what along with power increase the acceleration forces directed to pelvis and upper body raise. In the dynamics of horizontal plane GRF components deviation were found significant differences between LS and HS cyclists groups. The LS group had larger body swaying around vertical axis in all workloads and anterior-posterior direction on higher workloads in anterior-posterior direction, which seems to be sensitive direction for stability decrease during strenuous cycling exercise (Wiest, Diefenthaeler, Mota & Carpes, 2011). The named results are supporting the previous statements about beneficial effect of the core stability training on cycling stability (Fordham, Garbutt & Lopes, 2004; Asplund & Ross, 2010). At the same time the FMS^{TM} score did not have any significant relationships with pedalling kinetic variables like TE and PS. The previous research of Abt et al. (2007) also found that trunk muscles state does not alter the pedalling kinetics.

The smoother, less negative torque producing pedalling technique and lower bilateral asymmetry were related with smaller vertical direction linear movement and lower cyclist's body swaying around sagittal and frontal axis of bicycle. These correlations were stronger at AeL cycling and were less significant in AnL. One of the reasons may be the raised efficiency level and lowered asymmetry that was found in our study and was in line also with previous findings (Sanderson, et al., 1991; Carpes, et al., 2008).

Conclusions

Results of the present study indicate that during an incremental cycling exercise the pedalling effectiveness, smoothness and cyclist's body swaying in all three planes are increasing according to the combined effect of workload and fatigue. The cyclists with FMS^{TM} score higher than 14 showed lower bilateral pedalling asymmetry and greater cycling specific postural stability, but had no differences in the pedalling effectiveness and smoothness compared with the cyclists of a low FMS^{TM} score. Cyclists FMS^{TM} score was moderately linked with the stability components acting along the horizontal plane. The pedalling effectiveness, smoothness and bilateral asymmetry were inversely related with the components acting perpendicularly to the horizontal plane.

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ORIGINAL RESEARCH PAPER

CRANIAL ELECTRICAL STIMULATION IN FITNESS WITH WEIGHTLIFTING TOOLS

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Abstract

Sport trainings are based on two essential components: the preparatory process and the athlete's level of training as the result of the training process. The most important task of the coach is to find the most efficient way how to prepare an athlete so that he would achieve the highest capacity and would be able to implement it. Application of cranial electrical stimulation in sport is not fully explored. The aim of the study was to determine the influence of cranial electrical stimulation on the strength parameter indicators of fitness athletes who use weightlifting tools. In the study participated 10 men (representatives of fitness sport, of Latvian Academy of Sport Education, who use weightlifting tools in the training process). The age of these athletes was 21±3 years. The average weight of the athletes was 76±3.2kg and the average height was 156±15.5cm. An exercise set "lifting a weight bar to the chest" was developed. A 10 minute session of cranial electrical stimulation was applied. During the test a weightlifting bar of the company "Eleiko" was used and FiTRO Dyne Premium cable was attached on one end of the bar which was connected to a computer system and registered the data obtained during the control exercise performance. During the experiment the results obtained during two tries of control exercise performance were compared, which are the difference between the average strength parameters and the difference between the maximum strength parameters before the application of cranial electrical stimulation (hereinafter – CES), performing the first three repetitions, comparing them to the last three repetitions performed after the application of the stimulation. After cranial electrical stimulation the maximum strength parameters improved by 533.23±11.09N ($\alpha<0.05$).

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Fitness sport representatives and coaches, in order to improve the level of training of their student, must pay attention to the application of CES in the training process with weightlifting tools.

Key words: *weightlifting tools, cranial electrical stimulation, strength.*

Introduction

The specific characteristics of muscles can be evaluated in the process of interaction with external and internal objects. In sport, strength measuring equipment, sport gears, counteraction of an opponent, resistance forces of the external environment and other objects are counted as the external objects. Body parameters, muscle strength of antagonists, biomechanical peculiarities of the movement apparatus functions are counted as the internal objects. The mechanical parameters (strength, speed, strength expression time) registered during the performance of physical exercises only relatively characterize muscle properties, because they are exposed to motivation, testing conditions and duration, the contingent's ability to implement their motor potential, individual technique, body mass geometry, anatomical peculiarities of the movement apparatus. Therefore, only the expression of the muscle physical properties can be judged by the testing results.

Sport exercises according to the mechanical and physiological parameters significantly differ from a person's daily work activity. Therefore, evaluation of muscle physical properties for people who are engaged in sports is topical and provides an opportunity to receive new information about the adaption of a person's movement apparatus to physical load. The correlation "strength-height" reflects the strength development level (relevant in combined sports) and muscle topography (very topical for trauma prevention). The correlation "strength-speed" characterizes muscle power (the ability to perform fast and strong movements). Quantitative evaluations provide an opportunity to determine muscle physical property development dynamics and if there is a need to organize a necessary training process adjustment. One of the training process management options is to be based on the dynamic similarity principle. What it means: knowing the peculiarities of the competition exercise performance muscles, it is possible to determine the pace, speed, weight amount in special exercises with the dynamic similarity aim for the competition exercise. It is very important that the tools and methods, which are used in physical property preparation, would create not only a functioning environment of the movement apparatus similar to the competition conditions, but also record modelling in the future.

Continuous increase of sport results takes place by increasing the amount of training loads and intensity, by improving the training material provision, as well as by applying a complex scientific approach in the training process. Along with psychological, biological and methodological factors it all makes one look for new reserves for the increase of sport training efficiency. Thoroughly developed divisions into periods, method and tool dynamics, harmonized training regimen create levels of diversity category with the highest degree. These are socio-psychological, efficiently-energetic and kinematic-dynamic variations for the interaction of the athlete's body with the external environment during the performance of an exercise. An athlete's development and improvement, functioning of the body is a targeted training process in different environmental conditions in order to achieve a goal. Biological systems are considered to be a prerequisite for the operation of the system, but the amount of information – the cause of development rate change. Information between the body and the external environment is considered to be a process with different coherence in time and space. The management efficiency of such process depends on how much the internal, targeted body diversity surpasses the external diversity, how much the leading system's diversity exceeds the subordinated diversity system. Training influences retain the qualification criteria and lead the main movement programme to a successful solution of a movement task in different conditions of the external environment.

The training range and nature creates an information reserve for a successful action in the future, providing further opportunities for targeted development. If the influence accents do not coincide with a useful development direction and movement elements, structure, states, then the information-to-be-acquired obtains a role of a destructive factor, which will destroy the natural development algorithm, which is in harmony with the development of all the rest of the body systems.

Sport training is based on two essential components: the preparatory process and the athlete's level of training as the result of the training process. The most important task of the coach is to find the most efficient way how to prepare an athlete so that he would achieve the highest capacity and would be able to implement it. Application of cranial electrical stimulation in sport is not fully explored. There is no detailed analysis of cranial electrical stimulation's influence on the functional state of athletes, on the movement dynamic parameters. The cranial electrical stimulation therapy is considered safe and the therapy is based on an electric micro current. Athletes use cranial electrical stimulation to increase concentration abilities before competition. (Mateo, 2011; Song, 2007) The physiological operation mechanism of cranial electrical stimulation is being studied. (Braverman, 1990; Brotman, 1989; Gilula, 2005) Cranial electrical stimulation is suitable for athletes to solve the problem with stress. (Song, 2007; Hefferman, 1996) One electrical stimulation session is enough for improving a person's functional state and preserving the capacity. (Ковалев, 2004) A situation is marked in studies that the greatest effect of cranial electrical stimulation was when the subjects had high level of fatigue. (Kirsch, 2004; Overcash, 1989) By applying cranial electrical stimulation, it is possible to perform vegetative state adjustments, characterized by changes of heart rate variability indicators. More effectively cranial electrical stimulation affects athletes who have a high level of training. (Троянов, 2005) A cranial electrical stimulation session increases the subjects' functional state, reduces the blood pressure by 11%, reduces anxiety level by 15% and the short-term memory test results improve by 25%. (Ковалев, 2004) Milostnoj in his study developed the methodology of the optimal cranial electrical stimulation frequency application for wrestlers. During the maximum load the stimulation was applied with the current strength from 0 to 3.5mA for four minutes, then the pulse incidence, duration and current strength was changed. The session duration was 24 minutes. After the session, positive dynamics of beta-endorphin indicators was observed in the wrestlers' blood. Cranial electrical stimulation positively influences the renewal of hemodynamic and psycho physiological processes for wrestlers after the maximum loads. (Милостной, 2007)

The aim of the study was to determine the influence of cranial electrical stimulation on the strength parameter indicators of fitness athletes who use weightlifting tools.

Material and Methods

In the study participated 10 men (n=10), (representatives of fitness sport, of Latvian Academy of Sport Education, who use weightlifting tools in the training process). The age of these athletes was 21±3years. Body weight was measured with electronic scales SENCOR SBS60115. The average weight of the athletes was 76±3.2kg. Height was determined with the help of an anthropometer and the average height was 156±15.5cm.

An exercise set "lifting a weight bar to the chest" was developed, (Fig.1.)

Figure1. The Phases of Control Exercise

Which consisted of 12 repetitions and between the repetitions a 15 second rest was taken. (Fig.2.)

1-3	3 repetitions with a 15s rest between the repetitions
	15min rest
4-6	3 repetitions with a 15s rest between the repetitions
	15min CES session
7-9	3 repetitions with a 15s rest between the repetitions
	5min rest
10-12	3 repetitions with a 15s rest between the repetitions

Figure 2. Exercise Set with a Weightlifting Bar

These twelve repetitions were divided into four tries. Between the first and the second try the athlete rested for 15min, after performing the second try a 10min cranial electrical stimulation session was applied, while after the performance of the third try the athlete rested for 5min and performed the last – closing try (Fig.3.).

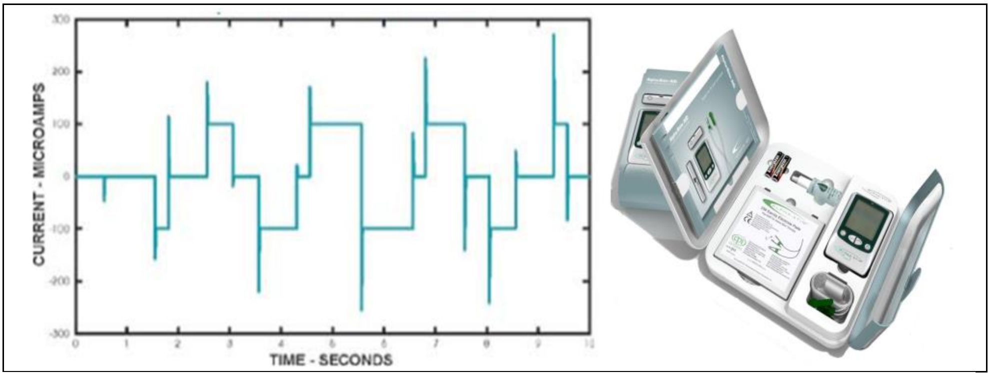

Figure 3. Alpha Stim SCS (USA) and Elecrtical waves (Kirch, 2002, 2004)

Before starting the control exercise, the athlete was instructed on what awaits him during the stimulation. One was told about the duration of the session (10min), about the anticipated changes in the body during the influence. When the athlete was introduced with everything, the stimulation session was initiated. The athlete was seated. The electrodes were moistened with a salt water fluid, put on the earlobes and the stimulation session was initiated. Initially, the current level was on level „0”, then it was gradually increased until the moment when one starts to feel the first unpleasant feelings. At this point the current was slightly reduced again until the unpleasant feelings passed, and the therapy was continued with such current. If the unpleasant feelings returned again, then the current was reduced again, but it was never allowed to be less than the mark „1”, as then the Alpha-Stim SCS is not turned on and stimulation is not performed. After the Alpha-Stim SCS stimulation the control exercise test was repeated – lifting a weightlifting bar to the chest at the utmost strength and speed.

Each performed repetition during the exercise performance was recorded by the computer software Fitronic Premium, which portrayed the data obtained – numbers, in the form of tables – curves, showing each and every smallest change in a numerical form in each performed try and repetition. FiTRO Dyne Premium (Slovakia) is a computer technology based system created for representing the athletes’ movement dynamic parameters in a graphical and numerical form (Fig.4). During the test a weightlifting bar of the company "Eleiko" was used and FiTRO Dyne Premium cable was attached on one end of the bar which was connected to a computer system and registers the data obtained during the performance of the control exercise.

The results obtained during the experiment were processed in the computer programme Excel Statistics 3.1., with the help of which the theoretical value of the Student's t-test was calculated and the increase was determined (is statistically believable or is not statistically believable) (Dravnieks, 2004).

Results

During the experiment some pedagogical functions were conducted: – control function (strength level during the performance of the control exercise was determined), – methodological function (the methodological sequence of the developed exercise set was determined), – comparative function (differences between the subjects in comparison with the presented results were determined).

During the experiment the results obtained during two tries of control exercise performance were compared, which is the difference of the average strength parameters and the difference of the maximum strength parameters before the application of cranial electrical stimulation (hereinafter – CES), performing the first three repetitions, comparing them to the last three repetitions performed after the application of the stimulation. (Fig. 4.)

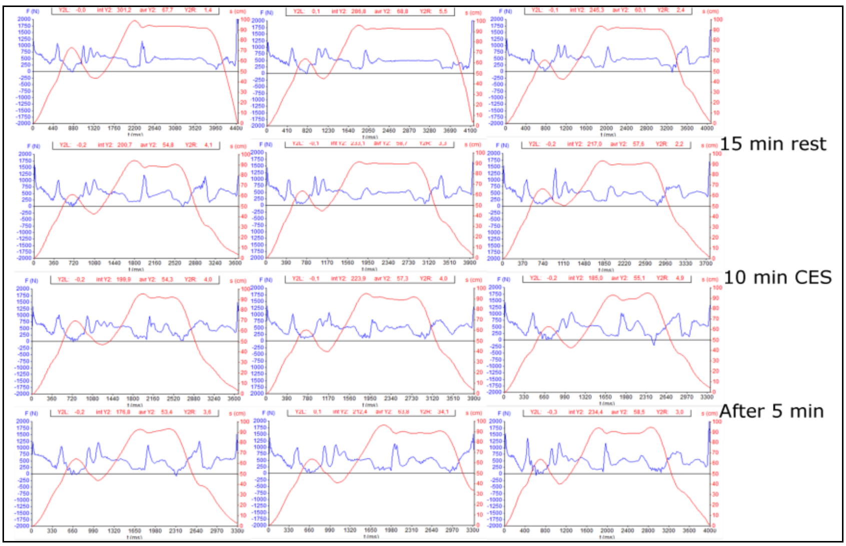

Figure 4. Graphs of Control Exercise Movement Performance

The average strength parameters during the performance of the first three repetitions before applying the CES session were in an average range of 597±25.3N.

After applying the CES session the average strength indicators during the performance of the last three repetitions (10 – 12) were 622.23±1.7N. (Fig. 5.)

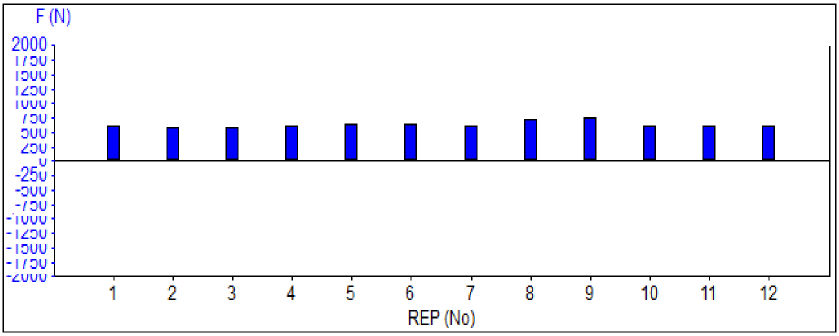

Figure 5. The Average Strength Indicators during the Performance of the Control Exercise Before and After CES (n=120)

After applying the CES session, the resulting difference improved by 24.6±2.1N. The average strength parameter difference obtained during the performance, according to the data obtained by the computer programme Excel Statistics 3.1., the theoretical value of the Student's t-test and the increase are statistically believable $\alpha<0.05$.

By contrast, the maximum strength parameters when performing the first three repetitions before applying the CES session were in an average range of 1204.3±113.5N. After applying the CES session, the maximum strength indicators during the performance of the last three repetitions (10 – 12) were 1383.13±319N (Fig.6). After applying the CES session, the resulting difference improved by 178.83±11.2N. The maximum strength parameter difference obtained during the performance, according to the data obtained by the computer programme Excel Statistics 3.1., the theoretical value of the Student's t-test and the increase are statistically believable $\alpha<0.05$.

The maximum strength parameters recorded during the experiment when performing all twelve repetitions of the control exercise, which were divided into four tries, before the application of the cranial electrical stimulation session were in an average range of 1163.93±17.7N. After applying the CES session the maximum strength indicators during the control exercise performance improved by 533.23±11.09N and amounted to 1697.16±28.8N. (Fig. 6.)

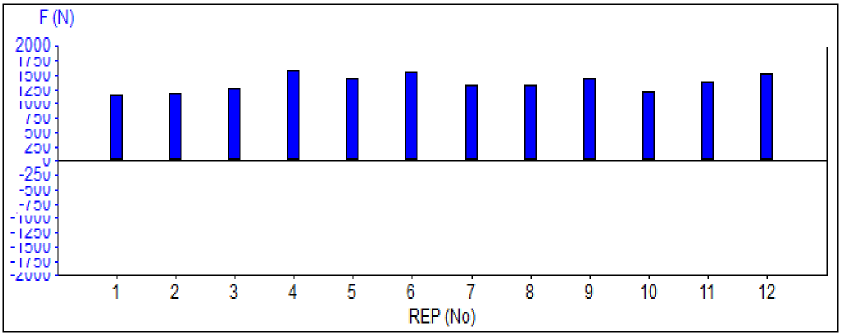

Figure. 6. The Maximum Strength Indicators during the Performance of the Control Exercise Before and After CES (n=120)

The maximum strength parameter difference obtained during the performance, according to the data obtained by the computer programme Excel Statistics 3.1., the theoretical value of the Student's t-test and the increase are statistically believable $\alpha<0.05$.

Also, the average indicator strength parameters during the control exercise performance improved after the cranial electrical stimulation session from 493.02±19.06N to 890.69±21.3N, which is by 397.67 higher than without applying the CES session. According to the data obtained by the computer programme Excel Statistics 3.1., the theoretical value of the Student's t-test and the increase are statistically believable $\alpha<0.05$.

Discussion

The results obtained confirm that cranial electrical stimulation has an immediate effect. Immediately after CES the first phase is the „delay phase", 5min after CES the second phase the „activation phase" begins. During the delay phase the strength indicators are reduced. CES application is effective for athletes who feel depressed, anxious, too worried or tired before competition. The results obtained in the study could be helpful for optimizing the athletes' pre-competition state. When preparing fitness representatives for competitions, using the effect of cranial electrical stimulation and strength indicator control, it is possible to predict the training performance efficiency. In order to optimize the fitness training performance efficiency with weightlifting tools, cranial electrical stimulation is an effective tool.

Often one subject with higher average strength indicators is also the owner of higher maximum strength. This can be explained by the overall physical preparation, which is obtained before the experiment, the muscle fibre type, the feeling of comfort in the respective day, as well as by the fact that the strength and power development specifics and the control exercise performance technique was taken into consideration.

The positive results and harmlessness of using Alpha-Stim have been proven. (Bravermans, 1990) So far a precise physiological mechanism of cranial electrical stimulation has not yet been fully understood, it is still being intensively studied. Scientists follow the hypothesis that cranial electrical stimulation indirectly affects brain tissue, in the hypothalamus portion (the highest centre of vegetative function regulation, nervous and endocrine system coordination) so accustoming brain to produce neurohormones and neurotransmitters, until the right balance of these substances is restored in the brain. Cranial electrical stimulation activates the endogenous opioid peptide system of the brain, mainly β-endorphin. (Kirsch, 2004; Brotman, 1989) Experts note that cranial electrical stimulation is a non-pharmacological treatment type for depression, anxiety and insomnia. (Hefferman, 1996) Cranial electrical stimulation normalizes the psychophysical state, the result of which is the anti-stress and anti-depression effect (Gigula, 2005), increases capacity, reduces fatigue, improves sleep quality (Kirsch, 2002), improves tissue healing processes and is an effective anaesthetic (Foster, 2001; Gibson, 1987). Cranial electrical stimulation normalizes the activity of the autonomic nervous system, vascular tone, and arterial pressure and stimulates the immune system (Троянов, 2005), influences the parasympathetic nervous system, resulting in reduced vascular tone, increased amount of oxygen in blood and normalized activity of the cardiovascular system as a whole. Cranial electrical stimulation influences the respiratory cycles, they become less frequent and the breathing depth deepens. (Баевский, 2005)

Conclusions

The results compiled and obtained during the test confirm that the application of a cranial electrical stimulation session has an immediate effect on athletes' physical capacity, which during the test reflected in the increase of the athlete's average and maximum strength indicators. After cranial electrical stimulation the maximum strength parameters improved by 533.23±11.09N ($\alpha<0.05$), while the average strength parameters improved from 493.02±19.06N to 890.69±21.3N ($\alpha<0.05$), which is by 397.67N higher than without applying the CES session. According to the data obtained during the experiment it can be concluded that cranial electrical stimulation can be applied not only in medicine, but also in sport as a tool that positively influences the athlete's functional state, which is based on the movement dynamic parameters. According to the compiled and registered data it can be judged that only one cranial electrical stimulation session is sufficient for the improvement of a person's functional state and capacity preservation.

After the performance of the control exercise by all subjects and the analysis of the data obtained, it can be concluded that the Apha Stim session had a more positive effect on athletes who have a higher level of training.

Fitness sport representatives and coaches, in order to improve the level of training of their student, must pay attention to the application of CES in the training process with weightlifting tools. During the CES therapy very weak electrical impulses are used, which indirectly stimulate and normalize brain activity and affect brain tissue in the hypothalamus portion, as well as positively affect the athlete's strength expression parameters.

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ORIGINAL RESEARCH PAPER

ASSESSMENT OF MOTOR CAPACITY IN THE COMPETITION PERIOD – FEMALE SPORTS GAMES (SOCCER AND RUGBY SEVENS)

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Abstract

In the rugby and soccer sevens, players need special motor capacities, such as aerobic and anaerobic resistance, proper force in the muscles that work during game actions, as well as speed and agility. The purpose of the papers was to assess the motor capacity in the competition period, among female athletes who practice team sports. The study comprised 26 subjects, 12 of whom activate in the female rugby team of CS Politehnica Iasi, and 14 of whom belong to the soccer team of Naviobi Iasi. Both teams are champions in their leagues. We applied the following tests: 250m run, long jump without take-off, throwing the 2kg medicine ball, 30second abdominals, and 5m back and forth run. The data obtained were interpreted in SPSS 20.0 for IBM, by applying the t test for independent samples. Results have shown a significant difference (p<0.05). Significant differences were found only for the test that measured the force of abdominal muscles for which the female rugby players scored significantly higher than the rest. In all the other tests, the mean results were similar or very close. We found that the motor experience within the game influenced the results obtained, just like general physical training; they are both important for supporting the specific effort. The tests we applied mid-competition period.

Key words: *motor capacity, rugby sevens, female soccer, competition period.*

Introduction

The value of motor capacity, of exercise capacity and mostly of performance capacity results from the higher bodily adjustment to the intense physical and mental effort required by sports training (Dragnea,

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1991). Adjustment to effort is a self-regulation response of the body, which undergoes functional and morphological modifications and which reacts by optimizing the mechanisms that ensure fitness (Dragnea, 1996).

Stating the type of effort required by a competition within a certain sporting branch or event is the most important action of a coach (alongside the supporting team of specialists) and it represents the premise for a scientific planning and scheduling of the training. In sports games, this objective is significantly harder to attain than in individual sports, considering the specificity of actions corresponding to each function within the team.

Among the classification criteria for effort, the most objective and scientifically based one is the determination of the main source of energy necessary to support these efforts (Grosu, 2008; Ursanu, 2014).

Women's soccer and rugby sevens are relatively recent sports. Women's soccer participation continues to grow worldwide, with a concomitant increase in our understanding of the physical demands of women's matches (Bradley & Vescovi, 2015; Higham, et al., 2012; Vescovi & Favero, 2014).Their working methodology has not been scientifically founded yet and it has actually been taken over from the methodology of men's teams.

Under such circumstances, it is necessary to delimit the nature of the effort required by the competition, in order to schedule sports training.

In both sports branches, effort acquires the characteristics (Javier, et al., 2014; Morgans, et al., 2014, Elloumi, et al., 2012; Chihaia & Pop, 2012):

- an important anaerobic alactacid component during singular actions;
- an important anaerobic lactacid component while analyzing motor actions within technical and tactical combinations;
- a mixed effort component when analyzing the effort on game sequences (halves);
- an aerobic component when considering the entire process of a half.

One of the main principles of training in any sporting branch or event is represented by the specificity of the effort required by the competition period. In sports games, it is significantly more difficult to determine the type of effort than in individual sports. This aspect includes even more interesting aspects in women's sports. This is the reason why we considered it necessary to assess the motor capacity of female athletes within two relatively recent women's sports games: soccer and rugby sevens. The analysis was conducted during the competition period (2014 – 2015 championship tour) of the training macro cycle.

Material and methods

Period and place of the research

The research was conducted in the period October – November 2014, in the "Emil Alexandrescu" Stadium Sports Complex in Iasi. We also mention that, in conformity with the Declaration of Helsinki, the Amsterdam Protocol and the Directive 86/609/EEC, we obtained the approval of the Ethics Committee of the Faculty of Physical Education and Sport in Iasi for research on human subjects, as well as the oral consent of coaches and of athletes who participated in the study.

Subjects and groups

The study included 26 female players, members of women's soccer teams (C.S. Navobi Iasi) and women's rugby sevens (C.S. Politehnica Iasi); their age mean is 21.92±2.35 (rugby, n=12) and 19.57±3.61 (soccer, n=14). Subjects usually have 6 – 7 hours of weekly practice, considering that most of them are high school students or university students. We add that both teams are in the higher rankings of the national championship for their sports.

Tests applied

To measure and assess motor capacity, we have applied the following tests:

- 250m run from a standing start (seconds) – it assesses the anaerobic lactacid endurance capacity. The test was conducted on the stadium, with start on command and one repetition (MacKenzie, 2005).
- standing long jump – SLJ (metres) – to assess the elastic leg strength. The athlete stands, arms at shoulder length, then crouches, leans forward, swings their arms backwards, then jumps horizontally as far as possible. Two attempts were performed and the best score was recorded (MacKenzie, 2005).
- 3kg medicine ball throw – MBT (meters) ball held overhead in two hands – to assess the elastic arm, back and abdominal strength. The athlete throws the ball for distance; a follow through step is allowed (MacKenzie, 2005). Each subject performed two attempts and the best throw was recorded.
- 30s sit up test – SUT (number of repetitions) – to assess the endurance of abdominal muscles (MacKenzie, 2005). Subjects had to lie on a mat with the knees bent, feet flat on the floor, then to curl up slowly at 90 degrees and return slowly to the starting

position and maintain it for 30s. We recorded the number of executions performed in one session.

- 5m repeating sprint test – 5m RST (meters) – to measure the player's endurance speed capacity and agility (Durandt, 2009). On a distance of 25m, the running course was marked by cones in 5m intervals. The subjects were asked to perform the test at full speed. The subjects started the test at the first cone and, upon the signal, they sprinted to cone 2, touching the base of the cone with one hand, then returned to the first cone, sprinted to the 10m point, then returned again to the first cones, and continued in this manner for 30s. The player's distance was recorded upon each repetition; the subjects executed six repetitions, with 35s rest.

Statistical processing

For statistical processing, we used SPSS 20.0 for Windows (minimum value, maximum value, mean±SD). The difference between means was calculated by applying the *t* test. However, the differences were considered significant at $p<0.05$. The correlations between testing results were determined using Pearson's coefficient (significance of $r>0.50$).

Results

Elastic strength of legs and arms. The values recorded in standing long jump indicate higher scores obtained by female rugby players in the two tests conducted: 1.94±0.19m and 7.95±0.99m, compared to the members of the soccer team, with 1.88±0.19m and 7.24±1.41m (Table 1 and Table 2).

Table 1

Motor capacity testing results, women's rugby sevens

	250m (s)	SLJ (m)	MBT (m)	SUT (no)	5m RST (m)
	52.52	1.75	7.10	41	680
	48.43	1.70	6.50	35	639
	41.01	1.78	6.90	39	666
	40.04	2.10	8.60	38	695
	46.18	2.10	10.00	34	661
	42.49	2.03	8.70	36	734
	41.02	2.05	8.50	38	674
	43.48	1.68	8.20	38	676
	44.33	1.92	7.40	34	658
	37.62	2.25	7.80	35	744
	47.01	1.83	7.10	38	642
	39.65	2.12	8.60	34	688
Minimum	37.62	1.68	6.50	34	639
Maximum	52.52	2.25	10.00	41	744
Mean	43.64	1.94	7.95	36.67	679.75
SD	±4.27	±0.19	±0.99	±2.30	±32.35

Table 2

Motor capacity testing results, women's soccer

	250m (s)	SLJ (m)	MBT (m)	SUT (no)	5m RST (m)
	38.66	2.10	8.00	33	712
	43.08	1.80	7.00	28	705
	40.84	2.00	6.20	46	720
	42.83	1.80	8.80	24	673
	45.58	1.60	5.80	27	658
	38.56	2.00	8.50	35	755
	46.74	2.10	8.90	25	715
	42.78	2.00	6.50	28	699
	44.98	1.80	6.10	31	665
	42.26	2.25	9.80	29	715
	44.73	1.70	7.70	27	637
	42.91	1.70	6.50	25	660
	44.53	1.80	4.80	30	680
	43.87	1.70	6.80	28	657
Minimum	38.56	1.60	4.80	24	657
Maximum	46.74	2.25	9.80	35	755
Mean	43.02	1.88	7.24	29.71	689.36
SD	±2.39	±0.19	1.41	±5.59	±32.81

However, it must be noted that both categories of subjects record values "below the mean" (by 1.50m) compared to values predicted for performance athletes (MacKenzie, 2005).

We did not find statistically significant differences in any of the tests conducted (Table 3).

Table 3

T tests between independent samples (Rugby -Ro – Soccer-So)

	Ru-So	Ru-So	Ru-So	Ru-So	Ru-So
Difference	0.61	0.06	0.70	6.95	-9.60
t	0.463	0.802	1.451	4.013	-0.749
p	>0.05	>0.05	>0.05	<0.05	>0.05

Medicine ball throw recorded a statistically insignificant difference (Table 3) of 0.70 m between the two groups (mean of 7.95m vs. 7.24m).

Strength of abdominal muscles. The test for assessing abdominal muscles (curl up test – 30s) has shown significant differences between the two groups: the rugby players obtained a significantly higher mean, namely 36.67±2.30 repetitions (Table 1) compared to soccer players: 29.71±5.59 repetitions (Table 2). It is worth highlighting that, in this test, both groups recorded values ranging in the category of "excellent" according to MacKenzie, (2005) while the difference between groups was significant (Table 3).

Endurance speed capacity ("shuttle" test) underscores higher values for soccer players, with a mean of 689.36m, compared to the rugby players, with a mean of 679.75m; however, the difference is not significant (Table 3).

The test conducted to assess *anaerobic lactacid endurance* (250 m run from a standing start) highlights almost equal values: the difference is just 0.61 seconds in favour of soccer players (Table 3).

Table 4 features the results obtained by the rugby team after applying Pearson's correlation for the five tests. The 250m test correlated significantly with SLJ and MBT, while the SLJ test correlated with MBT and 5m RST

Table 4

Pearson's correlation – rugby

	SLJ	MBT	SUT	5m RST
250m	-0.661*	-0.345	0.307	-0.571*
SLJ		0.644*	-0.488	0.628*
MBT			-0.351	0.341
SUT				-0.077

*correlation is significant at the 0.05 level (2-tailed)

In women's soccer team, the 250m test correlates significantly with all the other tests except SLJ (Table 5).

Table 5

Pearson's correlation – soccer

	LFE	AMM	ABD	5m RST
250m	-0.448	-0.266	-0.566**	-0.623*
LFE		0.606*	-0.335	0.793**
AMM			-0.194	0.411
ABD				0.511

*correlation is significant at the 0.05 level (2-tailed)
**correlation is significant at the 0.01 level (2-tailed)

The correlation between SLJ and 5m RST is also significant.

Discussions

Within the past few years, the number of female players in soccer and rugby sevens in Romania has increased. The female athletes are part of various clubs that participate to competitions of various levels (from local to international level, and for different age categories). This provided the athletes with the possibility of training and competing in different environments, – either recreational or competitive – thus leading to an increase in expectations for female athletic performance. This also requires further studies and research to support specialists, in order to improve physical, technical or other types of training levels.

The purpose of our study was to assess the motor capacity of female athletes within two relatively new sports in Romania: women's soccer and rugby sevens. We conducted the analysis during the competition period (2014 – 2015 championship tour) of the training macro cycle.

The endurance speed capacity assessed through the 5m RST test showed an insignificant difference ($p>0.05$) between rugby and soccer players; the same result was obtained at the 250m test. The capacity to accelerate is a primordial quality for the soccer game (Little & Williams, 2005) and an important indicator for assessing the player's skills in the rugby game (Henne & Basset 2013).

The results obtained by the two groups at tests that measured elastic leg and arm strength did not show any significant differences ($p>0.05$). In the soccer game, elastic leg strength is believed to correlate positively with the attaining of performance (Turnerm, et al., 2011). In the game of rugby sevens, Paquet (2014) suggests that high speed and force are indispensable qualities.

The abdominal muscle force is the only test that showed significant differences between the two groups ($p>0.05$).

Because we found no model of effort drafted by specialized federations for comparison, we posit – based on the results recorded and analyzed – that the effort parameters of the two team members are at an ideal level. This statement is also highlighted by the results recorded in the national competition and at international events.

In order to formulate a series of reliable appraisals of the training level recorded by the subjects of our study (in this stage of the training macrocycle), we considered it useful to analyze the correlation between the control tests administered. Therefore, concerning the female rugby players (Table 4), we found high values of the correlation ($r>0.05$) between the 250m test (that requires good anaerobic lactacid effort) and the SLJ and 5m RST tests. The rather high value of the correlation between 250m and 5m RST acquires connotations that are significantly more relevant if we consider that the two control tests involve anaerobic lactacid effort and a high rate of lactic acid (thus very close to the competition-specific effort within both sports branches).

Concerning women's soccer team subjects, the correlation index between the 250m and the 5m RST is even closer to the significance level (-0.623), which further highlights the similar efforts required by the two tests. The correlation between 250m and 5m RST with SLJ and MBT shows insignificant values: this aspect is justified by the fact that both the SLJ and the MBT underlined, almost exclusively, values of elastic strength.

Following the studies conducted during FIFA Women's World Cup in Germany, 2011(http://www.fifa.com/womensworldcup/archive/germany2011/index.html), Martinez-Lagunas et al. (2014) studied the topic of motor capacities. They concluded that female players should be tested regularly using objective evaluations and considering certain performance standards, in order to pinpoint their strong and their weak points. This may prove useful for assessing the efficiency of a specific training program and for identifying the training levels by training stage. Despite the growing popularity and development of women's soccer around the world, the scientific research specific to female players compared to male players is still far from exhaustive, especially concerning the physical and physiological characteristics of players.

The female rugby sevens is a relatively new sport: it has been listed as an Olympic sport for the 2016 Rio de Janeiro Olympic Games (Paquet, 2014; Higham, et al., 2014). Female players need great physical skills, from speed and agility to aerobic and anaerobic resistance, as well as muscle force (Henne, et al., 2011). In the scientific sports literature, varieties of tests have been used in rugby to measure the motor capacity of players. This means that it is impossible to compare the results obtained in the previous studies (Johnston & Gabbett 2011; Lockie, et al., 2012).

In the competition period analyzed in our study, both teams had two or three specific physical training practices included in their weekly training microcycle. The practices were meant to maintain performance capacity at an optimal level, specific to athletic form plateau. The results recorded for tests concerning the dominant motor skills for both sports branches (endurance during strength training and endurance during speed training) highlight a judicious methodical orientation specific to the effort required by their training stage.

In the opinion of Clark et al. (2003), athletes are well trained when they have enough energy to reach and maintain balance in terms of competition effort; they believe it is an essential condition for obtaining optimal sports performance. Therefore, the capacity of elite players to acquire and maintain performance capacity in the pre-season and in the season period has become an extremely important element (Caldwell & Peters 2009).

Conclusions

The female soccer players scored higher in elastic leg and arm strength, but the values were insignificant and below the mean, compared to the results expected for performance athletes.

Abdominal muscle force showed significant differences between the groups: the components of the rugby team had higher scores.

Similar values were recorded for both the test assessing the lactic anaerobic resistance, and the endurance speed.

Concerning the rugby team, it is worth underscoring the high values of the correlation between the 250m, 5m RST, and the SLJ tests; concerning the soccer team, the correlations between the 250m, the 5m RST, and the SUT tests are notable. In both groups, we found a strong and positive correlation between SLJ and 5m RST.

The correlation between the 5m RST and the SLJ and the MBT tests showed insignificant values; this aspect is justified by the fact that the SLJ and the MBT highlight, almost exclusively, values of elastic strength.

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REWIEV PAPER

THE APPLICATION AND EFFECTIVENESS OF YOGA IN PREVENTION AND REHABILITATION OF SPORT INJURIES IN ATHLETES PARTICIPATING IN COMPETITIVE SPORT

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Abstract

The purpose of the study is to review literature for scientific studies about application and effectiveness of yoga in rehabilitation & prevention of sports injuries in athletes participating in competitive sports. The author conducted a comprehensive search of open access articles of major scientific databases including PuBMed, SCIENCEDIRECT, EBSCO, SCOPUS, Web of Science, etc.. No significant scientific studies were found relating to the application of yoga in rehabilitation and prevention of sport injury. Four studies were selected based on inclusion criteria. One pilot study has included yoga as part of sport conditioning and has investigated use of yoga for flexibility and incidence of non-contact injuries in baseball athletes. The other studies include a clinical example that has used yoga as part of the seven point program in injury treatment of elite football players, an intervention that has included yoga in high-volume training program and a randomised control trial that has evaluated effect of yoga in flexibility and balance among athletes. Conclusions: There is scope for further studies to examine the effect of yoga as an adjunct intervention in rehabilitation of select sports injuries for athletes in competitive sport. There is potential to include sport-specific yoga programs in athletic training for prevention of non-contact injuries.

Key words: *yoga, sport, injury, pain, prevention, flexibility*

Introduction

Global participation in organized and competitive sport is increasing. As per combined epidemiological studies from the United States (Powell &

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Barber Foss, 1999), Europe *(2008-2010, EU IDB)*, almost 10 million Sports injuries are reported among people in the kids and youth (6 to 24 years). While sport injuries cause direct and indirect physical and psychological effect on self and/or team, it poses economic burden on the health ecosystem in the community. Sprains and strains, fractures, contusions, abrasions and concussions top the list of sport-related ER diagnoses for kids in United States ages 6 to 19 — at a cost of more than $935 million each year, according to the Safe Kids Worldwide report. Similarly in Europe, estimated cost of player injuries in top 4 soccer leagues was USD 12.4$ million per team in 2015 (Forbes 2015). Approximately 4,500 people in Victoria (Australia) drop out from participation in five of the top team sport due to sport injuries and the number could increase to about 20,000 in the absence of effective sport injury prevention strategies and plans (Sport Injury Prevention Taskforce Final Report, Australia, 2013).

With the available evidence, Yoga (specifically yoga postures and pranayama) maybe associated with improvement in cardio-vascular fitness (KVV Prasad, et al., 2001; Tran, et al., 2001) and scientifically proven to positively effect on a person's physical and psychological conditions (Birch, 1995; Lidell, et al., 1983), bringing a better mind-body equilibrium. There are also studies that practice of yoga postures and pranayama have improved sports performance (Snehal, et al., 2014; Polsgrove, et al., 2016; Brynzak, et al., 2013; Powell, et al., 1999; Goodman, et al., 2014). However, there are no evidence based scientific studies about effectiveness of yoga in treatment of sport injuries.

The research questions of the study were,

1. how can yoga be used for rehabilitation & prevention of sport injuries?
2. how effective is yoga in rehabilitation & prevention of sport injuries?

Materials and Methods

The study incorporated varied search methods for relevant content including scientific substantiation. A comprehensive systematic search was conducted of open access articles of major complementary medicine and yoga databases including PuBMed, SCIENCEDIRECT, EBSCO, SCOPUS, Web of Science etc and relevant literature was identified. *Inclusion Criteria:* The review included research studies documented in English from 1985 to 2015.

- Randomised control trials, clinical example / case report, pilot study
- Studies that included injury, rehabilitation, flexibility etc as one of the outcome variables (Fig. 1).

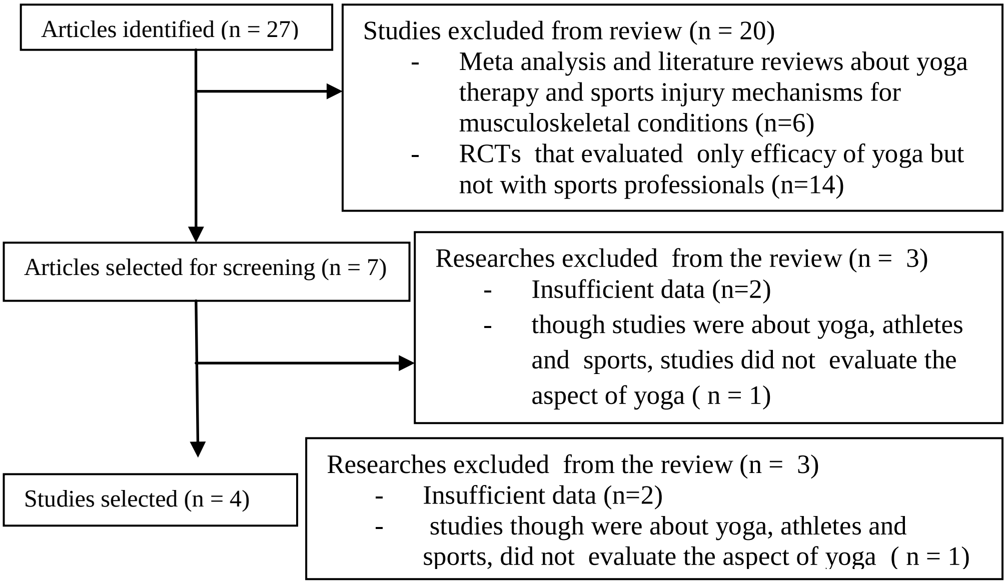

Figure 1. Results of the Review

Results

There were no significant studies for application of yoga in rehabilitation of sport injuries or prevention of sport injuries. However, one study attempted to investigate using yoga for flexibility and incidence of non-contact injuries in baseball athletes. None of the studies in the review are blinded trials. Among the other three studies selected for review, there is an individual clinical example with yoga as part of the injury treatment, a pilot study that examines the impact of a sport-specific yoga program on the enhancement of segment range of motion (ROM) and the effect upon non-contact injuries among athletes. The fourth study is about examining impact of yoga on flexibility and balance in athletes.

Table 1

Demographics of subjects and sport

Study Reference	*Sample Size*	*Gender (M/F) and Age (years) and Condition*	*Sport*	*Key focus*
Brukner et al. 2012	1	M = 1 Age – 26 years	Football	Rehabilitation for Grade 2 Femoris musculotendinous junction strain
McLean, 2009	30	M = 30	Base Ball	Flexibility and injury incidence
Brunelle et al. 2015	15	F= 7 ; M = 8 Age – 21 to 25 years	Skating	Postural skills in speed skating
Polsgrove et al. 2016	26	M = 26 Age – 19 to 21 years	Soccer and basket ball	Flexibility and balance in college athletes

Researchers have established that musculoskeletal or any other physical injury, depending on the grade of injury, have the potential to impact ROM, flexibility and endurance (in-case of long inactivity). There are studies that indicate yoga to enhance strength, flexibility and range of motion as part of injury rehabilitation or as prevention of injury. Studies are available about effect of yoga as a non-invasive, non-drug method of treating several musculo-skeletal, neurological conditions of the human. For example, Kirkwood et al. (2005) have found positive effect of yoga for arthritis, anxiety, depression, eating disorder etc., and suggest the need for further research. Ross et al. (2012), in their national survey of yoga practitioners have found that yoga might be beneficial for a number of populations including elderly women and those with chronic health conditions.

Table 2

Results from studies selected for Review

<table>
<tr><th>Study Reference</th><th>Type of intervention</th><th>Yoga intervention / practice duration and Intensity</th></tr>
<tr><td>Brukner et al. 2012</td><td>Yoga as part of 7 point rehabilitation program</td><td>12 weeks
60 minutes per session, twice per week</td></tr>
<tr><td colspan="3">Findings: The injury was managed successfully with a seven-point programme-biomechanical assessment and correction, neurodynamics, core stability, eccentric strengthening, an overload running programme, injection therapies and stretching/relaxation. The evidence for each of these treatment options is reviewed.</td></tr>
<tr><td>McLean, 2009</td><td>Yoga as sport conditioning</td><td>12 weeks
45 minutes per session, twice per week</td></tr>
<tr><td colspan="3">Findings: Significant improvements in shoulder flexibility (SH) and Hamstring (HS) (p<0.05). improvement in average mean of 5 cm was observed from pre-intervention (M=29.7cm, SD±7.9) to post-intervention, (M=34.9cm, SD±9.9). 14.49% improvement during the course of the intervention. Hamstring flexibility – an improvement with a mean value of 7cm was seen from pre-intervention (M= 9.01cm, SD±7.41) to post-intervention (M=36.0cm, SD±5.16). 24% improvement in the mean. Decline in lower and upper extremity injuries (may be due to yoga).</td></tr>
<tr><td>Brunelle et al. 2015</td><td>Yoga as motor time-on-task</td><td>36 yoga session during 8 weeks</td></tr>
<tr><td colspan="3">Findings: The 36 yoga sessions totalized 986 minutes of motor time-on-task, registering a proportion of 30% of the global motor time-on-task of the training cycle. Improvements were found in eleven of the 14 angles measured when comparing pre- and post-postural tests (P-value from 0.01 to 0.005). During the 8 weeks, excepting traumatic injuries due to short track speed skating accidents, no skaters suffered injuries linked to the high volume of training.</td></tr>
<tr><td>Polsgrove et al. 2016</td><td>Yoga with regular athlete training</td><td>10 weeks
2 times a week (intensity not specified)</td></tr>
<tr><td colspan="3">Findings: Significant gains were observed in the yoga group for flexibility (SR, P=0.01; SF, P=0.03), and balance (SS, P=0.05). Significantly, greater joint action were observed in the yoga group for: RFL (dorsiflexion, l-ankle; P=0.04), DD (extension, r-knee, P=0.04; r-hip; P=0.01; flexion, r-shoulder; P=0.01) and C (flexion, r-knee; P=0.01). Significant JA differences were observed in the NYG for: DD (flexion, r-knee, P=0.01: r-hip, P=0.05; r-shoulder, P=0.03) and C (flexion r-knee, P=0.01; extension, r-shoulder; P=0.05). A between group comparison revealedthe significant differences for: RFL (l-ankle; P=0.01), DD (r-knee, P=0.01; r-hip; P=0.01), and C (r-shoulder, P=0.02).</td></tr>
</table>

*RFL – right foot lunge; DD – downward dog; NYG – non-yoga group

* content of the table is from the selected studies for review

Discussion

The studies selected in this review (Table 2.) are discussed herewith to understand and explore possibilities of effectiveness of yoga in athletes.

1. *Yoga as part of Seven point program*

Brunker et al. (2012) have described treatment of hamstring injury in an elite football player. They have made a detailed investigation of aetiological and pathological factors of the injury and designed a seven point program to address the clinical challenge and have been successful.

Biomechanical assessment and correction was possibly a significant aspect as the asymmetry in ankle dorsi-flexion was identified and remedial actions were implemented with specific orthotic and manual therapies.

The example does not detail the cause of asymmetry in the athlete. Though we cannot assume that asymmetry could be one of the causes for the player's injury, researchers like Monro et al. (2014) have noted that there are possibilities including incomplete recovery from initial injury, incomplete rehabilitation, uncorrected biomechanical problems, et al. The athlete should be assessed not only for the acutely injured tissue but also for the underlying biomechanical problems along the kinetic chain and subclinical adaptations.

This provides a significant input to adopt an injury prevention mechanism in elite athletes by treating signals and symptoms of imbalances in the physical structure of the body.

Neurodynamics clinical tests were normal, but the player had complaints about numbness, aching and restriction in movement of right leg. The authors of the study suggested that the proximity of the sciatic nerve to the hamstrings implicates scarring potentially compromising the normal mobility and nutrition of the sciatic nerve. The rehabilitation included sliding techniques and single leg raising (SLR) biased technique sensitized with hip rotation, adduction and dorsiflexion.

The example considers an input from an earlier study by Orchard et al. (2004) that L5 nerve root may be associated with the increasing age predisposition trend of hamstring and calf injuries in Australian Football players although injury rates of muscle groups supplied by nerve roots. This aspect of correlating age with possibilities of injuries, is significant as it implies the importance of considering age related factors in rehabilitation and prevention of athlete injuries.

Nee et al. (2006) have detailed about the mechanism of clinical manifestation of peripheral neuropathic pain and have proposed that conservative management incorporating neurodynamic and neurobiology education, non-neural tissue interventions, and neurodynamic mobilization techniques can be effective in addressing musculoskeletal peripheral neuropathic pain states.

Earlier studies refer that the nerves may respond to mobilization procedures and techniques similar to those for the musculoskeletal system, with purpose to correct such abnormal neural tensions and re-establish the proper movement of the neural tissue (Monro, et al., 2014). This will result in a pain free state with subsequent improvement in the patient's functional ability level which is most of times the final goal. The basis of the ability of the nervous system for gliding and for transmission of tension has been thoroughly researched. The studies refer to the median nerve slides longitudinally in its bed when the limb is moved.

There are studies that illustrate the impact of yoga as therapy in conditions with low back pain. An exploratory study by Garfinkel et al. (1998) has tested effects of yoga therapy on pain and disability associated with lumbar disc extrusions and bulges. 62% of the 61 adults treated in the group had sciatica. The subjects underwent a 3 month yoga course and home practice. The Roland Morris Disability Questionnaire (RMDQ) score of the yoga group was 3.29 points lower than the control group. The researchers have recommended that yoga therapy can be a safe and beneficial for people with nonspecific low back pain or with sciatica, accompanied by disc extrusions and bulges.

A randomized control trial by Richard et al. (2007) for carpel tunnel syndrome observes that a yoga-based regimen was more effective than wrist splinting or no treatment in relieving some symptoms and signs of carpal tunnel syndrome.

The study has found significant improvement in hand grip strength (increased from 162 to 187mm/Hg; P =.009) and pain reduction (decreased from 5.0 to 2.9mm; P=.02).

The athlete's core stability programme was redesigned during the treatment. Sessions comprised a circuit of proprioceptive, neuromuscular control, core stability/strength and a varied lower limb strength exercise.

Core strengthening was supplemented using document based care (DBC), where core strengthening machines were designed to isolate the specific muscles involved in trunk core stability through a series of specific loaded exercises incorporating the main global lumbar movements (extension, rotation, flexion and side flexion) while limiting movement and activity in the muscles around the hips and thoracic spine.

Earlier study by Arnason et. al. (2008) has highlighted importance of core stability program for prevention of athletic injuries and to enhance sport performance.

Eccentric strengthening was applied to strengthen hamstrings. Arnason et al. (2008), have earlier used this program and have found that the eccentric training with Nordic lowers combined with warm-up stretching appears to reduce the risk of hamstring injuries in elite soccer players.

The programme comprised eight sets of 3 day cycles with consecutive days of running followed by a day off. This improved not only the player'saerobic running power but also served as aerobic fitness. In conjunction with video-based tracking of matches, the programme provides an objective measure of each player's 'standard week' in terms of training and match loads.

The physician's decision of injections, a mixture of Traumeel and Actovegin were performed in the lumbar regions centrally, over the facet joints and the iliolumbar ligaments bilaterally and the right sacroiliac joint (SIJ).

The treatment exclusively had 60 minutes of yoga sessions twice a week during the rehabilitation period and found Yoga to be effective. The fact of including yoga based breath training in the treatment the importance of mindfulness and relaxation in sport. However, the extent of yoga's efficacy in comparison to the other methods was not part of the study.

Overall, the clinical example has attempted to design a treatment that diagnoses the player's limitations and imbalances, and to address them at the physical, physiological and mind-body levels. One of the theoretical models, the integrated approach of yoga therapy (IAYT) considers correction of imbalances at the physical, mental and emotional levels. The duration of treatment, cooperation of the patient and the patient's awareness of his/her own situation are considered important aspects in accelerating the effect of IAYT. According to the theory of Pancha Kosha defined in the vedic texts (*Taittariya Upanishad*), the human existence comprises of five layers or sheaths. The gross body is the annamaya kosha (food sheath), the subtler energy is the pranamaya kosha (vital sheath), the third layer is that of emotion and feelings and is called manomaya kosha (mental sheath), the layer of imagination, knowledge, insight and understanding forms the vignanamaya kosha (the intellectual sheath). The fifth is the anandamaya kosha (sheath of bliss). This conceptual of yoga explains the intervention for injury and prevention of physical, physiological, psychological conditions.

The inclusion of neurodynamics, core strengthening and hamstring strengthening suggest a possibility in prevention mechanism of injuries too. A research by Croisier (2004) has found that players with strength imbalances were more likely to sustain a hamstring injury than those without imbalance. Another review of studies by Rachiwong et al. (2015) observes the effectiveness of an adapted and specific rehabilitative intervention in hamstring muscle re-injury prevention.

The breath training (increase in lung capacity, stamina and relaxation response) could specifically the hamstring freeing might have added to the effectiveness of overload running programme. However, correlation between muscle relaxation, strengthening on effective injury rehabilitation in competitive sport is an area to be further investigated.

Though sustained and continued practice of yoga is advocated in several texts of yoga, there are few evidenced researches about positive effects of yoga in physical and psychological fitness.

Williams et al. (2005), mention in their study about implementation of a 8 week (60 minutes per day thrice a week) modified hatha yoga program for male and female workers in the age group of 18 to 55 years as part of industrial rehabilitation for injured workers. The injuries included in the study were paraplegia acquired absence of limb as classified by International Classification of Diseases (ICD). The yoga group (9 people) practiced, a set of yogasanas and relaxation postures using suitable props. The combination of selected postures required lengthy contractions of all major muscle groups, including ROM of joints in the leg, spine and upper body. The researchers have found a 82% increase in ROM and also an improvement in flexibility in of lower back, hamstring and hand-grip.

The yoga group also showed significant increase in vital capacity, which the researchers attribute to pranayama (slow and deep breathing). Birkel et. al. (2000) observe that pranayama enhances vital capacity in healthy subjects. Hovsepian et al. (2013) study about pranayama's effect on pulmonary capacities in people with physical activity limitation.

A randomised control study was conducted by Bedekar et al. (2012) to evaluate the efficacy of iyengar yoga on chronic low back pain and results were assessed for 12 weeks (midway), 24 weeks (immediately after) and 48 weeks (6 months) after the therapy. There were significant reductions in functional disability, pain intensity and depression in the yoga group in both 12 and 24 weeks. There were also significant reductions of pain medication in yoga group in slightly less than 24 weeks compared to the group that received standard medical care.

A cohort study by Moriello et al. (2014), has compared effects of conventional physiotherapy and additional yoga asanas, on 51 patients undergoing total knee arthroplasty (TKR) due to osteoarthritis and has noted significant improvement on pain, stiffness and functional scores in the experimental group as compared to the conventional group at day 3 after operation, 6 weeks and 3 months. Similarly, a case report by Engebretsen et al. (2008) has documented improvements in balance, flexibility; endurance; posture; muscle strength of the hip extensors, hip abductors and knee extensors; and in performance of functional goals in a 12 week program designed for an individual with spinal cord injury. Yoga was used along with conventional physiotherapy.

There is a potential for yoga to be included as adjunct intervention in sport physical therapy as well. Posadzki and Parekh (2009), mention that conceptually, both physiotherapy and yoga, each through its own procedures, improve muscle strength, increase joint mobility and soft tissue flexibility, mobilize the nervous system, improve body posture, improve proprioception and thereby encourage better awareness of the body, releasing trigger points and relieving pain. It may be worthwhile to explore further researchers that include yoga as an adjunct intervention in sport physical therapy.

2. *Sport-specific yoga program*

Mclean (2009) examines the longitudinal impact of sport-specific yoga program on ROM and effects on non-contact injuries among baseball athletes. The author details several evidenced research studies about shoulder injury mechanisms and considers the assumption that shoulder injuries could possibly be prevented by maintaining flexibility (through reducing strain mechanism on the anterior and posterior joint capsule).

It is useful to note that yoga training was sequenced after athletic conditioning and that the series of yoga postures varied each day in accordance with sport conditioning. This re-emphasises the athlete centric approach and importance of collaboration among key stake holders during sport training. The study mentions about all participants attending this 12 week training, signifying the importance of adherence to training for success of the program.

Observing a control group that did not adhere to the training schedule maybe another insightful study to make useful observations about the effect of the sport specific yoga training program. A randomized control trial by Sager et al. (2014) identified high-risk and low-risk injuries in Norwegian 1st, 2nd, or the top of the 3rd division teams, through a questionnaire, however the introduction of individual specific preventive training programs did not affect the injury risk in this intervention, most likely due to a low compliance with the training programs prescribed.

The study by Mclean does not detail the exercises used for conditioning and also accepts its limitation about considering only one pre-season cycle prior to the competitive sport. The study certainly extends scope to conduct research studies with yoga interventions in specific sport training for prevention of non-contact sport injuries.

3. *Yoga in high-volume training*

Brunelle et al. (2015) have included yoga program into the pre-season high volume training and have found positive results. The study observes improvements in eleven of the 14 angles measured, and no injuries linked to the high volume of training thus signifying possibility to integrate yoga in high-volume athlete trainings.

This pilot study is significant as it uses yoga as a training stimulation to enhance postural skills and details importance of postural adjustments in short track speed skating. The intervention was successful in developing a new range of functional skills specific to the sport. The coaches were able to observe the efficiency in the skating strides of athletes which is correlated to the dissociation of the hip and torso (effect of yoga training). This is one of the very few researches about a sport specific yoga intervention.

A study by Pauline et al. (2011) has compared static stretching to yoga and found that yoga has a greater effect on range of motion at the shoulder and hip than static stretching in a healthy population. Another study by Schleip et al. (2011) has observed significant improvement in shoulder and hip flexion, hip extension and abduction range of motion following a 12 week yoga practice.

A study by Green et al. (2002) suggests that tissue loading procedures could eventually induce a period in which the tissue stiffness increases beyond the original state provided that the amount of tissue strain is high enough and that the duration of the subsequent resting period is sufficiently long. Another study by Goodman et al. (2014) has observed that a common sport injury prevention regime involves repetitive active stretching followed by periods of seated resting. They have demonstrated that this sequence of preparation tends to augment lumbar spine stiffness.

4. *Yoga in regular athlete training*

Polsgrove et al. (2016) have examined the effect of yoga in athletes. They have included yoga as an additional component in the regular athlete training and observed significant improvements in balance and flexibility. The researchers have considered 3 specific postures, the right foot lunge, downward dog and chair and hence makes it easier to comprehend the effects of these postures in sport and possibly help to create a standardised training schedule.

The study is important as it brings correlation between the kinetic chain and differences of usage of varied muscle groups for balance. This study furthers the insight that practice of yoga helps to reduce muscle tightness caused during sport training and also enhance flexibility and balance required for the sport. A comparison for the right foot lunge (RFL) indicates that the yoga group athletes utilized more dorsiflexion of left ankle position while the non-yoga athletes adopted a more plantar flexed position. These variations are suggestive that yoga athletes are better able to balance their body weight and eccentrically stretch their posterior shank muscles than non-yoga athletes. During the downward dog, it was observed that the non-yoga group had tightness in hamstring and lower back muscles.

Ce et al. (2015) conducted a pilot study of a 5 week yoga intervention for mens' division 1 athletic team in the age group 17 to 20 and have found that participants after 5 weeks of yoga practice reported greater mindfulness, greater goal-directed energy, and less perceived stress than before the intervention. Boyle et al. (2004) have examined how a regular yoga practice delayed the onset of muscles soreness (DOMS), a form of muscle trauma and/or damage at the level of the connective tissue and cell. Brynzaket et al. (2013) have observed the effect of yoga exercises on preparedness of student basketball team and have found that 13 players of experimental group demonstrated more preparedness in their game after the 9 month yoga intervention. There was increase in the following level indicators, namely, vertical jump, speed endurance, speed, retention of equilibrium (balance), free throw, with the movement, three-point shots, free throws, tactical execution.

Singh et al. (2015) have found significant increase of muscular strength (t-6.946*), muscular endurance (t-9.863*), flexibility (t-11.052*) and agility (t-14.068*) among female hockey players (18 to 25 years of age). An earlier study by Brown et al. (2005) has observed that yoga group showed a high level of maximal anaerobic alactic power and maximal force and the group required low energy expenditure and cardiopulmonary effort to maintain the yoga postures. According to Ghiya et al. (2012), yoga also uses breath control to alter the autonomic state as well as the control of the attention. Yoga explicitly aims at establishing a more optimal overall psychophysical state (New York, North Point Press, 1999).

Gore (2004) in his book Anatomy and Physiology of Yogic Practices has detailed variations between yoga and exercise. He explains that during exercise, a specific movement is repeated to strengthen that group of muscles and there is a possibility of asymmetrical development.

Conclusions

With the paucity in the scientific research in application of yoga in sport injury rehabilitation and in prevention, there is potential for researchers to consider studies about application and maybe effectiveness of yoga for specific sport injuries. It is more useful if studies can include mechanism of yoga in rehabilitation and prevention of sport injuries. Detailed studies about yoga as an intervention for prevention of sport injuries is an interesting area that will throw light on modification in sport training.

Further, it would certainly help fellow researchers if yoga is considered as a non-pharmacological, no-invasive intervention in treating specific sport injuries. There are evidence based studies about application of yoga as non-invasive and non-pharmacological intervention in treatment of musculoskeletal, psychosocial, neuromuscular conditions etc. It may be useful to extend these studies in symptomatic treatment in sport related injuries.

Only one study in the current review is a randomized control trial (RCT). This warrants for further blinded RCTs to understand validity of using yoga as an intervention in competitive sport.

The application of yoga as adjunct intervention in various conditions majorly observe pain management, functional mobility, muscular endurance, quality of life etc. Most of the studies have documented the physical therapy applications. It may be of significance to detail the pharmacological interventions as well, so it helps the sport researchers understand the correlation between physical therapy treatments and pharmacology in elite athletes.

The pilot studies that have included yoga in athlete training program have observed efficacy of yoga in flexibility and low incidence of injuries. This could be a potential area of research to address a pertinent issue with reference to prevention of sport injuries in elite and non-elite athletes.

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REWIEV PAPER

THE TRAINING OF HIGHLY SKILLED BASKETBALL PLAYERS AND ITS EVALUATION: THE CONTEXT OF A MICROSTRUCTURE

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Abstract

The search for methods of optimisation of the training of highly skilled basketball players is very relevant due to an increased volume of competition activities. It is important for trainers to properly distribute training loads throughout micro-cycles and, thus, strive for more rapid regeneration, accumulation of physical and psychic efficiency of athletes. Appropriate distribution of training loads in a micro-cycle is related to reception of athletes' feedback, too.Another highly relevant problem deals with athletes' endeavours to develop their capacities through individual training. An athlete should be able to assess efficiency of this activity, too. The research objective is to investigate the change of highly skilled basketball players' training loads (training conducted by trainers, additional individual training and competition activities) and the evaluation of them throughout training micro-cycles. The research methods of theoretical analysis and generalisation, observation, evaluation, mathematical statistics are applied. A fragment of an initial part of the basketball players' training and competitions period (20 initial micro-cycles of the season 2014 – 2015) of "Šiauliai" basketball team was observed and analysed. An experienced basketball player evaluated the load undergone by the team as well as his own individual training load. Optimal sports training should be based on analysis of three activities: the training conducted by trainers, additional individual training of an athlete, athletes' competition activities. An average duration of a sports training micro-cycle is 88.6min. The training conducted by trainers constitutes 73.1%, athlete's additional individual training constitutes 6.0%, and the competing constitutes 20.9% of the total sports training. A major criterion of the tasks being solved throughout micro-cycles and their filling with the content are

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matches and the amount of them in one micro-cycle. An average evaluation of the volume of the training conducted by trainers throughout a cycle was 6.2±0.70 points; evaluation of intensity was 7.0±0.51 points. The change of evaluation of the work load, intensity throughout the micro-cycles was similar. Highly skilled basketball players do not pay appropriate attention to additional individual activities.

Key words: *Highly skilled basketball player, sports training, training conducted by trainers, additional individual training of athletes, evaluation, training micro-cycle, feedback information.*

Introduction

The search for methods of optimisation of the training of highly skilled basketball players is very relevant due to an increased amount of competition activities and irregularity of their distribution. It is important for trainers to properly apply training loads in micro-cycles and, thus, strive for more effective regeneration of basketball players, accumulation of their physical and psychic efficiency. Appropriate distribution of training loads throughout a micro-cycle is related to reception of feedback from athletes, too (Bompa, 1999; Bompa & Buzzichelli 2015; Karoblis, 2005; Skernevičius, 2011; Stonkus, 2003; Верхошанский, 1985; Платонов, 1988; Платонов, 2004). An athlete, evaluating the volume of undergone physical load, intensity, own condition could contribute to optimisation of training loads. Such instant information should be highly important to a trainer, though still there is lack of scientific publications grounding the ways of reception of instant information, effectiveness.

Another relevant problem lies in athletes' endeavours to develop their skills during individual training workouts. During this training an athlete could develop one's weaker manifesting capacities, skills of movement techniques with regard to subjective feelings and planned action of the team in a particular cycle of training. An athlete should be able to evaluate efficiency of this activity as well. Activity of such a kind shows athlete's education and endeavours to perfect and solve the tasks set for a team (Stonkus, 2003).

One more problem reveals that distribution of loads of basketball players competing in national basketball leagues, international and national cups tournaments in a micro-cycle is very similar, whereas sports results are different. Likely, a talent, rapidness of recovery processes between training workouts, matches become determining factors.

In micro-cycles, competitions are held every 3 – 4 days. Both preparatory training and competition loads are highly intense; basketball players' physical regeneration becomes more complex. Therefore, the modelling of athletes' rapid adaptation to training loads throughout micro-cycles becomes highly important (Bompa & Buzzichelli 2015; Верхошанский, 1985; Платонов, 2004). An athlete evaluating the quality of training conducted by trainers and additional individual training should become an essential axis of optimisation of training loads.

Established researchers on sports hold that a recovery micro-cycle should follow after 3 – 5 competition micro-cycles (Bompa, 1999; Karoblis, 2005; Skernevičius, 2011; Платонов, 2004). However, implementation of this regularity is disturbed by the timetable of matches. Therefore, trainers should search for possibilities to apply purposeful physical load for recovery and support throughout competition micro-cycles.

Sports scientists have designed methods for optimisation of athletes' training loads applying tests, surveys, biochemical and physiological examinations; nevertheless, these research methods are time-consuming, whereas a trainer needs instant information.

The research objective is to investigate the change of highly skilled basketball players' training loads (training conducted by trainers, additional individual training, and competition activities) and the evaluation of them throughout training micro-cycles.

Materials and Methods

"Šiauliai" basketball club players' loads undergone during preparatory training and competition periods throughout micro-cycles were being observed and evaluated (Table 1). A title was given to a micro-cycle on the basis of dominating measures. Six training micro-cycles (Mi1In, Mi1Pr, Mi1Tp, Mi2 Tp, Mi3Tp, Mi4Tp) constituted the preparatory period of the team, and the remaining 14 (Mi1C, Mi2C, Mi4C, Mi5C, Mi6C, Mi7C, Mi8C, Mi9C, Mi10C, Mi11C, Mi12C, Mi13C, Mi2P) constituted the competition period.

Duration of one micro-cycle (Mi1In) was 4 days, and duration of the remaining was 7 days each. Duration of a micro-cycle was standard and met the requirements set for duration of a micro-cycle. Bompa (1999), Karoblis (2005), Skernevičius (2011), Platonov (2004) state that minimal duration of a micro-cycle may be 3 days, and maximal duration may be 14 days.

During the period under analysis, the team played test, Lithuanian Basketball League, European "Challenge Cup" matches and in this way was preparing for upcoming matches of the Baltic Basketball League, Lithuanian Basketball Federation Cup. Collaborating with a trainer for physical training of the team according to designed minutes of observation, a player of the basketball team (RG), a final-year student of Physical Education study program, was registering major measures of common activities together with the team and individually as well as time allocated for these activities. After team and individual training, the basketball player would evaluate the volume, intensity of the training in a 10-point system. While both studying and training, the basketball player had accumulated appropriate competences for evaluation of the sports training process. In 2011, RG became a World Youth (under 19) Basketball Champion, in 2012 a European Youth (under 20) Basketball Champion, in 2014 a Baltic Basketball League Champion. After the championship of 2014 – 2015 was finished, the player was invited to Lithuanian National Men's Basketball Team and was preparing for the European Basketball Championship in 2015.

Table 1

An implemented microstructure of the training of the investigated team

Title of a micro-cycle	No. of a micro-cycle	Duration (from–to)
Mi1In	1	21.08.2014–24.08.2014
Mi1Pr	2	25.08.2014–31.08.2014
Mi1Tp	3	01.09.2014–07.09.2014
Mi2Tp	4	08.09.2014–14.09.2014
Mi3Tp	5	15.09.2014–21.09.2014
Mi4Tp	6	22.09.2014–28.09.2014
Mi1C	7	29.09.2014–05.10.2014
Mi2C	8	06.10.2014–12.10.2014
Mi3C	9	13.10.2014–19.10.2014
Mi4C	10	20.10.2014–26.10.2014
Mi5C	11	27.10.2014–02.11.2014
Mi6C	12	03.11.2014–09.11.2014
Mi7C	13	10.11.2014–16.11.2014
Mi8C	14	17.11.2014–23.11.2014
Mi9C	15	24.11.2014–30.11.2014
Mi10C	16	01.12.2014–07.12.2014
Mi11C	17	08.12.2014–14.12.2014
Mi12C	18	15.12.2014–21.12.2014
Mi13C	19	22.12.2014–28.12..2014
Mi2Pr	20	28.12.2014–04.01.2015

Abbreviations: Mi1In – the first introductory micro-cycle, Mi1Pr – the first preparatory micro-cycle, Mi1Tp – the first test preparatory micro-cycle, Mi2 Tp – the second test preparatory micro-cycle, Mi3 Tp – the third test preparatory micro-cycle, Mi4 Tp – the fourth test preparatory micro-cycle, Mi1C – the first competition micro-cycle, Mi2C – the second competition micro-cycle, Mi4C – the fourth competition micro-cycle, Mi5C – the fifth competition micro-cycle, Mi6C – the sixth competition micro-cycle, Mi7C – the seventh competition micro-cycle, Mi8C – the eighth competition micro-cycle, Mi9C – the ninth competition micro-cycle, Mi10C – the tenth competition micro-cycle, Mi11C – the eleventh competition micro-cycle, Mi12C – the twelfth competition cycle, Mi13C – the thirteenth competition cycle, Mi2Pr – the second preparatory micro-cycle,

Compliance of the volume of athlete's performed individual additional training to standard duration (90min) of the volume of the training was carried out according to a simple algorithm: duration of the entire training is 9min; thus, 1min of individual activities corresponds to

0.9min of the training conducted by trainers. For instance, 35min of additional individual sports training of the basketball player constitute 0.32 of a training workout.

The volume of athletes' sports training conducted by trainers expressed by time was obtained by summing up two constituent parts. The first constituent part included duration of the training. The second constituent part included duration of trainers' activities related to competitions:

1. duration of athlete's direct preparatory training for a match (workout before a match) was 40 – 60min;
2. duration of a match was 40min;
3. short body warming-up during the long break during a match 3 –5min;
4. duration of relaxation exercises after a match was 10–15 min.

The days of training and rest were calculated according to the following algorithm: if only one training workout was carried out or one competition was held per day, the research minutes recorded as 0.5 of the training day and 0.5 of the rest day; if 2 training workouts were carried out per day, one training workout and one match per day, the research minutes recorded 1 day of training and 0 days of rest.

The investigation applies research methods of theoretical analysis and generalisation, observation, evaluation, mathematical statistics.

Results

Organised sports training and its distribution**.** The training conducted by trainers constituted the first part of the volume of basketball players' sports training organised by trainers, expressed by duration. Throughout 20 sports training micro-cycles that lasted 137 days, athletes led by trainers performed 143 training workouts (Table 2). The training workouts were allocated 12263min, or 204 hours and 23min. On the average per cycle the training workouts were allocated 613min, or 10 hours and 13min.

Table 2

Indices of the basketball players' sports training organised by trainers

Structures of the training	Amount of training days	Amount of rest days	Amounts of training	Amounts of matches	Amount of organised activities	Duration of training (min)	Activities related to competitions (min)	Duration of activities (min)
Analysed period	89	48	143	35	178	12263	3510	15773
One micro-cycle	4.45	2.4	7.15	1.75	8.9	613.15	175.5	788.65

Variants of two, three, three-and-a-half and six training days per one micro-cycle were applied 1 time, four training days 2 times, four-and-a-half and five 7 times. Thus, 6 variants of training days per one micro-cycle were applied (Table 3).

Table 3

The change of indices of basketball players' activities organised by trainers throughout training micro-cycles

No.	Title	Amount of training days	Amount o rest days	Amount of training workouts	Duration of training	Amount of matches	Activities related to competitions (mins)	Amount of activities	Total duration (mins)	Numerical expression of work and rest days	Duration of one activity of basketball players
1	Mi1In	2	2	4	424	0		4	424	3–1	106.0
2	Mi1Pr	5	2	10	1075	0		10	1075	3–1+2–1	107.5
3	Mi1Tp	4.5	2.5	8	828	1	102	9	930	2–1+2–1+1–	103.3
4	Mi2Tp	5	2	7	570	3	308	10	878	2–1+3–1	87.8
5	Mi3Tp	5	2	5	338	5	500	10	838	4–1+2–	83.8
6	Mi4Tp	4.5	2.5	7	590	2	200	9	790	–1+6–	87.8
7	Mi1C	4.5	2.5	6	525	3	300	9	825	6–1	91.7
8	Mi2C	5	2	8	751	2	200	10	951	4–1+1–1	95.1
9	Mi3C	6	1	10	809	2	200	12	100[illegible]	1–1+4–	84.1
10	Mi4C	5	2	8	616	2	200	10	816	–1+3–1+2–	81.6
11	Mi5C	4.5	2.5	7	529	2	200	9	729	2–1+4–	81.0
12	Mi6C	4.5	2.5	8	655	1	100	9	755	2–1+2–1+1–	83.9
13	Mi7C	4.5	2.5	7	531	2	200	9	731	3–1+2–1	81.2
14	Mi8C	3	4	5	412	1	100	6	512	3–2+1–	85.3
15	Mi9C	5	2	8	660	2	200	10	860	3–1+2–1	86.0
16	Mi10C	3.5	3.5	6	563	1	100	7	663	3–1+1–1+1–	94.7
17	Mi11C	5	2	8	714	2	200	10	914	2–1+2–1+1–1	91.4
18	Mi12C	4.5	2.5	7	559	2	200	9	759	2–1+3–1	84.3
19	Mi13C	4	3	6	445	2	200	8	645	2–2+2–1	80.6
20	Mi2Pr	4	3	8	669	0	0	8	669	2–3+2–	83.6

The amount of training workouts throughout micro-cycles was determined by the tasks being solved during them, projected with regard to the time of matches and regularities of athlete's adaptation to physical loads. The variants of four and nine training workouts in one micro-cycle were applied 1 time each, the variant of five training workouts was applied 2 times, the variant of six training workouts per one micro-cycle 3 times, the variant of seven training workouts per one micro-cycle 5 times, the variant of eight training workouts per micro-cycle 7 times.

Variants of one, three-and-a-half and four days of rest were applied 1 time each, the variant of two days of rest was applied 8 times, the variant of two-and-a-half days of rest 7 times, the variant of three days of rest 2 times.

Throughout the period under analysis, 16 variants of distribution of work and rest days were applied. Variants of distribution of work and rest days 3–1+2–1, 2–1+2–1+1, 2–1+3–1 were repeated 2 times each; and 10 variants of distribution of work and rest days were applied one time each. The analysis of the variants of distribution of work and rest days allows stating that for an athlete in both physical and psychic senses it is difficult to adjust to a highly unstable rhythm of work and rest days.

Competitions-related activities of trainers constituted the second part of the volume of basketball players' sports training organised by trainers. 35 matches were played, 1.75 matches on the average per one training micro-cycle. Activities related to competitions covered 3510minutes, or 58 hours and 30min. On the average, activities related to competitions per one micro-cycle were allocated 176min, or 3 hours.

Throughout 6 micro-cycles of the preparatory period, 11 matches were performed, 2.2 matches on the average throughout the entire micro-cycle of the preparatory period. The first test match was played on the sixteenth day of the training of basketball players for a new season, after physical training workouts which lasted for two weeks.

Throughout 14 micro-cycles of the competitions period, 24 matches were played, 1.7 matches on the average per one micro-cycle.

Throughout the period under analysis, there were five variants of frequency of matches in micro-cycles. Most often, the variant of two matches per micro-cycle would repeat. Micro-cycles of such a type constituted 50% of the micro-cycles throughout the entire period under analysis. Only one match was played in four training micro-cycles. Micro-cycles of such a kind constituted 20 per cent of the micro-cycles throughout the entire period under analysis. No matches were played during 3 (15% of all training micro-cycles) competition micro-cycles, and three matched were played during 2 competition micro-cycles (10% of all training micro-cycles).

Two stages of stable repetition of two matches per micro-cycle were registered. Duration of one was 4, of another 3 micro-cycles.

The matches were played every 3.9 days (3 days and 21 hours). On the day of a match athletes would perform morning training workout, too.

There were 30 days of such a kind, and only 5 competition days were without a morning training workout.

The timetable of matches of the analysed team was not intense. On the average, the team would play every 4 days.

All activities of trainers organising the training of basketball players throughout the period under analysis consisted of 15773 minutes, or 262 hours and 53 minutes. Thus, during one micro-cycle sports training lasted 788.7 minutes, or 13 hours and 8 minutes on the average. Average duration of one activity in a training micro-cycle covered 88.6 minutes. Duration of one activity conducted by trainers throughout training micro-cycles varied from 81 to 108 minutes. Throughout three first micro-cycles of the preparatory training period (Mi1In, Mi1Pr, and Mi1Tp), average duration of one training workout varied from 103 to 108 minutes.

To organise training of basketball players trainers allocated 77.6 per cent of their work time, and for activities related to competitions, they allocated 22.4% of their time.

Additional individual activities. Characteristics of sports training can be analysed in detail having calculated the volume of time allocated to the three types of activities (activities related to training workouts conducted by trainers and competitions, self-training of athletes) (Table 4).

During the analysed period of 137 days, the athlete was involved in sports for 1010 minutes (Table 4) in total. According to the designed system of the transfer of independent training volumes (in minutes) to the numerical system of the amount of training workouts, we can state that the basketball player independently performed 11.2 training workouts. On the average per week, the athlete performed 0.6 independent training workouts, and during one day of the analysed period 0.1 independent training workouts was performed.

Duration of sports training workouts conducted by trainers constituted 73.1% of the entire training, athlete's independent physical training constituted 6.0 %, activities related to competitions constituted 20.9% of the entire training. Throughout three sports training micro-cycles (Mi1In, Mi1Pr, Mi2Pr), parts of sports training conducted by trainers were vast and constituted from 90% to 100% of the entire training.

Table 4

Expression of the volumes of individual training workouts, entire sports training and its part throughout training micro-cycles

No.	Micro-cycle	Individual training		Overall sports training		Average duration of one activity	Expression of the parts of training (%)		
		Amount	Duration (mina)	Amount of activities	Summed up duration of activities		Activities conducted by trainers		Individual
							Training	Competitions	
1	Mi1Įn	0.6	50	4.6	474	104.0	89.5	0.0	10.5
2	Mi1Pr	0.2	15	10.2	1090	107.2	98.6	0.0	1.4
3	Mi1Tp	0.5	45	9.5	975	102.6	84.9	10.5	4.6
4	Mi2Tp	0.4	40	10.4	918	87.9	62.1	33.6	4.4
5	Mi3Tp	0.7	65	10.7	903	84.2	37.4	55.4	7.2
6	Mi4Tp	10	90	10.0	880	88.0	67.0	22.7	10.2
7	Mi1C	0.6	50	9.6	875	91.6	60.0	34.3	5.7
8	Mi2C	0.5	45	10.5	996	94.9	75.4	20.1	4.5
9	Mi3C	0.7	65	12.7	1074	84.4	75.3	18.6	6.1
10	Mi4C	0.5	45	10.5	861	82.0	71.5	23.2	5.2
11	Mi5C	0.6	55	9.6	784	81.6	67.5	25.5	7.0
12	Mi6C	0.7	60	9.7	815	84.3	80.4	12.3	7.4
13	Mi7C	0.0	0	9.0	731	81.2	72.6	27.4	0.0
14	Mi8C	0.3	25	6.3	537	85.5	76.7	18.6	4.7
15	Mi9C	0.7	65	10.7	925	86.3	71.4	21.6	7.0
16	Mi10C	0.7	65	7.7	728	94.3	77.3	13.7	8.9
17	Mi11C	0.9	85	10.9	999	91.3	71.5	20.0	8.5
18	Mi12C	0.7	65	9.7	824	84.8	67.8	24.3	7.9
19	Mi13C	0.9	80	8.9	725	81.6	61.4	27.6	11.0
20	Mi2Pr	0.0	0	8.0	669	83.6	100.0	0.0	0.0

Athlete's reflection on undergone loads during training organised by trainers and sports self-training.

The athlete evaluated the volume of training workouts organised by the trainer by 6.2±0.6 points (Table 5). Variation of this variable was slight. Such evaluation of the volume of the entire period of training allows stating that the loads recommended by trainers were too low.

As the amount of matches in micro-cycles was quite stable and, therefore, the volume of training load was very stable. Training micro-cycles including large volumes of competition activities should include reduced volumes allocated for training. Without diminishing the volume of training load, athletes will feel tiredness during matches and this will result in poorer indices of competition activities. Athletes should be prepared for competitions psychologically, too, and psyche recovers when the time allocated for athletes' training is diminished, a character of training exercises is changed, environment of training workouts is changed.

Table 5

Athlete's reflection on undergone loads during sports training organised by trainers

No.	Micro-cycle	Evaluation of activities conducted by trainers		Evaluation of individual training	
		Volume of load	Intensity of load	Volume of load	Intensity
1	Mi1Įn	6.0±0.7	4.7±0.4	1.3±0.2	1.3±0.2
2	Mi1Pr	7.8±0.8	6.4±0.6	1.2±0.3	1.0±0,1
3	Mi1 Tp	7.8±0.7	6.4±0.6	1.2±0.2	1.0±0,1
4	Mi2 Tp	6.0±0.1	7.4±0.5	1.0±0.1	1.0±0,1
5	Mi3 Tp	5.7±0.9	7.5±0.5	1.3±0.3	1.0±0,1
6	Mi4 Tp	5.8±1.1	6.8±0.2	1.3±0.3	1.0±0,1
7	Mi1C	4.5±0.4	7.0±0.8	1.2±0.2	1.2±0.1
8	Mi2C	6.0±0.9	7.5±0.5	1.4±0.3	1.0±0,1
9	Mi3C	7.2±0.8	7.7±0.7	1.2±0.2	1.0±0,1
10	Mi4C	6.6±0.8	7.0±0.2	1.4±0.3	1.0±0,1
11	Mi5C	5.3±0.9	7.0±0.5	1.2±0.2	1.0±0,1
12	Mi6C	6.8±0.8	7.6±0.4	1.6±0.3	1.0±0,1
13	Mi7C	5.8±0.7	7.8±0.8	1.0±0,1	1.0±0,1
14	Mi8C	5.3±0.7	7.3±0.6	1.3±0.3	1.0±0,1
15	Mi9C	6.2±0.3	7.2±0.8	1.0±0,1	1.0±0,1
16	Mi10C	5.0±0.8	6.2±0.5	1.6±0.5	1.2±0.2
17	Mi11C	6.8±0.3	8.2±0.5	1.4±0.4	1.2±0.21
18	Mi12C	5.8±0.6	7.0±0.3	1.4±0.4	1.0±0,1
19	Mi13C	6.0±0.3	6.8±0.2	1.5±0.3	1.0±0,1
20	Mi2Pr	7.3±0.7	7.5±0.4	1.0±0,1	1.0±0,1

Evaluation of intensity of the entire period of training that lasted 20 weeks was 7.0±0.5 points. Such evaluation of intensity of the entire period of training allows stating that the loads recommended by trainers were optimal. Such evaluation could be determined also by the fact that a high amount of matches were played and trainers applied intensive short-term, intensive interval exercises for development of fastness, fastness-power. Development of fastness, fastness-power require long intervals allocated for rest; therefore, sometimes an impression may occur on too extended training workouts of such a character.

Athlete's evaluation of intensity of the load tells that the most intensive physical loads were undergone in Mi11C (evaluation of intensity of physical load was 8.2±0.5 points), Mi7C (evaluation of intensity of physical load was 7.8±0.8 points) Mi3C (evaluation of intensity of physical load was 7.7±0.7 points). Throughout these training micro-cycles they played 1 match per week and trainers could increase intensity of training exercises.

Another noticed tendency indicated that the higher amount of matches per week, the lower evaluation of intensity of physical load. This observed regularity is easy to explain: throughout micro-cycles including high volume competition activities intensity of performed exercises must be diminished (Bompa & Buzzichelli, 2015; Karoblis, 2005; Skernevičius, 2011; Stonkus, 2003; Платонов, 2004). Without reducing intensity of training loads, athletes will feel tiredness during matches and this will result in poorer indices of competition activities. Athletes should be prepared for competitions psychologically, too. Performance of fastness exercises requires high potential of psyche. Therefore, exercises for development of fastness exhaust an athlete and he needs a longer period for recovery (physical regeneration) after such exercises. Therefore, it is not recommended to apply many exercises for development of fastness in micro-cycles of competitions.

Another observed tendency points out that the tendency of the change of points in assessment of the volume of work, intensity was similar. As supporters of the sports theory underline, there should be an inverse ratio between the volume of training loads and intensity.

The highly skilled basketball player who participated in the research understands that his individual additional work is insufficient. This is decided on the ground of evaluation of individual additional work throughout the entire period of research, on the average it was 1.3±0.16 points. The volume of individual additional work was stable low. The surveyed limited him with development of technical skills of play only.

Intensity of individual additional training of the highly skilled basketball player who took part in the research is too low. Average evaluation of the volume of individual load throughout the period under analysis was 1.0±0.07 points.

Dynamism of assessment of the volume of individual training, intensity of individual load was very similar. The volume of individual training load is evaluated slightly better. It is understood because the index of intensity is related to more powerful action, psychic tension, the leaving of a comfort state, and also the remaining impact of physical load.

Discussion

Researchers of the sports field analysing the volume of sports training of basketball players organised by trainers expressed in time sum up two constituent parts (Bompa 1999, Stonkus 2003, Платонов, 2004). The first part is duration of the training workouts. The second is duration of a match. It is necessary to provide details of this constituent part because if activities related to competitions include competition activities (40 minutes) only, a mistake is made. Trainers' activities related to competitions are not limited with matches only. Duration of trainers' activities related to competitions consists of:

1. direct athlete's training for a match (warm-up before a match), duration 40 – 60 minutes;
2. duration of matches was 40 minutes;
3. short warm-up during the long break of a match was 3 – 5 minutes;
4. duration of relaxation exercises after a match was 10 – 15 minutes.

The first test match of the basketball players was played in the third micro-cycle of the training for a new season, after physical training workouts which lasted for two weeks and four training workouts in a basketball hall. Awareness of adaptation of the support and movement system to specific physical loads becomes an essential problem. Another problem deals with the failure to implement a recovery micro-cycle during the preparatory period, and the team had to start the period of competitions in a condition of background physical tiredness. And the third problem deals with too short preparatory period which consisted of 6 training micro-cycles. The highly skilled athlete who maintained physical capacity during the transitional period can reach a sportive form in the 2^{nd} – 3^{rd} month of training (Bompa, 1999; Bompa & Buzzichelli 2015; Karoblis, 2005; Skernevičius, 2011; Платонов, 1988; Платонов, 2004). Thus, he will need 9 – 14 training micro-cycles to reach his sportive form.

13 competition micro-cycles in a row prove poor planning of matches. This noticed tendency allows stating that a timetable of matches could be more compact and a rhythm of matches more stable. As the amount of matches' increases, micro-cycles without matches would be formed. Such micro-cycles would provide trainers an opportunity to apply recovery or preparatory micro-cycles. A major task of recovery micro-cycles would be the recovery and retaining of working capacity, and in a case of a preparatory micro-cycle it would be more purposeful application of functional technical-tactical training.

Five variants of frequency of matches per one micro-cycle of competitions prove instability of timetables of matches, and this makes the training difficult. Only one match was played even in four training micro-cycles. In one micro-cycle basketball players played even 5 matches. In the senses of both preparations for next matches and athletes' physical and psychic regeneration this is an irrational amount of matches per one week.

The timetable of the investigated team was not intense. On the average, the team would play every 4 days; therefore, intensity of training workouts had to be higher.

Analysis of distribution of work and rest days allows stating that for the athlete, in both physical and psychic senses, it is difficult to adjust to highly instable rhythm of work and rest days; and for trainers planning loads of training in a micro-cycle it is highly difficult to implement a classical variant of distribution of athlete's work and rest days 3–1+2–1. Those who support a standard system of person's 7-days work state that person's most workable days of the week are Wednesday and Thursday, and during the last three days of the week person's working capacity gradually decreases (Karoblis, 2005; Skernevičius, 2011; Stonkus, 2003; Платонов, 2004). Therefore, trainers, applying the rhythm of work and rest days, should search for more effective ways to change a regular weekly rhythm of working capacity building. Awareness of particularities of athlete's biorhythms of the day, week, month is one of the possibilities to increase effectiveness of trainers' activities.

The amount of training and rest days, training workouts, the filling of training micro-cycles with the content, duration of training workouts during training micro-cycles etc. were determined by the tasks being solved; they were projected with regard to the time of matches and regularities of athlete's adaptation to physical loads. Such actions met the recommendations provided by scientists.

Trainers needed 13 hours and 8 minutes to organise the training of basketball players per one training micro-cycle. Critically treating this index, it should be assumed that these are hours of contact work with basketball players. Obviously, trainers allocate much time to analysis of the play of opponents, development of models of matches with opponents-to-be, plans of training workouts intended for implementation of these models. Such volume of sports training on the average per one micro-cycle of training is sufficient.

Effectiveness of the training workout throughout micro-cycles could be increased by varying criteria of volume and intensity of physical load. Established scientists of sports theory state that there is inverse ratio between intensity of physical load and volume of physical load (Bompa, 1999; Bompa & Buzzichelli 2015; Верхошанский, 1985; Платонов, 1988).

In the analysed period of the training of basketball players, the volume and intensity of physical load are directly related. This is decided from athlete's evaluation of the training conducted by trainers.

A highly important factor of athlete's development is individual activity. It is understood that when training during organised training workouts conducted by trainers it may seem that there is no wish, neither physical nor psychic powers to work additionally. However, the implemented model of training basketball players was not intensive, and basketball players could allocate more time to additional individual training workouts. We cannot ground such assumption because we could not find any data on the volume and intensity of additional individual training workouts of highly skilled basketball players in scientific literature. It is likely that a decisive factor for such a low volume and intensity of additional activities was athlete's unawareness of importance of individual additional activities.

Highly skilled basketball players' individual additional work is insufficient. It is important that they understand that their work is insufficient, that intensity of physical self-training is too low. Evaluation of the volume of individual load throughout the period under analysis on the average was 1.3±0.16 points; evaluation of intensity of individual load was 1.0±0.07 points.

Dynamism of evaluation of the volume of individual load, individual load intensity was very similar. The volume of the individual training load is evaluated slightly better. This is understood because the index of intensity is related to more powerful action, concentration of attention and also the remaining impact of physical load.

Conclusion

The volume of sports training of a basketball player organised by trainers is expressed by time and obtained after summing up two constituent parts. The first constituent part is duration of activities related to training workouts. The second constituent part is duration of trainers' activities related to competitions: duration of direct training of an athlete for a match (warming-up before a match), duration of a match, and duration of a short warming-up of athlete's body during the long break of a match, duration of relaxation exercises after a match.

The amount of training and rest days per one micro-cycle, the amount of training workouts per one micro-cycle, the filling of training micro-cycles with the content, duration of training workouts throughout (self-)training micro-cycles etc. are determined by the tasks being solved; they are projected with regard to the time of matches and regularities of athlete’s adaptation to physical loads.

Highly skilled basketball players conducted by trainers undergo training of 10 hours and 13 minutes on the average per one micro-cycle. Six variants of application of training workouts throughout training micro-cycles are implemented. A variant of eight training workouts throughout training micro-cycles is applied most often. Six variants of rest days in micro-cycles are applied. Usually, a variant of two rest days per micro-cycle is applied. 16 variants of distribution of work and rest days are applied. Most often repeated variants of work and rest days distributed throughout a micro-cycle are 3–1+2–1, 2–1+2–1+1, 2–1+3–1.

Trainers’ activities related to organisation and implementation of competitions cover 3 hours per one training micro-cycle on the average. 1.75 matches are played. Variants of five matches in competition micro-cycles repeat. Usually, a variant of two matcher per one micro-cycle repeats. Matches are played every 4 days.

The entire activities of trainers organising basketball players’ training per micro-cycle is 13 hours. Average duration of one activity in a micro-cycle lasted 89 minutes.

Duration of sports training conducted by trainers constituted 73.1%, athlete’s individual physical self-training constituted 6.0%, activities related with competitions constituted 20.9% of the entire training.

The volume of training workouts organised by a trainer during the period under analysis is evaluated by athletes by 6.2±0.6 and intensity by 7.0±0.51 points. Loads recommended by trainers were too low. The tendency of change of points given for the volume, intensity of work was very similar.

On the average, athletes perform 0.6 of individual training workout per one micro-cycle. Highly skilled basketball players assess the volume of additional individual training workouts by 1.3±0.16 points and intensity by 1.00±0.07 points. Dynamism of the volume of individual load, intensity of individual load is very similar.

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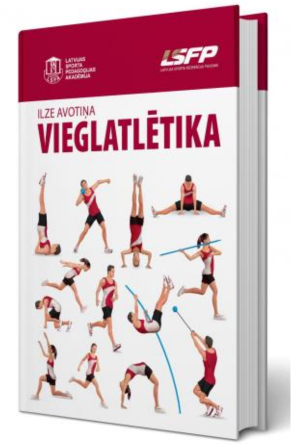
SHORT COMMUNICATION

Review of Ilze Avotiņa book „Track and Field Athletics"



The basic events of athletics – walking, running, jumping, throwing and hurdling – are the component of many sports, as well as excellent means for developing physical preparedness. Therefore, "Athletics" can be recommended to everyone interested in different sports – athletes, sport education students, as well as the parents of young athletes.

The book incorporates separate chapters, devoted to sports walking, running, jumping, throwing and multisports. In the chapters are further sub-divisions for in-depth analysis of athletics events. However, the technical analysis is easy to understand and not too "intrusive". Each sub-chapter has a brief historical overview, insight into Olympic and world records, but the major part is devoted to exercises that are useful not only for athletes, mastering track and field events, but also for athletes of other sports athletes both as the means for promoting physical preparedness and increasing movement arsenal. High-quality and up to date illustrations complement the exercise description and create a complete picture. Each chapter contains the rules of the competitions that allow the reader to link each athletic event technique and its implementation, participating in competitions.

In my opinion, an interesting detail is the fact that the author has added a track and field event classification, allowing readers to assess their achievements in this sport; there are not many sports (including swimming), in which it is so easy to understand sport achievement classification.

The book "Athletics" is both informative enough and compact source of information (more than 100 references to the literature used, as well as the list of recommended reading) for all lovers of athletics.

Imants Upītis, Dr.biol., Assoc. Professor,
Head of the Department of Swimming,
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We congratulate Helēna Vecanāne, PhD student from the Latvian Academy of Sport Education with the defence of her Thesis "CORRELATIONS BETWEEN STUDENTS' HEALTHY LIFESTYLE AWARENESS AND HABIT FORMATION" (Sport Science) at the Latvian Academy of Sport Education on January 19, 2016. Supervisor: Dr. paed., assoc. prof. Andra Fernāte.

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GUIDELINES FOR CONTRIBUTORS

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Author's declaration on the sources of funding of research presented in the scientific article or of the preparation of the scientif ic article.

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Following artificial text shows different types of in-text citation:

Claessens (2010) found evidence that attention will be given to multi-compartment models, such as the 3-water, 3-mineral and 4-compartment models, to assess percentage of body fat.

However, Raslanas, Petkus and Griškonis (2010) noted that Aerobic physical load of low intensity got 35.1 % of total trainings time. Research on physical loading also focused on identifying the basis of many years' research of physical activity (Bytniewski et al. 2010). According to Ezerskis (2010), "… heavy physical loads had the undulating character depending on the dynamics of workloads…" (p. 71) yet girls are more ascertained that the Track & Field training helps to develop courage.

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