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Original article

Abdominal wall tension increases using Dynamic Neuromuscular Stabilization principles in different postural positions

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A R T I C L E I N F O

Keywords:
Postural stabilization
Intra-abdominal pressure
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A B S T R A C T

Background: Intra-abdominal pressure (IAP) is an important mechanism stabilizing the spine and trunk. IAP regulation depends on the coordination of abdominal muscles, diaphragm and pelvic floor muscles.
Objective: To determine the differences in abdominal wall tension (AWT) of various postural positions, first without any correction, then after verbal and manual instructions according to Dynamic Neuromuscular Stabilization (DNS) principles.
Methods: In a cross-sectional observational study, thirty healthy individuals (mean age = 22.73 ± 1.91 years) were fitted with two Ohmbelt sensors contralaterally above the inguinal ligament and in the upper lumbar triangle. AWT was measured during five postural positions: sitting, supine with legs raised, squat, bear and hang position. First, spontaneous AWT was measured, then again after manual and verbal instructions following DNS principles.
Results: AWT increased significantly with DNS instructions compared to spontaneous activation. Both sensors recorded significant increases ($p < .01$; Cohen's d = −1.13 to −2.06) in all observed postural situations. The increase in activity occurred simultaneously on both sensors, with no significant differences noted in pressure increases between the sensors. The greatest activation for both sensors occurred in the bear position. Significant increases in activity were identified for both sensors in the supine leg raise position and in the bear position compared to spontaneous activation in sitting ($p < .001$). There were no statistically significant differences (for both sensors) between women and men in any position.
Conclusion: The amount of AWT significantly increases after verbal and manual instructions according to DNS. The greatest abdominal wall activation was achieved in the bear position.

1. Introduction

Optimal spinal stabilization is dependent on the balanced coordination between the diaphragm, pelvic floor and abdominal muscles to regulate intra-abdominal pressure (IAP). IAP provides ventral spinal stabilization (Stokes et al., 2010), reduces compressive loads on the spine (Cholewicki et al., 1999; Stokes et al., 2010) and works in coordination with lumbar paraspinal muscles to secure spinal stabilization dorsally (Cholewicki et al., 1999). Spinal stabilization is closely related to respiratory stereotype (Hodges and Gandevia, 2000) and also to diaphragmatic and pelvic floor sphincter function (Bitnar et al., 2015, 2021; Hwang et al., 2021). Global coordination of core muscle activity stabilizes the trunk. Sole activation of a single trunk muscle or one component of the trunk stabilization complex would not be sufficient to dynamically generate adequate IAP in response to actual postural demands (Stokes et al., 2011). Ineffective spinal stabilization, or poor postural function of the pelvic floor and diaphragm can cause low back pain (LBP) (Panjabi, 2003). Previous research using electromyography has demonstrated different trunk muscle activation patterns in patients with LBP compared to individuals without LBP (Suehiro et al., 2021). An unbalanced activation of the trunk stabilizers and insufficient regulation of IAP can be related to urinary incontinence (Hwang et al., 2021), gastroesophageal reflux (Bitnar et al., 2015, 2021), hernias (Qandeel and O'Dwyer, 2016), and LBP among other problems in the

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musculoskeletal system (Hagins and Lamberg, 2011).

Activation of the diaphragm, pelvic floor and abdominal wall precede movements of the limbs (Hodges and Gandevia, 2000). IAP increases in proportion to the reactive forces from the limb movement (Hodges and Gandevia, 2000). Several studies have demonstrated various positive effects of abdominal and core stabilization exercises which include increasing core muscle strength (Kitagawa et al., 2020) and grip strength (Kobesova et al., 2015), promoting athletic performance (Clark et al., n.d.; Davidek et al., 2018; Saeterbakken et al., 2021), preventing sport injuries, and reducing LBP (Hlaing et al., 2021; Tsai et al., 2020).

Still, it remains questionable how optimal core function is defined, and how to best test and measure trunk stabilization(Clark et al., n.d.; Maaswinkel et al., 2016). In clinical practice, most clinicians rely on observation and palpation (Clark et al., n.d.; Hebert et al., 2015; Kobesova et al., 2020; Valentín-Mazarracin et al., 2021). IAP is one such variable commonly measured that closely relates to trunk muscle coordination and core stabilization. IAP can be measured in various ways with wireless technology becoming popular in recent years. Most techniques monitoring IAP can be highly invasive using intravesical sensors, peritoneal cavity catheters, and intravaginal or intragastric sensors (Liao et al., 2021). Due to such invasiveness of these techniques, they are not routinely used in clinical rehabilitation practice. It has recently been shown that IAP can be predicted from AWT through the use of a capaciative force sensor (Novak et al., 2021a,b). Since IAP correlates with the AWT (Jacisko et al., 2021; Novak et al., 2021a,b), it is possible to understand changes in IAP indirectly by monitoring AWT using capacitive force sensors. For such purposes, devices called the DNS Brace (Jacisko et al., 2021; Novak et al., 2021a,b) and Ohmbelt (Novak et al., 2021a,b) have been used.

Activation of the abdominal wall and the amount of IAP is posture and task specific (Arjmand and Shirazi-Adl, 2006; Jacisko et al., 2021; Novak et al., 2021, 2021, 2021). Therefore in attempt to further understand the impact of different postural positions on AWT (and subsequent regulation of IAP), this study investigated which positions exhibit the greatest effect on AWT, and determine if AWT can be increased with the instruction according to Dynamic Neuromuscular Stabilization (DNS) principles (Kobesova et al., 2016, 2020).

In this study we measured AWT in the following positions correlating with developmental positions: Sitting (9 months developmental position), Supine leg raise position (3 months developmental position), Hand and feet support called Bear (12 months developmental position), Squat (12 months developmental position), and Straight arms hang which is not a developmental position but it is a frequently used exercise position in the gym with trunk stabilization stereotype that correlates with the 3 month developmental position. It was hypothesized that spontaneous AWT would be higher in the challenging postural positions compared with sitting, and DNS instruction, provided by trained clinicians, would increase AWT above values exhibited spontaneously.

2. Methods

2.1. Participants

Thirty healthy college students (15 males, 15 females; aged 20–25 years) with no prior experience of physical therapy or IAP-training participated in this study. Exclusion criteria constituted any presence of acute or chronic musculoskeletal pain, any neurological, internal or other disease, and prior history of any trunk surgery or injury, and body mass index (BMI) above 30. Participants were recruited via email, and all data collection occurred at a hospital rehabilitation clinic. Demographic characteristics of all participants are presented in Table 1. Participants were instructed not to consume any food 90 min before the measurement. A written informed consent was signed by each participant. The study conforms with The Code of Ethics of the World Medical Association and was approved by an Institutional Ethics Committee. This study adheres to the Helsinki declaration.

Table 1
Participant's anthropometric characteristics. N = 30, 15 males, 15 females.

	Age (years)	Height (cm)	Weight (kg)	BMI
Mean	22.7	175.0	69.8	22.6
SD	1.9	9.2	13.0	2.7
Min	20.0	158.0	50.0	18.3
Max	25.0	191.0	97.0	29.3

2.2. Instruments

To measure the activity of the abdominal wall, the Ohmbelt device (Nilus Medical LLC, OHMBELT, Redwood City, CA, USA) was used. The Ohmbelt registers increases in pressure by the abdominal wall through a capacitive force sensor located in the device, and is attached by an adjustable strap. For this study two devices were used. Data from both sensors were recorded simultaneously and processed by a software application. Details of the device technology and measurement is further explained in a previous study by Novak et al., 2021a,b). The Ohmbelt software using Bluetooth digital signal graphically displays data from the sensors, and exports data to MS Excel allowing for immediate statistical analysis (Novak et al., 2021a,b).

2.3. Assessments

All assessments were performed under the same conditions by a single trained clinician. The Ohm belts were fixed to participant's trunk, one to monitor the force of abdominal wall expansion above the inguinal ligament (anterior sensor - Fig. 1A) and the other one in upper lumbar triangle contralaterally (posterior sensor - Fig. 1B).The order of the measured positions and the allocation of the sensors were randomized in each subject.

The Ohmbelt was attached under the force of 110g (±10g), which was determined by repeated measures, in order to sufficiently maintain contact with the abdominal wall during the whole measurement while not affecting trunk movement (Novak et al., 2021a,b). Every participant was informed in detail how to adopt the positions: sitting, (Fig. 1A and B), supine position with leg raise (Fig. 1C) bear (Fig. 1D), squat (Fig. 1E) and hang (Fig. 1F).

Activity of the abdominal wall was monitored in each position for four breathing cycles, i.e. approximately 15 s of activation in each position (Novak et al., 2021a,b). Each subject took one testing breath and then the measurement began at start of the inspiratory phase and ended at the end of the expiratory phase of the fourth breathing cycle. The subject breathed naturally using the spontaneous rhythm. First, the spontaneously adopted position was measured without any corrections. Immediately after the spontaneous measurement the participants were verbally and manually instructed by the clinician how to optimally stabilize the trunk according to Dynamic Neuromuscular Stabilization (DNS) principles (Kobesova et al., 2016, 2020). Detailed instructions on how to properly activate the trunk in each position are explained in figure captions (Fig. 1A–E). Subjects were asked to push against both sensors and maintain expansion of the abdominal wall throughout the whole measurements, both during inspiration and expiration while maintaining neutral spine position (avoiding increased spinal kyphosis or lordosis) in the given position. After being instructed, the subject took one testing breath and then, four breathing cycles were measured again starting with the inspiratory phase of the first breath and ending at the end of expiratory phase of the fourth breath. The relaxation time between each position was 5 min. The assessment of all subjects were performed under the same conditions, the same verbal and manual instructions were given by the same examiner (Kobesova et al., 2020).

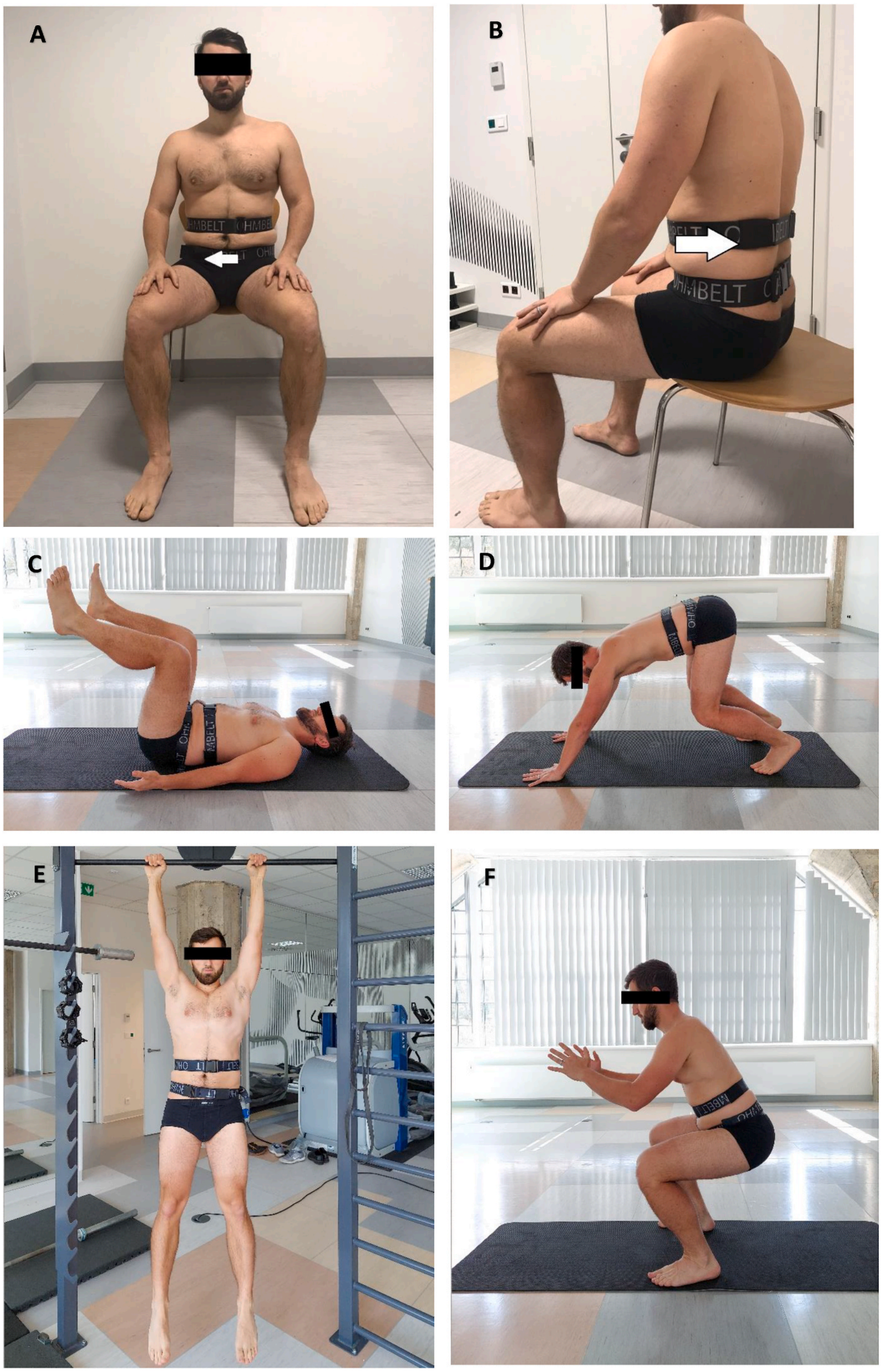

Fig. 1. A–B: Initial sitting position: the arrows indicate location of the sensors. 1A – anterior sensor, placed above the inguinal ligament, 1B – posterior sensor, placed in the upper lumbar triangle contralaterally.
Manual and verbal instructions for optimal stabilization: Keep the spine upright, avoid increasing kyphosis or lordosis, relax your shoulders, support the feet on the floor, push with your abdominal wall against both sensors and maintain the pressure during the whole measurement, i.e. both during inspiration and expiration.
Fig. 1 C: Supine leg raise position
Manual and verbal instructions for optimal stabilization: Lift your legs above the floor, keep 90° flexion at hips and knees, with slight external hip rotation, establish pelvic support on the upper sections of the gluteal muscles. Keep the whole spine, including the cervical spine upright (i.e. straight). Support your head across the nuchal line and keep it in a midline position avoiding inclination. Relax your shoulders, maintain caudal position of your chest (do not pull your shoulders cephalad) throughout the entire respiratory cycle. Push with your abdominal wall against both sensors and maintain the pressure during the whole measurement, i.e. both during inspiration and expiration.
Fig. 1 D: Bear position
Manual and verbal instructions for optimal stabilization: Keep the support on hands and forefeet. The hands are weight-bearing equally on thenar and hypothenar pads. Keep your shoulder blades adhering to the rib cage, medial borders nearly parallel to the spine. Focus on proportional weight bearing of feet, the support on the front of the foot needs to be evenly distributed between the head of the first and fifth metatarsus, knees being in line with feet, hips are slightly flexed with pelvis situated higher than the head. Keep your head in midline position avoiding inclination. The spine is elongated and straight. Maintain neutral (caudal) position of your chest throughout the entire respiratory cycle, do not pull your shoulders up. Push with your abdominal wall against both sensors and maintain the pressure during the whole measurement, i.e. both during inspiration and expiration.
Fig. 1 E: Hang position
Manual and verbal instructions for optimal stabilization: Keep your spine upright including your neck, pull your head towards the ceiling, pull your shoulders wide and down from your ears, lower the lower ribs, maintain the caudal position of the thorax. Push with your abdominal wall against both sensors and maintain the pressure during the whole measurement, i.e. both during inspiration and expiration.
Fig. 1 F: Squat
Manual and verbal instructions for optimal stabilization: Keep your spine straight including your neck, relax your shoulders, maintain caudal chest position, load the entire soles of your feet proportionally, the support must be evenly distributed between the head of the first and fifth metatarsus, keep your knees in line with feet. Push with your abdominal wall against both sensors and maintain the pressure during the whole measurement, i.e. both during inspiration and expiration.

2.4. Statistical analysis

Descriptive statistics were calculated for all variables. Data are mean ± standard deviation, unless otherwise noted. The data was processed by averaging four monitored breathing cycles. One variable (Hang-front sensor) was not normally distributed, as assessed by Shapiro-Wilk's test ($p < .05$), however all skewness and kurtosis values were within acceptable range and z-scores were assessed with no values outside the range of -3-3 for all variables (Hair et al., 2010). Twelve outliers were detected as univariate outliers in the data, as assessed by boxplot, which did not all occur on the same variables. After winsorization (where outlier values were replaced with the next largest or smallest value), there were no appreciable differences found comparing true values to the winsorized values. Therefore we proceeded with the raw data, and initial correlations were performed to assess the relationship between front and back sensors. Paired-samples t-tests were used to assess the abdominal wall activity between normal sitting posture and spontaneous activation; and also to assess spontaneous activation with activation after correction by a DNS instructor in all four DNS postural positions. Power analysis, using G*Power 3.1, indicated an 80% chance of detecting a medium effect size of 0.5 in 27 subjects with statistical significance determined *a priori* at $p < .05$ (one tailed). In highly correlated dependent variables, Bonferroni corrections were utilized to reduce the chance of Type I error, in which statistical significance was determined at $p < .0125$. Effect sizes were interpreted as very small (<0.2), small (0.2–0.5), medium (0.5–0.8), or large (>0.8). Data analyses were conducted with the Statistical Package for the Social Sciences (SPSS v27 for Mac; IBM Corp, Armonk, NY).

3. Results

Descriptive data for all participants are presented in Table 1. All participants who met the inclusion criteria completed the study. In comparing sensor readings between the initial sitting position with spontaneous activation in the adopted postural positions, paired sample *t*-tests revealed significantly higher activity in the supine leg-raise position (Front: $p < .001$, Back: $p = .001$) and bear position (Front: $p < .001$, Back: $p < .001$), but not for the hang or squat positions (Table 2). When comparing the spontaneous activation readings for the adopted positions with activation readings after manual and verbal correction according to DNS, paired *t* -tests revealed significantly higher activity in both sensors (Front: $p < .001$, Back: $p < .001$) for all four postural positions (Table 3). There were no significant differences between the front and back sensors in any monitored position; as they trended similarly with each increase. The maximum sensor activity was identified in the bear position, both for spontaneous and instructed situations (Fig. 2). There were no significant differences according to gender in our cohort of healthy individuals.

4. Discussion

The results of this study demonstrated that AWT increases in two of the monitored postural positions when compared to the seated position. IAP is strongly correlated to AWT, which can voluntarily be increased beyond spontaneous activation via specific instructions to activate the abdominal wall with eccentric contraction. To measure the corrected positions, subjects were instructed to push against both sensors and maintain expansion of the abdominal wall throughout the whole measurement while keeping the spine neutral. Detailed instructions for stabilizing the trunk appropriately were based on DNS method principles (Kobesova et al., 2016, 2020). Since IAP plays a critical role in spinal stabilization (Cholewicki et al., 1999; Hodges and Gandevia, 2000; Mokhtarzadeh et al., 2012; Stokes et al., 2010, 2011), the aim of training is to increase IAP during posturally challenging situations or when lifting loads to protect the spine (Cresswell et al., 1994; Cresswell and Thorstensson, 1989). Also, in patients with LBP the rehabilitation goal may be to activate muscles that generate IAP (Stokes et al., 2011), or to use lumbar belts (Ludvig et al., 2019) to increase IAP and unload the spine. According to Arjmand & Shirazi-Adl (Arjmand and Shirazi-Adl, 2006), the unloading and stabilizing actions of IAP are posture and task specific. Therefore, it is important to identify the positions and instructions that significantly increase AWT and thus also IAP.

The greatest increase in AWT noted was in bear position, i.e. quadruped position with feet and hands support, and supine position with leg raise. We attribute this effect not only to abdominal wall activation but also to the postural diaphragmatic function. Brown demonstrated position-dependent demands on the diaphragm with ultrasound assessment (Brown et al., 2018). Diaphragmatic activity measured as diaphragm thickening fractions significantly increased in sitting and standing in comparison to supine position. Brown's team suggest differences in diaphragm contractility by position are attributable to gravitational forces on the diaphragm and abdominal viscera, and the physiological response of the diaphragm and abdominal wall muscles to these forces (Brown et al., 2018). Essendrop et al. (2002) confirmed increases in IAP as a response to small sudden loads, arguing this is due to the concomitant increase in muscle co-activation needed to generate IAP, and the IAP itself. He also reports that increases in IAP and spinal stiffness reduces movement caused by the sudden loading (Essendrop et al., 2002). Significant increases in AWT were also confirmed during lifting a load of 20% body weight compared to initial seated position by Novak et al., 2021a,b). Such findings demonstrate the need for increasing IAP to secure posture that is labile or requires power output. This was also demonstrated in the supine position with leg raise, monitored in our study where it was necessary to keep the weight of the lower limbs against gravity and for the bear position which is rather unstable and not entirely natural for humans and thus physically challenging. In the hang and squat position, the change in AWT did not differ significantly from the initial sitting position. We can only speculate why only insignificant increases were recorded in those two positions. Perhaps stabilization in the hang position is more dependent on shoulder girdle power and endurance with core strength and endurance becoming a secondary determinant noted during climing (MacKenzie et al., 2020). Yoon et al. (2015) compared trunk muscle activity in quadruped position with a leg raise and arm raise, reporting significantly greater activity of back, abdominal and trunk muscles during leg raise than during arm raise. Using dynamic magnetic resonance imaging Kolar et al. (2010) identified significantly greater diaphragmatic excursions during lower extremity movements than with upper extremity movements. So, it seems that leg movement challenge postural stabilization more than arm movement. In the squat position there was almost no change on the front sensor and insignificant increases on the back sensor compared

Table 2
Abdominal wall activity comparison of sitting and after spontaneous trunk stabilization interventions (Mean [Standard Deviation]).

Position	Sensor Location	Sitting	Spontaneous Activation	95% CI	Mean Difference	Effect Size	*P Value*
Supine leg raise	Front	132.2 (27.7)	171.4 (45.9)	(-55.8, −22.7)	−39.4	−0.89	<.001*
	Back	137.5 (34.0)	167.8 (50.7)	(-47.5, −13.1)	−30.3	−0.66	.001*
Bear	Front	132.2 (27.7)	180.1 (61.5)	(-69.6, −26.3)	−48.0	−0.83	<.001*
	Back	137.5 (34.0)	192.2 (65.7)	(-79.0, −30.4)	−54.7	−0.84	<.001*
Hang	Front	132.2 (27.7)	158.9 (60.0)	(-49.6, −3.8)	−26.7	−0.81	.024
	Back	137.5 (34.0)	166.4 (60.6)	(-54.5, −3.3)	−28.9	−0.42	.028
Squat	Front	132.2 (27.7)	132.9 (27.4)	(-11.3, 9.9)	−0.7	−0.03	.892
	Back	137.5 (34.0)	150.6 (38.5)	(-28.5, −2.3)	−13.1	−0.32	.091

*Statistically significantly difference observed (Bonferroni Correction $P < .0125$).
Values are kilopascals (kPa).
Effect size = calculated Cohen's d.

Table 3
Abdominal wall activity changes before and after correction during trunk stabilization interventions (Mean [Standard Deviation]).

Position	Sensor Location	Spontaneous Activation	After Correction	95% CI	Mean Difference	Effect Size	*P* Value
Supine Leg Raise	Front	171.4 (45.9)	263.4 (67.5)	(-108.9, −75.0)	−92.0	−2.03	<.001*
	Back	167.8 (50.7)	267.6 (64.9)	(-117.91, −81.7)	−99.8	−2.06	<.001*
Bear	Front	180.1 (61.5)	276.3 (73.5)	(-116.6, −75.5)	−96.2	−1.76	<.001*
	Back	192.2 (65.7)	288.0 (73.9)	(-120.5, −71.0)	−95.8	−1.45	<.001*
Hang	Front	158.9 (60.0)	235.4 (70.8)	(-93.9, −59.8)	−76.5	−1.71	<.001*
	Back	166.4 (60.6)	248.7 (92.4)	(-109.6, −55.0)	−82.3	−1.13	<.001*
Squat	Front	132.9 (27.4)	194.4 (38.4)	(-76.1, −47.1)	−61.6	−1.59	<.001*
	Back	150.6 (38.5)	228.9 (74.0)	(-104.1, −52.5)	−78.3	−1.13	<.001*

*Statistically significantly difference observed (Bonferroni Correction $P < .0125$).
Note.
Values are kilopascals (kPa).
Effect size = calculated Cohen's d.

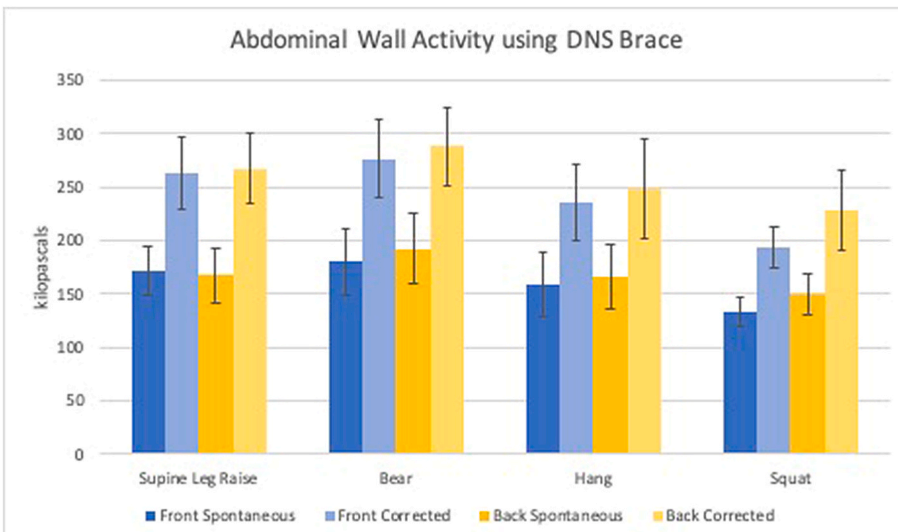

Fig. 2. Abdominal wall activity changes before and after correction during trunk stabilization interventions.

with sitting. This is rather surprising because prior research has reported significant IAP increases in squat positions (Blazek et al., 2019). These differences are likely due to measuring AWT at a higher squat position (90 degrees of knee flexion) for a short period of time (15 s) without any load. Perhaps the short duration squat does not result in IAP increase but a longer lasting squat position or a squat with a load which is frequently applied in strength training in various modifications would cause significant change (Blazek et al., 2019). Lander reports the IAP changing throughout the squat motion, with the greatest IAP occurring when the lifter is in the beginning movement of concentric muscle actions coming "out" of the squat (Lander and Hundley, 1992; 1986). AWT was only recorded during static positions, which may not have captured the phase of maximum activation of the abdominal wall during squatting.

In all measured positions, significant increases in both front and back sensors were noted when instructing the subjects to actively push against the sensors and maintain the targeted pressure during the whole measured period of time (4 breathing cycles, approximately 15 s) both during inhalation, and exhalation. The highest pressures were identified in bear position on both sensors, spontaneously and after instructing the subjects to actively push and breathe toward the sensors. The variability of the measured pressures (minimum 132.9 kPa on front sensor during spontaneous hang, maximum 288 kPa on back sensor during corrected bear) is in line with studies reporting the activation of the abdominal wall and amount of IAP is posture and task specific (Arjmand and Shirazi-Adl, 2006; Jacisko et al., 2021; Novak et al., 2021, 2021, 2021). Egger et al. (2015) suggest that some activities do not produce consistent IAP, and certain activities with higher maximal IAP tend to have greater variability between sessions. We cannot confirm this hypothesis because we only performed one measurement for each position for each subject.

Based on our data we can suggest bear and supine leg raise positions to be the most powerful from the five monitored positions (sitting, supine with leg raise, bear, hang, squat) to train AWT and IAP trunk stabilization. Increasing IAP may be part of an effective support strategy for the spine and used in cases where trunk stability needs to be improved. At the same time, we must keep in mind that the ultimate goal is to restore optimal coordination among muscles stabilizing the trunk without reaching the absolute maximum IAP. Some authors warn that maximum activity of the abdominal muscles and related IAP peak can cause an inguinal hernia (Hemborg et al., 1985), pelvic girdle pain (Mens et al., 2006), pelvic floor dysfunction (Rosenbluth et al., 2010), or increased blood pressure which can possibly result in cerebrovascular and cardiovascular events (Hackett and Chow, 2013). A sustained increase in IAP can result in abdominal compartment syndrome and intra-abdominal hypertension which is a life threatening condition (Pereira, 2019). From a practical perspective, it is important to determine which exercises optimally stabilize the trunk and favorably regulate IAP, improve physical performance, and offer preventive and therapeutic effects on musculoskeletal pain. One aspect to consider is the difference between concentric and eccentric abdominal wall activation. Vicente-Campos et al. (2021) state that hypopressive-abdominal exercises increase diaphragm thickness, thus significantly activate the key stabilizer assisting in IAP creation and regulation. The Canadian Society for Exercise Physiology states that abdominal bracing has been shown to be more effective than abdominal hollowing in optimizing spinal stability (Behm et al., 2010). In our study we have instructed the subjects to push against the sensors (“corrected scenario” for all measured positions), i.e. to activate the abdominal wall eccentrically. This maneuver resulted in significant AWT increases and thus indirectly also increasing IAP (Novak et al., 2021a,b). The diaphragm lowers its position and flattens during inhalation and also during postural loading (Kolar et al., 2009, 2010), as this mechanism pressurizes internal organs and pushes them caudally evoking higher activity in pelvic floor muscles (Hodges et al., 2007) that must support viscera from below and ensure continence. Since intra-abdominal contents are mostly liquid and therefore incompressible, the abdominal wall must react eccentrically as the diaphragm descends. In our experiment, we placed the sensors where only the attachments of the abdominal muscles are located (above the inguinal ligament and in the upper lumbar triangle contralaterally) and therefore the abdominal wall is easily accessible and IAP can be accurately measured. Previous research studies also monitored abdominal wall activity in these specific locations to evaluate AWT and spinal stabilization (Jacisko et al., 2021; Kumar et al., 2012; Novak et al., 2021, 2021, 2021). Reduced diaphragmatic excursions (Kolar et al., 2012), delayed postural activity of trunk stabilizing muscles (Hodges and Richardson, 1996) and changes in motor control of the abdominal muscles were identified in LBP populations (Hides et al., 2009).

No significant differences were noted between front and back sensors in any monitored position under both spontaneous or corrected scenarios. This results from the physical law defining behavior of the fluid in a closed container. If the AWT reflects IAP (Novak et al., 2021a,b; Ramshorstvan and WCJ, 2011) that is hydraulic pressure within the abdominal canister, according to Pascal’s law the fluid pressure is transmitted equally in all parts of the container acting perpendicular to the enclosing walls. In addition, no significant differences were evidenced between males and females, so it appears the amount of AWT and IAP in various body positions is not gender specific, which supports prior findings (Chen et al., 2015; Cobb et al., 2005).

This study is not without limitations. First, only asymptomatic, 20–25 year old’s were assessed. The results cannot be generalized for older populations, individuals with LBP, or individuals who experience movement system or neurological disorders. Secondly, although the Ohmbelt device was used previously to explore postural stabilization and the methodology was described in detail (Novak et al., 2021a,b), there may be influences that affect the measurement results such as identical placement of the sensors in all subjects, sufficient tightening of the straps fixing the sensors, or body mass index of analyzed subjects. Due to the variability in thickness of subcutaneous abdominal fat, measurements could be adversely affected due to a greater distance between the pressure sensor and the abdominal muscles. To avoid such influence, only subjects with a BMI below 30 were included to participate in the study. Also, only static positions were monitored for short periods of time. Dynamic movement, endurance and loading may strongly affect the results.

5. Conclusion

Measuring AWT using the Ohmbelt device confirms significantly higher activity in the spontaneously adopted supine position with leg raise and bear position relative to a sitting position. This work also confirms that it is possible to change AWT voluntarily. With specific verbal and manual instructions following Dynamic Neuromuscular Stabilization principles, the amount of AWT significantly increased in four monitored positions (supine with leg raise, bear, hang and squat). The greatest abdominal wall activation was achieved in the bear position both for spontaneous and instructed situations.

Ethics committee

This study was approved by Institutional ethics committee University Hospital Motol, Prague, Czech Republic.

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Declaration of competing interest

None.

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