South African Journal for Research in Sport, Physical Education and Recreation, 2018, 40(3): 73 - 88.
Suid-Afrikaanse Joernaal vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2018, 40(3): 73 - 88.
ISBN: 0379-9069

EVALUATING ACTIVITY OF DEEP STABILISING SYSTEM OF THE SPINE IN YOUNG ELITE ICE-HOCKEY PLAYERS

Jana PYSNA, Ladislav PYSNY, Dominika PETRU, Vaclav ENDAL
Pedagogical Faculty, Department of Physical Education and Sport, University of Usti nad Labem, Usti nad Labem, Czech Republic

ABSTRACT

Research focused on an assessment of the activity and reactivity of DSSS muscles in premier league ice hockey players from youth teams of the Czech hockey club in Karlovy Vary. DSSS examinations of 35 players were administered by using a series of tests of provoked postural activity according to Kolar. Results from the junior and younger adolescent categories were compared. Manifestations of postural stabilisation disorders, indicating DSSS function disorders in all players, were revealed. A pathological position of pelvis in anteversion was noted, as well as non-expansion of abdominal cavity and lower chest against palpation, cranial migration of ribs without lateral chest extension, concavity in the area of the inguinal canal and abdominal diastasis. When the groups of younger (mean age=14.5yrs) and older players (mean age=17.9yrs) were compared, the older players achieved inferior values for the monitored indicators, indicating an even more profound insufficiency of deep spine stabilisers with respect to the duration of hockey practice. The results indicate that repeated one-sided intensive training may have an unfavourable effect on the activity of deep spine muscles in ice hockey players. The strain experienced by players during training sessions and matches should be compensated through targeted and intentional activation.

Keywords: Low back pain; Deep stabilising system; Ice hockey; Injury; Training.

INTRODUCTION

According to Dwyer *et al*. (2013), Kiefer *et al*. (2017) and Farahbakhsh *et al*. (2018), the high strain on the motor system of ice hockey players during their training and competitions is reflected in rising rates of injuries, pain of the motor apparatus, development of muscle imbalances and of asymmetries (Liberman & Mulder, 2007; Dwyer *et al*., 2013; Hänninen *et al*., 2017; Kiefer *et al*., 2017; Krolowski *et al*., 2017; Trofa *et al*., 2017). These may be influenced by some functional disorders of the motor system (Clarsen *et al*., 2010; Myer *et al*., 2012; Hegedus *et al*., 2015; Choi *et al*., 2016). DSSS (Deep Stabilising Spine System) muscle function disorder is one such disorder.

DSSS represents muscle coordination that ensures stabilisation of the spine during all movements. DSSS muscles are activated upon any static strain and they accompany every targeted movement of the upper and lower extremities. The stabilising function of the muscles occurs without volitional action; it is automatic (Arjmand & Shiraziadl, 2012; Lim *et al*., 2016). Not one, but an entire chain of muscles is involved in the stabilisation process. The muscles are involved in all movements and are the source of considerable inner forces that act on the spine segment. These inner forces have the same importance for the load or excessive load on the segment as forces acting from the outside.

Muscle imbalance in the engagement of muscles while they provide their stabilising function is mainly concerned (Hodges *et al.*, 2005; Kobesova & Kolar, 2014). However, the problem is not merely about the insufficiency of muscle stabilisers. Excessive and one-sided activity of muscles that compensate this insufficiency is important for excessive loads, in particular. In the course of movement, individual segments are insufficiently fixated, or they are fixated in an inappropriate position. This results in considerable chronic overloading and insufficient muscle protection of individual spinal segments during movement, static strain and action of external forces (Kobesova & Kolar, 2014; Lim *et al*., 2016; Iverson & Luoto, 2017).

Intensification of hockey is a characteristic tendency of this sport, which places ever higher demands on the loading of players, and is associated especially with the development of speed, strength and skilfulness (Kokinda *et al*., 2012; Clifton *et al*., 2015; Kriz *et al*., 2016; Roczniok *et al*., 2016). According to some authors (Burr *et al*., 2008; Hegazi *et al*., 2009; Gonzalo-Skok *et al*., 2015; Legault *et al*., 2015), this ever increasing load is associated with the development and subsequent fixation of postural stereotype disorders. Consequently, unfavourable overloading of a player's motor apparatus develops, where the engagement of specific thoracic muscles is impaired in their responses to external stimuli occurring in the course of playing activities. The engagement of muscle stabilisation is thus absolutely necessary for the protection of the spine (Frank *et al.*, 2013).

For this reason, numerous authors (Panjabi, 2003; Tsai *et al*., 2006; Kolar *et al*., 2011; Kucera *et al*., 2011; Fullam *et al*., 2014; Müller *et al*., 2017) emphasise the proper function of deep muscles, which are especially important for the postural (stabilisation) function. From the clinical point of view, postural stabilisation is characterised as the ability of the human body to ensure the most economic possible holding of body segments where the tension in the superficial muscles is minimum and the joints are found in the so-called 'functionally centred' position, characterised by an optimum loading of joint surfaces and ligament structures (Kolar *et al*., 2011; Kobesova & Kolar, 2014).

Proper functioning of the diaphragm is crucial for faultless stabilisation, in coordination with abdominal muscles and pelvic floor muscles, which provide support to the lumbar spine by exerting intra-abdominal pressure (Frank *et al.*, 2013). Although the activation of these muscles is automatic, in a number of athletes it is controlled volitionally only to a limited extent and may become insufficient in a particular postural function (Kobesova & Kolar, 2014; Lim *et al*., 2016). If such changes occur, stereotypical overloading sets in, which is an important aetiopathogenetic factor in numerous motor disorders, most commonly manifested by vertebrogenic pain (Shamus & Shamus, 2001; Schmoelz *et al*., 2003; Tsai *et al*., 2006; Hegazi *et a*l., 2009; Kanosue *et al*., 2015).

Besides very limited volitional activation of the deep stabilising muscles, their attenuation and subsequent inhibition occur in connection with one-sided loading (Kobesova & Kolar, 2014; Lim *et al*., 2016). The activity of stabilising muscles is subsequently assumed by superficial muscles that cannot perform a stabilising function of good quality (Grossclaude *et al*., 2012; Belair *et al*., 2016). Besides vertebrogenic problems, ineffective engagement of DSSS leads to intervertebral disc herniations, blocks of individual spinal segments and other injuries (Bird & Stuart, 2012; Bukac & Studnicka, 2012). Also, for example, Kuhn *et al*. (2016)

found a disorder in the position of the hip joints as a consequence of deep stabiliser dysfunction in ice hockey players. Locomotion affected in this way may have a significantly unfavourable effect on the development of chronic pain in the lumbar spine, in the groin, in the knee, hip and tarsal joints, and also on the development of sports injuries (Schmoelz *et al*., 2003; Mitchell *et al*., 2008; Sung *et al*., 2009; Moazzaz & Wang, 2010; Shakeri *et al*., 2013; Murphy & Ierna, 2014; Karlsson & Doral, 2015).

As reported by some authors, lower back pain is a common problem in adolescent athletes and occurs in 10% to 15% of young athletes (De Luigi, 2014; Triki *et al*., 2015; Fett *et al*., 2017). The risk groups with a considerably higher incidence of back pain include specifically ice hockey players, and the rate of detected muscle imbalances and the consequent vertebrogenic problems has been rising (Schroeder *et al.*, 2014; Chen *et al*., 2017; Trompeter *et al*., 2017). These problems are the most common reason for exclusion from the training process, and in some athletes, including ice hockey players, the ever rising incidence rate is associated with the length of their professional career (Liberman & Mulder, 2007; McKeown *et al*., 2014; Cook & Hsu, 2016; Fett *et al*., 2017).

Premature specialisation in the training process is one of the aspects of the onset of health problems and injuries and has a negative impact on the development of the young body (Mann *et al*., 2013; Nessler, 2013; McCunn *et al*., 2016). In ice hockey, systematic training starts as early as six years old, and maximum specialisation of training to achieve particular motor abilities and skills, already occurs in the period of adolescence (Peric, 2006; Kucera *et al*., 2011). The consequences of this specialisation thus have unfavourable effects on the function of deep stabilisers and become an important 'disadvantage' for players in their further professional sports life (Moore *et al*., 2012; Tuominen *et al*., 2015; Meron *et al*., 2017).

Based on specialised studies (Sangwan *et al*., 2014, Lim *et al*., 2016) the insufficient stabilising function of muscles is assumed to result in an inadequate loading of joints and ligaments of the spine. Engagement disorders can be examined using a series of tests (Kolar *et al*., 2011). The tests do not assess muscle strength, as is the case of muscle tests; instead they assess the qualitative mode of their engagement. According to Kolar (2005), the coordination of ventral and dorsal muscles is considered to be important for spine stability. In the area of the cervical and thoracic spine, the coordination concerns deep extensors (*m. semispinalis capitis et cervicis*, *m. splenius capitis et cervicis* and *m. longissimus capitis et cervicis*) and deep flexors (*m. longus coli et capitis*). In the lumbar spine, the coordination involves the extensors of the lumbar and lower thoracic spine, the diaphragm, pelvic floor and abdominal muscles. Examinations of postural stabilisation and reactibility assess the postural muscle function using tests focused on the quality and mode of engagement and are able to assess muscle function during stabilisation (Kolar *et al*., 2011).

These examinations thus assess any deviation of the joint during stabilisation or maintenance of a neutral position, the extent to which deep and superficial muscles are involved in stabilisation, any excessive activation of muscles not mechanically related to the given movement during stabilisation (namely, how much the activity of stabilisation irradiates in other segments), the symmetry, or rather asymmetry, of engagement of the stabilising muscles, and the sequence (timing) of their engagement. The testing is able to identify insufficiencies in any muscles during stabilisation, and on the other hand, also any excessive engagement of muscles serving to compensate these insufficiencies. These tests are classified as 'passed' or 'failed'. Not only one muscle is involved in deep stabilisation. Stabilisation is accomplished through an interplay of muscles in the entire muscle chain. The assessment of the ability to control sagittal stabilisation of the spine is of considerable informative value and creates room for targeted therapy. Thus, it is assumed that if a disorder is found in postural stabilisation, this disorder can be expected to act as a factor leading to sports injuries, as documented by some studies (Frank *et al*., 2013, Kobesova *et al*., 2015).

PURPOSE OF RESEARCH

The purpose of the study is to ascertain the activity of deep stabilisers in young elite ice hockey players (younger adolescents and juniors). Their adequate function is an important precondition for the management of maximum sports strain with a reduced risk of the development of subsequent health problems, particularly injuries occurring due to insufficient muscular protection of individual spine segments during movement.

METHODOLOGY

Research design

The approval of the Ethics Committee No. 3.4. 2014 of J. E. Purkyne University in Usti nad Labem was obtained. The research involved a group of 35 elite ice hockey players. Before initiating the investigation, the hockey club management of HC Energie Karlovy Vary was contacted and informed consent acquired. The players were informed about the data collection methods. Essential somatic indicators, weight and height, were measured.

Through structured interviews, the basic information needed for the investigation was obtained. The interview included the following questions: How long have you been playing ice hockey? What is your date of birth? A series of tests that provoke postural activity, according to Kolar *et al*. (2011), was used in the clinical investigation to determine the activation of DSSS muscles. The results were assessed for the entire group first, and subsequently, the junior group and the younger adolescent group were compared, assuming the effect of the duration of ice hockey practice on the change in DSSS activity indicators.

Participants (14-20 years old) from on 24 January 2017

The research was conducted in January 2017 on elite ice hockey players consisting of younger adolescents aged 14-16 years and juniors aged 18-20 years from HC Karlovy Vary. The group included 35 players where the younger players had a mean age of 14.5 years and a mean ice hockey practice duration of 10.8 years, while the older players, with a mean age of 17.9 years, had a mean ice hockey practice duration of 14.2 years. All players started their careers at the same age. None of the players had had any serious injuries according to their medical history, and none suffered any injury during the research investigation that could have an impact on the results. The players undergo annual functional sports examinations focused on checking their health status and eligibility for playing performance.

Data collection methods

A Gallet PEP 801 calibrated scale, precision 0.1kg, was used to measure body weight and a calibrated portable Tanita HR stadiometer, precision 0.1cm, was used to measure height. The structured interview method was used to collect essential data (Hendl, 2005).

A clinical investigation commonly used in rehabilitation was used as the measurement technique to assess provoked postural activity, i.e. functional deficits and their impacts on the functional abilities of the players. As reported by Kolar *et al*. (2011), given that rehabilitation is primarily focused on function, objectivity is difficult in some cases. In this case, rehabilitation has to rely on clinical examination to a considerable extent. However, clinical examination does not always comply with standardisation criteria. The assessment of functional deficits significantly depends on the assessor's experience. Vorackova (2011) conducted a breakthrough pilot study focused on determining the reliability of inspection tests of postural stabilisation who confirmed the assessment significantly depends on the assessor's experience.

The complex evaluation of deviations in the stabilising muscular function was based on Kolar *et al*. (2011). Examinations of provoked postural activity using the thoracic extension test, thoracic flexion test and the diaphragm test were conducted. The following aspects were assessed:

- Joint deviation during stabilisation or maintenance of a neutral position;
- The rate of engagement of deep and superficial muscles in stabilisation;
- Excessive activation of muscles during stabilisation, not mechanically related to the given movement, namely the extent to which the stabilising activity spreads to other segments;
- Symmetry, or rather, asymmetry of the engagement of the stabilising muscles and the sequence (timing) of their engagement.

Measures

Thoracic extension test

Participants lie on their tummy during the test. Their arms are positioned along the body in the central position, or they are bent and supported by the hands. The patient raises his head above the mat and makes a movement to achieve mild extension of the spine where he stops the movement. When performed properly, the muscles of the lateral group of abdominal muscles are also activated in addition to the spinal extensors. The evaluated aspects include the balance of the spinal extensions, the lateral group of abdominal muscles, and the activity of the ischiocrural muscles. The pelvis should remain in the central position, it should not be tilted to anteversion, and the support should remain on the level of the symphysis.

Thoracic flexion test

Participants lie on their back. The participant is asked to perform slow flexion of the neck and gradually also of the trunk. When performed properly, abdominal muscles are uniformly activated during the flexion of the neck, and the chest remains in the caudal position.

Diaphragm test

This test is performed in the sitting position, with the spine straightened. The chest is in the expiration (caudal) position. The area under the lower ribs is palpated dorsolaterally and a slight pressure is exerted against the group of abdominal muscles. This activity also serves to check the position and behaviour of the lower ribs. The participant is then asked to exert counter pressure while breathing in, thereby extending the lower part of the chest. When performed properly, the patient perceptibly tries to push out the abdominal wall and the lower part of the chest against the direction of our palpation. The intercostal spaces become enlarged, and the lower part of the chest also becomes enlarged in the lateral and dorsal directions.

Additional co-indicators were identified and observed in two of the three tests in order to achieve a more precise assessment of activity and reactibility of the monitored stabilising muscles. The indicators *(E1–E4 and F1–F3)* were concerned in the thoracic extension and thoracic flexion tests. Specifically, for the thoracic extension test: *Engagement of the lateral* *wall of the abdominal muscles (E1), neutral position of the pelvis (E2), activity of paravertebral muscles (E3) and external rotation of the lower angles of the shoulder blades (E4).* For the thoracic flexion test: *Functionality of the chest (F1), activity of rectus abdominis (F2), engagement of the lateral side of the abdominal muscles (F3), and concavity in the area of the inguinal canals (F4).* In the diaphragmatic breathing test, we assessed *one indicator – the functionality of the diaphragm in the dorsal region of the lower costal arches (B1).*

As instructed by the tester, without any corrections or previous instructions, the participant performed repeated extensions of the chest while holding the position briefly while lying on the mat, followed by flexion of the chest while holding the position briefly while lying on their tummy, and finally followed by the diaphragmatic breathing test, when the participant breathed in while sitting on a stool, focusing the pressure into the lower costal arches. In the course of performing the movements, inspection and palpation was used to assess the activity of the deep stabilisers – individual indicators were assessed dichotomically. If any stabilisation disorder manifested and a co-indicator of the given test was not met, 'No' was checked and if stabilisation was achieved and the test indicator was met, 'Yes' was checked. The assessment criterion of the individual tests comprised of a positive evaluation of all individual indicators. Thus, if only a single co-indicator of a test was not met, the entire test was assessed as failed.

Statistical analysis

Microsoft Excel 2016 was used for the data analysis. The non-parametric Chi-square (χ^2) test with $p<0.05$ probability value was used to detect differences in DSSS activity between the study groups. Substantive significance was calculated using Cramer's Phi (Riffenburgh, 2012), which is assessed as follows: 0.10-0.29= low effect; 0.30-0.49= medium effect, 0.50= high effect. Percentage substantive significance was obtained by multiplying the calculated Phi value by 100. Where the result was below 10%, the studied difference was assessed as not practically significant according to Hendl (2005).

RESULTS

***Table 1*. DSSS ACTIVITY IN YOUNG ELITE ICE HOCKEY PLAYERS**

DSSS activity tests		**Passed** n	%	**Failed** n	%
Engagement of lateral abdominal muscles	(E1)	12	34.3	23	65.7
Neutral pelvic position	(E2)	2	5.7	33	94.3
Paravertebral muscle activity	(E3)	12	34.3	23	65.7
External rotation of inferior angles of scapula	(E4)	26	74.3	9	25.7
Chest functionality	(F1)	18	51.4	17	48.6
Activity of rectus abdominis	(F2)	3	8.6	32	91.4
Engagement of lateral abdominal muscles	(F3)	21	60.0	14	40.0
Concavity in the area of the inguinal canals	(F4)	2	5.7	33	94.3
Diaphragmatic functionality in dorsal lower ribs	(B1)	2	5.7	33	94.3

Sample: n=35

The results of the investigation on 35 young elite ice hockey players, based on the assessment of provoked postural activity, are presented in Tables 1–3. The overall assessment of individual indicators of the provoked postural stability test showed manifestations of stabilisation disorders in every test. The following indicators failed in the thoracic extension test: E2 (33 players), E1 and E3 (23 players) and E4 (9 players). The thoracic flexion test was not successful in: F4 (33 players), F2 (32 players), F1 (17 players) and F3 (14 players). The B1 indicator of the diaphragm test was unsuccessful for 33 players (Table 1).

Table. 2 **DSSS ACTIVITY IN GROUPS OF YOUNGER AND OLDER PLAYERS**

	Younger players				**Older players**			
	Passed		Failed		Passed		Failed	
DSSS activity tests	n	%	n	%	n	%	n	%
Engagement of lateral abdominal muscles (E1)	9	45	11	55	3	20	12	80
Neutral pelvic position (E2)	2	10	18	90	0	0	15	100
Paravertebral muscle activity (E3)	10	50	10	50	2	13	13	87
External rotation of inferior angles of scapula (E4)	16	80	4	20	10	67	5	33
Chest functionality (F1)	13	65	7	35	5	33	10	67
Activity of rectus abdominis (F2)	3	15	17	85	0	0	15	100
Engagement of lateral abdominal muscles (F3)	14	70	6	30	7	47	8	53
Concavity of the inguinal canals (F4)	1	5	19	95	1	7	14	93
Diaphragmatic functionality in the dorsal lower ribs (B1)	2	10	18	90	0	0	15	100

Younger players: n=20 Older players: n=15

Comparing the groups of younger and older players, there was a higher incidence of stabilisation disorder manifestations in the thoracic extension and flexion tests in the older players, specifically, in six of nine indicators. In the thoracic extension test, E1 was failed by 55% of younger players (YP) and by 80% of older players (OP); E2 by 90% of YP and 100% of OP; E3 by 50% of YP and 87% of O; and E4 by 20% of YP and 33% of OP. In the thoracic flexion test, F1 was failed by 35% of YP and 67% of OP; F2 by 85% of YP and 100% of OP; F3 by 30% of YP and 53% of OP; and F4 by 95% of YP and 93% of OP. In the diaphragm test, 90% of YP and 100% OP failed (Table 2).

The results presented in Table 3 do not indicate any statistically significant differences. Substantive significant differences in values with a low effect were found for E1, E2, E3 and E4 indicators in the thoracic extension test, for F1, F2 and F3 indicators in the thoracic flexion test, and for B1 indicator of the diaphragm test.

Table 3**. DSSS ACTIVITY: DIFFERENCE BETWEEN YOUNGER AND OLDER GROUPS**

DSSS activity tests	**χ^2 Value**	**p-Value**	**Cramer's coefficient**	**Substantive significance**
Engagement of lateral abdominal muscles (E1)	2.38	0.12	0.26	#
Neutral pelvic position (E2)	1.59	0.21	0.21	#
Paravertebral muscle activity (E3)	5.11	0.02*	0.38	#
External rotation of inferior angles of scapula (E4)	0.80	0.37	0.15	#
Chest functionality (F1)	3.44	0.06	0.31	#
Activity of rectus abdominis (F2)	2.46	0.12	0.27	#
Engagement of lateral abdominal muscles (F3)	1.94	0.16	0.24	#
Concavity in the area of the inguinal canals (F4)	0.04	0.83	0.04	–
Diaphragmatic functionality in the dorsal lower ribs (B1)	1.59	0.21	0.21	#

*$p<0.05$ Critical χ^2-value=3.84 # =small effect of substantive significance of value differences

DISCUSSION

This research found a lack of success in individual tests, revealing DSSS insufficiency. There is agreement with the opinion of Kolar *et al*. (2011) and Kobesova *et al*. (2015) who mention that although a muscle achieves maximum values while performing its anatomic function, the engagement of the same muscle in a particular postural stabilising function may be quite insufficient. The wrong muscle engagement in stabilisation is automatically and inadvertently fixated by the given individual in all performed exercises and movements. This causes excessive loading of the motor apparatus structures, which is the cause of the development of numerous motor disorders and injuries. This problem can be observed in ice hockey players whose muscles are well developed, but who fail to show physiological engagement of muscles in specific stabilising functions (Peroutka, 2012; Belavy *et al*., 2016; Meron *et al*., 2017).

The most important manifestations of postural stabilisation determined in this study include pelvic tilting into anteversion (E2) where the support was shifted to the level of the umbilicus, the abdominal cavity and the lower part of the chest failed to be pushed out against the direction of palpation, cranial migration of the ribs without lateral expansion of the chest (B1), together with the concavity in the area of the inguinal canals (F4) and bulging of the lateral group of abdominal muscles with the manifestation of abdominal diastasis (F2). The findings agree with those of other studies where insufficient activity of deep stabilisers was found (Kolar *et al*., 2011; Kucera *et al*., 2011; Sitthipornvorakul *et al*., 2011; Gescheit *et al.*, 2017; Noll *et al*., 2017; Ondra *et al.*, 2017).

The thoracic extension test (E2) revealed postural instability of the lumbosacral segment, manifested by pelvic movement into anteversion in 94% of the participants. As reported by Panjabi (2003), McGill (2010) and McGill (2015), this result indicates that muscles that should reinforce this segment are weakened or their stereotype has learned in the wrong way. It should be realised that this postural instability is not limited only to the lumbosacral segment, but that it also has an important effect on muscle coordination in the upper and lower extremities.

The diaphragmatic respiration test (B1) was a no less important indicator. This indicator was met by only two players in the entire group. This indicator represents an inability to control the activation of the diaphragm together with the lateral group of abdominal muscles, where the lower part of the lumbar spine is excessively loaded due to insufficient anterior stabilisation of the spine and excessive activity of paravertebral muscles. In the phase of inspiration, the diaphragm works in the concentric mode and abdominal muscles in the eccentric mode, while in the phase of expiration the situation is inverted. This maintains the intra-abdominal pressure, and therefore also the dynamic support of the lumbar spine from the ventral side is maintained (Rychnovsky & Pivec, 2009). According to Doubkova *et al*. (2018) and Obstová (2014), disorders of the function of the abdominal press, which ensures anterior stabilisation of the spine, are one of the most common aetiopathogenetic causes of backache and have morphological consequences particularly in the lower segments of the lumbar spine.

These results are closely related and correspond to the thoracic flexion test results (F2), indicating bulging of the lateral group of abdominal muscles with manifestations of abdominal diastasis in 91% of the ice hockey players. The results of this indicator are also confirmed by the studies of Kolar *et al*. (2011) and Fett *et al*. (2017). Abdominal diastasis has a similar effect on the spine as a relaxed abdominal wall, which bulges outwards upon increased intra-abdominal pressure and thus fails to provide proper support for the spine (Doubkova *et al*., 2018). As reported by Mohseni-Bandpei *et al*. (2011) and Benjamin *et al*. (2014), when diastasis is found in a relaxed abdominal wall, the overall rate of instability becomes even greater and the effect on the spine is even worse.

Proper stabilisation of the trunk provides a fixed point (punctum fixum) for the movements of the extremities. When the stabilising system is insufficient, individual parts of it are poorly or insufficiently fixed. This results in an inadequate loading of the supportive structures (joints, ligaments), and if this condition lasts for a prolonged period of time, it results in chronic overloading, both in connection with static strain and in movement (Kolar *et al*., 2011; Safarova & Kolar, 2011).

Similarly to the reports in the studies of Rychnovsky and Pivec (2009) and Kolar *et al*. (2012), the concurrent presence of an unsuitable way of breathing, indicated also by the current results of the diaphragm test, may have an adverse effect not only on the corresponding position of the chest, but probably also on the ventilation skills during playing activities, where the non-physiological position of the spine complicates the respiratory mechanisms. In addition, poor inspiration and expiration cause negative stimulation of the deep muscles along the spine, chest, back and abdominal cavity.

Results from the thoracic flexion test (F4) showed yet another unfavourable finding. In this test, the concavity in the area of the inguinal canals was tested and the test was passed by only 2 of the 35 players. According to Bartlett and Bussey (2012) and Karlsson *et al*. (2013), the concavity of the inguinal canals is associated with inguinal injuries – one of the most common reasons why players are excluded from training or a match. Various causes of the groin pain syndrome exist and the aetiology is multifactorial (Niebuhr *et al*., 2018). As reported by Kolar *et al*. (2011) and Mosler *et al*. (2015), pain in the soft groin is caused most commonly by chronic enthesopathy of adductors developing due to an insufficient function of the diaphragm, pelvic floor and deep abdominal muscles (Doubkova *et al*., 2018). According to Bartlett and Bussey (2012), it occurs in 11% of all hockey-related injuries in professional ice hockey players. The current results indicate changes assessed by Kolar *et al*. (2011) as the wrong engagement of muscles in stabilisation. Although a muscle achieves its maximum values while performing its anatomic function, its engagement in a particular postural stabilising function is insufficient.

Poorer results from the assessments of individual tests were found after comparing the study groups. The group of older players showed poorer results in 8 out of 9 test indicators. These results indicate a postural stabilisation disorder, and an even higher insufficiency of DSSS activity with respect to the duration of ice hockey practice, which is also confirmed by the studies Mikkelsson *et al*. (2006), Peric (2006), Kucera *et al*. (2011), Peroutka (2012), Conley *et al*. (2014), Headlee *et al*. (2014) and Meron *et al*. (2017).

The greatest differences in the incidence of stabilisation disorder manifestations were found for *E3* and *E1* indicators in the thoracic extension test and *F1* indicator in the thoracic flexion test. These indicators represent considerable activation of paravertebral muscles with the maximum value in the area of the lower thoracic and upper lumbar spine *(E3)* and with minimum or no activation of the lateral group of abdominal muscles, especially in their lower part, with pulling in (concavity) of *m. transversus abdominis* at the site of the thin aponeurosis *(E1)*. With the flexion of the head, cranial synkinesis of the chest and clavicles occurred, and the chest entered the position of inspiration *(F1)*. The adverse results of the group of older players indicate a further increase of the incidence rate of DSSS insufficiency in connection with duration of ice hockey practice. This brings an additional and even higher risk of developing health problems, especially in connection with premature specialisation in the training process (Peric, 2006; Kucera *et al*., 2011; Tuominen *et al*., 2014; Meron *et al*., 2017).

According to Kolar *et al*. (2011), Obstová (2014) and Perich *et al*. (2014), training without targeted involvement of DSSS usually results only in strengthening of superficial muscles. Generally, exercises focused on the strengthening of superficial muscles result in predominant activation and hyperactivity of global stabilisers to the detriment of local stabilisers, which, according to Suchomel (2006), leads to DSSS insufficiency. The gradual excessive loading of the muscle system then has adverse consequences for the ligament and bone apparatus, associated especially with the development of sports micro traumas (Grossclaude *et al*., 2012; Hänninen *et al*., 2017; Rempel *et al*., 2017).

CONCLUSION

In the overall assessment of the activity of the deep stabilisation system of the spine based on the series of tests of provoked postural stability, according to Kolar *et al*. (2011), it was found that there was a high failure rate of individual tests in the players. In particular, the following disorders of postural stabilisation were revealed by the assessment of individual indicators: pelvic tilting into anteversion, cranial migration of the ribs without lateral expansion of the chest upon activation, the concavity of the inguinal canals with an inverse function of the diaphragm, and bulging of the lateral group of abdominal muscles with manifestations of abdominal diastasis.

Comparing the groups of older and younger players, a worsening of the indicators in connection with the duration of ice hockey practice in the older players was noted. Players with a shorter ice hockey experience (younger adolescents) were more successful in 8 out of 9 tests than the group of juniors. The greatest differences in the incidence rate of postural stabilisation disorders can be understood as including considerable activation of paravertebral muscles with the maximum value in the area of the lower thoracic and upper lumbar spine. However, there was minimum or no activation of the lateral group of abdominal muscles, namely in their lower part, with pulling in (concavity) of *m. transversus abdominis* at the site of the thin aponeurosis, cranial synkinesis of the chest, but also the clavicles and the chest in the position of inspiration.

The results of this investigation indicated an insufficiently active deep stabilising system of the spine in ice hockey players. This result in excessive loading, especially of superficial muscles, very often are associated with injuries and increased pain in the motor apparatus. Adequate activity of the deep stabilisers in ice hockey players is an important precondition for the management of maximum sports load with a reduced risk of subsequent health problems, especially injuries occurring due to insufficient muscular protection of individual spinal segments during movement.

It is, therefore, very important to emphasise the adequate performance of compensatory and activating exercises focused on the intentional activation of the DSSS in the training process, where the specialisation gradually increases (especially at a young age). This will result in a good quality of muscle coordination in the given area, ensuring stabilisation of the spine, pelvis and trunk as a fundamental frame for the movement of the limbs, for improving the health status of the players and for minimising the rate of injuries. At the same time, it is recommended to expand the study group and encourage further research investigation of these issues.

REFERENCES

ARJMAND, N. & SHIRAZIADL, A. (2012). Role of intra-abdominal pressure in the unloading and stabilization of the human spine during static lifting tasks. *European Spine Journal*, 15(8):1265-1275.

BARTLETT, R. & BUSSEY, M. (2012). *Sports biomechanics: Reducing injury risk and improving sports performance* (2nd ed.). New York, NY: E and FN Spon.

BELAIR, J.A.; HEGAZI, T.M.; ROEDL, J.B.; ZOGA, A.C. & OMAR, I.M. (2016). Core injuries remote from the pubic symphysis. *Radiologic Clinics of North America*, 54(5): 893-911.

BELAVY, D.L.; ALBRACHT, K.; BRUGGEMANN, G.P.; VERGROESEN, P.P.A. & VAN DIEÄN, J.H. (2016). Can exercise positively influence the intervertebral disc? *Sports Medicine*, 46(4): 473-85.

BENJAMIN, D.R.; VAN DER WATER, A.T. & PEIRIS, C.L. (2014). Effects of exercise on diastasis of the rectus abdominis muscle in the antenatal and postnatal periods: A systematic review. *Physiotherapy*, 100(1): 1-8.

BIRD, S.P. & STUART, W. (2012). Integrating balance and postural stability exercises into the functional warm up for youth athletes. *Journal of Strength and Conditioning Research*, 34(1): 73-79.

BUKAC, L. & STUDNICKA, P. (2012). *Dlouhodoby trenink mladeze* (trans.: *The long youth training*) (1st ed.). Praha, Czech Republic: Cesky svaz ledniho hokeje (*trans*.: Czech Ice Hockey Association).

BURR, J.F.; JAMNIK, R.; BAKER, J. MACPHERSON, A.; GLEDHILL, N. & MCGUIRE, E.J. (2008). Relationship of physical fitness test results and hockey playing potential in elite-level ice hockey players. *Journal of Strength and Conditioning Research*, 22(5): 1535-1543.

CHEN, C-H.; YANG, Y.H.; CHEN, P.Y.; YANG, T.J.; CHEN, C.P.C.; CHEN, CH.J.; LU, M.L.; LEE, Y.; MCINTYRE, R.S. & HUANG, Y.C. (2017). Factors affecting lumbar surgery outcome: A nation-wide, population-based retrospective study. *Journal of Affective Disorders*, 22(2): 98-102.

CHOI, H.R.; ELATTAR, O.; DILLS, V.D. & BUSCONI, B. (2016). Return to play after sports hernia surgery. *Clinics in Sports Medicine*, 35(4): 621-636.

CLARSEN, B.; KROSSHAUG, T. & BAHR, R. (2010). Overuse injuries in professional road cyclists. *The American Journal of Sports Medicine*, 38(12): 2494-2501.

CLIFTON, D.R.; GROOMS, D.R. & ONATE, J.A. (2015). Overhead deep squat performance predicts Functional Movement Screen™ score. *International Journal of Sports Physical Therapy*, 10(5): 622-627.

CONLEY, K.M.; BOLIN, D.J.; CAREK, P.J.; NEAL, T.L. & VIOLETTE, D. (2014). National athletic trainers' association position statement: Preparticipation physical examinations and disqualifying conditions. *Journal of Athletic Training*, 49(1): 102-120.

COOK, R.W. & HSU, W.K. (2016). Return to play after lumbar spine surgery. *Clinics in Sports Medicine*, 35(4): 609-619.

DE LUIGI, A.J. (2014). Low back pain in the adolescent athlete. *Physical Medicine and Rehabilitation Clinics of North America*, 25(4): 763-788.

DOUBKOVA, A.; ANDEL, R.; PALASCAKOVA-SPRINGROVA, I.; KOLAR, P. & KOBESOVA, A. (2018). Diastasis of rectus abdominis muscles in low back pain patients. *Journal of Back and Musculoskeletal Rehabilitation*, 31(1): 107-112.

DWYER, T.; PETRERA, M.; BLEAKNEY, R. & THEODOROPOULOS, J.S. (2013). Shoulder instability in ice hockey players: Incidence, mechanism, and MRI findings. *Clinics in Sports Medicine*, 32(4): 803-813.

FARAHBAKHSH, F.; AKBARI-FAKHRABADI, M.; SHARIAT, A.; CLELAND, J.A.; FARAHBAKHSH, F.; SEIF-BARGHI, T.; MANSOURNIA, M.A.; ROSTAMI, M. & KORDI, R. (2018). Neck pain and low back pain in relation to functional disability in different sport activities. *Journal of Exercise Rehabilitation*, 14(3): 509-515.

FETT, D.; TROMPETER, K. & PLATEN, P. (2017). Back pain in elite sports: A cross-sectional study on 1114 athletes. *PLoS One*, 12(6): 1130-1135.

FRANK, C.; KOBESOVA, A. & KOLAR, P. (2013). Dynamic neuromuscular stabilization and sports rehabilitation. *International Journal of Sports Physical Therapy*, 8(1): 62-73.

FULLAM, K.; CAULFIELD, B.; COUGHLAN, G.F. & DELAHUNT, T. (2014). Kinematic analysis of selected reach directions of the Star Excursion Balance Test compared with the Y-Balance Test. *Journal of Sport Rehabilitation*, 23(1): 27-35.

GESCHEIT, D.T.; CORMACK, S.J.; DUFFIELD, R.; KOVALCHIK, S.; WOOD, T.O.; OMIZZOLO, M. & REID, M. (2017). Injury epidemiology of tennis players at the 2011-2016 Australian Open Grand Slam. *British Journal of Sports Medicine*, 51(17): 1289-1294.

GONZALO-SKOK, O.; SERNA, J.; RHEA, M.R. & MARIN, P.J. (2015). Relationships between functional movement tests and performance tests in young elite male basketball players. *International Journal of Sports Physical Therapy*, 10(5): 628-638.

GROSSCLAUDE, M.; NAJIHI, N.; LÄDERMANN, A.; MENETREY, J. & ZILTENER, J.L. (2012). Teres major muscle tear in two proffesional ice hockey players: Cases study and literature review. *Orthopaedics and Traumatology: Surgery and Research*, 98(1): 116-128.

HÄNNINEN, T.; PARKKARI, J.; TUOMINEN, M.; OHMAN, J.; HOWELL, D.R.; HAWKER, G.A; MIAN, S.; KENDZERSKA, T. & FRENCH, M. (2011). Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). *Arthritis Care and Research,* 63(11): 240-252.

HEADLEE, D.; NORD, W. & HUNTINGTON, M.K. (2014). Preparticipation physical evaluations in youth sports: A systematic review of current recommendations. *South Dakota Medicine*, 67(7): 273-277.

HEGAZI, T.M.; BALAIR, J.A.; McCARTHY, E.J.; ROEDL, J.B. & MORRISON, W.B. (2009). Sports injuries about the hip: What the radiologist should know. *Radiographics*, 36(6): 1717-1745.

HEGEDUS, E.J.; MCDONOUGH, S.M.; BLEAKLEY, C.; COOK, C.E. & BAXTER, G.D. (2015). Clinician-friendly lower extremity physical performance tests in athletes: A systematic review of measurement properties and correlation with injury. Part 2 – The tests for the hip, thigh, foot and ankle including the star excursion balance test. *British Journal of Sports Medicine*, 49(10): 649-656.

HENDL, J. (2005). *Kvalitativni vyzkum: Zakladni metody a aplikace* (trans.: *Qualitative research: Basic methods and applications*) (2nd ed.). Praha, Czech Republic: Grada.

HODGES, P.W.; ERIKSSON, A.E.; SHIRLEY, D. & GANDEVIA, S.C. (2005). Intra-abdominal pressure increases stiffness of the lumbar spine. *Journal of Biomechanics*, 38(9):1873-1880.

IVERSON, G.L. & LUOTO, T.M. (2017). Sport concussion assessment tool: interpreting day-of-injury scores in professional ice hockey players. *Journal of Science and Medicine in Sport*, 17(3): 1824-1828.

KANOSUE, K.; OGAWA, T.; FUKANO, M. & FUKUBAYASHI, T. (2015). ***Sports injuries and prevention*** (1st ed.). Berlin-Heidelberg, Germany: Springer-Verlag.

KARLSSON, J. & DORAL, M. (2015). *Sports injuries: Prevention, diagnosis, treatment and rehabilitation* (1st ed.). Berlin-Heidelberg, Germany: Springer-Verlag.

KARLSSON, M.K.; MAGNUSSON, H.; SCHEWELOV, T. & ROSENGREN, B.E. (2013). Prevention of falls in the elderly. A review. *Osteoporosis International*, 24(3): 747-762.

KIEFER, A.W.; DICESARE, C.; NALEPKA, P.; FOSS, K.B.; THOMAS, S. & MYER, G.D. (2017). Less efficient oculomotor performance is associated with increased incidence of head impacts in high school ice hockey. *Journal of Science and Medicine in Sport*, 21(1): 4-9.

KOBESOVA, A. & KOLAR, P. (2014). Developmental kinesiology: Three levels of motor control in the assessment and treatment of the motor system. *Journal of Bodywork and Movement Therapies,* 18(1): 23-33.

KOBESOVA, A.; DZVONIK, J.; KOLAR, P.; SARDINA, A. & ANDEL, R. (2015). Effects of shoulder girdle dynamic stabilization exercise on hand muscle strength. *Isokinetics and Exercise Science*, 23(8): 21-32.

KOKINDA, M.; KANDRAC, R. & TUREK, M. (2012). The construction of the factor model for fitness assessment in ice hockey players. *Baltic Journal of Health and Physical Activity*, 4(1): 21-26.

KOLAR, P.; BITTNAR, P.; DYRHONOVA, O.; HORACEK, O. & KRIZ, J. (2011). *Rehabilitace v klinicke praxi* (trans.: *Rehabilitation in Clinical Practice*) (2nd ed.). Praha, Czech Republic: Galen.

KOLAR, P.; SULC, J.; KYNCL, M.; SANDA, J.; CAKRT, O.; ANDEL, R.; KUMAGAI, K. & KOBESOVA, A. (2012). Postural function of the diaphragm in persons with and without chronic low back pain. *Journal of Orthopaedic and Sports Physical Therapy*, 42(4): 352-362.

KRIZ, K.; STEIN, C.; KENT, J.; RUGGIERI, D.; DONALD, E.; O´BRIEN, M. & MEEHAN, W.P. (2016). Physical maturity and concussion symptom duration among adolescent ice hockey players. *Journal of Pediatrics*, 17(1): 234-239.

KROLOWSKI, M.P.; BLACK, A.M.; PALACIOS-DERFLINGHER, P.L.; BLAKE, T.A.; SCHNEIDER, K.L. & EMERY, C.A. (2017). The effect of the "zero tolerance for head contact" rule change on the risk of concussions in youth ice hockey players. *American Journal of Sports Medicine*, 45(2): 468-473.

KUCERA, M.; KOLAR, P. & DYLEVSKY, I. (2011). *Dite, sport a zdravi* (trans.: *Child, sport and health*) (1st ed.). Praha, Czech Republic: Galen.

KUHN, A.W.; NOONAN, M.D.; KELLY, D.B.; LARSON, CH.M. & BEDI, A. (2016). The hip in ice hockey: A currents concepts review. *Journal of Arthroscopic and Related Surgery*, 32(9): 1928-1938.

LEGAULT, E.P.; DESCARREAUX, M. & CANTIN, V. (2015). Musculoskeletal symptoms in an adolescent athlete population: A comparative study. *BMC Musculoskeletal Disorders*, 16(1): 1-9.

LIBERMAN, M. & MULDER, D.S. (2007). Airway injuries in the professional ice hockey player. *Clinical Journal of Sport Medicine,* 17(1): 61-67. Singapore:

LIM, Y.L.; LEPSIKOVA, M. & SINGH, K.A. (2016). Effects of dynamic neuromuscular stabilization on lumbar flexion kinematics and posture among adults with chronic non-specific low back pain: A study protocol. In Nor Azizah Yacob, Nur Asmaliza Mohd Noor, Nor Yuziah Mohd Yunus, Rahmah Lob Yussof, Shaikh Abdul Karim Yamani Zakaria (Eds.), *Regional Conference on Science, Technology and Social Sciences (RCSTSS 2016): Theoretical and Applied Sciences* (pp. 715-724) [Conference proceedings]. Singapore: Springer.

MANN, K.; EDWARDS, S.; DRINKWATER, E.J. & BIRD, S.P. (2013). A lower limb assessment tool for athletes at risk of developing patellar tendinopathy. *Medicine and Science in Sports and Exercise*, 45(3): 527-533.

MCCUNN, R.; AUSDERFÜNTEN, K.; FULLAGAR, H.H.K., MCKEOWN, I. & MEYER, T. (2016). Reliability and association with injury of movement screens: A critical review. *Sports Medicine*, 46(6): 763-781.

MCGILL, S. (2010). Training: Evidence translating to better performance and injury prevention. *Strength and Conditioning Journal*, 32(3): 33-46.

MCGILL, S. (2015). *Low back disorders: Evidence-based prevention and rehabilitation* (3rd ed.). Ontario, Canada: Human Kinetics.

MCKEOWN, I.; TAYLOR-MCKEOWN, K.; WOODS, C. & BALL, N. (2014). Athletic ability assessment: A movement assessment protocol for athletes. *International Journal of Sports Physical Therapy*, 9(7): 862-873.

MERON, A.; MCMULLEN, C.H.; LAKER, S.R.; CURRIE, D. & COMSTOCK, D. (2017). Epidemiology of cervical spine injuries in high school athletes over a ten-year period. *Physical Medicine and Rehabilitation*, 10(4): 365-372.

MIKKELSSON, L.O.; NUPPONEN, H.; KAPRIO, J.; KAUTIAINEN, H.; MIKKELSSON, M. & KUJALA, U.M. (2006). Adolescent flexibility, endurance strength, and physical activity as predictors of adult tension neck, low back pain, and knee injury: A 25 year follow-up study. *British Journal of Sports Medicine*, 40(2): 107-113.

MITCHELL, T.; O'SULLIVAN, P.B.; BURNETT, A.F.; STRAKER, L. & SMITH, A. (2008). Regional differences in lumbar spinal posture and the influence of low back pain. *BMC Musculoskeletal Disorders*, 18(9): 152-159.

MOAZZAZ, P. & WANG, J.C. (2010). Lumbar disk herniation and degenerative disc disease in athletes. *Seminar in Spine Surgery*, 22(4): 206-209.

MOHSENI-BANDPEI, M.A. RAHMANI, N.; BEHTASH, H. & KARIMLOO, M. (2011). The effect of pelvic floor muscle exercise on women with chronic non-specific low back pain. *Journal of Bodywork and Movement Therapies*, 15(1): 75-81.

MOORE, N.R.; KERTESZ, A.H.M. & BIRD, S.P. (2012). A modified movement screen for pre-elite youth athletes. *Journal of Australian Strength and Conditioning*, 20(1): 44-53.

MOSLER, A.B.; AGRICOLA, R.; WEIR, A.; HÖLMICH, P. & CROSSLEY, K. (2015). Which factors differentiate athletes with hip/groin pain from those without? A systematic review with meta-analysis. *British Journal of Sports Medicine*, 49(12): 775-781.

MÜLLER, J.; MÜLLER, S.; STOLL, J.; FRÖHLICH, K.; OTTO, C. & MAYER, F. (2017). Back pain prevalence in adolescent athletes. *Scandinavian Journal of Medicine Science and Sport*, 27(4): 448-454.

MURPHY, R.D. & IERNA, F.G. (2014). *Cervical spinal stabilization exercises* (2nd ed.). New York: McGraw Hill Medical.

MYER, G.D.; FORD, K.R.; BRENT, J.L.; HEWETT, E.T. (2012). An integrated approach to change the outcome Part I: Neuromuscular screening methods to identify high ACL injury risk athletes. *Journal of Strength and Conditioning Research*, 26(8): 2265-2271.

NESSLER, T. (2013). Using movement assessment to improve performance and reduce injury risk. *International Journal of Athletic Therapy and Training*, 18(1): 8-12.

NIEBUHR, H.; WEGNER, F.; HUKAUF, M.; LECHNER, M.; FORTELNY, R.; BITTNER, R.; SCHUG-PASS, C. & KÖCKERLING, F. (2018). What are the influencing factors for chronic pain following TAPP inguinal hernia repair: An analysis of 20,004 patients from the Herniamed Registry. *Surgical Endoscopy*, 32(4): 1971-1983.

NOLL, M.; SILVEIRA, E.A. & AVELAR, I.S. (2017). Evaluation of factors associated with severe and frequent back pain in high school athletes. *PLoS One*, 12(2): 107-113.

OBSTOVÁ, L. (2014). *Vyuziti aktivace hlubokeho stabilizacniho systemu v prevenci urazu u hokejistu* (trans.: *Use activation of the deep stabilization system to prevent dangerous hockey*) (1st ed.). Ceske Budejovice, Czech Republic: Jihoceska Univerzita.

ONDRA, L.; NATESTA, P.; BIZOVSKA, L.; KUBONOVA, E. & SVOBODA, Z. (2017). Effect of in-season neuromuscular and proprioceptive training on postural stability in male youth basketball players. *Acta Gymnica*, 47(3): 144-149.

PANJABI, M.M. (2003). Clinical spinal instability and low back pain. *Journal of Electromyography and Kinesiology*, 13(4): 371-379.

PERIC, T. (2006). *Vyber sportovnich talentu* (trans.: *Selection of sport talent*) (1st ed.). Praha, Czech Republic: Grada.

PERICH, D.; BURNETT, A.; CAMPBELL, A. & O'SULLIVAN, P. (2014). Self-reported prevalence, pain intensity and risk factors of low back pain in adolescent rowers. *Journal of Science in Medicine and Sport*, 17(3): 266-270.

PEROUTKA, M. (2012). Vliv ledniho hokeje na pohybovy aparat hrace (*trans*.: Influence of ice hockey on the movement apparatus of the player). *Medicina Sportiva Bohemica et Slovaca* (trans.: *Sports Medicine Bohemica et Slovaca*), 21(1): 21-22.

REMPEL, J.; BUSSE, J.W.; DREW, B.; REDDY, K.; CENIC, A.; KACHUR, E.; MURTY, N.; CANDELARIA, H.; MOORE, A.E. & RIVA, J.J. (2017). Patients' attitudes toward non physician screening of low back and low back related leg pain complaints referred for surgical assessment. *Spine*, 42(5): 288-293.

RIFFENBURGH, R. (2012). *Statistics in medicine* (3rd ed.). Salt Lake City, UT: Academic Press.

ROCZNIOK, R.; ARKADIUSZ, S.; GABRYS, T.; GABRYS, S.U.; GOLAS, A. & STASTNY, P. (2016). Physical fitness and performance of polish ice-hockey players competing at different sports levels. *Journal of Human Kinetics*, 51(1): 201-208.

RYCHNOVSKY, T. & PIVEC, M. (2009). Vyska a funkce branice zavisi na pohybu hrudniku pri dychani (*trans*.: Height and diaphragm function depends on the chest movement during respiration). *Medicina Sportiva Bohemica et Slovaca*, 18(2): 58-66.

SAFAROVA, M. & KOLAR, P. (2011). Posturalni stabilizace a sportovni zatez (*trans*.: Postural stabilization and sporting activity). In M. Macek & J. Radvansky (Eds.), *Fyziologie a klinicke aspekty pohybové aktivity* (trans.: *Physiological and clinical aspects of physical activity*) (1st ed.) (pp. 177-188). Praha, Czech Republic: Galen.

SANGWAN, S.; GREEN, R.A. & TAYLOR, N.F. (2014). Characteristics of stabilizer muscles: A systematic review. *Physiotherapy Canada*, 66(4): 348-358.

SCHMOELZ, W.; HUBER, L.; NYDEGGER, T.; CLAES, L. & WILKE, H.J. (2003). Dynamic stabilization of the lumbar spine and its effects on adjacent segments: An in vitro experiment. *Journal of Spinal Disorders and Techniques*, 16(4): 418-423.

SCHROEDER, D.; MENDOZA, M.; DALEY, E.; LA BELLA, C.; SAVAGE, J.S. & PLATEL, A. (2014). The role of athletic activity on structural lumbar abnormalities in adolescent patients with symptomatic low back pain. *Spine Journal*, 14(11): 139-140.

SHAKERI, H.; FATHOLLAHI, Z.; KARIMI, N. & ARAB, A.M. (2013). Effect of functional lumbar stabilization exercises on pain, disability, and kinesiophobia in women with menstrual low back pain: A preliminary trial. *Journal of Chiropractic Medicine*, 12(3): 160-167.

SHAMUS, E. & SHAMUS, J. (2001*). Sports injury prevention and rehabilitation* (1st ed.). New York, NY: McGraw Hill Medical.

SITTHIPORNVORAKUL, E.; JANWANTANAKUL, P.; PUREPONG, N.; PENSRI, P.; VAN DER BEEK, A.J. & ALLARD, J. (2011). The association between physical activity and neck and low back pain: A systematic review. *European Spine Journal*, 20(5): 677-689.

SUCHOMEL, T. (2006). Stabilita v pohybovem systemu a hluboky stabilizacni system – podstata a klinicka vychodiska (*trans*.: Stability in motion system and deep stabilization system: Nature and Exit Clinic). *Rehabilitace a fyzikalni lekarstvi* (trans.: *Rehabilitation and physical medicine*), 13(3): 112-125.

SUNG, U.K.; YERUN, Z.; JUN, L.; TSAI, K.J. & YOON, S.T. (2009). A comparison of three cell types as potential candidates for intervertebral disc therapy: Anulus fibrosus cells, chondrocytes and bone marrow derived cells. *Joint Bone Spine*, 76(1): 70-74.

TRIKI, M.; KOUBAA, A.; MASMOUDI, L.; FELLMANN, N. & TABKA, Z. (2015). Prevalence and risk factors of low back pain among undergraduate students of a sports and physical education institute in Tunisia. *Libyan Journal of Medicine*, 10(1): 268-272.

TROFA, D.P.; PARK, C.N.; NOTICEWALA, M.S.; LYNCH, T.S.; AHMAD, C.S. & POPKIN, C.A. (2017). The impact of body checking on youth ice hockey injuries. *Orthopaedic Journal of Sports Medicine*, 5(12): 662-670.

TROMPETER, K.; FETT, D. & PLATEN, P. (2017). Prevalence of back pain in sports: A systematic review of the literature. *Sports Medicine*, 47(6): 1183-1207.

TSAI, K.J.; MURAKAMI, G.; LOWERY, W. & HUTTO, C.W. (2006). A biomechanical evaluation of an interspinous device used to stabilize the lumbar spine. *Journal of Surgical Orthopaedic Advances*, 15(3): 162-172.

TUOMINEN, M.; STUART, J.M.; AUBRY, M.; KANNUS, P. & PARKKARI, J. (2015). Injuries in men's international ice hockey: A 7-year study of the international ice hockey federation adult world championship tournaments and Olympic winter games. *British Journal of Sports Medicine*, 49(1): 30-36.

VORACKOVA, H. (2011). *Reliabilita aspekcnich testu posturalni stabilizace* (trans.: *Reliability of postural stabilization aspects*) (1st ed.). Praha, Czech Republic: UK, 2. Lekarska fakulta (*trans*.: UK, 2nd Faculty of Medicine).

Corresponding author: Dr. Jana Pysna; **Email:** jana.pysna@ujep.cz

(Subject editor: A/Prof. Leon Lategan)