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Short-term effects of 90/90 breathing with ball and balloon on core stability

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Abstract

Background Breathing is a life preserving mechanism that can influence muscles of the core and its stabilizing mechanisms, especially by the function of the diaphragm and intra-abdominal pressure (IAP) build-up. The 90/90 bridge with ball and balloon (90/90 breathing) is one technique doing so, thereby affecting the core and core stability (CS). Both have been shown to influence injury, and in some studies performance, and are therefore deemed important. In the Functional Training branch exercises that influence CS are used as core activations in the warm-up to increase performance in the short-term, but scientific proof for that is lacking.

Objective The aim of this study was therefore to investigate if a core activation in the form of the 90/90 breathing can increase the short-term CS. Methods To test this an intervention trial was designed where the subjects were divided into a control group (CG) and a breathing group (BG). Three CS-tests were done to assess the CS at two times, Pre and Post. The double-leg-lowering (DLL), the unilateral-hip-bridge (UHB) and the single-leg-stand (SLS). The BG did the 90/90 breathing in between Pre and Post, whereas the CG did nothing. The data was checked for group differences at Pre and Post as well as the difference in the performance change from Pre to Post between groups using Independent t-test and Mann-Whitney U test. Improvements from Pre to Post within groups were calculated with Pared Samples t-test and Wilcoxon tests.

Results No consistent effect of the intervention was found. The DLL showed the most positive results with a performance improvement in the BG and a greater performance change for the BG than for the CG. The UHB showed mixed results with a better performance at Post for the BG in both legs but only an improvement for the non-dominant leg in the BG. The SLS showed no improvement for the BG in any test. Conclusion The inconsistent results show no general positive effect of the 90/90 breathing on CS. However, the positive effects in the DLL make a position and task specific effect of the 90/90 breathing on CS possible. Practitioners and coaches should consider this task specificity when planning warm-ups. Future research should also choose CS tests and training exercises more task specific to the studied objectives to obtain more distinct results. More research on the short-term effects of CS interventions is needed for a clearer understanding of the subject.
# List of Abbreviations

<table>
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>90/90 breathing</td>
<td>90/90 bridge with ball and balloon</td>
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<tr>
<td>AB</td>
<td>Abdominal bracing</td>
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<tr>
<td>APA</td>
<td>Anticipatory postural adjustment</td>
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<td>BG</td>
<td>Breathing Group</td>
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<td>CG</td>
<td>Control Group</td>
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<td>COM</td>
<td>Center of mass</td>
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<td>COP</td>
<td>Center of pressure</td>
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<td>COPD</td>
<td>Chronic obstructive pulmonary disease</td>
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<td>CS</td>
<td>Core stability</td>
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<td>DB</td>
<td>Dysfunctional breathing</td>
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<td>DL</td>
<td>Dominant leg</td>
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<td>DLL</td>
<td>Double leg lowering</td>
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<td>EMG</td>
<td>Electromyography</td>
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<td>FB</td>
<td>Functional breathing</td>
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<td>FT</td>
<td>Functional Training</td>
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<td>HLT</td>
<td>High-low-test</td>
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<td>IAP</td>
<td>Intra-abdominal pressure</td>
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<td>ICC</td>
<td>Intra-class correlation coefficient</td>
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<td>LBP</td>
<td>Lower back pain</td>
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<td>LRET</td>
<td>Lateral rib expansion test</td>
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<tr>
<td>N</td>
<td>Newton</td>
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<tr>
<td>NDL</td>
<td>Non-dominant leg</td>
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<tr>
<td>PDB</td>
<td>Partly dysfunctional breathing</td>
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<td>SLS</td>
<td>Single leg stand</td>
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<tr>
<td>SSPW</td>
<td>Sport sessions per week</td>
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<td>TSDS</td>
<td>Time spent doing sports per week</td>
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<tr>
<td>UHB</td>
<td>Unilateral hip bridge</td>
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<tr>
<td>YTE</td>
<td>Years of training experience</td>
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<td>ZOA</td>
<td>Zone of apposition</td>
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1. Introduction

In this Master Thesis it was investigated whether a breathing technique could have a positive influence on core stability (CS) and improve it in the short-term. This is of importance since breathing is a basic, life preserving mechanism of the body with more impact on non-respiratory mechanisms than many people are aware of. Breathing is actively used in the practical field, especially by traditional sportive or meditative activities like Yoga, and recently more by upcoming branches of the fitness industry like Functional Training. There breathing is mainly a technique for relaxation and working against disbalances (Boyle, Olinick & Lewis, 2010). But in recent years it has also become a focus for increasing stability during exercises and overall sports performance by using different breathing techniques (Bradley & Esformes, 2014; Tayashiki, Mizuno, Kanehisa, & Miyamoto, 2017; Illi, Held, Frank, & Spengler, 2012; Hodges & Gandevia, 2000b). One of the newer breathing techniques that gained more popularity recently is the 90/90 bridge with ball and balloon, that was originally designed to work against disbalances and pain in the upper body and torso (Boyle et al., 2010). However, this type of breathing also works on and activates a lot of different muscles in the core (Goldman, Lehr, Millar & Silver, 1987; Kim & Lee, 2017). In the Functional Training these muscles are seen as an important part of the warm-up, where exercises like plank variations are designed to activate them. This is supposed to increase the core stability for the strength or dynamic exercises to come. However, this effect has barely been scientifically proven yet and the question stands if a short-term improvement in core stability with exercises that work on the core is really possible. This led to the question if an activation of the core muscles, by doing the 90/90 bridge with ball and balloon, could increase the short-term core stability. Answering this question has implications for the Functional Training (FT) field by being able to design the warm-up part of training sessions more efficiently. It could also benefit the general-public especially for people with lower back pain (LBP), since core stability as well as breathing have been shown to play a role in its rehabilitation and prevention (Boyle et al., 2010; Chang, Lin, & Lai, 2015). Taken together, the results of this study could provide helpful information for people suffering from conditions like LBP and the FT community for a more efficient warm-up, as well as for the scientific community concerning CS research.
2. Background

2.1 Breathing mechanism

2.1.1 Functional Breathing

The lungs are passive extensible organs; therefore, they need the respiratory muscles to inflate, and in some situations to deflate. The muscles responsible for inspiration are the diaphragm, external intercostals, parasternal, sternomastoid and scalene muscles (Ratnovsky, Elad, & Halpern, 2008). The muscles responsible for expiration are the internal intercostal, rectus abdominis, external and internal oblique and transversus abdominis muscles (Ratnovsky et al., 2008). They are all located around the torso (see Figure 1).

![Position of the respiratory muscles in the torso (Ratnovsky et al., 2008).](image)

In this group of breathing muscles, the diaphragm has a special role. Amongst other reasons because it is the main inspiratory muscle during correct breathing, especially while being at rest (Sharma, 2012). All the respiratory muscles are important for the function of the lungs, but they have different times and situations when they are supposed to be active. During quiet breathing there is supposed to be synchronized motion of the lower and upper rib cage as well as the abdomen. All this motion is mainly produced by the diaphragm with help of the scalene, upper parasternal and intercostal muscles (Sharma, 2012; Bradley & Esformes, 2014). The magnitude of help of the accessory respiratory muscles differs between studies. Some show no activity during quiet breathing (Costa, Vitti & de Oliveira Tosello, 1997), while others show activity during quiet breathing (Perri & Halford, 2004; Ratnovsky, Zaretsky, Shiner & Elad, 2003). Therefore, normal breathing is also called diaphragmatic breathing. It is characterized by a
three-dimensional expansion of the lower ribcage in combination with movement of the abdominal wall (see Figure 2) as main mechanisms of breathing (Bradley & Esformes, 2014; Courtney, 2009). During normal breathing, only the inspiratory muscles are active, and the expiration happens automatically by the elastic recoil of the lung (Ratnovsky et al., 2008).

![Figure 2: Representation of functional breathing with diaphragm activity and lateral rib expansion (Rakhimov, n.d.)](image)

This breathing is sufficient during rest, but there are situations when the oxygen need of the body is increased. Most commonly this happens during exercise, when the greater number of active muscles and muscle fibers consume more energy and thereby need bigger amounts of oxygen to make the energy production possible (Your lungs and exercise, 2016). To make this increased airflow possible the diaphragm must increase its activity and get help from the accessory muscles (Sharma, 2012). Studies show their activity goes up when inspiratory effort increases (Ratnovsky et al., 2003), which leads to the increase in chest movement during breathing that is commonly seen in people engaging in strenuous effort.

### 2.1.2 Dysfunctional Breathing

This chest dominant breathing is known as abnormal breathing if seen during rest, when the increased need for oxygen is not given (Perri & Halford, 2004). Its characteristics are an increased upper rib cage motion compared to the motion of the lower rib cage and the abdominal area (Bradley & Esformes, 2014). This decreased abdominal motion in comparison to the increased thoracic motion is not only a sign of thoracic breathing produced by the accessory
muscles, it might also be an indicator of poor diaphragm activity (Bradley & Esformes, 2014). In this faulty pattern muscles that are usually no breathing muscles, like the pectoralis major and minor, the latissimus dorsi, serratus anterior and trapezius, become accessory respiratory muscles (Perri & Halford, 2004). This faulty pattern increases the risk of their overuse (Courtney, 2009), possibly reducing their function in other tasks.

The prevalence for dysfunctional breathing differs between studies. Some report that between 5-11% of the people in the healthy population suffer from dysfunctional breathing (Courtney, 2009). Others show numbers of 56.4% dysfunctional breathing during rest and 75% during deep breaths in the average population (Perri & Halford, 2004). Considered that the average person takes around 21,000 breaths per day (Courtney, 2009), a dysfunction in every one of them has the potential of detrimental effects on the body and the heavily overused accessory respiratory muscles.

2.2 Effects of functional and dysfunctional breathing

If dysfunctional breathing patterns have become a habit several negative short- and long-term effects can develop out of that. The study done by Bradley and Esformes (2014) shows that movement efficiency might be affected by dysfunctional breathing, which could be explained by the fact that “breathing is one of the most basic patterns directly related to human movement” Cavaggioni, Ongaro, Zannin, Iaia and Alberti (2015, p. 1). Dysfunctional breathing can also have negative effects on the posture due to an overload in the accessory breathing muscles (Courtney, 2009). This overload can lead to several adverse effects with symptoms like headache (Hruska, 1997) and neck pain (Perri & Halford, 2004; Bradley & Esformes, 2014; Hruska, 1997). Another common disorder in the general public, that is strongly influenced by dysfunctional breathing, is lower back pain (LBP). Studies show that a dysfunction in breathing muscles like the diaphragm, the transversus abdominis or the pelvic floor, can increase the chance to develop conditions like LBP or to get injured (Bradley & Esformes, 2014; Courtney, 2009; Roussel et al., 2009; Kolář et al., 2012). This is because besides their role in breathing they are important for the motor control and postural support of the body and especially of the spine. These negative postural effects in combination with the impaired motor control can also lead to a decrease in stability (Bradley & Esformes, 2014).

As made clear now it can have several negative effects on the body if the breathing pattern is dysfunctional. However, proper breathing patterns in form of breathing techniques can be used for actively working against problems. Probably the most popular use for breathing as a
therapeutic measure is against stress (Courtney, 2009; Jerath, Edry, Barnes & Jerath, 2006). Evidence also points towards an effect of breathing therapies in diseases like asthma, heart disease, anxiety, depression (Courtney, 2009), obstructive pulmonary disease (COPD), sciatica or thoracic outlet syndrome (Boyle et al., 2010). Correct breathing can also work against pain, especially in the neck and lower back area (Boyle et al., 2010) and increase overall stability and posture (Obayashi, Urabe, Yamanaka & Okuma, 2012). Because proper breathing is not automatic (Nelson, 2012), training of functional breathing is necessary for those who have lost it and suffer under the bad effects of dysfunctional breathing. Moreover, breathing exercises can enhance performance (Levine, 2002; Illi et al., 2012; Enright, Unnithan, Heward, Withnall & Davies, 2006). However, effects of breathing on performance and stability have mostly been researched with longer training regimes. The short-term effects of breathing interventions in these areas have hardly been studied so far.

2.3 Breathing and stability

2.3.1 The role of the diaphragm in stability

Decreased diaphragmatic activity, as evident in dysfunctional breathing, could be detrimental for performance since the diaphragm plays an important role in the stabilization of the lumbar spine area. Hodges, Butler, McKenzie and Gandevia (1997) found the first evidence for the postural role of the diaphragm by proving that it activates in an anticipatory postural adjustment (APA) fashion before the onset of muscles producing limb movement. Thereby the diaphragm contracts to help the abdominals and the pelvic floor to increase the intra-abdominal pressure (IAP), as can be seen in Figure 3. This activation occurs irrespective of the respiratory phase, proving that the diaphragm exerts a double role for respiration and postural stability (Hodges et al., 1997). Other studies confirmed this finding directly and indirectly, bringing further evidence for the importance the diaphragm plays in generating IAP (Kolář et al., 2012; Hodges & Gandevia, 2000a, 2000b; Hagins & Lamberg, 2011; Kawabata, Shima & Nishizono, 2014; Shirley, Hodges, Eriksson & Gandevia, 2003).

The generation of IAP is the main stability mechanism of the diaphragm, as several studies showed that an increase in IAP helps to stabilize the spine (Essendrop, Andersen & Schibye, 2002; Cholewicki, Juluru, Radebold, Panjabi & McGill, 1999; Hodges, Eriksson, Shirley & Gandevia, 2005). One explanation for how IAP might cause enhanced stability is by creating an extensor moment that seems to increase spinal stiffness and unload the spine when force is
applied (Stokes, Gardner-Morse & Henry, 2010). According to a more famous theory, IAP helps preserving the hoop like geometry around the lumbar spine. Thereby the hip and chest are kept in optimal positions relative to one another, which allows optimal tension and force generation (Kawabata et al., 2014; Hagins, Pietrek, Sheikhzadeh, Nordin & Axen, 2004). However, some studies show that the ability to increase IAP of the diaphragm is position specific (Arjmand & Shirazi-Adl, 2006; Lopes, Nunes, Niza & Dourado, 2016).

Another possible mechanism for the diaphragm to increase spinal stability are its fascial connections. These go to the spinal vertebrae, the thoracolumbar fascia and the pelvic floor muscles (Shirley et al., 2003; Bordoni & Zanier, 2013; Hodges, Sapsford & Pengel, 2007) thereby creating stabilizing forces (Hagins et al., 2004). All of which are influenced by proper diaphragm function.

2.3.2 The effect of 90/90 breathing on stability

The 90/90 bridge with ball and balloon is one example of a breathing technique that actively works on proper diaphragm mechanism and thereby also IAP generation. It will be called 90/90 breathing for convenience reasons throughout the thesis. The 90/90 breathing “was designed to optimize breathing and enhance both posture and stability to improve function and/or decrease pain” (Boyle et al., 2010, p. 1). These effects are supposed to be achieved by improving the zone of apposition (ZOA) of the diaphragm, which is the part of the muscle shaped like a dome (see Figure 4). If the ZOA is decreased the ability of the diaphragm to inhale sufficient air in a correct way is diminished. This affects the diaphragms ability to build up IAP.
The transversus abdominis activation also decreases with a smaller ZOA (Boyle et al., 2010), which again affects lumbar stabilization ability (Roussel et al., 2009).

However, when the ZOA is optimized the diaphragm can work efficiently. This is achieved by the 90/90 breathing because of the muscles that get activated and the specific body position, which is described in detail in the methods section. Doing the technique, the pelvic floor and the diaphragm get repositioned into a parallel alignment to each other (Boyle et al., 2010), thereby working against the lower and upper crossed syndromes (Boyle et al., 2010; Perri & Halford, 2004). It also works against lumbar extension, rib elevation and external rotation, anterior pelvic tilt and paraspinal activity (Boyle et al., 2010), thereby improving the ZOA. Moreover, the increased activation of the rectus abdominis, transversus abdominis, internal oblique and external oblique muscles during the technique may improve their ability to oppose the diaphragm, increasing the ability to maintain an optimal ZOA (Boyle et al., 2010). The increased activation of the abdominals might also contribute to a more stable spine in general. This is possible since all four are an important part in the concept of spinal stability, or core stability as it has been called over the past two decades.

The optimal ZOA restored with the 90/90 breathing helps the diaphragm fulfill its respiratory and postural dual role. Especially when doing physical activity this optimal functioning of the dual role is important because exercise increases both the demand on the respiratory and stability function of the diaphragm (Boyle et al., 2010; Hodges et al., 1997; Hodges, Heijnen & Gandevia, 2001). If the respiration is dysfunctional the body must give more attention to it,
thereby possibly decreasing the stabilizing potential of the diaphragm as well as of other important core muscles, like the transversus abdominis (Hodges & Gandevia, 2000b). Hodges et al. (2001) showed this in their study, where they found that the postural activity of the diaphragm decreases when the respiratory demand increases. Reduced activity in the main breathing muscles might be compensated by other breathing and non-breathing muscles, thereby possibly overloading them (Courtney, 2009).

Even though, the literature suggests the 90/90 breathing should affect the stability, the author of this thesis found no studies that actually investigated the effect that 90/90 breathing has on stability. This is part of the research gap that will be examined with this thesis.

### 2.4 Anatomical and functional definition of the core

In the scientific literature the definitions of the core differ in terms of how many and which structures are included. McGill (2010) includes the spine, the abdominal wall muscles, the back-extensor muscles, the quadratus lumborum as well as the latissimus dorsi, the psoas and gluteal muscles. Kibler, Press and Sciascia (2006) include the proximal lower limbs, hips, pelvis, spine and abdominal structures. Behm, Drinkwater, Willardson and Cowley (2010) define it as the axial skeleton including the shoulder and hip girdle and all soft tissues originating from the axial skeleton with proximal attachments. Richardson, Jull, Hodges and Hides (1999) describe it as “a box with the abdominals in the front, paraspinals and gluteals in the back, the diaphragm as the roof, and the pelvic floor and hip girdle musculature as the bottom” (Akuthota & Nadler, 2004, p. 1). 29 pairs of muscles are part of that ‘core box’ (Akuthota, Ferreiro, Moore & Fredericson, 2008). Including the transversus abdominis and the multifidus muscles, that are often stated as specifically important for core stability in the literature (Martuscello et al., 2013; Sharma, 2012; Key, 2013). This definition comes the closest to the concept of the core the 90/90 breathing technique wants to restore. With the diaphragm and pelvic floor as the top and bottom parallel to each other as in a real box and the muscles surrounding the lumbar spine as the wall of the box. All of them get activated with the breathing technique, thereby stabilizing it and creating a rigid cylinder (see figure 5). We will refer to that definition of the core when talking about it in this thesis.

Functionally the central structure of the core is the thoracolumbar fascia, because it is an important connection between several structures within that box (Bordoni & Zanier, 2013). All these connections allow a better formation of the stable hoop around the spine. They also play
an important part in the diaphragm's role in stability, as mentioned in section 2.3.1. Moreover, by the connections to the latissimus dorsi and gluteus maximus it connects the lower to the upper limbs, thereby making the core the center of the integrated kinetic chain (Kibler et al., 2006; Akuthota & Nadler, 2004). However, the core also fulfills important local functions, namely force generation and even more important stability. This stability is achieved in part by the APAs mentioned in section 2.3.2. Another stability mechanism of the core is when several core muscles become synergists and co-contract to form a stiff muscular corset (McGill, 2010; Borghuis, Hof & Lemmink, 2008; van Dieën Luger & van der Eb, 2012).

Figure 5: Anatomical view of the core-cylinder with the diaphragm as the top, the pelvic floor as the bottom, the paraspinals in the back and the abdominals in the front (Chauhan, n.d.)

2.5 Core stability definition and components

Hodges (2004) defined core stability as “dynamic process of controlling static position in the functional context but allowing the trunk to move with control in other situations” (Waldhelm & Li, 2012, p. 1). Panjabi (1992) defined CS as the active, the passive and the neural and feedback subsystem. Liemohn, Baumgartner and Gagnon (2005) defined CS based on this concept as “the functional integration of the passive spinal column, active spinal muscles, and the neural control unit in a manner that allows the individual to maintain the intervertebral neutral zones within physiologic limits while performing activities of daily living” (Liemohn et al., 2005, p. 1). Grenier and McGill (2007) defined core stability as the spine’s ability to survive perturbations. Kibler et al. (2006) defined it as “the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities” (Kibler et al., 2006, p. 2). Controlling the trunk over the pelvis keeps the center of mass (COM) over the center of pressure
(COP), which is important for balance, especially in single leg activities (Cinar-Medeni, Baltaci, Bayramlar and Yanmis, 2015).

This overall disunity in the literature concerning CS definitions can be explained, besides the wide spread anatomical definitions, by the fact that the exact function of CS and which structures contribute how much is task specific (McGill, Grenier, Kavcic & Cholewicki, 2003). For this thesis we will refer to CS as a mixture of the definitions from Kibler et al. (2006) and Liemohn et al. (2005). Core stability will be defined as the ability to control the position and motion of the trunk over the pelvis by the functional integration of the passive, active and neural subsystem. For the purpose to maintain the intervertebral neutral zones within physiologic limits during daily and athletic movements as well as the optimum production, transfer and control of force and motion in integrated kinetic chain activities.

This disunity of definitions also explains why there is no consent on what the components of CS are. Some include a combination of neuromuscular control and muscular capacity (Borghuis et al., 2008; Leetun, Ireland, Willson, Ballantyne & Davis, 2004; Butowicz, Ebaugh, Noehren & Silfies, 2016). Muscular capacity consists of muscle strength and endurance, with neuromuscular control being the ability to orchestrate and coordinate both capacities (Borghuis et al., 2008). Of the three components neuromuscular control is of specific importance since it allows the precise coordination of muscle actions at the right time to produce movement and stability (Borghuis et al., 2008). This in the first place makes CS possible and is aided by muscular endurance, strength or both depending on the situational demands on the system. Other researchers include more components as central to the concept of core stability, like flexibility and function (Waldhelm & Li, 2012) or even power and balance (Sharma, 2012). However, for this study we will refer to the components of core stability as the combination of neuromuscular control and muscular capacity.

2.6 Measuring Core stability

With the complexity and disunity of the topic comes a wide variety of different tests that aim on measuring core stability. Depending on the definition the researchers had of CS, they chose tests with different qualities that measure different components of CS. The most widely used test is probably the trunk endurance test battery from McGill, Childs and Liebenson (1999). It consists of 4 different measurements of the anterior, posterior and lateral trunk endurance. However, endurance is only a part of what CS consists of as detailed in the section
above. Apart from that a wide variety of tests claim to measure CS ranging from strength tests to neuromuscular control tests and functional tests (Waldhelm & Li, 2012). However, a true gold-standard measurement for CS is missing. This makes the choice for a core stability test difficult. Especially because evidence suggests that important core muscles and stabilizing mechanisms work task specific (McGill et al., 2003; McGill, 2010; Frank et al., 2013). When not researching CS in connection with a certain movement or performance, but the concept of CS at whole, it makes thereby sense to use several tests. A logical approach to choosing the right tests for measuring CS in its complexity is to look at the movement planes the core works in. These are the frontal plane, the sagittal plane and the transversal plane. The core allows and restricts movement in all three planes, making local force production, distal mobility and movement along the kinetic chain possible.

Three tests that fall into these movement planes are the double leg lowering (DLL), the unilateral hip bridge (UHB) and the single leg stand (SLS). In the DLL the legs of a supine lying person move from a vertical to a horizontal position which represents the sagittal plane. The UHB, where a supine lying person with the feet on the floor lifts the hip up and extends one leg once in the neutral position, challenges CS multi-planar (Butowicz et al., 2016). Namely in the sagittal and transversal plane. Lastly, the SLS is a test where the person stands on one leg with the other leg held in the air. Looking at how the feet are lined up in the frontal plane in a normal stand one could argue that a stand on only one leg makes frontal stabilization harder, challenging CS in that plane. Besides their categorization to certain movement planes, all three tests were chosen because they are supposed to measure the neuromuscular control component of CS (Butowicz et al., 2016; Waldhelm & Li, 2012; Sharrock, Cropper, Mostad, Johnson & Malone, 2011). The 90/90 breathing is more likely to affect this component rather than muscular capacity, because it teaches proper stabilization mechanisms and posture.

### 2.7 Core stability and its influence on injury and performance

#### 2.7.1 Core stability and injury

Looking at the definitions of core stability and the functional connections of the core it makes sense that a badly functioning core could have a wide variety of negative impacts on the body. The spine is specifically prone to these impacts, considering it would buckle under a load as small as 20 Newton (N) or 2 kg without the structures surrounding it creating stability (Panjabi, 1992). One of the most recognized impacts of CS is on lower back pain. Several
studies show that LBP is associated with poor control and function of the core muscles and structures (Borghuis et al., 2008; Hubley-Kozey & Vezina, 2002; McGill et al., 2003). And even though it is not clear yet if these factors cause LBP or are caused by LBP, studies show that a functioning and stable core can play an important role in the prevention of LBP (Biering-Sørensen, 1984; McGill, 2015).

Table 1: Overview of the most important literature studying the effect of core stability (CS) or core stability training (CST) on lower back pain (LBP).

<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Aim</th>
<th>Positive effect of CS on injury</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chang, W. D., Lin, H. Y., &amp; Lai, P. T. (2015)</td>
<td>Core strength training for patients with chronic low back pain</td>
<td>To review the effect of different CST methods on LBP</td>
<td>Yes</td>
<td>All CST methods reviewed decreased LBP. More than general resistance training</td>
</tr>
</tbody>
</table>

More evidence has been compiled to show that CS training can be an effective means in the rehabilitation of patients that are already suffering from LBP (Wang et al., 2012; Carpes, Reinehr & Mota, 2008; Shamsi, Rezaei, Zamanlou, Sadeghi & Pourahmadi, 2016). These findings become especially important when looking at the occurrence for LBP with a general prevalence in the USA and Europe ranging from 15-40%, (Carpes et al., 2008; Shamsi et al., 2016). For a summary of the most important literature of CS and LBP see Table 1.

2.7.2 Core stability and performance

When it comes to performance parameters the literature agrees much less on the effect of core stability training or if there even is an effect. A big body of literature has been produced so far on CS training and its effects on several different types of sport and performance

Table 2: Overview over the most important literature studying the effect of core stability (CS) or core stability training (CST) on performance

<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Aim</th>
<th>Positive effect of CS on performance</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schilling, J. F., Murphy, J. C., Bonney, J. R., &amp; Thich, J. L. (2013)</td>
<td>Effect of core strength and endurance training on performance in college students: randomized pilot study</td>
<td>If CS endurance and strength training have an effect on strength, core endurance and performance tests</td>
<td>Inconsistent</td>
<td>CST improved core endurance and partly strength but no performance measurements</td>
</tr>
<tr>
<td>Araujo, S., Cohen, D., &amp; Hayes, L. (2015)</td>
<td>Six weeks of core stability training improves landing kinetics among female capoeira athletes: a pilot study</td>
<td>If CST affects landing kinetics during a drop jump in female capoeira athletes</td>
<td>Yes</td>
<td>Peak landing force of landing phase 1 and 2 was reduced after CST. Jump height did not improve</td>
</tr>
<tr>
<td>Imai, A., &amp; Kaneoka, K. (2016)</td>
<td>The relationship between trunk endurance plank tests and athletic performance tests in adolescent soccer players</td>
<td>If CS is related to athletic performance tests</td>
<td>Inconsistent</td>
<td>Core endurance tests showed positive correlations with the Yo-Yo, Cooper and step 50 agility test but not with any jump or sprint measurements</td>
</tr>
<tr>
<td>OZMEN, T. (2016)</td>
<td>Relationship between core stability, dynamic balance and jumping performance in soccer players</td>
<td>If CS is related to dynamic balance and jumping performance in male soccer players</td>
<td>No</td>
<td>No positive relationship between CS and balance or jump performance was found.</td>
</tr>
</tbody>
</table>
However, these findings are not consistent throughout the literature with a different body of studies showing no effect of CS training on performance in balance, soccer, handball or overall athletic performance (McCartney & Forsyth, 2017; Schilling, Murphy, Bonney & Thich, 2013; Nesser & Lee, 2009; Chittibabu, Ramesh Kannan & Jayakumar, 2013).

Several reasons could be the cause of this disunity. First, as mentioned above, core stability seems to be task specific. With the wide variety of different tests claiming to measure CS it might be easy to pick a test that does not capture the components of CS that are mainly active in the studied movement or task. Moreover, it might be easy to test the CS components in a wrong set-up. A second reason might be that a lot of general exercises automatically train the core, especially the ones used in athletic training. Thereby any advantage specific CS training might have over general exercise could be diminished.

As shown, a lot of research exists on the effect of CS training interventions. However, the short-term effects of CS exercises on performance lack research so far. Methods like abdominal bracing (AB) and hollowing have been mainly used as acute CS interventions in the literature and AB has been proven to increase spinal stiffness (Liebenson, Karpowicz, Brown, Howarth & McGill, 2009; Vera-Garcia, Elvira, Brown & McGill, 2007). Studies on the effect of these interventions on performance however are scarce. Apart from these two techniques the author only found one other study on short-term effects of a CS intervention on performance. Kaji, Sasagawa, Kubo and Kanehisa (2010) found positive effects of a CS intervention on a bipedal postural balance task done directly afterwards. For a summary of the most important literature of CS and performance see Table 2.

2.8 Functional Training

The beforehand mentioned research gap about the transient effects of core stability exercises is important when it comes to Functional Training. According to Cosio-Lima, Reynolds, Winder, Paolone and Jones (2003, p. 1) FT is “the ability of the neuromuscular system to perform dynamic concentric, eccentric, and isometric stabilization contractions in response to gravity, ground-reaction forces, and momentum.” This shows that stability is an important part in FT and one method coaches try to achieve this for the dynamic or heavy exercises of the main part in training sessions are core activations. They consist of either general or more training specific exercises that work on the core and its stability. Examples for core activations are plank variations or certain exercises in the quadruped position (Boyle, 2012).
Core activations are used as a short-term way to enhance CS, with the intention to make the following exercises more safe and effective because the stability and functionality of the integrated kinetic chain are supposedly improved. However, scientific proof for these claims is almost all but missing. Apart from the study by Kaji et al. (2010) the author of this thesis did not find any other study on the short-term effects of core activations on performance or studies if core activations even improve core stability in the first place.

This research gap leads to the main rationale for conducting this study; to find out if a core activation can really enhance CS. Breathing techniques lend themselves to use as core activations. This is because breathing has a big body of literature showing it could affect CS positively by working on the core muscles, IAP generation as well as causing negative effects for CS and the whole movement function if not working properly. Especially diaphragmatic breathing seems to be important for CS. However, studies concerning short lasting stability enhancements through breathing have not been found. Moreover, in the general public as well as among some practitioners and coaches, breathing is still not recognized for the beneficial effects it can have on performance and disbalances as much as the literature suggests. Therefore, the author chose the diaphragmatic breathing technique 90/90 breathing as a core activation to study whether this strategy of short-term CS enhancement done so frequently in FT actually works, and if it could be done with a breathing technique.

2.9 Aim

The Aim of the study was to test if a short-term activation of the core by doing the 90/90 breathing would impact core stability.

The research question was thereby if it is possible to influence the short-term core stability with an activation of the core muscles by doing the 90/90 breathing.

3. Methods

3.1 Subjects

To test whether 90/90 breathing influences core stability 44 subjects (43% women) were tested. They were all students at a university in the southern part of Sweden and aged between 18 and 35 years. This age span was chosen to test young adults. All subjects were known
personally by the author and asked verbally in person or written via the social media platform Facebook. 53 subjects were asked, 9 subjects declined participation out of time reasons or because they fell into one of the exclusion criteria. Exclusion criteria were a BMI over 25, current illness or disease, major injuries like broken bones or torn ligaments within the past 6 months, extended experience in breathing techniques or practice of them on a regular basis like in yoga and doing heavy lifts like squats or deadlifts on a regular basis. The BMI was limited because a study on children showed that those with normal weight had a better core stability than overweight ones (Haggag, 2017). Heavy lifters usually already have developed breathing strategies like the Valsalva maneuver to increase core stability and are thereby less likely to benefit from the short-term effects of 90/90 breathing. People doing yoga or other breathing techniques on a regular basis might already possess a good control over their diaphragm breathing and would be thereby also less likely to benefit from the intervention. “Regular” in this study was defined as performing yoga or heavy lifting at least once a week for longer than a month. Being a heavy lifter meant lifting more than 1.5 times the bodyweight in the squat or deadlift for at least 5 repetitions.

Four subjects were excluded from the data analysis due to fulfilling exclusion criteria which was unknown when inviting them to participate. Therefore, 40 subjects were included in the data analysis.

3.2 Experimental Design

A quantitative study was conducted in the form of an intervention trial to test the research question. The subjects were randomly divided into a control group (CG) and a breathing group (BG) that did the intervention. This was done to be able to tell if possible results of the breathing technique are due to the effect of the intervention or due to repeated measures effects. Moreover, to see if there was a difference between doing the intervention or not. Twenty-one subjects were in the CG and 19 in the BG.

Three tests were chosen to measure core stability, the double leg lowering, the unilateral hip bridge and the single leg stand. One test for each movement plane of the core. They will be described in detail later on. The tests were done in a pre-test post-test manner with the first test round at the beginning of the testing session and the second round at the end. The BG did the breathing intervention in between whereas the CG did nothing but stayed in a similar position to the one the subjects had during the intervention.
3.3 Testing procedure

Before the start of the testing each subject was advised not to engage in any sport on the day of the tests and to avoid intense exercise on the day before, especially of the legs and the core. This was done to avoid muscle soreness on the testing day or impaired muscle function during the tests. After arriving the subjects were asked to fill out the informed consent as well as a questionnaire. In the latter they were asked about their weight, height, age, gender as well as about their engagement in sport in hours and times a week and their training and breathing experience.

Next three assessments were performed. The first two were the high-low-test (HLT) and the lateral-rib-expansion-test (LRET) (Nelson, 2012), as can be seen in Figure 6 and Figure 7. Both test the functionality of breathing in different situations. For the HLT the subject stood in front of the examiner and placed one hand on the chest, the other on the lower abdomen. The examiner then observed the movement of the hands caused by the inhalation. As described in the background during quiet breathing the abdomen was supposed to move first as an indicator of functional diaphragmatic breathing. Dysfunctional breathing was indicated by the chest moving first and more dominantly than the abdomen. For the LRET the examiner positioned himself behind the subjects and placed his hands with permission on the side of the lower ribs. The subjects were then instructed to take three deep breaths. If the ribcage expanded lateral and the shoulder area rose only minimal the breathing was functional. With a dominant shoulder movement upwards and or a mainly upwards movement of the lower ribs breathing was classified as dysfunctional. For both tests the subjects were not told beforehand what the examiner was looking for to not influence their natural breathing behavior.

Figure 6: High-low-test starting position. One hand on the chest and one on the abdomen to see which area dominantly moves during quiet breathing (Nelson, 2012)

Figure 7: LRET-test set-up. The examiner's hands are on the side of the lower chest to feel the motion of the lower ribs during deep breathing (Nelson, 2012)
The third assessment was a kicking test to find out which leg was the more stable dominant leg (DL) one in a single leg stand. For that purpose, the examiner rolled a ball to the subjects and they were instructed to kick it back. Reed, Jennings, Nakamura and Wilson (2015) found that the leg used as standing leg during the ball kicking legs showed longer unipedal standing times compared to the kicking leg and thereby seems to be the more stable leg. After the assessments the subjects randomly chose which group they would belong to by picking one folded paper out of a pile with either control or breathing written on them. The papers were matched for the number of participants so that in the end the same number of subjects would be tested for both groups.

The three tests done in the first testing round (Pre) as well as in the second testing round (Post) were a single leg stand, a unilateral hip bridge and a double leg lowering. These tests were chosen because each test dominantly tested one of the three motion planes the core can move in. In the DLL subjects were lying on a mat on the floor with the examiners hand below the L4-5 area of the lumbar spine and the legs as straight as possible vertically in the air. The subjects then lowered them in a steady speed taking 10 seconds (s) from the top position all the way down (see Figure 10). This was counted down out loud by the examiner. The procedure was shown to the subjects beforehand and the examiner made sure they understood how to do it. Before the DLL started the subjects were shown how to do a posterior pelvic tilt to preserve the natural form of the spine during the exercise. They were told to hold that posterior pelvic tilt by pressing the lumbar spine into the ground throughout the DLL. Once in the start position a wooden stick with a digital inclinometer (Model MDP01, Shenzen Temie Technology Co. Ltd., Shenzhen, China) attached to it was placed alongside the femur to measure the angle in degrees the participants were able to achieve. The test was stopped when the subjects could not hold the posterior pelvic tilt anymore and the spine started lifting off the ground (Krause, Youdas, Hollman & Smith, 2005). Two repetitions of the DLL were performed, and the best try was taken for the analysis. The DLL represented the test for the sagittal movement plane of the core. For the UHB the subjects were instructed to lie in a supine position on a mat with their feet on the floor in a position where their fingers could still touch their heels. A belt (Hip Belt, Exxentric AB, Bromma, Sweden) was placed around their hip with a wooden stick plus the digital inclinometer attached to it. The subjects were instructed to cross the arms on the chest, lift up their hip into a normal hip bridge and once in the neutral position extend one leg while trying
to keep the hip as stable in the neutral position as possible (see Figure 9). Time was taken for how long the participants could hold the position. The examiner placed a goniometer (12 Inch plastic, 66fit, West Pinchbeck, United Kingdom) fixed to a 10° angle on the joint axis of the knee to track the sagittal movement of the hip while the inclinometer measured the transversal movement of the hip. Once the movement of the hip broke 10° in one of both planes the time was stopped (Butowicz et al., 2016). The test was first done with the dominant leg and repeated with the non-dominant leg (NDL). The UHB represented the test for the transversal movement plane of the core. For the SLS the subjects were instructed to step on a force plate (Model PJB-101, Advanced Mechanical Technology, Inc., Watertown, USA) with their stable foot, lifting up the other leg with the knee and the heel in front of the standing leg and the arms across the chest (see Figure 8). Once in position subjects were supposed to find a stable stand and close the eyes on the command of the examiner while trying to stand as stable as possible for 10 seconds (Lee et al., 2015). They were given one trial round and were tested three times after with 30 seconds pause in between each repetition. When the subjects fell over or started twisting their foot away from the starting point the try was repeated. The center of pressure in its maximum range was measured in X- and Y-direction on the force plate and used as test variable. The test was done barefoot.
The breathing group then performed the 90/90 breathing detailed below after a pause of 5 minutes. These 5 minutes were used to explain the technique to the subjects and let them try it under the supervision of the examiner, so he could correct them and make sure they did it right for the actual exercise. All subjects of the BG were able to perform the breathing after the explanation. The intervention itself took 3 minutes. The control group did nothing during these 8 minutes, but subjects were instructed to go into similar positions as the BG to exclude the possibility that any other movement could have had an effect on their performance. Therefore, they sat for the first 2.5 minutes before lying in a supine position on the mat with the feet on the floor for the next 5.5 minutes.

In the Post-test the three tests were performed in a random order. This was done so that no specific order of the tests could have an impact on the effect of the intervention. For this purpose, the name of each test was written on a paper that was folded with the subject picking a random one before each test.

### 3.4 Breathing intervention

The 90/90 breathing was done as described in detail in the paper of Boyle et al. (2010). Subjects lay in a supine position on a mat, the feet against a wall with 90° in the knees and hip, a soft ball between the thighs. One hand was holding a balloon on the lips, the other hand was held overhead (see Figure 12). Subjects were instructed to inhale through the nose via diaphragmatic breathing into the abdomen and lower ribs, then exhale into the balloon. During the exhale the feet were pushed into the wall and pulled down isometrically with moderate force. Moreover, the legs pushed the ball together during the exhale.

![Figure 11: Position during the 90/90 breathing (Boyle et al. 2010)]
This tension was constantly held for one set. After the exhale a one second pause followed and then the inhale during which the air was supposed to stay in the balloon without pinching it. The posture of the core created with the exhalation was also supposed to be kept. After four breaths into the balloon subjects released the air of the balloon and relaxed. This was one set and four of them were performed with short pauses in between, only as long until the subjects felt ready to go for the next set. After two sets the setup of the arms was switched.

3.5 Ethical and Social Considerations

The study will follow the guidelines of the Declaration of Helsinki. None of the tests done in this study involved invasive techniques. The core stability tests wielded, as every physical intervention an existing, albeit very small injury risk. The breathing itself could induce dizziness because of the high volume of inhaled air and thereby a high amount of oxygen in a short time, to which subjects might have not been used to. This was clearly communicated to the subjects as well as their freedom to end the participation whenever they wanted without having to justify themselves.

From a social perspective the study did wield some advantages for the general population. The breathing technique could help people with lower back pain or neck pain as described in the background. This benefit would be even more prominent in certain situations when the 90/90 breathing would show to increase CS, which works against LBP as shown in the background. For recreational active people, but also sedentary people, the knowledge gained could help reduce LBP also by increasing the awareness for the 90/90 breathing.

Another benefit would be that the knowledge gained could help make training and preparation more effective, by improving the warm-up and thereby possibly enhancing performance or making training and activity safer. It would be especially interesting for the Functional Training community, since the exercises and methods like the ones used in this study are common practice there.

3.6 Statistical Analysis

All data analyses were conducted using Statistical Package for the Social Sciences (SPSS v24, Chicago, United States of America). The data was first tested for normal distribution with the Shapiro-Wilk test. It showed normal distribution for the double leg lowering data and not
normal distribution for the unilateral hip bridge and center of pressure data. Therefore, all calculations with DLL variables were done with parametric tests whereas all calculations with UHB and COP variables were done with none-parametric tests.

An Independent t-test and Mann-Whitney U tests were done to test for differences in the test performance between CG and BG in the Pre- and Post-test. This was the first test series. The same tests were used for the calculation for differences in the performance change from Pre to Post between groups. This was the third test series. A Paired Samples t-test and Wilcoxon tests were done to test for performance improvements from Pre to Post within the groups. This was the second test series. To check for any group differences between the dominant leg and the non-dominant leg in the UHB at Pre or Post a Wilcoxon test was calculated in addition to the second test series. The significance level was set at $p \leq 0.05$ for all tests.

A secondary analysis to check for group differences in all CS variables in several sub-categories of the population was also done. This had the aim to find out if any particular group of the subjects had specific influence on the results. Sub-categories were gender, breathing pattern and time spent doing sports per week in hours (TSDS). For gender the subjects were divided into men and women. The statistical calculations were done with an Independent t-test for the DLL data and Mann-Whitney U tests for the UHB and COP data. For breathing pattern, the subjects were divided into three categories, functional breathing, partly dysfunctional breathing and dysfunctional breathing. The calculation was done with an ANOVA. Moreover, a Spearman correlation between all CS variables and the TSDS was calculated. The strength of the correlation was evaluated after the study of Hinkle, Wiersma and Jurs (2003), with an $r=0.0$ to 0.2 being negligible, $r=0.2$ to 0.4 being low, $r=0.4$ to 0.6 being moderate, $r=0.6$ to 0.8 being high and $r>0.8$ being excellent.

4. Results

4.1 Descriptive statistics

The descriptive statistics of the most important subject variables can be seen in Table 3. According to the two tests for breathing functionality, the high-low-test and the lateral-rib-expansion-test, 10 people had completely functional breathing, 15 had partly dysfunctional and 15 had completely dysfunctional breathing. 34 subjects had gym experience to some degree, 20 had experience in team sports, namely soccer, volleyball, basketball, American football, rugby
and hurling and 9 had experience in individual sports, namely running, high jumping, thai boxing, swimming, cycling, tennis, gymnastics and water skiing.

Table 3: Descriptive Subject Data

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Age (y)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>TSDS (h)</th>
<th>SSPW</th>
<th>YTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full population</td>
<td>40</td>
<td>23.3</td>
<td>70.5</td>
<td>175.9</td>
<td>5.4</td>
<td>3.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Women</td>
<td>17</td>
<td>21.87</td>
<td>62.73</td>
<td>168.13</td>
<td>4.50</td>
<td>3.57</td>
<td>5.03</td>
</tr>
<tr>
<td>Men</td>
<td>23</td>
<td>24.08</td>
<td>75.16</td>
<td>180.56</td>
<td>5.94</td>
<td>3.54</td>
<td>7.32</td>
</tr>
<tr>
<td>CG</td>
<td>21</td>
<td>23.2</td>
<td>71.9</td>
<td>176.3</td>
<td>6.05</td>
<td>3.95</td>
<td>7.14</td>
</tr>
<tr>
<td>BG</td>
<td>19</td>
<td>23.3</td>
<td>69.0</td>
<td>175.4</td>
<td>4.68</td>
<td>3.11</td>
<td>5.76</td>
</tr>
</tbody>
</table>

y = years, kg = kilogram, cm = centimeters, h = hours, TSDS = Time spent doing sports per week, SSPW = Sport sessions per week, YTE = Years of training experience

4.2 Main effect calculations

4.2.1 Group difference at the first and second test round

The first series of tests done was to see if there were differences between the control group and the breathing group for Pre or Post. No significant differences were found between the groups at baseline (see Table 4). However, the UHB data at Post showed a significant difference for the dominant leg (p=0.029) with a mean holding time of 42.11s for the BG and 27.24s for the CG as well as for the non-dominant leg (p=0.031) with a mean holding time of 51.51s for the BG and 30.35s for the CG (see Table 5). No significant difference between groups was found in the Retest for the DLL data as well as for COP data in X- and Y-direction (see Table 5).

Table 4: Group differences between breathing group and control group at the first test round.

<table>
<thead>
<tr>
<th></th>
<th>Mean Value BG</th>
<th>Mean Value CG</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHB-DL- Pre (s)</td>
<td>36.28 ± 14.73 *</td>
<td>29.61 ± 18.93</td>
<td>0.233</td>
</tr>
<tr>
<td>UHB-NDL- Pre (s)</td>
<td>44.87 ± 25.52</td>
<td>31.80 ± 25.96</td>
<td>0.091</td>
</tr>
<tr>
<td>DLL- Pre (°)</td>
<td>52.82 ± 17.83</td>
<td>59.31 ± 17.00</td>
<td>0.246</td>
</tr>
<tr>
<td>COP-X- Pre (mm)</td>
<td>66.82 ± 22.34</td>
<td>62.98 ± 19.94</td>
<td>0.336</td>
</tr>
<tr>
<td>COP-Y- Pre (mm)</td>
<td>42.86 ± 7.86</td>
<td>45.96 ± 11.98</td>
<td>0.924</td>
</tr>
</tbody>
</table>

BG = breathing group, CG = control group, UHB = unilateral hip bridge, DLL = double leg lowering, COP = center of pressure, DL = dominant leg, NDL = non-dominant leg, Pre = first test round, * = standard deviation
Table 5: Group differences between breathing group and control group at the second test round.

<table>
<thead>
<tr>
<th>POST</th>
<th>Mean Value BG</th>
<th>Mean Value CG</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHB-DL-Post (s)</td>
<td>42.11 ± 21.71</td>
<td>27.42 ± 17.47</td>
<td>0.029*</td>
</tr>
<tr>
<td>UHB-NDL-Post (s)</td>
<td>51.52 ± 31.09</td>
<td>30.35 ± 25.49</td>
<td>0.031*</td>
</tr>
<tr>
<td>DLL-Post (°)</td>
<td>61.39 ± 19.75</td>
<td>57.30 ± 15.70</td>
<td>0.470</td>
</tr>
<tr>
<td>COP-X-Post (mm)</td>
<td>61.83 ± 34.02</td>
<td>52.27 ± 11.49</td>
<td>0.473</td>
</tr>
<tr>
<td>COP-Y-Post (mm)</td>
<td>42.79 ± 10.14</td>
<td>41.68 ± 6.06</td>
<td>0.860</td>
</tr>
</tbody>
</table>

BG = breathing group, CG = control group, UHB = unilateral hip bridge, DLL = double leg lowering, COP = center of pressure, DL = dominant leg, NDL = non-dominant leg, Post = second test round, * = significant at p < 0.05, a = standard deviation

4.2.2 Performance change within groups from the first to second test round

The second series of tests was conducted to see if there was a change in performance within the groups from Pre to Post (see Table 6). The data for the UHB showed no difference in the CG in both legs and in the BG for the dominant leg but a significant difference in the BG for the non-dominant leg (p=0.02) with a mean holding time of 38.01s for Pre (see Table 6) and 40.40s for Post (see Table 6). The data for the DLL showed no difference from Pre to Post for the CG but a significant difference for the BG (p=0.001) with a mean leg lowering distance of 52.82° for Test (see Table 6) and 61.39° for Retest (see Table 6). The COP data showed no significant difference for the BG in X- or Y-direction and no significant difference for the CG in Y-direction. But the data showed a significant difference from Pre to Post for the CG in X-direction (p=0.011) with a mean range of 62.98mm for Pre (see Table 6) and 52.27mm for Post (see Table 6).

The additional test for group differences between the dominant and non-dominant leg in the UHB showed no significant difference between both legs at Pre (p=.136) and Post (p=.243) (see Table 7).
Table 6: Performance change within groups from Pre to Post

<table>
<thead>
<tr>
<th></th>
<th>Mean Value Pre BG</th>
<th>Mean Value Post BG</th>
<th>p-values Pre-Post Performance Change BG</th>
<th>Mean Value Pre CG</th>
<th>Mean Value Post CG</th>
<th>p-values Pre-Post Performance Change CG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UHB-DL</strong></td>
<td>36.28 ± 14.73</td>
<td>42.11 ± 21.71</td>
<td>0.227</td>
<td>29.61 ± 18.93</td>
<td>27.42 ± 17.47</td>
<td>0.067</td>
</tr>
<tr>
<td><strong>UHB-NDL</strong></td>
<td>44.87 ± 25.52</td>
<td>51.52 ± 31.09</td>
<td>0.020*</td>
<td>31.80 ± 25.96</td>
<td>30.35 ± 25.49</td>
<td>0.689</td>
</tr>
<tr>
<td><strong>DLL</strong></td>
<td>52.82 ± 17.83</td>
<td>61.39 ± 19.75</td>
<td>0.001**</td>
<td>59.31 ± 17.00</td>
<td>57.30 ± 15.70</td>
<td>0.336</td>
</tr>
<tr>
<td><strong>COP-X</strong></td>
<td>66.82 ± 22.34</td>
<td>61.83 ± 34.02</td>
<td>0.198</td>
<td>62.98 ± 19.94</td>
<td>52.27 ± 11.49</td>
<td>0.011*</td>
</tr>
<tr>
<td><strong>COP-Y</strong></td>
<td>42.86 ± 7.86</td>
<td>42.79 ± 10.14</td>
<td>0.601</td>
<td>45.96 ± 11.98</td>
<td>41.68 ± 6.06</td>
<td>0.170</td>
</tr>
</tbody>
</table>

BG = breathing group, CG = control group, UHB = unilateral hip bridge, DLL = double leg lowering, COP = center of pressure, DL = dominant leg, NDL = non-dominant leg, Pre = first test round, Post = second test round, * = significant at p < 0.05, ** = significant at p < 0.01, a = standard deviation

Table 7: Mean values and p-values between the legs of the unilateral hip bridge at the first and second test round.

<table>
<thead>
<tr>
<th>Difference at Pre (s)</th>
<th>Mean Value DL</th>
<th>Mean Value NDL</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>36.28</td>
<td>44.87</td>
<td>0.136</td>
<td></td>
</tr>
<tr>
<td>42.11</td>
<td>51.52</td>
<td>0.243</td>
<td></td>
</tr>
</tbody>
</table>

Pre = first test round, Post = second test round, DL = dominant leg, NDL = non-dominant leg

4.2.3 Difference in the performance change between groups

The third series of tests was calculated to see if there was a difference in the performance change from Pre to Post between groups (see Table 8). The data for the UHB showed no group difference in the performance change for the dominant leg or the non-dominant leg. The DLL data showed a significant difference between groups in the performance change (p=0.001) with a mean difference of -2.01° from Test to Retest in the CG and 8.58° in the BG (see Table 8). The COP data showed no difference in the performance change between groups in X- or Y-direction (see Table 8).
Table 8: Difference in the performance change between groups

<table>
<thead>
<tr>
<th></th>
<th>Mean Performance Change Difference CG</th>
<th>Mean Performance Change Difference BG</th>
<th>p-values Performance Change Difference CG-BG</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHB-DL</td>
<td>-2.37 ± 10.96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.83 ± 19.84</td>
<td>0.330</td>
</tr>
<tr>
<td>UHB-NDL</td>
<td>-1.45 ± 16.30</td>
<td>6.64 ± 16.88</td>
<td>0.088</td>
</tr>
<tr>
<td>DLL</td>
<td>-2.01 ± 9.35</td>
<td>8.58 ± 9.90</td>
<td>0.001&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>COP-X</td>
<td>1.66 ± 10.65</td>
<td>-0.94 ± 25.14</td>
<td>0.456</td>
</tr>
<tr>
<td>COP-Y</td>
<td>0.72 ± 5.73</td>
<td>0.88 ± 8.67</td>
<td>0.440</td>
</tr>
</tbody>
</table>

BG = breathing group, CG = control group, UHB = unilateral hip bridge, DLL = double leg lowering, COP = center of pressure, DL = dominant leg, NDL = non-dominant leg, Pre = first test round, Post = second test round, ** = significant at p < 0.01, <sup>a</sup> = standard deviation

4.3 Secondary calculations

After these calculations for the main effects secondary tests were done to see if any of the gathered questionnaire variables had an influence on the results. First all the variables were tested for gender differences. Therefore, it was calculated if the data of any test showed group differences between men and women for Pre or Post (see Table 9). No difference between men and women was found for the UHB and DLL in Pre or Post. For the COP data there was no difference found for Pre in X- or Y-direction and for Post in X-direction but a significant difference between genders in Y-direction was found (p=0.002) with men having a mean COP range of 44.61mm and women having a mean range of 38.20mm.
Table 9: Group differences between men and women for all test variables at the first and second test round.

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Mean Value Men</th>
<th>Mean Value Women</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHB-DL-Pre (s)</td>
<td>34.07 ± 18.48(^a)</td>
<td>30.63 ± 15.15</td>
<td>0.468</td>
</tr>
<tr>
<td>UHB-NDL-Pre (s)</td>
<td>39.82 ± 28.68</td>
<td>35.00 ± 22.28</td>
<td>0.706</td>
</tr>
<tr>
<td>UHB-DL-Post (s)</td>
<td>34.62 ± 20.53</td>
<td>33.77 ± 21.84</td>
<td>0.867</td>
</tr>
<tr>
<td>UHB-NDL-Post (s)</td>
<td>43.25 ± 33.83</td>
<td>35.67 ± 22.12</td>
<td>0.665</td>
</tr>
<tr>
<td>DLL-Pre (°)</td>
<td>57.78 ± 14.65</td>
<td>53.31 ± 21.66</td>
<td>0.421</td>
</tr>
<tr>
<td>DLL-Post (°)</td>
<td>60.44 ± 13.59</td>
<td>57.25 ± 23.29</td>
<td>0.634</td>
</tr>
<tr>
<td>COP-X-Pre (mm)</td>
<td>66.34 ± 24.07</td>
<td>62.23 ± 14.70</td>
<td>0.922</td>
</tr>
<tr>
<td>COP-Y-Pre (mm)</td>
<td>46.43 ± 12.16</td>
<td>41.24 ± 4.47</td>
<td>0.067</td>
</tr>
<tr>
<td>COP-X-Post (mm)</td>
<td>59.52 ± 28.63</td>
<td>52.25 ± 17.37</td>
<td>0.645</td>
</tr>
<tr>
<td>COP-Y-Post (mm)</td>
<td>44.61 ± 7.97</td>
<td>38.24 ± 7.02</td>
<td>0.002**</td>
</tr>
</tbody>
</table>

\(\text{UHB} = \text{unilateral hip bridge, DLL = double leg lowering, COP = center of pressure, DL = dominant leg, NDL = non-dominant leg, Pre = first test round, Post = second test round, ** = significant at } p < 0.01, a = \text{standard deviation}\)

Next the results were checked for the influence of the breathing pattern. Therefore, subjects were divided into three groups. Those with functional breathing (FB) that had no dysfunction in either of both breathing tests. Those with partly dysfunctional breathing (PDB) that had a dysfunction in one of the two breathing tests. And those with dysfunctional breathing (DB) that had a dysfunction in both breathing tests. No group differences between breathing patterns have been found for any of the CS test data (see Table 10).
Table 10 Group differences between functional breathing, partly dysfunctional breathing and dysfunctional breathing.

<table>
<thead>
<tr>
<th></th>
<th>Mean Value FB</th>
<th>Mean Value PDB</th>
<th>Mean Value DB</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHB-DL- Pre (s)</td>
<td>27.14 ± 18.32 (a)</td>
<td>39.43 ± 18.06</td>
<td>29.07 ± 13.99</td>
<td>0.175</td>
</tr>
<tr>
<td>UHB-NDL- Pre (s)</td>
<td>51.89 ± 33.19</td>
<td>38.35 ± 25.65</td>
<td>29.33 ± 19.56</td>
<td>0.254</td>
</tr>
<tr>
<td>UHB-DL-Post (s)</td>
<td>41.57 ± 26.40</td>
<td>36.94 ± 22.28</td>
<td>27.14 ± 13.14</td>
<td>0.468</td>
</tr>
<tr>
<td>UHB-NDL-Post (s)</td>
<td>58.99 ± 39.31</td>
<td>36.76 ± 27.64</td>
<td>33.14 ± 22.24</td>
<td>0.240</td>
</tr>
<tr>
<td>DLL- Pre (°)</td>
<td>52.16 ± 8.12</td>
<td>62.78 ± 20.74</td>
<td>51.67 ± 16.47</td>
<td>0.154</td>
</tr>
<tr>
<td>DLL-Post (°)</td>
<td>55.87 ± 11.22</td>
<td>63.98 ± 19.23</td>
<td>56.22 ± 18.84</td>
<td>0.392</td>
</tr>
<tr>
<td>COP-X-Pre (mm)</td>
<td>59.56 ± 26.70</td>
<td>65.86 ± 16.39</td>
<td>66.82 ± 22.40</td>
<td>0.496</td>
</tr>
<tr>
<td>COP-Y-Pre (mm)</td>
<td>41.58 ± 9.19</td>
<td>47.98 ± 13.12</td>
<td>42.70 ± 6.10</td>
<td>0.619</td>
</tr>
<tr>
<td>COP-X-Post (mm)</td>
<td>58.56 ± 16.69</td>
<td>51.27 ± 12.62</td>
<td>61.63 ± 36.75</td>
<td>0.736</td>
</tr>
<tr>
<td>COP-Y-Post (mm)</td>
<td>45.17 ± 7.74</td>
<td>40.99 ± 5.61</td>
<td>41.73 ± 10.49</td>
<td>0.343</td>
</tr>
</tbody>
</table>

UHB = unilateral hip bridge, DLL = double leg lowering, COP = center of pressure, DL = dominant leg, NDL = non-dominant leg, Pre = first test round, Post = second test round, FB = functional breathing, PDB = partly dysfunctional breathing, DB = dysfunctional breathing, \(a\) = standard deviation

Last it was calculated whether the time spent per week doing sports (TSDS) was correlated with the CS-tests. The TSDS showed a significant correlation with low strength for the UHB in the dominant leg at Pre \((p=.021, r=.364)\) as can be seen in Figure 12.
Figure 12: Correlation between the time spent doing sports per week (TSDS) and the dominant leg (DL) of the unilateral hip bridge (UHB) at the first test round (Pre)

The TSDS showed a significant correlation with low strength for the UHB in the non-dominant leg at Pre (p=.020, r=.367) as can be seen in Figure 13.

Figure 13: Correlation between the time spent doing sports per week (TSDS) and the non-dominant leg (DL) of the unilateral hip bridge (UHB) at the first test round (Pre)

The TSDS showed a significant correlation with low strength for the UHB in the dominant leg at Post (p=.021, r=.363) as can be seen in Figure 14.
The TSDS showed a significant correlation with low strength for the UHB in the non-dominant leg at Post (p=0.014, r=0.387) as can be seen in Figure 15.

The DLL data showed a significant moderate correlation with TSDS for DLL-Test (p=0.007, r=0.420) as can be seen in Figure 16. The DLL data at Post and the COP data overall showed no significant correlations with TSDS with negligible positive and negative correlations.
5. Discussion

In this study the question was investigated whether an activation of the core and its muscles through the 90/90 breathing technique can increase the short-term core stability. Therefore, the influence of the 90/90 breathing on three core stability tests was tested with an intervention group called breathing group. This was compared to the influence of no intervention on the CS tests with a control group. The main results show the three tests were each affected differently by the intervention and thereby an inconsistency of the effect. The biggest effect of the 90/90 breathing on the performance was seen in the double leg lowering. Both, the performance change from Pre to Post within groups and the difference in the performance change between groups were positive for the intervention favoring of the BG. The unilateral hip bridge showed less positive results with a better performance in the Post for the BG and an improvement only in the DL of the CG. However, the single leg stand showed no difference apart from an improvement in the CG for the COP-sway in X-direction. Thereby the SLS was the test the least affected by the intervention. These main findings lead to answer the research question with no when taking all the tests together, there is no general CS improvement in all three tests combined after doing the 90/90 breathing technique. When looking at each test alone, the intervention leads to an improvement in the DLL and a partly improvement in the UHB.

Figure 16: Correlation between the time spent doing sports per week (TSDS) and the double leg lowering (DLL) at the first test round (Pre)
5.1 Results Discussion

5.1.1 Inconsistency in the results

To give a detailed answer of the research question, one must first look at the main calculations. First, it was tested whether the study population was homogenous in their performance at the beginning of the experiment. Testing this was important since their division into the CG and the BG was not done by a pre-performance-test and an identical distribution according to their performance. However, the testing for group differences at Pre showed no significant distinction in any variable and thereby a similar distribution of the performance in both groups. This finding was expected since the distribution of the subjects to the groups was done randomly and the population itself was similar in its traits.

The most important finding in answering the research question was the inconsistency in the results of the three CS tests. The DLL showed mostly positive results (see Table 6), the UHB showed mixed results (see Table 5 and 6) and the SLS showed no effect of the intervention at all (see Table 5 and 6). Looking at the research done so far in the field of core stability this outcome was expected. This is because of the disunity in the field, that is best showcased with the two different bodies of research on the importance of CS for performance and injury. One body of literature shows there is a positive effect of CS and its training on performance in different aspects like stability, balance, biomechanics and athletics (Sharrock et al., 2011; Araujo et al., 2015; Lee et al., 2015; Sandrey & Mitzel, 2013; Imai & Kaneoka, 2016; Nesser et al., 2008). Moreover, literature shows a positive effect of CS on injury prevention (McGill, 2010; McGill, 2015; Leetun et al., 2004; Biering-Sørensen, 1984; Jamison, McNally, Schmitt & Chaudhari, 2013) and rehabilitation (Carpes et al., 2008; Shamsi et al., 2016; Berglund, Aasa, Hellqvist, Michaelson & Aasa, 2015). A whole different body of literature shows no specific positive effect of CS and its training on performance in aspects like balance, agility or athletics (McCartney & Forsyth, 2017; Schilling et al., 2013; Nesser & Lee, 2009; Chittibabu et al., 2013). Neither do some studies show an increased effect of CS over general exercise on injuries (Wang et al., 2012). These studies used different methods of testing and training CS, which is a possible explanation for the overall disunity in the literature. Most of the studies used endurance-based measurements and exercises like the McGill battery explained in section 2.6 (Sandrey & Mitzel, 2013; Imai & Kaneoka, 2016; Nesser et al., 2008; McCartney & Forsyth, 2017; Schilling et al., 2013; Nesser & Lee, 2009; Chittibabu et al., 2013). However, this approach might not be best suited to capture CS in its vital elements because endurance is only one part of CS. Also, only measuring this component fails to capture neuromuscular control,
which allows for the integration of the passive and active subsystems to control the trunk over the pelvis, as stated in our chosen CS definition. Jamison et al. (2012), support this claim in their research. Other researchers used strength-based measurements and exercises like Russian twists or Sit-ups (Araujo et al., 2015; Schilling et al., 2013). And some used other types of tests, for example motor control tests like the DLL (Sharrock et al., 2011). Seeing that different approaches to test core stability in the literature lead to mixed results it comes not very surprising that the method of selecting three different CS measurements in this study also leads to a certain disunity in the outcome.

This inconsistency in the results of this study leads us to answer the research question, if 90/90 breathing as an activation of the core has a short-term effect on core stability, with no. The inconsistent results do not lead to the conclusion of a general positive effect of 90/90 breathing on CS.

5.1.2 Core stability enhancing effect of the 90/90 breathing

However, despite the disunity in the findings of all three tests combined, there were outcomes indicating that a short-term core stability improvement by doing the 90/90 breathing might be possible. This was mainly shown by the double leg lowering. It displayed an improvement from Pre to Post in the BG only and a significant difference in the performance change Pre -Post between BG and CG in favor of the BG. Both, at least for the DLL, showed that the intervention caused an improved performance from Pre to Post. The only study with a comparable design by Kaji et al. (2010) supports these positive findings. In said study two plank versions were done in between a bipedal postural measurement. There are a few reasons that could explain why the DLL was the most positive test. It might have been the easiest test to absolve and thereby the one with the least interference of uncontrollable factors or factors the subjects were not used to. However, the most probable reason is task specificity. As mentioned earlier CS seems to be task specific (McGill, 2010; McGill et al., 2003; Frank et al., 2013). This is supported by the research of Keogh, Aickin and Oldham (2010), who showed that CS lead to improvements specifically in similar positions as it was trained in. The study by Kaji et al. (2010) also supports task specificity. Both plank variations in their core activation regime were very close to the tested position of a bipedal stand, thereby giving a likely explanation for the positive results. Jamison et al. (2012) too support task and training specificity when it comes to choosing the right CS exercises to increase overall performance. More literature back these claims of task specificity (Sharma, 2012; Willardson, 2007; Nikolenko, Brown, Coburn, ...
Spiering & Tran, 2011; Lederman, 2010). Looking at the 90/90 breathing done here and the three CS tests, the DLL has the most similar position to the intervention. If we apply the principle of task specificity it makes sense, that the 90/90 breathing had the biggest positive effect on the DLL. Especially because the 90/90 breathing teaches the core and its central structures to keep the pelvis and the trunk in alignment, with the forced exhale and the pressure of the feet on the wall while in a supine position. Specifically, in a form that the DLL expects the subjects to hold for as long as possible. The research of Kaji et al. (2010) indicates that the multifidus and rotatores muscles could have played a significant role here. Due to their high content of muscle spindles the core activation might have led to a position specific postural after effect. The effect 90/90 breathing has on CS in the DLL makes even more sense considering the fact, that one of the main mechanisms it could work on CS, IAP generation and its unloading effect of the spine, seem to be position specific (Frank et al., 2013; Arjmand & Shirazi-Adl, 2006; Lopes, Nunes, Niza & Dourado, 2016). Moreover, the ability to form a rigid cylinder in the 90/90 breathing, produced by the co-contraction of the forced exhale combined with the pressure of the feet against wall and ball, might have transferred to the DLL as well. However, since no electromyography (EMG) measurement of the core muscles was done, this cannot be said for sure and only hypothesized. Nevertheless, some literature shows that co-contraction of the core can decrease fatigue effects, thereby increasing performance (van Dieën et al., 2012). This could have been the case here too.

The UHB supports these positive findings in part. Mainly by showing a better performance of the BG at Post compared to the CG. This and the performance improvement of the non-dominant leg in the BG show that also in this test, the 90/90 breathing had a certain effect. This might be explained by an improved IAP build up during the exercise caused by the 90/90 breathing. The possible fatigue decreasing effect of co-contraction (van Dieën et al., 2012) might have had even more effect here than in the DLL. This is because the UHB, with the longer holding times, is more prone to fatigue. Moreover, in the literature diaphragmatic breathing might have an effect on abdominal endurance and movement efficiency (Cavaggioni, Ongaro, Zannin, Iaia and Alberti, 2015). Even though this was found under different circumstances, a short-term effect of diaphragmatic breathing on movement efficiency seems thinkable and might have played a role in the positive outcomes of the DLL and the UHB. This is because of the influence the diaphragm has on the core and its stability (Hodges et al., 1997; Hodges & Gandevia, 2000) and the negative effects dysfunctional breathing can have on movement efficiency (Bradley & Esformes, 2014).
Therefore, it can be concluded that at least for the position specific DLL, the 90/90 breathing leads to an increase in CS. And that this increase is probably caused by a position and task specific increase in the ability of the diaphragm and the core overall to increase IAP and to co-contract and thereby increasing the neuromuscular control over the spine.

5.1.3 No effect of the 90/90 breathing on core stability

A bit contradictory however, there was no performance difference at Post between the groups in the DLL and no improvement in the of the dominant leg in the BG during the UHB-test. The former might be explained by the not significantly different, but still higher mean value of the CG at Pre. Even though the BG improved, the non-significant change in the CG from Pre to Post might have caused this statistical equal performance at Post. The latter could be explained by the fact that the non-dominant leg had a higher, even though non-significant, mean value at Pre compared to the dominant leg. As the leg with a better performance the subjects might have had an easier time to implement the benefits of the intervention in the NDL. But it could have also been caused randomly by chance. However, this highlights again the main finding of the inconsistent results overall. Another big finding showcasing this inconsistency are the negative results of the SLS with no effect of the intervention at all. If we take the construct of task and position specificity it would make sense that the SLS, the test with the least similar position to the intervention, shows the smallest effect. However, there is evidence in the literature of an effect of CS exercises on balance performance (Sandrey & Mitzel, 2013; Cinar-Medeni et al., 2015; Lee et al., 2015). The discrepancy in the results of the literature and our results might be explained by the fact they conducted a training regime over a longer time instead of looking at short term effects as done in this thesis. Also, the different core exercise might be a cause of the difference. Another factor could be the appropriateness of the SLS to test CS which will be discussed in more detail in the methods discussion. Nevertheless, the completely missing effect of the intervention on the SLS is in line with some studies showing no effect of CS interventions on balance (McCartney & Forsyth, 2017; Ozmen, 2016). Moreover, it is an indicator that a general effect on CS through the 90/90 breathing seems not be the case.

Taken together, the 90/90 breathing seems rather ineffective as a general core activation for a normal workout.
5.1.4 No impact of gender, breathing pattern and sportiveness on core stability

To be able to rightfully judge the findings of this study as well as to give future research the opportunity to choose the right subjects, some population characteristics and their influence on the results had been tested. Because men and women have different physiological requirements (Cheuvront, Carter, DeRuisseau & Moffatt, 2005) that could cause a difference in the performance of the CS tests, the influence of gender was also investigated in the present study. However, there was no difference in the performance between men and women in all but one core stability variables (see Table 8). Only the COP data in Y-direction for the Post measurement showed a better performance for women. Therefore, at least in this population of students it seems not to make a difference if men or women or both are studied in CS research.

Second the influence of breathing functionality was researched. This was deemed important since some of the respiratory muscles take part in core stabilization, especially the diaphragm (Kolář et al., 2012; Hodges et al., 1997; Hodges & Gandevia, 2000a, 2000b; Hagins & Lamberg, 2011; Kawabata et al., 2014; Shirley et al., 2003). Moreover, because breathing is influencing movement as a basic pattern according to the literature and could cause motor control alterations when inefficient (Cavaggioni et al., 2015). However, no difference between all three breathing patterns in any CS variable was found (see Table 9). This finding was unexpected when looking at the research stated above, that suggests a performance distinction between functional and dysfunctional breathing would have been plausible. The distinction between the literature and our findings might have been the case because of reliability or validity flaws of the two breathing assessments. It could have also been the case, that the dysfunctionality in the breathing of the dysfunctional breathing group was not strong enough to evoke a difference. This means that at least in this study breathing functionality had no effect on core stability.

Lastly the influence of the weekly sportive activity on the results was researched. Since the TSDS ranged from zero to ten and more hours a week, different influences on the results towards one end of the range or the other would have made recommendations for the population of future studies easier. However, only the UHB and the DLL data at Pre showed significant positive correlations (see Table 10), but with a low correlational strength in all but one correlations that was moderate according to the paper of Hinkle et al. (2003). This means more active people had a non-random but weak tendency towards better results in the UHB. We expected to find a correlation like that, since better trained people tend to have an overall better strength and stability and thereby also a better CS. However, it was a bit surprising that the
COP data showed no correlation at all and the DLL data only for Pre. This shows that sportive activity had no consistent positive or negative effect on the test data.

5.2 Methods discussion

5.2.1 Appropriateness of the tests

In contrast to most of the literature this study did not choose to test CS with the test battery of McGill consisting of 4 endurance tests for the core (McGill et al., 1999). Instead three tests were chosen to represent the three movement planes the core works in, the sagittal, the frontal and the transversal plane. However, as with most CS tests their appropriateness to really test this complex construct is debatable.

The DLL challenges the muscles of the core to stabilize the spine and hip in a posterior tilted position (Krause et al., 2005) against the external load of the legs, to preserve the stable cylinder around the spine. This requires core strength but even more neuromuscular control (Sharrock et al., 2011). Literature supports the use of the DLL as a CS test, because it has been shown to elicit high levels of core muscle activation, promoting co-contraction of the abdominals (Shields & Heiss, 1997), as well as core stabilization during lower extremity movement (Lanning et al., 2006). This comes close to the part of the CS definition about maintaining the intervertebral neutral zones during movements. Moreover, of the three tests it has the least measurement artifacts to interfere with the CS measurement itself. However, compared to the values achieved for the DLL in the literature this study’s results stand out as very high. Performance in the literature ranges from 26.15° (Krause et al., 2005) in a normal population to 50.00° (Lanning et al., 2006) and 51.09° (Sharrock et al., 2011) in athletes. Considering we measured an average of 57.74° over Pre and Post in a mixed population our results do not represent the literature. One possible reason for this is the rather sportive nature of the students we tested with an average of 5.4h of sports a week and 6.5y of training experience. Only three subjects did no sport at all and 5 subjects had 10 or more h of sport a week. However, compared to more athletic populations as in two of the other studies our subjects should be still less sportive. Another reason might be a failure to reproduce the reliability reported for the DLL in the literature (Krause et al., 2005). This might have been the case because this study used a single-examiner measurement, compared to a two-examiner set-up one of the studies. Moreover, there was no prolonged practice phase for the examiner to get used to the measurement. This is a clear limitation of the study.
The UHB challenges CS multi-planar in the sagittal and transversal plane and has been hypothesized in the literature to assess neuromuscular control of the core as well as muscular capacity (Butowicz et al., 2016). This study chose it as test for the transversal plane because most people are less used to the transversal stabilization aspect, since the unilateral version is not as common as the double legged version. All our tests were supposed to challenge the motor control of the core, because the 90/90 breathing was most likely to affect this CS component rather than muscular capacity. However, muscular endurance plays an obvious factor in the holding times of the UHB. It is therefore not to exclude that neuromuscular control plays a minor role to muscular endurance in this test, which could have diminished the effect our intervention had on the UHB. Moreover, it was not captured if the subjects failed by breaking the sagittal or transversal plane. Therefore, it cannot be said with certainty that the UHB represented mainly the transversal plane of the core or if it was more a second test for the sagittal plane. As with the DLL the UHB is assessed by two examiners in the study of Butowicz et al. (2016) instead of just one like in this study. This might have reduced the reliability of the measurement. This can be also seen as major limitations of the study.

The SLS was categorized as neuromuscular control test by Waldhelm and Li (2012) and chosen to represent the frontal plane. This decision becomes more apparent when considering the fact, that the mediolateral balance in a SLS is mainly under hip-control, which is influenced by CS (Kaji et al., 2010). Moreover, the CS definition includes the control of the trunk over the pelvis. This keeps the center of mass over the center of pressure, thereby making balance in a unipedal stand possible in the first place. If COM and COP are not in line anymore, a fall in the direction of the COP would be the case. However, the SLS is the test with the most factors possibly influencing the measurement. Ankle- and knee-stability play a big role as well as overall balance, controlled by the vestibular organ in the ear. CS still seems to play a certain role in a unipedal stand (Cinar-Medeni et al., 2015), especially when considering the integrated kinetic chain. However, we cannot exclude the fact that the other stability factors influenced the outcome more than CS. This becomes even more apparent by the SLS being the test the least affected by the intervention.

5.2.2 Appropriateness of the intervention

The 90/90 breathing was chosen as intervention for a pair of reasons. First, it places and trains the body in a position that advocates the stable cylinder around the spine that is desired by proper core stability. Second, with its diaphragmatic breathing technique in combination
with the forced exhale it works on several structures of the core that play an important role in CS, as is shown by the literature (Hodges & Gandevia, 2000a, 2000b; Shirley et al., 2003; Boyle et al., 2010; Goldman et al., 1987). Moreover, one rationale behind this study was to guide the attention of people more towards the importance of breathing, and the positive effects it has on a wide variety of fields, with the 90/90 breathing as an intervention.

However, the literature on the short-term effects of core stability exercises is lacking much content and coaches in the Functional Training branch usually use more classic core exercises like plank variations as core activations. Therefore, it would have also been insightful to use a more typical core exercise to research the transient effects of CS activations as a warm-up.

5.2.2 Appropriateness of the study design

The design of a CG opposing the BG was chosen to see if any difference in the performance was caused by the intervention or happened through some random effect. As all but one change in performance happened in the BG it can be hypothesized that it was in fact the intervention causing the differences – at least to a certain degree. The pre-test post-test design was also chosen to judge if any effect was caused by the intervention itself or if there were differences between the groups in the beginning, that could have influenced the results. Since there were none for the Pre-test this possibility can be excluded. Overall the study design does not seem to have had negative influence on the results and seems fitting.

The study population was chosen rather wide than specific to test if the intervention had an effect on the average student. Furthermore, this student population was chosen since they might be more susceptible for LBP due to the high amount of sitting and stress. Also, they should have a reduced core activation than highly trained people which could make the breathing intervention for core stability more effective. However, the secondary tests show that no division of the population into categories made a big difference in the results or seemed to be the single cause of the results as they were in the main calculations. Therefore, the population is deemed fitting for the study and for future studies on the topic.

5.2.3 Reliability and Validity issues

The DLL showed an intra-class correlation coefficient (ICC) of 0.98 in inter-rater reliability, which was described as excellent in the paper of Krause et al. (2005). The study of
Moghadam et al. (2011) found a moderate to high test-retest reliability for the single leg stand with closed eyes. However, these values were obtained from tests with elderly people. Since this study tested a younger population the reliability might not have been the same. No reliability measurement has been found for the UHB. This and the single-examiner design are clear limitations of the study because reliability is very important. It tells if a test can be replicated and still bring the same results (Koo & Li, 2016).

The validity of the tests is harder to determine since literature that tests these specific tests for their validity on core stability is rare. Only for the UHB the study by Butowicz et al. (2016) tested for concurrent validity and was able to find a significant, moderate relationship of $r=-0.49$ and $r=-0.56$ with two lab based biomechanical measurements of core stability.

For the other tests the validity that they represent CS can be argued, as seen in chapter 5.2.1. But still, it has not been established by scientific research which is another definite limitation of the study.

Of the chosen equipment the AMTI force plate has the best validity and reliability and is considered the gold standard for balance measurements (Huurnink, Fransz, Kingma & van Dieën, 2013). No information about the reliability of the digital inclinometer model used here has been found. However, literature shows a general reliability of similar inclinometer models as well as concurrent validity compared to goniometers when measuring the angles of limb movements (Kolber & Hanney, 2012; Kolber, Fuller, Marshall, Wright & Hanney, 2012).

### 6. Conclusion

This study found that 90/90 breathing had inconsistent effects on three different core stability tests. The DLL was positively affected the most and showed a quite strong effect of the intervention on CS. The UHB showed somewhat mixed results with an effect of the intervention in half of the tested variables and no effect in the other half. The SLS was not affected by the intervention at all. No division of the population into sub-categories made a big impact on the results as just mentioned.

Nevertheless, it could be concluded that the positive effects seen in the DLL make a task and position specific effect of 90/90 breathing on CS likely. It thereby seems that core activations might increase the short-term CS in exercises and movements, that are done in similar positions or that produce similar demands on the integrated kinetic chain of the body.
However, due to methodological issues, the results from the present study must be considered with caution and no definite conclusions could be drawn.

6.1 Practical implications

Coaches and practitioners should choose the exercises they use as core activations with caution and not just use any that seem to work on the core. Core activations should be as specific as possible to the following exercises they are supposed to improve, regarding the performance in CS and the performance overall. Therefore, the rather supine position specific 90/90 breathing is not the best choice as a core activation since most movements in training sessions are done in standing positions. Other core activations would probably be more specific to a broader range of movements. However, the literature suggests that the 90/90 breathing might be still valuable as a training exercise. It could help teach proper diaphragmatic breathing and thereby improve or reinstall efficient movement and disbalance over time.

Moreover, according to the present study the double leg lowering could be recommended as a core stability test after interventions in similar positions.

6.2 Recommendations for future research

The body of literature on the short-term effects of core exercises on CS as well as performance overall is still very small according to the knowledge of the author with only two studies including this thesis. Future research should therefore study the effects of other core exercises as a warm-up tool on the performance in CS itself and general movements. Since 90/90 breathing seems to have some kind of effect on CS, this technique also deserves more scientific attention. Future research should study its effect as a training intervention over a longer time span on CS, overall performance as well as injuries and disbalances.

The main recommendation the author can make for future research is to choose CS tests as well as interventions task specific. Logical deduction and part of the literature suggest CS can influence performance positive. A lot of studies show opposite results. However, many studies in this body if literature used CS tests like the McGill battery, that are in some cases neither task nor position specific to the tested performance measurements. Moreover, endurance is only one component of core stability and might fail to capture it in its essence when tested alone. This might have diminished possible effects and lead to negative results.
7. References


Waldhelm, A., & Li, L. (2012). Endurance tests are the most reliable core stability related measurements. *Journal of Sport and Health Science, 1*(2), 121-128.


[http://doi.org/10.1183/20734735.ELF121](http://doi.org/10.1183/20734735.ELF121)
8. Appendix

Table 11: List of the equipment used for the different tests of the experiment with their specific use and their model and producer

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Use</th>
<th>Model and Producer</th>
</tr>
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</table>
| Digital Inclinometer | • To measure the angular displacement of the legs from start in the sagittal plane in the DLL  
                        | • To measure the angular displacement of the hip in the transversal plane in the UHB | Model MDP01, Shenzen Temie Technology Co. Ltd., Shenzhen, China                      |
| Manual Goniometer  | • To measure the angular displacement of the hip in the sagittal plane in the UHB | Model PJB-101, Advanced Mechanical Technology, Inc., Watertown, USA                  |
| Force Plate        | • To measure the COP displacement of the standing leg in the SLS      |                                                                                     |
| Softball           | • For the subjects to apply pressure with their adductors during the 90/90 breathing  
                        | • As a ball for the kicking test to find out the dominant leg of the subjects       |                                                                                     |
| Mat                | • For the subjects to lie on during the 90/90 breathing, the DLL and the UHB       | Airex                                                                               |

Table 12: Letter of consent every subject had to read and sign before participating in the study

**Letter of consent**

1. Background and purpose

Core stability is said to play an important role in sportive performance and especially the Functional Training community has a big emphasize on its training to enhance performance and reduce injury risk. Breathing techniques are also getting more common in this branch and some of them act on similar muscles as core stability training does. Therefore, the purpose of this study is to research whether breathing techniques can alter the short-term stability of the spine positive by activating its surrounding muscles.
| 2. Inquiry concerning participation | As a student of the Halmstad University without injuries or backpain in the last 6 months and without current illness or experience in breathing techniques and at least one year experience in strength training you have been chosen as a participant in this study. We found your name for this participation request through personal contact. |
| 3. How will the study be conducted | For the participation in the study you will have to come to the laboratory of the Halmstad University one time for circa 1 hour. The procedure will be as followed: first you will answer a small questionnaire about you and your lifestyle habits. Then you will do the tests with which we want to assess core stability for the first time. This part will consist of 3 different tests. The double leg lowering, a unilateral hip bridge and a single leg stance on a force plate. Afterwards you will get a break before doing the breathing exercise if you are in the intervention group or just lying on a mat in the laboratory if you are in the control group. After this you will get again a short break before doing the same tests as stated above again. For the participation we would like you to not engage in strenuous exercise that could exhaust you or induce muscle soreness for 48 hours before the testing. |
| 4. What are the risks? | There is no added risk than general sport exercises possess. You will be supervised by the experimenter and clearly instructed to minimize the injury risk. The breathing exercise can cause dizziness if one is not used to controlled, deep inhalation. |
| 5. Are there advantages? | Apart from that the consulted tests give the examiner a picture of the core stability of you as a subject. If wanted training advice can be given with exercises to increase possible diminished core strength or stability |
| 6. Dealing with the Data | The data collected from you during the experiment will be handled confidentially. The data collected will be coded to protect the personal identity. All Data will be only analyzed by the researcher of this study and will not be handed to third parties outside of the university. Halmstad University is responsible for your personal data. The data acquired from the questionnaire and the testing will be used to research the above-mentioned purpose of the study. Your answers and your results will be dealt with in such a way that no unauthorized person will have access to it. The data will be presented to the university in form of a master thesis. |
| 7. How do I obtain information about the study results | Your own data and results as well as the study as whole can be sent to you on your request (please contact lukalv17@student.hh.se). If you don’t wish to know about any results of the study, you will tell the researcher so and you will not be told about it. |
| 8. Insurance, compensation | In the unlikely case of injury your own insurance may cover. As a student you are covered by the insurance in school. No extra insurance to cover the experiment has been done. We |
cannot provide you with any compensation in the form of money for your time spent at the laboratory.

<table>
<thead>
<tr>
<th>9. Voluntariness</th>
<th>The participation in the experiment is completely voluntary and you can withdraw your participation at any time before or during the experiment. In that case a note to the researcher is enough without any further explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Responsibility</td>
<td>Responsible for the study are the Halmstad University as research body and Lukas Alverdes as researcher of the study. Contact information Telephone: +49 175 59 68 4 E-Mail: <a href="mailto:lukalv17@student.hh.se">lukalv17@student.hh.se</a></td>
</tr>
</tbody>
</table>

**Table 13: Subject questionnaire about personal information and sport habits and experience**

<table>
<thead>
<tr>
<th>Subject Questionnaire</th>
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<tbody>
<tr>
<td>Subject Number: ....................................................................................................</td>
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<tr>
<td>Subject Code: ...........................................................................................................</td>
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<td>Age: .........................................................................................................................</td>
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<td>Gender: .....................................................................................................................</td>
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<td>Weight: .....................................................................................................................</td>
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<tr>
<td>Time spent per week doing sports (h): ........................................................................</td>
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<tr>
<td>Sport Sessions per week: ..........................................................................................</td>
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<tr>
<td>Sports usually done: ..................................................................................................</td>
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<tr>
<td>Years of training experience: ....................................................................................</td>
</tr>
<tr>
<td>Experience in yoga or other activities with active breathing techniques: ..............</td>
</tr>
</tbody>
</table>
My name is Lukas Alverdes. I am 25 years old and come from Munich, Germany where I studied a B.Sc. in Sport Sciences and a M.Sc. in Diagnostics and Training. My work as a Personal Trainer brought the inspiration for writing this thesis.