THE SIGNIFICANCE OF INTRA-ABDOMINAL PRESSURE ON POSTURAL STABILIZATION: A LOW BACK PAIN CASE REPORT

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ABSTRACT

Intra-abdominal pressure is a hydraulic pressure within the abdominal cavity. Previous studies confirmed its direct association with both spinal stability and spinal unloading. The literature review part of the paper summarizes intra-abdominal pressure physiology and pathophysiology and explains the underlying mechanisms of intra-abdominal pressure regulation and its effects on the human body, especially spinal stability. Current methods of invasive and non-invasive intra-abdominal pressure measurement are described in detail. Second part of a paper presents a case report of a competitive athlete suffering from low back pain. The functional assessment and treatment focused on quality of patient's trunk stabilization. Training following principles of Dynamic Neuromuscular Stabilization resulted in better ability to activate abdominal wall muscles which is a critical mechanism of intra-abdominal pressure regulation and in this case caused significant low back pain reduction. The effect of the therapy was evaluated by DNS Brace which measures activity of the abdominal wall, thus intra-abdominal pressure indirectly, along with clinical Dynamic Neuromuscular Stabilization assessment tests.

Keywords: Intra-abdominal pressure, diaphragm, abdominal wall, spinal stability, objectification of postural stabilization

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INTRODUCTION

Stabilization of the lumbar spine - physiology

Postural stabilization is necessary for human body movement (1). External forces affect the human body during each movement. The body responds with the formation of internal forces mainly by muscular activity. This is so-called postural activity (2). The abdominal cavity is the space limited by the diaphragm superiorly and the musculo-aponeurotic perineum inferiorly, the lumbar spine posteriorly and the walls of the abdominal cavity anterolaterally (3). Postural activity is represented by strengthening/stabilizing function of these muscles and its ability to create intra-abdominal pressure IAP (4). It is all under the control of the central nervous system (CNS). The consequences of the pathological action of internal forces are often underestimated and the measurement options are still limited. The evaluation of IAP may be useful in a variety of clinical outcomes (5).

The postural role of IAP has been subject to research for almost 100 years. Dating back to 1923, Keith et al. suggested that IAP may affect spinal loading (6). In 1942 Bradford a Spurling published a study stating that spinal erectors put a 680 kg load on the spine during movement (7). In 1957 Bartelink experimented with a stress tests on intervertebral discs reporting structural damage occurring at the level of 136 kg load (8). In 1959

Davis reported IAP increase during load lifting (9). Without any compensatory unloading mechanism, the spine and especially the intervertebral discs would easily be damaged with every strenuous movement. Ground-breaking studies conducted by Hodges and colleagues have confirmed that IAP alone without any trunk muscle activity increases the stability of the lumbar spine, protects the spine from excessive loading, reduces axillary compression, and transfers the load to a larger area (4,10). For the stability in the lumbar spine is necessary proper coactivation between previously mentioned muscles that regulate IAP such as the diaphragm, pelvic floor muscles, abdominal muscles and spine extensors (4,11). It is important to mention that the diaphragm not only provides respiration and sphincter function but also a postural function (12,13). Electromyography (EMG) has shown that diaphragmatic contraction is modulated by postural and ventilation requirements (12). If the diaphragm contracts physiologically, the central tendon of the diaphragm drops inferiorly, creating a pressure gradient that drives air into the lungs and with the help of pelvic floor and abdominal wall activity increases the pressure in the abdominal cavity (14,15).

Activation of the trunk muscles keeps all segments of the spine in a biomechanically neutral position during movement (8). The pelvis and lumbar spine are reflexively stabilized before limb movements (12,16). Even if IAP is an important phenomenon in rehabilitation and is often studied, its specific function and role remains unclear (17,18). An obstacle in the studying IAP is the measurement complexity in experimental conditions especially in vivo. Many authors have already described the positive effect of IAP on spinal stability and spinal unloading but its importance still needs to be objectively studied (18).

Although several studies (4,11,19,20) have shown a connection between the increased IAP and spinal stability, it is not entirely clear whether this mechanical support for the spine is due to the increased IAP or the abdominal muscle activity itself which contributes to IAP (4). According to Mokhtarzadeh et al., the relative role of the IAP in spine mechanics has remained controversial and IAP alone without current muscle co-activation is not sufficient (15). On the other hand, Hodges et al. showed in their study that the stiffness of the lumbar spine during various functional movements is increased when IAP is elevated even without simultaneous muscle contraction (3). They suggest that IAP may be a beneficial tool for the CNS to increase spinal stability in all directions (4). Similarly, Stokes et al. reported that elevated IAP increased lumbar spine stability regardless of the primary muscle involved (18). Among others, Hodges et al. also described the fact that crura of diaphragm, by its contraction, causes direct traction of the lumbar spine in the area of their attachment and it promotes the effect of IAP (4). McGill et al. created a theory that elevated IAP increases lumbar spine stability by limiting intervertebral rotation and translation (16). According to these authors, the IAP helps to maintain the correct position of the moving parts of the spine by minimizing, or even completely eliminating, very small movements of shear forces in the area of the facet joints. This hypothesis could be a possible reason why patients, who are forced to move even with severe lumbar spine pain, hold their breath (21).

The lumbar spine complex is adapted to carry an external load. Stress is transmitted to the solid bodies of the vertebrae and relatively elastic disks. Excessive mechanical loading leads to damage to the intervertebral discs (22). Arshad et al. showed in a biomechanical model that IAP significantly reduced the compressive forces on the spine and at the same time reduced the need for muscle force involvement (23). According to some authors, higher IAP values lead to spinal relief, but maximum challenging activation such as the Valsalva maneuver have got the opposite effect due to the hight levels of muscle coactivation (24). However, Stokes et al. argue that the extension effect of IAP is greater than the flexion moment created by the abdominal wall muscles. In a biomechanical model of the spine, they have shown that IAP has the effect of relieving the spine in all directions of movement (18).

Other authors suggest that IAP creates a force caudally against the pelvic floor and cranially against the diaphragm, thus creating an extension moment of the spinal (4). Although IAP alone does not produce spine extension, it is associated with an antagonistic co-activation of flexors and extensors that increases the stability and strength of the spine (4). In addition, according to Daggfeldt et al., this mechanism could help reduce lumbar spine overloading indirectly by creating an extension moment thus reducing the need for spinal extensors activation (25). This thought is also supported by Cholewicki et al. that IAP is active in movements that require trunk strength for extension such as lifting objects or jumping can increase the stability of the spine without simultaneous co-activation of the spinal erectors (20). In order to achieve the greatest possible spinal protection, the cross-section of the lumbar part of the trunk must be as large as possible. The diaphragm and the pelvic floor must work exactly opposite each other (25). According to some authors, it is also important that IAP maintains the hoop-like shape of the muscles around the abdominal cavity, thus preventing their shortening and collapse towards the abdominal cavity which could impair their ability to contract (21).

Impairment of the trunk stabilization

Low back pain (LBP) is one of the most common reasons for seeing a health care provider (26). This is also often the cause of inability to work, as it mainly affects individuals of working age (26,27). Deficits in the lumbar spine stabilization are mostly of muscular or neural origin so the right chosen physical therapy and motor control training that would induce proper co-activation between muscles is recommended (28–30).

Poor postural muscle coordination and deficiency in its stabilizing function is considered to be an important etiological factor in spinal disorders associated with back pain such as deformed spondyloarthritis, intervertebral disc protrusion or spondylolisthesis (19,28,31). The results of studies confirm that abnormalities in motor control may be not only the cause of LBP but also its consequence (32,33). The dependence between the disorder of postural control and the delay in the reaction time of the trunk muscles is a prerequisite for the development of pathology in the lumbar spine. This disorder can be a significant risk factor for lumbar spine injuries (34).

Based on the research results stated above, in clinical practice it appears to be important to evaluate the quality of postural stabilization, to measure IAP and to objectivize individual’s ability to regulate the IAP in response to postural load. However, the methods of objective postural trunk assessment and especially of IAP evaluation in relation to postural stabilization are still not unequivocally defined and routinely used. This paper further summarizes currently available methods to evaluate the IAP within clinical assessment.

IAP evaluation

If IAP corresponds with postural stability (4,19,35), we can evaluate postural stability by assessing the IAP. There are various methods of

IAP evaluation with its pros and cons. IAP measurement can be divided into direct and indirect methods. Invasive measurement of the IAP can be done using the caval catheter or transperitoneal measurement during laparoscopic operation. Indirect measurement of IAP can be done using gastric/anorectal/vesical or vaginal probe. The common disadvantage of such IAP evaluation methods is that it is invasive and uncomfortable for the subject. On the other hand, it is the most accurate way of assessing the IAP (37,38).

A. Transperitoneal measurement

This method of direct IAP evaluation is the most accurate (36). In clinical applications it is used for peritoneal dialysis or continuous paracentesis. In the research field it is considered the gold standard for comparison with other invasive methods in case of evaluating IAP. However, it is not used in the rehabilitation and musculoskeletal research and practice because of its invasiveness (37,38).

B. Intracaval measurement

Another example of direct IAP measuring is intracaval measurement. The catheter is inserted via femoral vein to inferior vena cava. The position of the catheter is monitored by ultrasound or x-ray. This procedure is time consuming but allows continuous and accurate results. Disadvantage of this method is possibility of circulatory system infection, bleeding or thrombosis (39).

C. Intravesical measurement

Intravesical measurement is the most common and the most reliable indirect method of monitoring intra-abdominal hypertension (39). This method is recognized as the gold standard for monitoring intra-abdominal compartment syndrome. It may be advantageous way of IAP monitoring in patients having an intravesical catheter because of urinary drainage (39). This method is based on the fact that the urinary bladder can transduce IAP. The measuring itself is done in laying supine position (38).

D. Intravaginal measurement

In this method the pressure sensor is situated in the vagina. Advantage of this method is that wireless sensors can be used, so the IAP can be evaluated during everyday activities (40,41). Disadvantage is that it can only be used in women.

E. Intrarectal measurement

Another method is performed via the rectum. Advantage of this method is that the patient can move and do some physical activities, while the IAP is measured (42). According to Dolan et al., 20% of women refuse to undergo this examination because of fear and they prefer intravaginal measuring (43). Contraindications for examination are bleeding from lower gastrointestinal tract or diarrhea (38).

F. Intragastric measurement

The last option of indirect IAP measuring is a naso/orogastric or gastrostomy probe. Gastric measurement is not used in daily praxis because the patients report it as very uncomfortable. Moreover, it is more expensive compared to intravesical measurement. The other disadvantage of gastric measurement is that the IAP can be influenced by stomach contractions, which occur every 90 minutes lasting about 2 minutes (44). Advantage of this approach is that the IAP can be recorded continuously and can be measured during natural movements such as walking or running (45).

In conclusion, because of its invasiveness these methods are used more for evaluating IAP hypertension, compartment syndrome and for research, then in clinical care.

Trunk muscle activity evaluation

A. Electromyography (EMG)

A standard testing method for muscle activation is EMG. It can be assessed either by non-invasive surface EMG or invasive needle EMG.

Disadvantage to both is that they evaluate more local muscle changes versus coordination of all trunk muscles. Surface EMG cannot be used to assess deep spinal stabilizing muscles. EMG is used more in research than in clinical care (46).

B. Ultrasonography (US) evaluation

Trunk muscle activation can be assessed by real time US to measure the thickness of abdominal or spinal muscles. This method is non-invasive and quite inexpensive, but its reliability is dependent on the experience of the examiner. Compared to EMG, US evaluation can be utilized to assess the deep muscles (47). Similarly to EMG ultrasound provides information about local muscle contraction rather than global muscle coordination.

C. Dynamometry

Dynamometry represents another method to evaluate trunk muscle activation. This non-invasive method measures external forces produced by abdominal wall expansion. Malatova et al. described a tool which consists of four sensors attached to the human body (48). Similar method was introduced by van Ramshorst et al. who correlated IAP with abdominal wall tension. Ramshorst et al. used a special dynamometer to monitor abdominal wall tension resulting from IAP changes in corpses, in which the IAP was changed artificially by insufflation. This study reports that abdominal wall tension reflects the IAP (49).

D. Pressure biofeedback unit

Another possibility of evaluating trunk muscle activation is pressure biofeedback unit. It is basically a tool made from three air chambers and pressure sensors that is placed under the patient. Disadvantage of this method is that activation of the trunk muscles can be evaluated only in certain positions such as lying down. This method of assessment is not useful in dynamic evaluation in difficult postural positions (50).

E. OhmTrak sensor

A non-invasive measurement of the force production of the abdominal wall are sensors inserted in belt such as Ohmbelt device with the OhmTrak sensor (Ohm Belt, Nilus Medical LLC, 2019 © OHMBELT, Redwood City, CA, USA). It is a core activation and breathing tracker. A research version of the device was designed by the manufacturer for the trial purposes, which differs from the commercial version operating with one sensor. The research version utilizes two sensors recording data simultaneously with a software app to display and record both sensor force data. It consists of two capacitive force sensors of 15 mm diameter, 0.35 mm thickness, full scale range 0.45 kg, minimal detectable force 0.9 g, attached to the abdominal wall by adjustable straps. The force sensor which faces the subject's skin, is pressed against the abdominal wall by an adjustable strap. Abdominal wall expansion and retraction is recorded by the sensor as a force. The sensors register the force exerted by the abdominal wall during respiration and various postural tasks. The research version of Ohmbelt allows to monitor simultaneously the instantaneous muscle force at two different trunk locations. Both the amount of the force and its dynamics over time can be analyzed. The sensors are also equipped with accelerometers to capture any kyphotic trunk synkinesis, i.e. substitutive trunk movement replacing abdominal muscle activation. A built-in tensometric transducer converts the force to the digital signal that is transmitted wirelessly via Bluetooth to the computer where the software graphically displays the results. The program records any time sequences with the numerical values being automatically exported into Microsoft Excel. Immediate data analysis, graphical imaging and data saving is available (51).

F. Dynamic Neuromuscular Stabilization (DNS) Brace

DNS Brace device (Produced by Ortotika, FN Motol V Úvalu 84, Praha) is a trunk orthosis equipped with four sensors working on a mechanical-pneumatic-electronic principle. The brace can be fixed firmly to the trunk while not preventing the expansion of soft tissues.

Four mechanical-pneumatic-electronic sensors are placed on the inner wall of plastic trunk orthosis. Two ventral sensors are located bilaterally above the groin and two sensors are located on the brace parts adhering to latero-dorsal sections of the abdominal wall specifically the trigonum lumbale superius. The sensors consist of an air chamber, which detects changes in hydraulic pressure when the sensor is deformed. This chamber is connected by a capillary silicone tube to a digital pressure sensor. As the abdominal wall expands, the IAP increases, which is monitored through the pressure sensor and the pressure value is transmitted via a tube to the digital sensor. The brace sensors measure the pressure exerted by the abdominal wall in kilopascals (kPa) and transfer the data via Bluetooth to a smart-phone or computer so the data can be statistically processed and graphically displayed (52).

G. Clinical tests

The most common and used approach for trunk muscle activation assessment is subjective evaluation using clinical tests (53). Clinicians use their fingers to palpate the quality and symmetry of abdominal wall during client's activation. Further description of clinical tests can be found elsewhere (52,54,55).

Suggestions for clinical practice

80% of western population will experience a LBP at some time during their lives (56). To treat LBP properly and to achieve long lasting results it is necessary to measure trunk stabilization objectively. Evidence based data will help to set up optimal treatment plan, to review the therapy results, to evaluate self-treatment effect and to compare various methods of treatment. Monitoring and training postural stabilization also plays an important role in athletic population to treat and prevent repetitive strain back pain and to promote sports performance (57–59). Since human posture is dynamic, we need a tool to measure IAP and trunk muscle stabilization function in various postural situations. We need to combine clinical assessment with objective measurement. One way to do it, is to use core activation trackers such as Ohmbelt, DNS Brace and alike during dynamic clinical testing. Sensors attached to trunk can inform us objectively about trunk stabilization function and IAP regulation since the IAP correlates with the abdominal wall tension monitored by the sensors (60,61). Body position has significant effects on abdominal wall tension thus also IAP (62). Bellow we present a short case study of a patient with LBP demonstrating how a core tracker device specifically the DNS Brace can be used in an athlete to evaluate and train postural stabilization.

CASE REPORT

An 18-year-old male, competitive canoeist, training 5 times a week 4 hours a day (2 hours rowing, 2 hours gym work) presented with acute low back pain, radiating in L5 nerve root projection to his left leg and thumb. He reported 5/10 intensity of pain on visual analogue scale (VAS). During the preparation for a championship canoeing event, the patient could no longer straighten up after training. Magnetic resonance imaging (MRI) revealed narrowing of the spinal canal at the level of a broadly mediodorsally arched disc L4/5 (3 mm), small dorsal osteophytes L4-S1 and hypertrophic intervertebral joints L4-S1 bilaterally due to spondylarthrosis.

Clinical examination consisted of three tests according to DNS examination protocol, i.e. resting breathing, loaded breathing and the diaphragm test (52,54). All three tests showed that the patient was not able to sufficiently activate the dorsolateral parts of the abdominal wall, lacked lateral expansion of the lower part of the thorax, there was cranial migration of the ribs and the thoracic spine became kyphotic during DNS testing. At the same time, there was excessive activity of the upper part of the rectus abdominis muscle, cranial migration of the umbilicus, concavities of the abdominal wall above the inguinal canal and there was shoulder protraction. Clinically, these are the signs of compromised core stabilization and poor IAP regulation (54,63–65). When analyzing the patient's sport training stereotypes, the same abnormal patterns as in DNS testing were identified including insufficient uprighting of the lumbar and thoracic spine, lack of rotation at the thoracic spine, protraction of the head and shoulders along with de-centration of the shoulder blades. Such signs of suboptimal postural stabilization were present also in sitting positions which is a basic position for canoeing. For objective assessment DNS Brace measurement were performed to analyze abdominal wall activity during resting breathing, diaphragm testing and loaded breathing (51,52)(see Fig. 1,2, and 3 and Table 1).

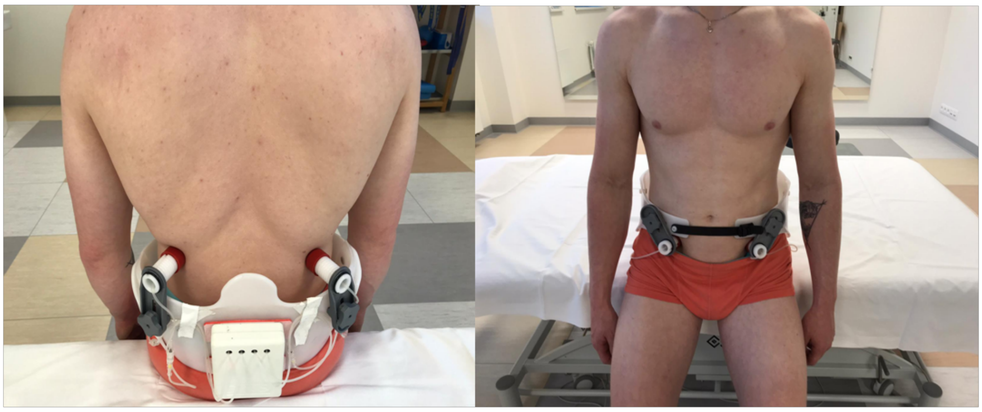
The patient underwent 12 individual therapies provided by an experienced physiotherapist. During each 60 minutes physiotherapy session soft tissue and mobilization techniques were first applied to treat trigger points and joint blockages in thoracic and lumbopelvic area. Following this, the main part of the therapy focused on trunk stabilization training utilizing DNS principles (63–65). Another goal was to train isolated movement in the hip and shoulder joints while maintaining optimal core stabilization and correct sitting position. During the first few physiotherapy sessions mostly static DNS developmental positions were trained (63–65). Later the training focused on dynamic variants of the DNS development exercises. At the end of the 3 months rehabilitation period load was added to the exercises. The patient was advised to perform DNS self-treatment daily and to integrate principles of DNS to sport training.

The clinical assessment after the therapy revealed improvement**.** In all three tests, resting breathing, loaded breathing and the diaphragm test, patient’s lower chest aperture expanded proportionally in all directions during inhalation, the intercostal spaces expanded appropriately and the patient was able to keep the spine upright during the entire tests. Balanced activation of all portions of the abdominal wall was observed and the ability to keep the chest in a neutral position was established. In the sitting position typical for canoeing, there was a noticeable adjustment in trunk stabilization, straightening of the thoracic and lumbar spine as well as proportional activation of all sections of the abdominal wall. Stability of the trunk allowed for improved optimal functional stereotypes of the upper limbs. At the end of the 3 months therapeutic intervention, the patient reported a VAS score of 1/10.

DNS Brace measurements

To monitor abdominal wall tension, a DNS Brace (52) was utilized. This was chosen specifically over other approaches because it allows non-invasive assessment with simultaneous recording from four sensors. It is safe, easy and fast method providing the most comprehensive information about the abdominal wall activity.

Figure 1 Initial position of the patient with DNS Brace before measurement



The following measured scenarios were taken with the patient sitting (Figure 1):

1) Resting breathing: The participant was breathing naturally
2) Loaded breathing: The participant held a load of 20 % of his body weight in hands in front of the trunk
3) Diaphragm test: The participant was expanding the abdominal wall pushing as much as possible against all four sensors attached to DNS Brace (two sensors located above inguinal ligament, two sensors in upper lumbar triangle bilaterally) both during inhalation and exhalation (54)

Fig 2-4 and Table 1 depict abdominal wall activity measured before and after the therapy. An improvement was identified in all three DNS Brace tests after the 3 months treatment period.

Figure 2 Resting breathing - comparison of DNS brace values before and after intervention

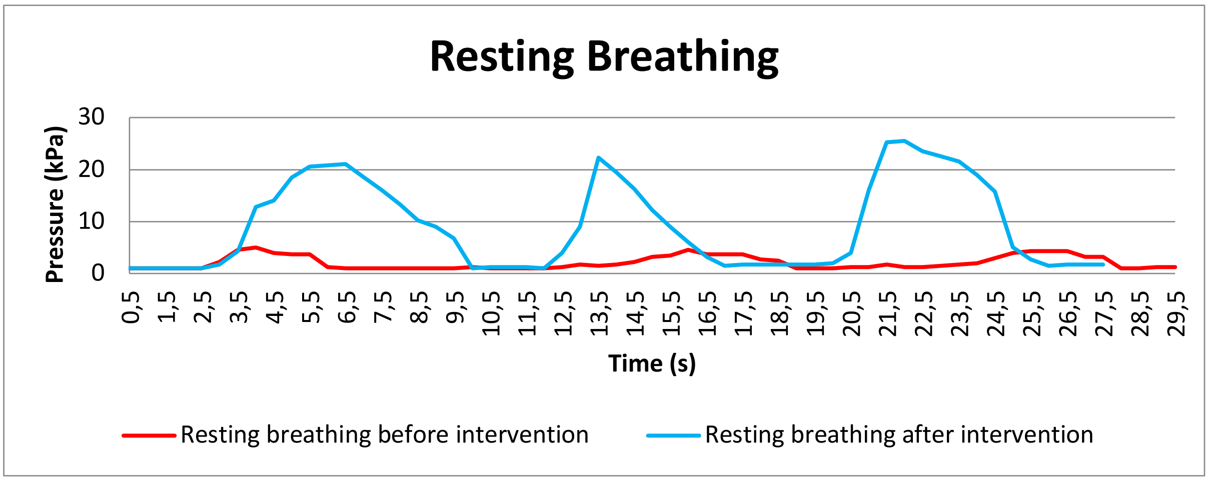


Figure 3 Loaded breathing - comparison of DNS brace values before and after intervention

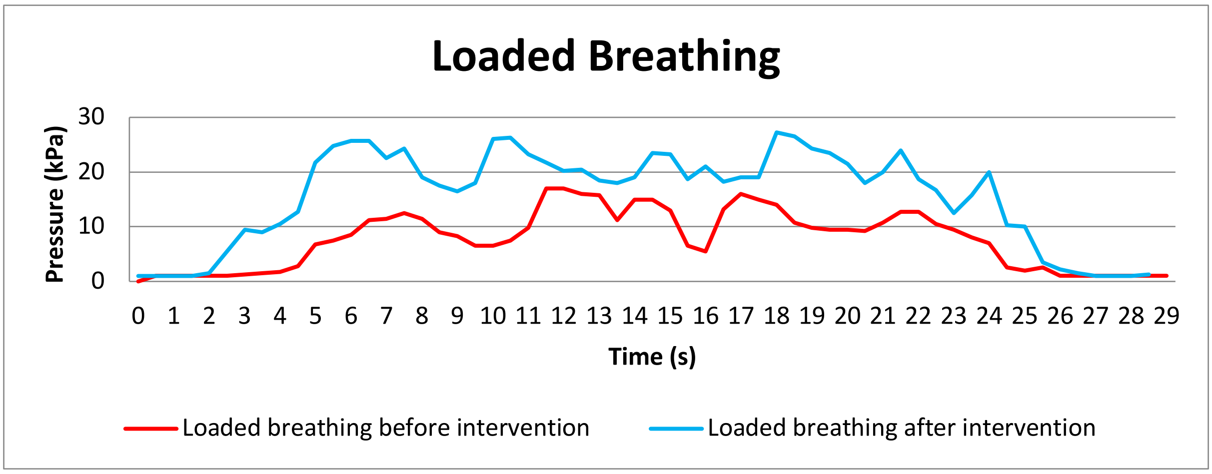


Figure 4 Diaphragm test - comparison of DNS brace values before and after intervention

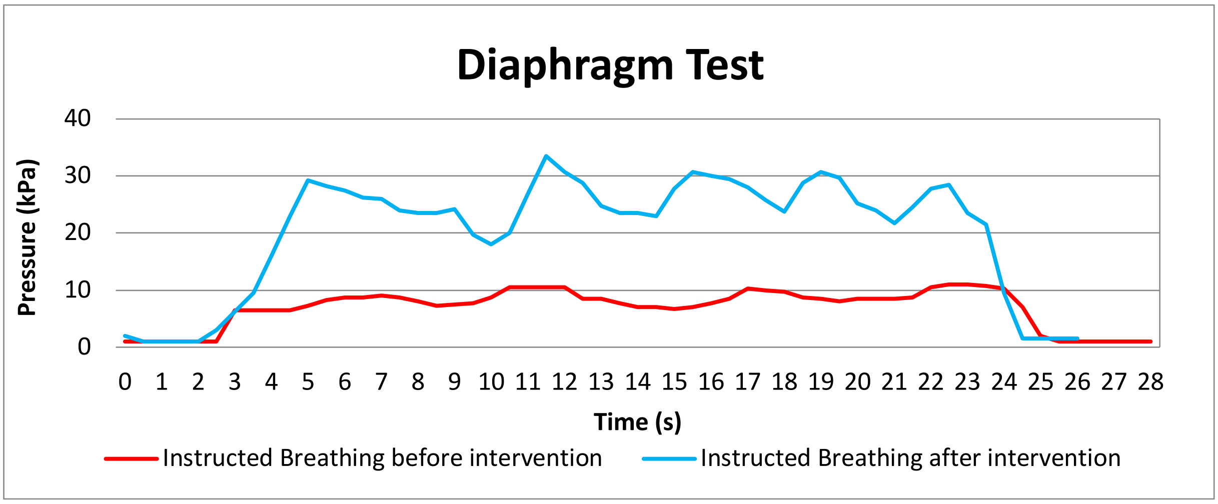


Table 1 DNS assessment protocol and DNS Brace measurement results

SCENARIO	RESTING BREATHING		LOADED BREATHING		DIAPHRAGM TEST	
	DNS assessment protocol (16 points max)	DNS Brace Average value (kPa)	DNS assessment protocol (28 points max)	DNS Brace Average value (kPa)	DNS assessment protocol (28 points max)	DNS Brace Average value (kPa)
Before intervention	6	2,28	13	11,06	11	8,13
After intervention	14	10,09	24	21,02	24	26,42
Difference	+57,2%	+ 79,1%	+45,8%	+ 47,4%	54,2%	+ 69,23%

Note: Clinical assessment performed according to DNS Assessment protocol (54): Breathing stereotype: 16 points = optimal stereotype; Loaded breathing and Diaphragm test: 28 points = optimal stereotype. The smaller the number the worse the stereotype (54).

DNS Brace: the values are given as the average of all 4 sensors

DISCUSSION

After the 3 months therapeutic intervention focusing on trunk stabilization training the patient became almost painless and was able to return to full training regime and competition. The critical part of rehabilitation was integration of proper postural stabilization in sports training to prevent repetitive overstrain of the musculoskeletal system. The positive effect of DNS training on the reduction of pain and the enhancement of sport performance has been previously demonstrated by Davidek et al (66). Six weeks DNS training resulted in significant increase of paddling force measured at kayak ergometer and in reduced pain when moving the arms above the head which is an important aspect in paddling (66). DNS exercises targeting trunk stabilization and segmental movement in the mid-thoracic spine also proved to be effective in the population of competitive cross-country skiers by decreasing back pain and improving sensory perception in thoracic region (67). The positive effect of DNS stabilization strategies on race walker performances has been proven by Panse et al (68). Jebavy et al. report that stabilization-oriented exercises prevent injury and overloading in elite futsal players (69). Jebavy (69) used the same DNS tests for deep stabilization system assessment, however, they evaluated the stabilization function only subjectively on a five-point scale using modified DNS examination protocols (54) without any additional objective measurement. Our case report combined clinical DNS assessments with objective measurements of abdominal wall tension using a DNS Brace.

The main goal of the canoeist's DNS treatment and training was to straighten the lumbar spine, practice segmental rotation in the thoracic spine segments and stabilize the pelvis when moving the upper limbs. Such movements form the basic paddling stereotypes. Similar strategy previously proved to be effective in training of other contralateral sport locomotion stereotypes such as flat water kayaking (66), cross country skiing (67) or futsal. (69) At the end of the therapy the patient was able to practice DNS positions with good quality as defined by DNS assessment protocols (54) as well as in the gym and on the rowing machine. Both clinical and DNS Brace measurements before therapy illustrate almost no expansion of the abdominal wall during resting inhalation. The red curve in the Figure 2 shows only a minimal increase in IAP during inspiration relative to resting expiration baseline. This is related to clinical observation that the patient elevated his chest during inspiration, i.e. used accessory respiratory muscles especially sternocleidomastoid and scalenes to assist in the rib cage elevation, instead of primary inspiratory muscles such as the diaphragm and external intercostal muscles. The post-treatment blue curve depicts much larger inspiratory wave which reflected in clinical assessment as abdominal wall expansion. At the end of quiet exhalation, the curve returns to the baseline, which we consider to be normal since at the end of quiet expiration the IAP value should be minimal (70). Based on DNS Brace and clinical assessment, it can be concluded that after the therapy, the respiratory function of the diaphragm and trunk muscle coordination were optimized.

The aim of the second measurement (Figure 3) was to verify how the patient reflexively reacts to holding a load and whether he uses IAP to stabilize the core during the postural challenging situation. Comparing to the red curve before the therapy, the blue post-treatment curve reflects more intensive activation of the abdominal wall both during inhalation and exhalation indicating higher IAP and better stabilization throughout the movement and more appropriate dual respiratory and postural function of the diaphragm. IAP increase during weight holding (31,35,61) is a critical mechanism of spinal stabilization and protection from injury and should be noted both clinically and by objective measurements.

The third test is called the diaphragm test (Figure 4). It serves to evaluate a patient's voluntary ability to engage the abdominal muscles with proper coactivation of the diaphragm and pelvic floor (54). During clinical assessment the individual is instructed to inhale and push actively against clinician's fingers palpating the latero-dorsal sections of the abdominal wall. With the DNS Brace he activates the abdominal wall against all four sensors placed in the upper lumbar triangle and above the inguinal ligament bilaterally. Prior to therapy, the patient could exert only very little force indicating an incorrect respiratory-stabilization pattern. After the DNS training period a similar increase in abdominal wall activation is observed as in the previous scenario of loaded breathing.

CONCLUSION

This paper summarizes available methods of intra-abdominal pressure assessment and indirect measurements of trunk stabilization. The competitive canoeist case report demonstrates positive results of postural DNS training confirmed by clinical testing, objective DNS Brace measurements and subjective pain perception reported in VAS. This case report methodology may serve as a pilot study for future larger randomized blinded studies where the complete DNS examination protocol (54) could possibly be used to analyze postural stabilization in full detail.

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Declaration of interest

The authors declare that they have no conflict of interest

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