The effect of a single osteopathic intervention on the trunk imbalance of patients with back pain: treatment of the four diaphragms

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STATUTORY DECLARATION

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ABSTRACT

Background: Back pain is one of the most common health care problems with a multifactorial etiology. One of the causes of back pain is postural change. The four diaphragms according to the Zink model have an important function in body posture. Trunk imbalance (mm) is a parameter that can be measured by Formetric 4D, giving information on back posture.

Aims: The objective of this study was to verify if an osteopathic treatment of the four functional transverse diaphragms using osteopathic techniques in patients with low back pain influences the trunk imbalance parameter (mm) compared to a control group.

Methods: 47 patients with a history of back pain participated in this randomized controlled trial. The trunk imbalance (mm) was measured before and after the intervention by Formetric 4D. Tester and patients were blinded. The treatment group (TG, n:24) got an individual and specific treatment of the four diaphragms according to the necessities of each patient while the control group (CG, n:23) received a sham treatment.

Results: The mean value of trunk imbalance found for TG before and after treatment was -8.53 ± 15.32 and -8.58 ± 13.70 respectively, and for CG measurements -2.56 ± 13.62 and -5.76 ± 13.47 before and after treatment respectively. The simulated treatment did not show statistical difference (p: 0.970) for both groups, probably due to the high standard deviations found in both groups

Discussion: The alternative hypothesis has not been confirmed. One treatment of the four diaphragms according to Zink did not present statistical influence on the trunk imbalance (mm) of patients with low back pain. The sample size was relatively small, qualitative and quantitative inspection about the pain before and after the treatment could have provided important information for the effect of the osteopathy. For further studies, a dynamic evaluation of the Formetric 4D is recommended.

Keywords: rasterstereography, trunk imbalance, diaphragms, posture, Zink model

KURZFASSUNG

Hintergrund: Rückenschmerzen sind eines der häufigsten Probleme in der Gesundheitsversorgung mit einer multifaktoriellen Ätiologie. Eine der Ursachen dafür ist eine Haltungsveränderung. Die vier Diaphragmen nach Zink haben eine wichtige Funktion in der Haltung. Lotabweichung ist ein Parameter, der mit einem Gerät namens Formetric 4D gemessen werden kann und Informationen zur Rückenhaltung liefert.

Ziele: Ziel dieser Studie war es zu überprüfen, ob eine Behandlung der vier Diaphragmen nach Zink mit osteopathischen Techniken bei Rückenschmerzen die Lotabweichung im Vergleich zu einer Kontrollgruppe beeinflusst.

Methoden: An dieser randomisierten, kontrollierten Studie nahmen 47 Patienten mit Rückenschmerzen teil. Die Lotabweichung (mm) wurde vor und nach dem Eingriff mit der Formetric 4D gemessen. Tester und Patienten waren verblindet. Die Behandlungsgruppe (BG n: 24) erhielt eine individuelle Behandlung der vier Diaphragmen entsprechend der individuellen Erfordernisse, die Kontrollgruppe (KG n:23) eine Schambehandlung.

Ergebnisse: Der mittlere Wert für die Lotabweichung in der BG vor (-8,53 ±15,32) und nach der Behandlung (-8,58 ±13,70) sowie in der KG vor (-2,56 ±13,62) und nach (- 5,76 ±13,47) der Behandlung zeigte für beide Gruppen keinen statistischen Unterschied (p: 0,970), in beiden Gruppen wurden höhere Standardabweichungen festgestellt.

Schlussfolgerung: Die alternative Hypothese wurde nicht bestätigt. Eine Behandlung der vier Diaphragmen nach Zink hat keinen statistischen Einfluss auf die Lotabweichung (mm) von Patienten mit Rückenschmerzen. Die Stichprobengröße war relativ gering. Durch qualitative und quantitative Untersuchungen der Schmerzen vor und nach der Behandlung hätten wichtige Informationen für die Analyse von Ergebnissen und Wirkung der Osteopathie gewonnen werden können. Für weitere Studien wird eine dynamische Bewertung von Formetric 4D vorgeschlagen.

Schlüsselwörter: Rasterstereographie, Lotabweichung, Haltung, Diaphragmen, Zink Modell

CONTENTS

1 Introduction

Back pain is a health problem with serious public and financial implications. “Small number of economic evaluations, inconsistent standards of comparison, and substantial heterogeneity” are found in the literature about back pain (Furlan et al., 2010, p. 1). The indicated treatment needs to be decided on after an individual clinical evaluation and different prognostic factors might be assessed (Airaksinen et al., 2006). The osteopathic intervention is determined individually and is a patient-centered form of therapy.

The osteopath J. G. Zink developed the respiratory-circulatory model of osteopathy. According to Parsons and Marcer (2006) the key feature of Zink´s model is that for favorable homeostasis there must be a free circulation in the body. The various diaphragms are thought to have a great influence on the circulation of fluids (Parsons & Marcer, 2006). “Recently four diaphragms have been discussed” (Bordoni & Zanier, 2015, p. 1): the thoracoabdominal diaphragm (thoracolumbar zone), the pelvic diaphragm (lumbosacral zone), the thoracic inlet (cervicothoracic zone) and the tentorium cerebellae (occipitoatlantal zone) are more generally seen as possible areas of circulation restriction in case of dysfunction (Parsons & Marcer, 2006) and they are areas, where anatomic structure and function changes first (Chila, 2010).

According to Bordoni and Marelli (2015) working on these connected parts of the body, in terms of fascia and neurological connections, it is theoretically possible to alleviate the patients’ symptoms, if the fascial system properly works (Bordoni & Marelli, 2015). In another study, Bordoni, Marelli and Bordoni (2016) cited the non-respiratory function of the diaphragm and the influence on the intensity of the pain. “The diaphragm muscle plays a key role in health and in the many activities of the human body.” (Bordoni, Marelli & Bordoni, 2016, p. 97). There is a relation between postural imbalance and somatic dysfunction (Pope, 2003).

Oddsson and Luca (2003) found that patients with low back pain, in different stages of chronification, demonstrate specific muscle activation imbalances during a symmetrical trunk extension, effort that seems to reflect physiological alterations related to their injury (Oddsson & Luca, 2003). Trunk imbalance (in mm) or trunk shift in the frontal plane is a parameter that can be calculated with Formetric 4D (Knott et al., 2010) and can be improved in patients after a specific training, with positive changes of posture (Cho, 2015). A good and valid measurement of trunk shift in the coronal plane plays a key role in the inspection of the subjects with imbalance problems in the back (Zhang et al., 2015).

The aim of this research was to verify the effect of one osteopathic treatment of the four transverse diaphragms on the trunk imbalance of patients with back pain. The therapy for each patient was determined individually with osteopathic techniques for the four transversal areas and the effects in the trunk imbalance (mm) parameter were compared with a control group; this should be used to demonstrate, if the osteopathic treatment of these areas has an influence on the trunk imbalance.

1.1 Theoretical background

1.1.1 Back pain

Back pain is the most common pain and causes massive health care costs. Absence from work accounts for more than half of these costs, but treatment and rehabilitation also contribute to the high costs (Henn et al., 2014). Braga et al. (2012) relate that “it mainly affects the population of economically active age, and can be highly incapacitating” (Braga et al., 2012).

Back pain has an anatomic classification that follows the segments of the spina: coccydynia pain, lumbar pain, thoracic pain and cervical pain. The term "back pain" describes strong painful conditions in different areas of the back, regardless of their cause (Casser, Hasenbring, Becker, & Baron, 2016).

Low back pain affects both genders equally and “is worldwide one of the most important medical conditions in terms of reduced quality of life, disability and socio-economic costs” (Beeckmans et al., 2016, p. 77). The risk for back pain is multifactorial and remarkably complex.

The specific etiology of low back pain is not clear, symptoms, radiological and clinical findings are not well correlated and only less than 15% of all back pain has specific causes while the major part of the causes for back pain is unspecific (Airaksinen et al., 2006).

Muscular injuries, reported by Oddsson and Luca (2003), are a common cause of incapacity and are the most common reason of low back pain. Better developed measurements methods for precocious diagnosis and approach of the population with low back pain may help to decrease the time of work absence, costs and chronification of the disease (Oddsson & Luca, 2003).

In the USA, a retrospective analysis with 211.551 patients, concluded that patients were likely to have chiropractic treatment first, followed by pharmacotherapy (Ivanova et al., 2011). Nevertheless, nonsteroidal anti-inflammatory medication should not be prescribed against back pain for a period longer than three months (Airaksinen et al., 2006). ”In the long run, surgical interventions show high rates of complications or nonsuccess” (Henn et al., 2014, p. 2)

The individual intervention in the treatment of back pain, including osteopathy, may be more effective in the outcomes when considering the multi-etiology characteristics of the pathology. There are different causes for back problems, some conventionally considered risk factors as BMI, physical activity and gender showed no association with back disorders in active persons (Burdorf & Sorock, 1997).

According to Henn et al. (2014), the majority of the therapies of back pain are not producing the expected result in the long term, have side effects, demonstrate little evidence of their result efficiency and usually have small sampling sizes (Henn et al., 2014).

The osteopathic treatment is individual, according to the symptoms and characteristics of each patient. “A comprehensive assessment of each patient and in particular of the complex comprising the spine and the pelvis, is essential for understanding each individual´s adaptation to the imbalance induced by disorders of the spine or lower limbs” (Lazennec, Brusson & Rousseau, 2011, p. 691). Osteopathy stands for a holistic treatment of the patient, interacting with the dynamic physiological connections present in the body.

1.1.2 Osteopathy and its models

Osteopathy provides different approaches to maintain health and ways to support the body dysfunction or disease, as reported in the *Benchmarks for Training in Osteopathy (2010).* Osteopaths understand that clinical symptoms and clinical prognosis of each person are the results of the correlation of many different causes. There is a dynamic connection of multifactorial influences, internal and external ones. Osteopathy is a patient-centered, rather than disease-centered, system of complementary medicine *(Benchmarks for training in Osteopathy, 2010).* Dr. Still, the founder of osteopathy, emphasized the importance of finding health and supporting mechanisms to enhance and maintain it; since illness is easier to be found.

According to the *Benchmarks for Training in Osteopathy (2010)* from the WHO, there are five principal models used in osteopathy that connect structure and function, one of the osteopathic principles *(Benchmarks for training in Osteopathy, 2010):*

1. The biomechanical structure-function model
2. The respiratory/circulatory structure-function model
3. The neurological structure-function model

4. The biopsychosocial structure-function model
5. The bioenergetics structure-function model

The present study is based on the respiratory/circulatory structure-function model, as defined in the *Benchmarks for Training in Osteopathy (WHO).* It describes the support of the cellular and interstitial conditions through the unobstructed distribution of oxygen and nutrients, a favorable fluid flow, and the removal of metabolic products, based on the fact, that a good and free circulation supports the self-healing mechanism of the body, another osteopathic principle. “This model applies therapeutic approaches, including osteopathic manipulative techniques, to address dysfunction in respiratory mechanics, circulation and the flow of body fluids” *(Benchmarks for Training in Osteopathy, 2010, p. 4).* The so-called “Common Compensatory Pattern” is part of this model.

1.1.3 Common Compensatory Pattern

J. G. Zink, osteopath and professor at the College of Osteopathic Medicine and Surgery, Des Moines, was the precursor of the terminology “Common Compensatory Pattern” (CCP), which describes the frequent patterns of dysfunction, that are presented in the whole body (Zink & Lawson, 1979). These “recurrent patterns of functional disturbance such as muscle imbalance and visceral dysfunction, coupled with common systemic complaints” (Pope, 2003, p. 176), with the concept of the common compensatory model being the foundation of the respiratory/circulatory structure-function model (Zink & Lawson, 1979).

Chaitow and Creshaw (2006) described the classification of the CCP in clinically useful ways:

- Ideal – similar degrees of normal range rotation are detected among the four transaction areas.
- Common compensated patterns (CCP): alternate in direction, from one crossover area to the other, a positive adaptive modification. “Zink found that approximately 80 percent of healthy people had body patterns of L/R/L/R, while the other 20 percent displayed the opposite R/L/R/L pattern” (Pope, 2003, p. 178).
- Uncompensated patterns (UCP): no alternation from one crossover area to the other is commonly the result of trauma, a negative adaptive modification. The adaptation potential of the patient through stress or disease for example is minimal or absent (Chaitow & Crenshaw, 2006, p. 23).

There are four crossover sites where tensions/restrictions can easily be noted: occipital-atlantal, cervico-thoracic, thoraco-lumbar and lumbo-sacral (see Table 1). According to Pope (2003), these are regions were the highest number of dysfunctions is found, defined as transitional zones. These zones are correlated with a functional transverse diaphragm: tentorium cerebelli, thoracic inlets/outlets, respiratory diaphragm and pelvic diaphragm (Pope, 2003).

Table 1: Transitional zones, Pope (2003, p. 177)

ZONES	**TRANSVERSE DIAPHRAGMS**
occipital-atlantal	tentorium cerebelli
cervico-thoracic	thoracic inlets/outlets
thoraco-lumbar	respiratory diaphragm
lumbo-sacral	pelvic diaphragm

The four zones, as described by Pope (2003) are:

1. **Zone Occipital-Atlantal:** The occipital-atlantal joint is a considerably mobile part of the spine. The immediate increase in the postural control in the standing position, after the modulation of the mandibular sensorimotor, might be involved in the reflex transmission in this area (Eriksson, Zafar & Backén, 2019). "Studies of posture in the adult show that the most stable segment of the body is the head and that displacement of the head is less than that of the trunk during balancing activities" (Pope, 2003, p. 187). The associated transverse diaphragm for this zone is the tentorium cerebelli (see Table 1).
2. **Zone Cervico-Thoracic:** This is the area where the most mobile part of the spine (cervical) is connected to the relatively inflexible thoracic spine and where many of the strong muscles of the arms and shoulders have their origins. This area is related to lymphatic vases, to the brachial plexus and to some important nerves, such as the phrenic and vagus nerve (Pope, 2003). The associated transverse diaphragm for this zone is the thoracic inlets/outlets (see Table 1).
3. **Zone Thoraco-Lumbar:** The abdominal diaphragm is located in this crossover area and its physiological function is considered the most significant among the four diaphragms. Its contraction and relaxation supports the good circulation in the veins and in the lymphatic vessels through the pumping mechanisms (Pope, 2003). The associated transverse diaphragm for this zone is the respiratory diaphragm (see Table 1). According to Bordoni, Marelli and Bordoni (2016), the diaphragm participates also in non-respiratory functions in the body. For

example, it sustains the posture and is involved in the movements of the lumbar and pelvic regions (Bordoni, Marelli & Bordoni, 2016).

Bordoni and Zanier (2015) reported that the diaphragm muscle is not an isolated segment but part of the body system, having a significant "crossroads of information for the entire body, from the trigeminal system to the pelvic floor, passing from thoracic diaphragm to the floor of the mouth: the network of breath" (Bordoni & Zanier, 2015, p. 1).

In the article of Janssens et al. (2015) is reported that the diaphragm performs an important postural control function of the back. Training of the inspiratory muscle improves the stabilization of the trunk, allowing a better proprioceptive adaptation to the demands of the posture (Janssens et al., 2015).

Kolár et al. (2012) related that patients with low back pain have a decreased diaphragm movement during postural demands, compared to healthy patients. They identified a superior diaphragm position in individuals with low back pain and an abnormal coordination during postural demands especially in the anterior and middle part of the muscle (Kolář et al., 2012). Based on their findings, is there a possibility to decrease the low back pain after the treatment of the diaphragm, assuming a physiological lowered position and improvement in its coordination?

According to Janssens et al. (2015), the training of inspiratory muscles also stimulates extra pulmonary muscles, junctions and skin receptors engaged in postural control, activating the spine proprioception in individuals with low back pain. This might improve the trunk-stabilizing function and/or is an additional control of the pain mechanisms (Janssens et al., 2015).

4. **Zone Lumbo-Sacral:** "This lumbosacral junction forms the base of the spine column and is therefore a major determinant of body statics" (Pope, 2003, p. 178). Through this zone, the movements of the lower extremities are transmitted to the back. The pelvic diaphragm or pelvic floor is related to the respiratory diaphragm through the fascia and muscular connections and to the lumbo-sacral zone. The lumbo-sacral zone gives support to the pelvic organs and involves important neurological structures. The pelvic and abdominal diaphragm work in synchrony, contributing to the lymph and venous circulation (Pope, 2003). The associated transverse diaphragm for this zone is the pelvic diaphragm/pelvic floor (see Table 1).

During the treatment of the four diaphragms, some techniques for the fascial tissue can be used. Bordoni and Marelli (2015) reported that "the fascial system is rich in proprioceptors, such as the Ruffini and Pacinian corpuscles, particularly in the areas of transition between the fascia and the articulation and between the fascia and the contractile tissue in the muscle" (Bordoni & Marelli, 2015, p. 491). The fascia system has a fundamental function in communicating mechanical tension, an important concept. This reflects another osteopathic principle: the body unit, the functional and dynamic connection of body, mind and spirit (*Benchmarks for Training in Osteopathy,* 2010). Bordoni and Zanier (2014) wrote that the different regions of the body are connected to another through the fascia and that the entire human body must work in harmony. Knowing this is essential for the osteopath to find the best treatment strategy for the patient (Bordoni & Zanier, 2014).

These patterns (ideal, CCP or UCP) can be evaluated at the beginning of the treatment of the four crossover areas in the supine position. In this position, according to Zink and Lawson (1979), there is the possibility to do a proper and valid assessment of the structure and its relationship to respiratory/circulatory function, when the effects of gravity on the musculoskeletal and respiratory/circulatory systems are minimized and the muscles, the "peripheral pumps" of venous blood and lymph, are not active in this position (Zink & Lawson, 1979).

As stated by Zink and Lawson (1979), the alteration of respiration/circulation may be subclinical and diaphragmatic breathing sustains proper circulation of fluids in the body when the patient is lying (Zink & Lawson, 1979).

According to Zink and Lawson (1979) the osteopath can, through manipulative method, treat the diaphragms and enable the patients to breathe completely with their diaphragms in the supine position. This can be included in the treatment, but it may require a series of osteopathic treatments for older patients and for more difficult cases (Zink & Lawson, 1979).

Pope (2003) concluded that the respiratory/circulatory structure-function model and the postural model are definitions of the same attribute – the human posture (Pope, 2003).

1.1.4 Posture

From the biomechanical aspect, as Park, Ahn, Lee, Park and Cho (2016) wrote, the body is composed of different parts and those segments communicate with each other. Additionally, these interactions are relevant for the function of muscles and bones (Park, Ahn, Lee, Park & Cho, 2016).

Strongly passive lifestyles can lead to the debilitation of the abdominal muscles and inadequate posture, including physical imbalance (Cho, 2015). Anomalous posture can be the reason for different problems, as for example disproportional and accelerated degeneration of the body joints, organ dysfunctions as well as difficulties with coordination and balance.

The postural improvement is possible through different methods. Cho concluded that running in place can improve for example postural alignment, as observed in the betterment of different trunk and pelvic parameters measured (Cho, 2015). No studies about postural correction and the treatment of the four diaphragms were found.

“A general postural model allows us to view human posture not as a simple static relationship between building blocks, one atop another, but as a lifelong interplay between genetics, development and postural symmetry“ (Pope, 2003, p. 201).

The respiratory diaphragm is normally involved in the postural control of the back during movements of the extremities together with the respiratory function, as they are correlated (Hodges, Heijnen & Gandevia, 2001). Janssens et al. (2010) studied the influence of inspiratory muscle fatigue on postural control in patients with low back pain. Low back pain patients utilize a different proprioceptive strategy for postural control during postural perturbations, which is more inflexible. The results of Janssens et al. (2010) suggest that inspiratory muscle fatigue might be a factor in the higher number of reoccurring low back pain. Considering these results might help to improve the clinical outcomes during the treatment of patients with low back pain (Janssens, Brumagne, Polspoel, Troosters, & McConnell, 2010).

One of the aims of the osteopathic treatment, like in the study of Bordoni and Marelli (2015), is to release the fascial restrictions, thus being abler to realize adjustments during the different activities of the body. Body structure is covered in the connective tissue and is proportionately found in the different parts of the body: blood vessels, organs, nerves, bones and muscles (Bordoni & Marelli, 2015).

According to Bordoni and Marelli (2015), the duration of treatment is subjective and depends on the answer of the tissue of each person, some patients need a higher number of treatments than others. An intervention is successful, if the tissue is free of restrictions (Bordoni & Marelli, 2015).

The treatment of the four diaphragms started with a precise examination of each area. Bordoni and Zanier (2015) suggested to begin distal with the pelvic floor, finishing in the tentorium cerebelli. After the examination, the osteopath can choose the most adequate manual treatment for each patient. The objective is to diminish pain, releasing the increased tension and consequently restore the normal function and position of the diaphragms (Bordoni & Zanier, 2015). In osteopathy there are different manual techniques to restore physiological function, which are altered by somatic dysfunction *(Benchmarks for Training in Osteopathy, 2010).* “Manual treatment is useful in most cases of disease, systemic and local, where there is always an alteration of the function and position of the diaphragm.“(Bordoni & Zanier, 2015, p. 3)

Bordoni and Zanier (2015) suggested some techniques for the treatment of the diaphragms and recognized that many of the treatment methods still need a scientific foundation. If there is an alteration of the function and position of the diaphragm, the osteopathic methods are a possibility of treatment (Bordoni & Zanier, 2015, p. 3).

There is a relation between posture alterations and dysfunction. To maintain the posture, the central nervous system utilizes afferent information from different areas to regulate the center of gravity (Pope, 2003).

Claeyes et al. (2015) reported on the relation between patients with non-specific low back pain and the alteration in the proprioceptive system, responsible to control the posture in the standing position. During postural control, patients decreased the utilization of the proprioceptive afferent information from the low back, increasing the use of proprioceptive afferent information from the ankle. The conclusion of Claeys et al. (2015) was that these alterations increase the occurrence of low back pain (Claeys et al., 2015).

A systematic examination of posture of back pain patients is fundamental in order to decide adequately and individually on the clinical treatment (Krautwurst, Paletta, Mendoza, Skwara, & Mohokum, 2018). One method that measures important spine parameter is rasterstereography.

1.1.5 Rasterstereography

Rasterstereography is a method for stereo photogrammetric surface measurement of the spine created by Hierholzer and Drerup and this equipment can automatically evaluate different anatomical landmarks of the spine, as for example the prominent cervical vertebra and the posterior superior iliac spine, without contact of the tester, decreasing the possibility of errors (Drerup & Hierholzer, 1987). Another advantage of this method in comparison with the gold standard radiographic images is the radiation free evaluation of the posture and spine parameters (Kwon, Song, Baek, & Lee, 2015). “The landmarks may well be used for the objective definition of a body-fixes reference coordinate system” (Drerup & Hierholzer, 1987, p. 961).

Mohokum et al. (2015) studied the validity of rasterstereography in a systematic review and concluded that rasterstereography facilitates clinical practice by analyzing the spinal column. Considering its advantages as cited above, it proves to be highly suitable for the diagnosis of spine postural parameters (Mohokum, Schülein, & Skwara 2015).

Another research concluded that the rasterstereography "reliability revealed very good results, both for intratester and for intertester reliability. The technique is well suited for analysis of the back in standing position" (Melvin et al., 2010, p. 1353).

Tabard-Fougère et al. (2017) studied the validity of this method compared to the radiologic images. They reported that the rasterstereography method permits the measurement of scoliosis patients "with a good validity compared with XR with an overall excellent intra- and interrater reliability" (p.98). According to their results, this noninvasive method can be utilized for follow-ups of adolescent idiopathic scoliosis in the growth period as a substitute of repetitive radiographs, decreasing the exposition to radiation and with less costs (Tabard-Fougère et al., 2017).

The rasterstereography system was used to measure the changes of the spinal posture during pregnancy, a period with a higher occurrence of low back pain. The etiology of the pain during the pregnancy is not well understood. In the study of Betsch et al. (2015), the potential to precisely measure the spinal posture and pelvic position during pregnancy using rastereography was assessed, avoiding the radiation of XR. This technique could lead to additional information to understand the relation between the alteration in the posture during the pregnancy and back pain, giving additional information to understand the causes of low back pain. With a better understanding of the etiology, prevention and treatment approaches can be developed (Marcel Betsch et al., 2015)

The principal function of the **Formetric 4D**, a rasterstereography system, is the three-dimensional measurement of the spine surface. The main objective is to capture shape parameters in order to establish the body posture and to measure the shape of the spinal column, the back surface and the pelvic position (Formetric+DIERS III 4D–Manual). The advantages of Formetric 4D are "short test time, low cost and no placement of any marking component, which reduced inspector measurement error" (Park et al., 2016, p. 1971).

Schülein et al. (2013) studied the reliability of the Formetric 4D, concluding that for the studied parameters this technique showed an excellent reliability. (Schülein, Mendoza, Malzkorn, Harms, & Skwara, 2013). One parameter that the rasterstereography can assess is the lateral shift, and that is an important clinical information. Lateral shift is a divergence from the spinal midline, in the Formetric 4D defined as trunk imbalance.

1.1.6 Trunk imbalance (mm)

According to Zhang et al. (2015), in the standing position the projection of C7 should be corresponding to the middle of the sacrum in the coronal plane, a symmetrical posture without deviation or trunk imbalance to the right or to the left side. Trunk imbalance appears as an inclination of the spine or the head to the side, when the projection of C7 does not corresponded to the middle of the pelvis or when there is a different height of the shoulders or of the iliac crest bones. It is estimated clinically by measuring trunk shift over the central sacral line (Zhang et al., 2015). The trunk imbalance parameter is defined as the frontal deviation of C7 from the midline of both posterior superior iliac spines (dimple middle) and can be measured in grade or in millimeter (mm) (Park et al., 2016). A positive value means that the coronal deviation of C7 is shifted to the right, a negative value indicates a shift to the left (Formetric+DIERS III 4D–Manual).

In some studies, trunk imbalance is also named trunk shift. Zhu et al. (2011) reported in their study that “trunk shift was determined by measuring the horizontal distance between C7 plumb line and the central sacral vertical line” (Zhu et al., 2011, p. 2). There are different causes for the deviation in the frontal plane such as leg length difference, scoliosis or pain in different parts of the spine, leading to an alteration in the posture of the back, among many others.

Trunk balance, Lazennec et al. (2011) wrote, is the “manifestation of a postural strategy conditioned by anatomic and functional characteristics, sometimes very different from one person to another” (p.686). If the patient is not able to maintain the trunk balance, functional alterations in different systems can occur, complications, which involve the neurological, respiratory or structural problems, as for example back pain (Lazennec et al., 2011).

For examination of the hip, the pelvis and for scoliosis follow-up the information obtained from the coronal plane is more often required than the information from the lateral plane (Lazennec et al., 2011). Nevertheless, the complete investigation of the sagittal, coronal and transversal balance of the pelvic gives important information to evaluate some back disorders and their association with the pelvis (Lazennec et al., 2011).

Some research was done using the trunk imbalance parameter. Guideti et al. (2011) studied the intra- and interday reliability of spine rasterstereography and among other parameters the trunk imbalance (Guidetti et al., 2013). März et al. (2016) also measured the trunk imbalance in different occlusal postural positions (März et al., 2016). Cho

(2015) studied the effect of running in place on the trunk imbalance and found statistical difference compared with a control group (Cho, 2015). The relation between trunk imbalance and back pain was examined by Fortin et al. (2016). They arrived at the conclusion that more studies about trunk imbalance and back pain need to be conducted (Fortin, Grunstein, Labelle, Parent, & Ehrmann Feldman, 2016). During the evaluation of the scoliosis in adolescents and follow-ups, the trunk imbalance is analyzed. The relation of the trunk imbalance to the back pain and its prognosis is still not well understood (Fortin et al., 2016).

Abe et al. (2015) considered in their study 20 mm of C7 plumb line shift in the coronal plane as significant trunk imbalance, based on the study of Schwab et al. (2000) (Abe, Sato, Abe, Masuda, & Yamada, 2015). Decreased coronal balance or decompensation of the spine balance occurs if a value higher than 2.0 cm of the trunk shift is found (Zhu et al., 2011).

Alterations in the posture of the spine were studied in 4915 11-year-old children in the Netherlands: 85.9% of the boys and 81.3 of the girls were symmetric, connoting that trunk imbalance is unusual in children (Hazebroek-Kampschreur, Hofman, van Dijk, & van Linge, 1992).

The trunk imbalance value and its association with the side of the scoliosis is also used for the prognosis of surgery in adolescents with scoliosis. The study of Bao et al. (2016) demonstrated that the side of pre-operative trunk shift might play a fundamental role in the development of post-operative complications in the frontal plane. They reported that those participants who had a pre-operative trunk shifted to the convex side of the coronal curve were predisposed to having a post-operative coronal imbalance when osteotomy was carried out. The results of the surgery suggest that patients with an imbalance in the coronal plane and a C7 plumb line shifted to the convex side of the curve may be at higher risk for post-operative coronal imbalance as well as provide valuable support during surgical decision-making in degenerative scoliosis patients (Bao, Yan, Qiu, Liu, & Zhu, 2016).

The review of Zhu et al. (2011) accompanied 26 adolescents with the diagnose of lumbar disc prolapse. First the patients went to their clinic for the evaluation of the scoliosis and then to the discectomy. The decision to perform surgery was made taking into consideration that the scoliotic posture and the coronal imbalance had physical implications and negative psychological consequences on the adolescents (Zhu et al., 2011).

“The correlation between the side of disc herniation and the direction of lumbosacral curve and the trunk shift was evaluated” (Zhu et al., 2011, p. 2). This possibly explains the high values of the trunk shift due to the pain caused by the lumbar disc hernia in adolescents. There are many different relations considering the position of the pelvis and the low back. The study of Abe et al. (2015) evaluated the relation between the position of the pelvis and the lumbar spine in patients with scoliosis. The results showed that there was no relation between the direction of the convexity or concavity of the scoliosis with the obliquity of the pelvis, and the extent of the lumbar curve showed no relation to the degree of the obliquity of the pelvis. “Lumbar scoliosis with tilted pelvis could be layered by idiopathic curve or be compensated by lumbo-sacral curve” (Abe et al., 2015, p. 3). The ways of the body to compensate and react are innumerous and individual. These compensations can be found in different planes of the movement. For the treatment of low back pain, there is no recipe, no technique that can be applied to all patients with success.

There are also studies about the **sagittal imbalance**. Liang et al. (2016) investigated the frontal and sagittal balance in 25 adults with spinal sagittal imbalance comparing the values before and after a discectomy. Trunk shift was the parameter analyzed in the frontal plane. The mean of the trunk shift found was (2.9 $\pm$ 6.1 cm) before the surgery and (0.2 $\pm$ 0.5 cm) after the discectomy. Considering the sagittal morphology of the lumbar spine, many factors, as for example age, gender, BMI and the ethnic group of the patient, contribute to the numerous individual variations found (Liang et al., 2016).

Zhang et al. (2015) studied the reliability of a new method to evaluate the coronal imbalance. In cases of spinal curvature, precise evaluation of trunk imbalance is essential for deciding on the treatment and determining the probable prognosis. Patients with secondary trunk imbalance due to inflammatory arthritis, tumors, neuromuscular diseases, full-leg length discrepancy, pelvic rotation and osteoarthritis or previous spine surgery were excluded from their study (Zhang et al., 2015).

“The Oswestry Disability Index has become one of the principal condition-specific outcome measures used in the management of spinal disorders” (Fairbank & Pynsent, 2000, p. 2940). The coronal spinal balance did not influence the Oswestry Disability Index in the cohort of Mac-Thiong et al. (2009), moderate coronal imbalance (less than 4 cm) did not influence the quality of life in adults with scoliosis. Since the coronal spinal of the majority of the participants did not exceed 4 cm of the central sacral vertebral line, it is impossible to conclude about the relationship between coronal balance and Oswestry Disability Index for severe imbalance greater than 4 cm. Maybe, this occurs only in patients with severe coronal imbalance greater than 4 cm (Mac-Thiong et al., 2009).

In the study of Bao et al. (2016), a total of 284 patients with degenerative lumbar scoliosis was recruited, 69 patients underwent surgery and the remaining 215 patients received a conservative treatment. The classification of the participants was established on the basis of the coronal balance distance: type A, coronal balance distance <3 cm; type B, coronal balance distance >3 cm and C7 Plumb line shifted to the concave side of the curve; type C, coronal balance distance >3 cm and C7 Plumb line shifted to the convex. In total, 99 of the 284 (34.8%) patients showed a coronal imbalance and this result was significantly more considerable than that of the balanced participants. Nevertheless, the coronally balanced and imbalanced patient groups did not differ significantly with regard to age, gender or the severity of the coronal spinal curvature (Bao et al., 2016). Some questions about the trunk imbalance, the factors that influence it and its relation to the back pain are still not answered.

1.2 Research question

Back pain is one of the most common problems in health care, with a multifactorial etiology. Among the causes for back pain are postural alterations. Bordoni and Marelli (2015) wrote about the association between the diaphragms and their support of a functional and balanced posture of the spine (Bordoni & Marelli, 2015). There are also studies that showed the connection between back pain and trunk imbalance (Oddsson & Luca, 2003), but there is no study about the association of trunk imbalance with the treatment of the four diaphragms in the crossover areas. The research question of this study is:

Can an osteopathic treatment of the four functional transverse diaphragms according to Zink using osteopathic techniques in patients with back pain influence the trunk imbalance parameter compared with a control group?

1.3 Hypothesis

1.3.1 Null hypothesis

The null hypothesis states that the treatment of the four functional transverse diaphragms according to Zink using osteopathic techniques in patients with back problems does not influence the trunk imbalance parameter.

1.3.2 Alternative hypothesis

The alternative hypothesis states that the treatment of the four functional transverse diaphragms according to Zink using osteopathic techniques in patients with back problems influences the trunk imbalance parameter.

1.4 Relevance of the study

Back disorders have been identified as “a major cause for sickness absence and disability among many occupational populations” (Burdorf & Sorock, 1997, p. 243). One possible factor for this might be the trunk imbalance of the spine influenced by the muscles, that ensure the mobility and stability of the back (Gatti et al., 2011). The four diaphragms have an anatomical and functional relation to the back and their dysfunction might be related to the origin or maintenance of the low back pain.

Treatment of the four diaphragms has the objective to create a healthy adaptive process in the four cross-over sites and the restoration of an alternating compensatory pattern is seen as evidence for a successful therapeutic treatment in osteopathy (Chaitow & Crenshaw, 2006). There is no research that shows the relation between the treatment of the four diaphragms according to Zink and the trunk imbalance.

The relevance of the study for the patients:

- Does the treatment of the diaphragms result in a better outcome of the trunk imbalance for patients with back pain?

The relevance of the study for osteopathy:

- How can an osteopathic treatment of the four diaphragms according to Zink influence the trunk imbalance of patients with back pain?

2 Methods

2.1 Research design

This is a randomized controlled study with a control group. The treatment group received the treatment of the four functional transverse diaphragms according to Zink, as described in the theory part (see p. 7) using osteopathic techniques related to the individual symptom of each subject. The treatments were documented (document sheet: see attachment D). The control group received a sham treatment, in which the subjects were laying and listening to music. Tester and subjects were blinded.

2.2 Subject

2.2.1 Sampling size

First, 48 subjects were selected for this study in cooperation with the Forum Energetix Institute in Leibnitz, Styria, according to the indications for this research. All subjects of the study gave their agreement to participate in this study. Due to health problems (untreated tachycardia) one of the subjects could not attend the sham treatment; the appointment was canceled at short notice. So finally, the study was executed with a total of 47 subjects (see Table 2).

Table 2: Group distribution

	n	Percent
Treatment Group	24	51
Control Group	23	49
Total	47	100

2.2.2 Inclusion criteria

The including factors for this study were:

- subject older than 18 years (Levy, Larcher, Kurz, & Cesp, 2003)
- back problems: strong painful conditions in different areas of the back, regardless of their origin; continuous or recurring back pain. The duration of the pain was classified in:
    - less than 6 weeks
    - between 6 and 12 weeks
    - longer than 12 weeks
- standing is possible without external support

2.2.3 Exclusion criteria

The following contraindications for an osteopathic treatment, according to Mayer-Fally (2006) and pregnancy, were the exclusion criteria for the participation in the present study (Mayer-Fally, 2006, p. 84):

- "Within 6 weeks after an operation

Internal medical diseases:

- Hypertension crisis: blood pressure value from 190/110 with symptoms (headache, impaired vision, paresis, speech impediments…)
- Acute abdomen
- Sudden, unexplained severe vomiting and/or diarrhea
- Collapse tendencies: vertigo, severe sweating, nausea (blood sugar impairment, syncope, a change in hormone levels…)
- Thoracic pain (with vegetative symptoms) without precedent complete diagnostic clarification
- Untreated cardiac failure II-IV: marked edema dyspnea...
- Untreated tachycardia – bradycardia arrhythmia: rate arrhythmic (with intervals of several seconds) and/or >95 or <50 beats per minute in resting adults)
- Unexplained acute dyspnea

Vascular disorders:

- Venous: suspicion of acute vascular obliterations, unexplained swellings (edema), tenderness
- Arterial: clear pallor in extremities, livid discolorations or marbling, pulselessness in extremities, severe pain

Neurological disorders:

- Acute, severe cephalea (meningitis/encephalitis, intracranial aneurysm, tumor
- Acute neck stiffness with fever and possible signs of meningism (meningitis)
- Newly occurred intense dizziness of unexplained genesis
- Unexplained acute paresis
- Conus-Cauda-Syndrome
- Unexplained sudden impaired vision like scotoma or aphasia"

Pregnancy: “pregnancy has an effect on the spinal posture” (Betsch et al., 2015, p. 1282).

Inclusion and exclusion criteria were evaluated during the selection of the patients (per e-mail or telephone), by means of questionnaires (Attachment B) and an interview before the beginning of the study.

2.2.4 Type of sampling

In this research, 10 men and 14 women participated in the treatment group, and 10 men and 13 women in the control group, as shown in Table 3. The distribution of gender among the control group (CG) and treatment group (TG) was relatively similar.

Table 3: Gender distribution among control and treatment group.

	Male (n)	**Male (%)**	**Female (n)**	**Female (%)**	**Total (n)**
TG	10	50%	14	51%	24
CG	10	50%	13	49%	23
Total	20	100%	27	100%	47

Table 4 shows the mean, minimum value and maximum value of the age distribution among the treatment group and the control group. The treatment group has a lower mean (48 years) than the control group (54 years) and a higher spreading (62 years) than the control group (31 years), as shown in the Table 4.

Table 4: Mean, minimum and maximum value of the treatment and control group.

Age (years)	**Mean**	**Minimum value**	**Maximum value**
TG	48	22	84
CG	54	31	68

Table 5 shows the weight distribution among the treatment group and the control group. The mean value was similar among the groups; the spreading was higher in the treatment group (67 kg) than in the control group (48 kg).

Table 5: Weight distribution – treatment and control group.

Weight (kg)	**Mean**	**Minimum value**	**Maximum value**
TG	73	47	114
CG	74	50	98

Table 6 shows the height distribution among the treatment group and the control group. The values were relatively similar among the groups.

Table 6: Height distribution – treatment and control group.

Height (cm)	Mean	Minimum value	Maximum value
TG	172	157	190
CG	171	157	191

Table 7 shows the region of the back pain among the treatment group and the control group, with the lumbar zone being the most affected area in both groups.

Table 7: Distribution of the areas of pain in the treatment and control group.

	Cervical	Thoracic	Lumbar	Total
TG	15	10	23	48
CG	14	6	20	40

2.3 Materials

2.3.1 Description of material

Formetric 4D: The radiographic image is the gold standard method for analyzing the morphology of the back, providing “a permanent record for serial evaluation and can be randomized and blinded for objective scoring”(van der Heijde, 2000, p. 9). Radiologic examinations expose the patients to a high quantity of radiation. In the last thirty years, non-invasive methods have been studied for measuring the spine, such as rasterstereography. The Formetric 4D (DIERS, International GmbH, Schlangenbad, Germany) is an extensively used rasterstereographic system, that “allows a radiation-free, three-dimensional analysis of the back surface and the spine” (Betsch et al., 2015, p. 845).

In rasterstereography, described by Kwon et al. (2015), two cameras record the back shape and a projector projects the raster containing the grid of the patient under examination. “Parallel white light lines are projected on the back surface of the subject by the slide projector” (Kwon et al., 2015, p. 960).

Examinations were done with the participants in underwear to recognize the landmarks, as for example the spinous process of C7, in the standing position with both arms lying parallel to the body. Similar to Park et al. (2016), the results of the tests were automatically analyzed (Park et al., 2016).

2.3.2 Parameter

The parameter trunk imbalance (mm) was tested by Formetric 4D before/after the treatment of the four diaphragms in the treatment group (n=24), and before/after the sham treatment in the control group (n=23).

2.4 Procedure

2.4.1 Recruitment, date of survey and intervals

The recruitment of the subjects was done two months before the start of the treatment with the support of Forum Energetix. The subjects were contacted by telephone. The sample was randomly divided into two groups, into the treatment group and the control group.

The practical part of the study was realized in June 2017. The treatment of the four diaphragms and the sham treatment (control group) were done on two different days. On each day 24 subjects had appointments to be treated and tested.

The appointments for the treatment group and for the control group were distributed randomly. Depending on which of the two days the subjects had time, they were assigned to the treatment group or to the control group. Tester and patients were blinded.

2.4.2 Intervention

Practical part - treatment group (TG)

- Informative talk about the steps of the study
- Anamnesis (questionnaire) and consent form (see attachment A)
- Formetric test: trunk imbalance parameter (mm)
- Zink pattern test: compensated pattern (CP) or uncompensated pattern (UP)
- Treatment of the four functional transverse diaphragms according to Zink using osteopathic techniques. The four transversal areas were treated with different osteopathic techniques, depending on the symptom of the subject until release. The treatments were documented.
- Formetric retest: trunk imbalance (mm)

Practical part - control group

- Informative talk about the steps of the study
- Anamnesis (questionnaire) and consent form (see attachment A)
- Formetric test: trunk imbalance parameter (mm)
- Zink pattern test: compensated pattern (CP) or uncompensated pattern (UP)
- Sham treatment: the patient was lying for 20 minutes and listening to music.

- Formetric retest: trunk imbalance (mm)
- Treatment of the four functional transverse diaphragms according to Zink using osteopathic techniques. The four transversal areas were treated with different osteopathic techniques, depending on the symptom of the subject until release. The treatments were documented.

The study flow chart is shown in Figure 1:

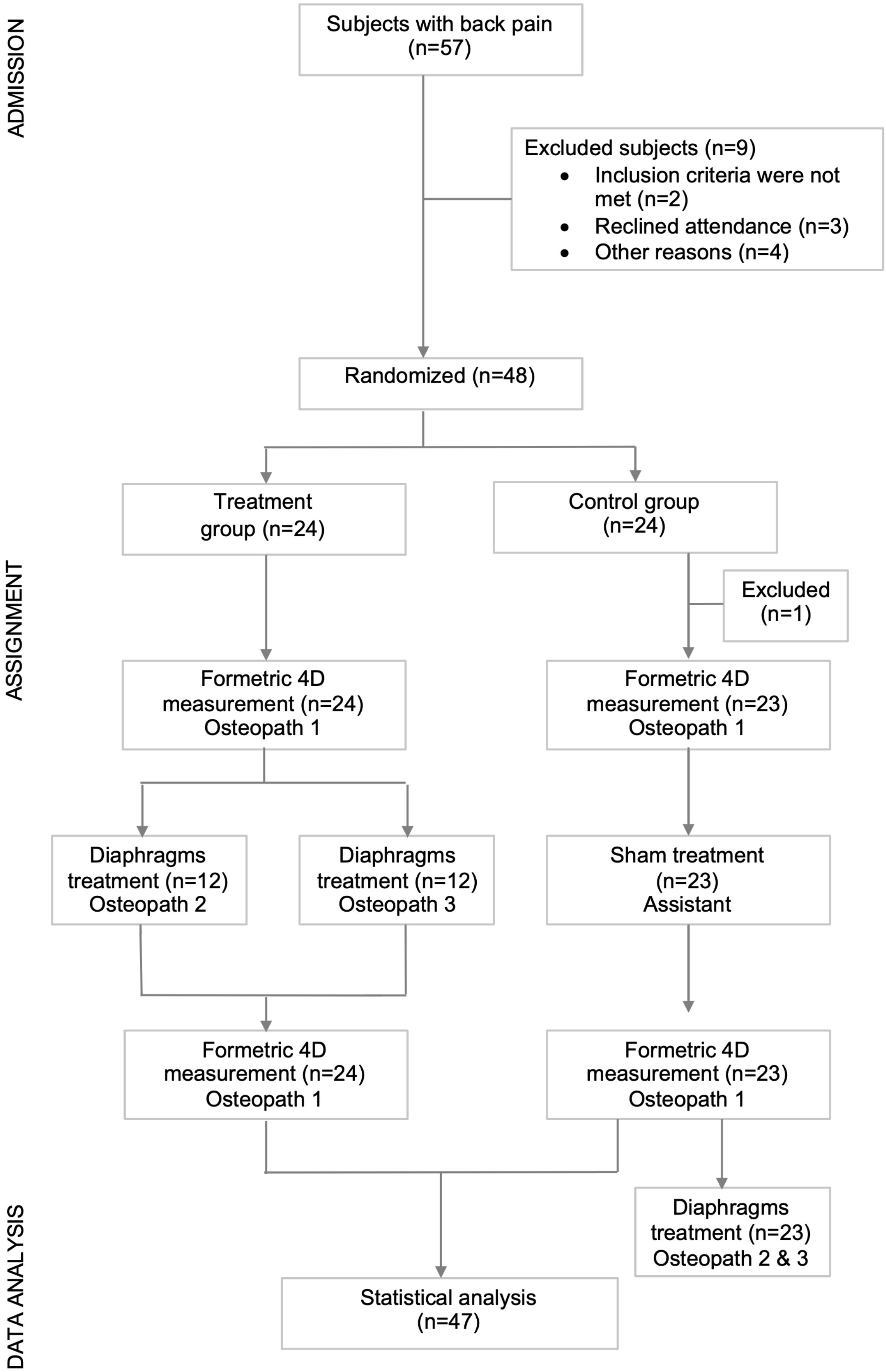

Figure 1: Study flow chart

2.4.3 Description of the osteopathic technique

- Direct technique: Pressure or tension was conducted, executed against the restriction, against the blockade (Huss & Wentzel, 2015; Liem, Puylaert, & Puylaert, 2005). The technique was applied until release of the treated area.
- Indirect technique: the technique was conducted in the direction of the restriction, of the tension; in the easier direction of movement, not against the tension (Assche, 2014; Liem et al., 2005. The technique was applied until release of the treated area.
- Mobilization: the treated area was gently mobilized in different directions (Liem et al., 2005) until release of the treated area. Here, also the scar mobilization was included.
- Strain counterstrain (SCS): When a significant counterstrain point was found, the patient was placed in a position of comfort that eliminated tenderness, the position was maintained for 90 seconds, at the end, the osteopath slowly returned the patient to the starting or neutral position, the tenderness of the counterstrain point was rechecked (Liem, Tozzi, & Chila, 2017).
- Trigger Point technique (TPP): Pressure at the treated area (trigger point) until release of the treated area.
- Recoil technique: The organ to be treated was put under tension and suddenly the therapist released the tension (Liem et al., 2005).

2.5 Tester

Osteopath 1 is physiotherapist and student of the osteopathy postgraduate programme of the Danube University Krems. He attended a course for the use of Formetric. The examiner was blinded; he was not informed if the subjects were treated or not. Similar to Park et al. (2016) measurements were realized by an independent, skillful tester, who was able to manage the equipment Formetric 4D (Park et al., 2016).

An assistant was responsible for providing information to the participants, distributing the questionnaires and consent forms as well as the management and organization of the study during the data collection. The tester and the two intervening osteopaths were not involved in the management of the study. Osteopath 1 was in the test room during the period of the practical part of the research, osteopath 2 and 3 stayed in the treatments rooms.

2.6 Intervening persons

Osteopath 2 is physiotherapist and student of the osteopathy postgraduate programme at the Danube University Krems.

Osteopath 3 is physiotherapist and student of the osteopathy postgraduate programme at the Danube University Krems and author of this study.

2.7 Cooperating institutions and persons

Forum Energetix Institut supported the study with the recruitment of patients, with the infra-structure, including a test room with the Formetric 4 D equipment, two treatment rooms, one sham treatment room and a waiting room.

Praxisgemeinschaft Rinder-Krischan supported the study with the recruitment of patients.

Mag. Gerhard Pukl and Wolfgang Ebner/Firma Triaflex instructed the osteopaths about how to use the Formetric 4D.

2.8 Type of literature research

During the period of June 2016 - March 2017 and February - March 2019 the literature research was done in the:

. PubMed: Medline (www.pubmed.com)

. Osteopathic research web (www.osteopathicresearch.com)

. Medical books

. Library of the Wiener Schule für Osteopathie (WSO)

. Words used for the literature review: posture, rasterstereography, diaphragms, Zink patterns, trunk imbalance, back pain, Formetric, neck postural reflex.

. Specialists, who were interviewed or consulted:

Dr. Paolo Tozzi, MSc. Ost, DO PT - Italy

Dr. Michael Kuchera DO., F.A.A.O - USA

Raphael van Assche MSc. DO - Austria

2.9 Data preparation and analysis

The measured data were evaluated by a statistical method with the support of the statistician Dr. Harald Lothaller. The purpose was to investigate if there was a change over the time in the trunk imbalance between the treatment group and the control group. In order to answer the research question, analyses were conducted of the variance (ANOVA) of the trunk imbalance (mm) with repetition measurement and grouping factor. For this, the average values were compared amongst the groups and measurements with each other to identify if there was a general significant change over time or a general significant difference between the groups, or an interaction effect. A p-value larger than 0.05 corroborates the null hypothesis, a smaller p-value than 0.05 rejects the null hypothesis.

2.10 Ethical considerations, including risk estimation

The subjects brought an assignment from a doctor, allowing them to receive an osteopathic treatment. Before the treatment, each subject was informed about the research procedure. An anamnesis form was filled in by each subject, where the contra-indications for the treatment were asked and the consent form was signed. The subject could at any moment stop and quit its participation in the research.

3 Results

3.1 Nominal group description

The following chapter covers the statistical evaluation of the results. The objective is to verify if the null hypothesis, which states that the treatment of the four functional transverse diaphragms according to Zink using osteopathic techniques in patients with back problems does not influence the trunk imbalance parameter is proven or rejected based on the results. A total of 47 patients (27 females and 20 males) were included in this study. Gender and Zink patterns, i.e. compensated and uncompensated patterns, were equally distributed between the treatment group (TG) and the control group (CG) (see Table 8). The initial situation of both groups was comparable.

Table 8: Cross-classified table - Zink pattern and gender for TG and CG

	TG	CG	Total
Zink pattern CP	3	3	6
Zink pattern UP	21	20	41
Total	24	23	47
Male	10	10	20
Female	14	13	27
Total	24	23	47

The Chi-square test verified whether any later difference between the groups could be found due to the side effects of Zink patterns or gender. They were evenly distributed. Therefore, it was not necessary to include these parameters in subsequent analysis (see Table 9).

Table 9: Chi-square test gender and Zink pattern for both groups (TG and CG)

Pearson Chi-square	Value	df	Asympt. Sig. (2-sided)
Gender	0.003	1	0.955
Zink pattern	0.016	1	0.900
N of valid cases	47		

An overview of the descriptive data is provided in the appendix (Attachment E).

3.2 Trunk imbalance (mm)

The interaction of the following two factors was tested:

1. Point in time of the trunk imbalance measurement:

. T1: Trunk imbalance values before intervention (treatment of the four diaphragms or sham treatment)

. T2: Trunk imbalance values after the intervention (treatment of the four diaphragms or sham treatment)

2. Groups:

   . TG: Treatment group (n=24)

   . CG: Control group (n=23)

An analysis of the variance (ANOVA) of the trunk imbalance (mm) with repetition measurement and grouping factor was conducted (see Table 10). For this reason, the average value from it group and the measurements were compared with each other to identify, if there was a general significant change over time or general significant difference between the groups or an interaction effect.

Table 10: Descriptive table of the trunk imbalance – T1 before the intervention, T2 after the intervention

Measurement	**Dependent variable**
1	T1 Trunk imbalance (mm)
2	T2 Trunk imbalance (mm)

Table 11 displays the arithmetical mean and standard deviation of the trunk imbalance (mm) before (T1) and after the treatment (T2) of both groups (TG and CG).

Table 11: Descriptive statistics - trunk imbalance TG and CG

Group	**mean**	**Standard deviation**	**n**
T1 TG	-8.5383	15.32890	24
T1 CG	-2.5635	13.62222	23
Total	-5.6145	14.67483	47
T2 TG	-8.5808	13.69890	24
T2 CG	-5.7665	13.47239	23
Total	-7.2036	13.51514	47

Figure 2 shows the trunk imbalance (mm) of the two groups, TG and CG, before and after the intervention. In TG, the first measure and the second measure of the mean trunk imbalance are similar, in CG the mean value of trunk imbalance is higher. A positive value means that the trunk imbalance has shifted to the right side, a negative value indicates an offset to the left.

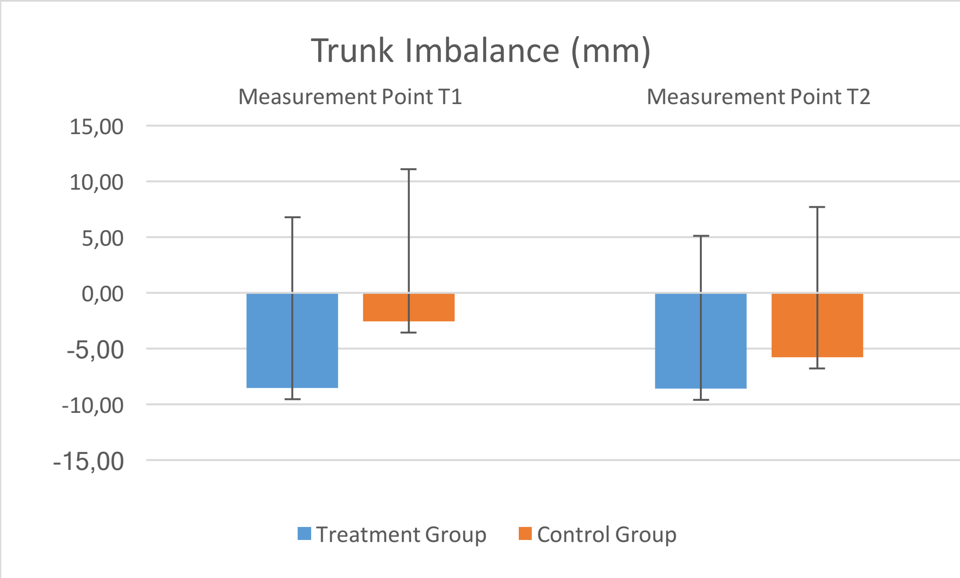

Figure 2: Trunk Imbalance (mm) before T1 and after T2 of both groups: treatment group (TG) and control group (CG)

Figure 3 shows a line graph illustrating the distribution of the mean of trunk imbalance (mm) data within the treatment group and control group before (T1) and after the treatment. (T2)

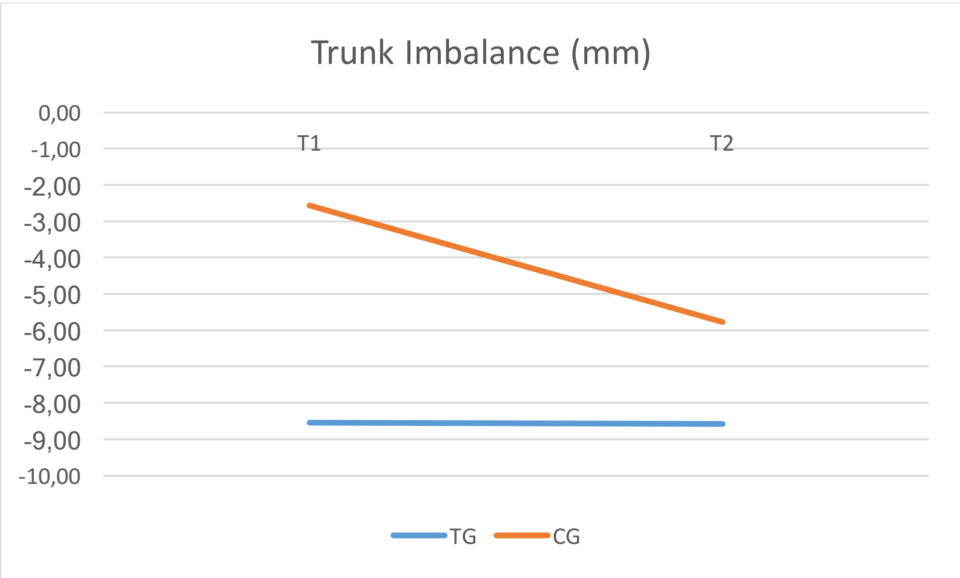

Figure 3: Mean of the trunk imbalance (mm) line diagram T1 and T2 of treatment group (TG) and control croup (CG) before (T1) and after the intervention (T2)

The T-test showed no statistical difference (p: 0.970) for both groups. A single treatment of the four functional transverse diaphragms according to Zink using osteopathic techniques in patients with back problems does not influence the trunk imbalance parameter.

The significance test of within subject-contrast with the two statistical values, measurement*group and measurement is shown in the Table 12:

Table 12: Test of within-subject contrast

	Sig
Measurement	.444
Measurement*group	.456

3.3 Relative change

The relative change shows how much the percentage changes between T1 and T2 in the treatment group and in the control group (see Table 13).

Table 13: Group statistic – relative change of the trunk imbalance in the TG and CG

	group	n	mean	standard deviation
Relative change trunk imbalance (mm)	TG	23	1.0426	1.57388
	CG	22	1.0187	2.54025

The relative variation of trunk imbalance in mm for TG was 1,04, around 4% and in CG it was 1.018, around 2%, between T1 and T2. Here, we observed a high standard deviation compared with the mean value (TG:1.04 and CG:1.01). The standard deviation of 1.57 in the TG or in the CG of 2.54 is high.

In the T-test for comparing the relative change, comparing the arithmetic mean of both groups, the value of 0.038 T1-T2 (T2 / T1 calculated) was obtained. A value below 1 means that there was a decrease in trunk imbalance in both groups (T2). But there is no statistical difference (p: 0.970) for the two groups. Even if the relative changes are used instead of the absolute values, there is no difference between T1 and T2, **confirming the null hypothesis.** One treatment of the four functional transverse diaphragms using osteopathic techniques in patients with back problems does not influence the parameter of trunk imbalance.

3.4 Correlation

As in the study of Fortin et al. (2016), the interpretation of the correlation coefficients was as follows: < 0.25 as poor as no relationship; 0.25 to 0.50 as low; 0.50 to 0.75 as moderate to good; and > 0.75 as good to excellent, based on the study of Schwab et al. (2000) (Fortin et al., 2016, p. 689).

3.4.1 Entire group weight and size

Table 14 shows the correlation between trunk imbalance and weight/size for the **whole group** (both groups, n=45):

Table 14: Correlation of trunk imbalance with weight (kg) and size (cm) for the entire group (n:45)

	weight (kg)	size (cm)
correlation	0.038	-0.108
significance	0.802	0.480
n	45	45

The correlation coefficient between weight (0.038) and size (-0.108) for the whole group. Both showed no significant difference (weight p: 0.802 and size p: 0.480). The change is independent of weight and size of the whole group.

3.4.2 Correlation TG and CG weight and size

In Table 15 the correlation between trunk imbalance and weight/size for the treatment group (n=24) is shown:

Table 15: Correlation trunk imbalance with weight (kg) and size (cm) for the treatment group (TG)

	weight (kg)	size (cm)
correlation	0.365	-0.087
significance	0.87	0.694
n	23	23

The correlation coefficient between weight (0.365) and size (-0.087) for the treatment group did not show significant difference for weight (p: 0.87) and size (p: 0.694). The change is independent of weight and size of the TG. No correlation was found between weight/size and trunk imbalance in the TG:

Table 16 the correlation between trunk imbalance and weight/size for the control group (n=24) is shown:

Table 16: Correlation of trunk imbalance with weight (kg) and size (cm) for the control group (CG)

	weight (kg)	size (cm)
correlation	-0.267	-0.259
significance	0.229	0.233
n	22	22

The correlation coefficient between weight (-0.267) and size (-0.259) for the control group did not show significant difference for weight (p: 0.229) and size (p: 0.233). The change is independent of the weight and size of the CG. No correlation between weight/size and trunk imbalance was found in the CG:

3.4.3 Correlation TG and CG operation

In Table 17 the correlation between the change of trunk imbalance and operation for the treatment group (n=24) is shown:

Table 17: Correlation of the change of trunk imbalance with operation for the treatment group (TG)

	T1	**T2**	**Change trunk imbalance**
correlation	-0.039	-0.215	0.545
significance	0.855	0.313	0.007
n	24	24	23

There is a **correlation** between the operations and the change in trunk imbalance for the treatment group (p: 0.007). A positive correlation (0.545), the higher the number of operations, the greater the value of its change.

In Table 18, the correlation between trunk imbalance change and operation for the control group (n=23) is presented:

Table 18: Correlation of the change of trunk imbalance with operation for the control group (CG)

	T1	**T2**	**Change trunk imbalance**
correlation	-0.005	0.194	0.309
significance	0.983	0.374	0.162
n	23	23	22

There is no significant correlation between the operations and the change in trunk imbalance to the control group (p: 0.162).

3.4.4 Correlation TG and CG period of pain

Table 19 shows the correlation of trunk imbalance for T1 and T2 and the pain period for the treatment group.

Table 19: Correlation of the change of the trunk imbalance with period of pain (week) for the treatment group (TG)

	T1	T2	Change trunk imbalance
correlation	0.34	0.207	-0.185
significance	0.879	0.356	0.423
n	22	22	21

There is no significant correlation between pain period (week) and the change in trunk imbalance for the treatment group (p: 0.423).

Table 20 shows the correlation of trunk imbalance for T1 and T2 and the pain period for the control group:

Table 20: Correlation of the change of trunk imbalance with period of pain (week) for the control group (CG)

	T1	T2	Change trunk imbalance
correlation	-0.256	-0.495	0.307
significance	0.275	0.027	0.202
n	20	20	19

There is a significant correlation between T2 and pain period (p: 0.027) in the control group. A negative correlation (-0.495), the longer the period of pain in weeks, the lower the T2 value. The longer the participants presented pain (more than 12 weeks), the lower (-) was the value of the trunk imbalance after the sham treatment, a relatively higher value of trunk imbalance (mm).

3.4.5 Other correlations

Healthy condition, stress level, age and energy level were also tested. There is no correlation of the other parameters with the change in trunk imbalance for T1 and T2 values.

4 Discussion

In this part of the paper, the results are presented, compared and discussed in relation to the current literature. As already mentioned in the introduction of the study, back pain is a health problem that affects a large part of the population.

Much of the demand for osteopathic professionals is due to problems in the spine: cervical, thoracic or lumbar spine. Professionals of osteopathy are often confronted with patients with pain in those regions in their clinics. The results of Dionne et al. (2006) suggest that "the frequency of severe back pain will rise sharply in the coming years as another important public health consequence of the ageing of populations in many countries" (Dionne et al., 2006, p. 233).

The relation between posture and back pain was analyzed by researchers (Cho, 2015). In this study, it was investigated if there is an alteration in the trunk imbalance in patients with back pain after the treatment of the four diaphragms.

There is a continuity of the four diaphragms (Bordoni & Zanier, 2015). It is assumed that by improving the mechanics of the diaphragms back pain can be reduced. The results of Martí et al. (2018) "suggest that low back pain and diaphragm dysfunction may be interrelated, and that improving diaphragm function may decrease pain and disability in patients with chronic non-specific low back pain" (Martí-Salvador, Hidalgo-Moreno, Doménech-Fernández, Lisón, & Arguisuelas, 2018). Unfortunately, the level of pain before and after the procedure was not measured in the present study. The qualitative and quantitative evaluation of pain before and after the treatment could have provided important information for the discussion of this work.

"The diaphragm influences the intensity of the pain and there is an indisputable association with emotions" and its "innervation may be responsible, directly and indirectly for the emotional state of the person " (Bordoni, Marelli, & Bordoni, 2016, p. 100). After a single intervention, the analysis of the emotions and their possible alteration after the treatment was not the objective of this study, but this information could have given important insights about the influence of the osteopathy.

Janssens et al. (2015) investigated if inspiratory muscle training influences the proprioceptive system during postural control in low back pain patients. They have shown that "individuals with recurrent nonspecific low back pain and healthy individuals breathing against an inspiratory load decrease their reliance on back proprioceptive signals in standing position" (Janssens et al., 2015, p. 1088). A suggestion for further studies in the area of trunk imbalance and the treatment of the four diaphragms is to compare patients with back pain with healthy participants and investigate, if a change in the trunk imbalance after the treatment occurs. It might be possible that healthy patients demonstrate a higher capacity to faster compensate and realize faster adaptations in the posture after the treatment.

Some research was done relating to **trunk balance** and back pain. Gatti et al. (2011) studied the effect of trunk balance exercises in patients with chronic low back pain. The conclusion was that “the use of trunk balance exercises appeared to be effective in reducing disability and led to improvements on the physical component of the quality of life” (Gatti et al., 2011, p. 542). A group of muscles, such as the transitional diaphragms, associated with balance exercises, can be effective in the treatment of spine disorders.

A recently published article about the use of osteopathic technique in the treatment of non-specific low back pain concluded that “an osteopathic manipulative treatment including diaphragm techniques produces significant and clinically relevant improvements in pain and disability in patients with non-specific low back pain compared to the same osteopathic manipulative treatment protocol using a sham diaphragm intervention” (Martí-Salvador et al., 2018, p. 1720)

With regard to the treatment of patients with pain originating in the structure system (muscular, fascial or skeletal), clinical experience shows that, in general, if the patients reach control in one or more axes of postural symmetry (frontal, sagittal or transversal), they will be able to compensate in a better way and pain will decrease (Pope, 2003). Trunk imbalance is also named coronal imbalance, the imbalance in the frontal plane.

4.1 Methodology

4.1.1 Subjects

Forty-seven subjects participated in this study. They were randomly distributed in two groups, the treatment group (TG=24 subjects) and the control group (CG= 23 subjects). In the literature, studies with a similar or smaller number of subjects can be found. In the study of Park et al. (2016), the participants were equally and randomly allocated to two groups, each one with 13 subjects (Park et al., 2016).

In the study of Janssens et al. (2015) 28 subjects with a history of nonspecific recurrent low back pain participated voluntarily (Janssens et al., 2015). In the present study, for statistical analysis and comparison with the literature, the number of participants was adequate. Nevertheless, in studies with a greater number of participants the statistical analysis can achieve greater accuracy of the data. Since in this study only a single treatment was performed, the accuracy of what had changed after the treatment could have been better understood or showed with a larger number of participants.

An important factor for the statistical analysis is the homogeneity of the groups. Bao et al. (2016) in their study, in a total of 284 patients, 99 patients showed a coronal imbalance (>3cm) and 173 participants showed a coronal balance (<3 cm). The coronally balanced and imbalanced patient groups showed no significant difference with regard to age, gender, or the severity of the coronal back curvature (Bao et al., 2016). In the present study, the groups also showed similar values with regard to gender, weight and height.

Henn et al. (2014) identified some predictors for back pain, for example, gender and BMI. The gender effect was strong. Women were more likely to report back pain than men (Henn et al., 2014). In the present study, among the 24 subjects in the treatment group 14 were women (58.4%) and from the 23 participants in the control group 13 were women (56.5%), a similar value among the groups.

Henn et al. (2014) also mentioned that a higher value of BMI, shows a higher probability for the incidence of back pain (Henn et al., 2014). In the study of Krautwurst et al. (2018), with participants that present a history of disc prolapse and a control group, no connection was stablished between the values of BMI and their results (Krautwurst et al., 2018). In the present study, there was no correlation of the results of the TG and the CG with weight and size. For TG and CG, the change was independent of weight and size

"A further interesting result is the absence of any age effect" with back pain in the study of Henn et al. (2014, p.4) after the analysis of questionnaires from 1007 patients in Germany and Poland (Henn et al., 2014). In the present study no correlation was found between age and trunk imbalance between T1 and T2 values in the TG and the CG.

4.1.2 Inclusion and exclusion criteria

The inclusion factors for this study were: 1. subject older than 18 years, 2. standing is possible without external support (necessary condition for the Formetric 4D test), and 3. back problems. The latter included strong, painful conditions in different areas of the back regardless of their origin (Casser et al., 2016, p. 4), and continuous or recurring back pain: in the last 6 weeks, between 6 and 12 weeks and longer than 12 weeks, as above described (see p. 19) . Dionne et al. (2006) reported that there is a great number of different definitions of back pain, and the influence of this can be seen in the analysis and comparison of the results in the literature. "This highlights the need for further standardizing definitions and measure of back pain for population and clinical research" (Dionne et al., 2006, p. 233).

“Low back pain is described as chronic by the persistence of pain beyond 3 months of symptoms” (Rozenberg, 2008). The inclusion criterion in the study of Gatti et al. (2011) was low back pain, with or without referred pain, in the lower extremities present for at least 3 months (Gatti et al., 2011). Some of the subjects did not present pain during the data collection of the present study but were included nevertheless in the research because of their history of recurring pain.

In the study of Janssens et al. (2015) participants were included, if they had had at least three occurrences of nonspecific low back pain in the last 6 months and reached a score of at least 10% on the Oswestry Disability Index. The patients did not have a more precise clinical diagnosis than nonspecific mechanical low back pain. The subjects that had undergone surgery in the spine were excluded from the study as well as patients with balance disorders with specific etiology, respiratory problems, lower limb dysfunction, cervical pain or use of analgesic medicaments or physiotherapy. A physical examination was executed by a physician to confirm eligibility (Janssens et al., 2015).

In the study of Henn et al. (2014), the information about back pain in the participants was assessed using the set of questions designed by Hardt. Answers were assessed with a five-point Likert scale including 5 possibilities: 1. “never”, 2. “rarely”, 3. “sometimes”, 4. “often”, or 5. “very often”. “The variables “never”, “rarely”, and “sometimes” were counted as no back pain and “often” or “very often” as back pain” (Henn et al., 2014, p. 2). For further studies it is suggested to consider a major homogeneity in the intensity parameter of pain, as for example in the study of Henn et al. (2014). In the present study, the factor of inclusion was simply pain in the spine. It would be advisable for further studies to be take into consideration only those subjects whose back pain was rated “often” or “very often”. Some participants with mild or moderate pain were included.

Krautwurst et al. (2018) reported that the posture or the lateral shift is not influenced by the period of pain. They included patients with acute or chronic back pain and healthy participants. To analyze the chronic stage of the participants the Mainz Pain Staging System was used and three chronification levels were found (Krautwurst et al., 2018). One point to discuss is if TG and CG subjects were homogeneous enough. It is important to point out the difficulty of having a homogenous group, concerning the etiology of the back problems. 85% of the low lback pain disorders have no specific etiology.

In the results of this study, a **significant correlation** between T2 and period of pain (p=0.027) in the control group was found. It was a negative correlation (-0.495): the longer the period of pain in weeks, the lower the value of T2 (T2 CG= -5.76659). A negative value of the trunk imbalance means that the body shifts to the left side. After the sham treatment, where the subjects were lying for 30 minutes, patients with a longer time of pain (more than 12 weeks of pain) reached with a greater value of trunk imbalance. This shows that, the longer the patients had pain, the less symmetrical was the value of trunk imbalance parameter after the sham treatment. In the treatment group there was no significant correlation between the period of pain (week) and the change of trunk imbalance (T2).

In an attempt to homogenize the groups, some exclusion criteria could have been taken into account. In Park et al. (2016), among the exclusion criteria applied were listed: (1) severe scoliosis, (2) leg length discrepancy (>2 cm), (3) discal pain (visual analogue scale >3), (4) lower extremity trauma or operation, (5) arthritis, (6) pregnancy (one of the exclusion criteria of this study), (7) muscle spasm or spasticity, and (8) vestibular system disturb that affects the postural control (Park et al., 2016). These are factors that can strongly influence the result of the trunk imbalance, and it is suggested to take them into consideration for an upcoming study in this area.

4.1.3 Time of intervention

In this study, the number of participants corresponds to the literature, the time of intervention, however differs from other studies. In the present study a single intervention of 20 minutes was applied. The data were collected before and after this intervention. In other researches, the number of subjects was similar to the present study, but the intervention time was longer, lasting, in most studies, a few months. For example, in the study of Lidegaard et al. (as cited in Henn et al., 2014) 15 patients were compared with controls. They had trained for ten weeks (intervention time), two minutes per day, showing “a promising reduction of back and neck pain” (Henn et al., 2014, p. 2).

In the research of Park et al. (2016), the participants in the biomechanical foot orthosis group (n=13) wore a foot orthosis for at least 3 hours/day. The tests were performed before the use of the biomechanical foot orthosis and after 2 and 4 weeks of wearing the biomechanical foot orthosis (Park et al., 2016). In the present study, the time of intervention was one 20-minute treatment. The short intervention time can be one of the reasons, why there is no significant difference in the trunk imbalance (mm) before and after the treatment between the two groups, control and treated.

Kwon et al. (2015) aimed “to investigate how an artificially created leg-length inequality would immediately affect the pelvic position and spinal posture” (p. 689). The research utilized the rasterstereographic device Formetric 4D, which can observe pelvic position and back posture at the same time. “There was no significant difference in spinal posture resulting from the leg-length inequalities” (1cm, 2cm, 3cm and 4cm) (p. 691). No statistical difference was found in the trunk resulting from the temporary leg-length discrepancy, but spinal changes in healthy participants of both genders were observed with different leg lengths during short periods of time. The alterations found for short periods of time appear to show a compensation mechanism in the pelvis, but not so clear for the spine (Kwon et al., 2015). It seems to be more difficult to identify alterations in the posture of the trunk, even with the artificial increase of the leg-length. The body adapts to these changes, perhaps to allow a lower energy expenditure, keeping the midline and the position of the head as centered as possible. Do healthy patients react differently? According to Zink, if the patients presented an uncompensated pattern, the period of treatment was longer (Zink & Lawson, 1979). In both groups, TG and CG, the numbers of uncompensated pattern were higher (TG: 21, CG: 20) than those of compensated pattern (TG: 3, CG: 3).

Similar to Gatti et al. (2011), for further studies a longer time of intervention is suggested. The collection of other parameters could be useful for the understanding of the outcomes, such as the visual analogue scale (VAS), disability (evaluated using for example the Roland and Morris Questionnaire RMQ), and quality of life (measured with the mental and physical components of the 12-item Short-Form Health Survey SF12 for example) (Gatti et al., 2011).

As in the study of Gatti et al. (2011), another limitation in the present study is the absence of a follow-up beyond the ending of the intervention duration. Further studies should include follow-up assessments (Gatti et al., 2011). In osteopathy, alterations or modifications after a treatment frequently take some days, the reason why a longer period of time passes between the treatments.

4.2 Materials – Rasterstereography

As already mentioned, “radiographs are used as the standard-of-care for evaluation, but have negative long-term side effects “due to the exposure to radiation, the rasterstereography alternative is a safer option (Knott et al., 2010, p. 1). Park et al. (2016) reported that “serial evaluations by plain radiography during follow up are unadvisable given a proper alternative” (Park et al., 2016, p. 1969).

Knott et al. (2010) wrote that Formetric 4D “provides fast and radiation-free images of the spine position using surface topography”. In their study with adolescent scoliotics patients, 30 repeated measurements were taken over a period of 1-2 hours on a single day (Knott et al., 2010, p. 2). The study of Knot et al. (2010) stated “that repeated measurements using the Formetric 4D gave very reliable and reproducible measurements with standard deviations that are consistent” compared with the standard deviations found by standing radiographs (Knott et al., 2010, p. 2).

One open question is: was the number of repetitions in the data collection sufficient? In some studies, the authors repeated the Formetric 4D test three times. Melvin et al. (2010) examined the results of 51 healthy volunteers tested by three different persons using rasterstereography. The reliability revealed very good results both for intratester and intertester reliability. They concluded that the technique is well suited for analysis of the back in standing position. The body mass index has no influence on the reproducibility. Each investigator made a series of 3 tests per participant (Melvin et al., 2010). As the Formetric 4D test is easy to apply, it is suggested to perform three repetitive measurements of each participant in future studies. According to the literature, in most of the studies, the data collection was performed with 3 or 4 repetitions.

In this study, one repetition of the Formetric 4D test was done. This is also found in the literature. Schülein et al. (2013) concluded that the analysis of the rasterstereography results of the idiopathic scoliosis parameters of adolescents after a surgery by one tester or more was efficient and a **single investigational** exposure was appropriate. The interobserver and intraobserver reliability of rasterstereographic 3-dimensional spine surface analysis and the reconstruction of back parameters was investigated (Schülein et al., 2013).

There are other techniques to measure the trunk imbalance, as for example using the plumb line without the utilization of the Formetric 4D. In the study of Fortin et al. (2016), a physical therapist measured the trunk imbalance of the participants using the plumb line, showing an excellent level of test retest reliability. The horizontal deviation between the plumb line (placed at C7 spinous process) and a marked S1 spinous process was tested with the help of a stable ruler. The tests were repeated four times. The mean of 4 trials was utilized for the statistical analysis (Fortin et al., 2016). Like in the present study, the same investigator performed all the tests.

Zhang et al. (2015) proposed the axis-line-angle technique to collect the data of the trunk shift in the frontal plane using 69 radiological images, presenting moderately significant correlation. The authors concluded that “the development of a different way to measure trunk imbalance is needed” and the axis-line-angle technique demonstrated efficient results (Zhang et al., 2015, p. 2459).

According to Park et al. (2016), the strengths of DIERS Formetric 4D were short test time, low costs, and no placement of any marking component, which decreased tester examination errors (Park et al., 2016). The results of the parameters are immediately available, without the necessity to be later calculated by an investigator or therapist, thus decreasing the possibility of mistakes made.

Another reason to use the Formetric 4D as method of evaluation, according to Krautwurst et al. (2018), is the collection of data in the upright position, where the posture control is more involved compared to when patients are lying, with different requirements of the muscles and bones. In patients with low back pain, symptoms decrease in the supine position and increase in the standing position, the reason why "rasterstereography is more functional than MRI or CT" (Krautwurst et al., 2018, p. 6).

4.3 Results – trunk imbalance (mm)

Trunk imbalance is a parameter that has been evaluated in different studies. Its correction or improvement, showing a symmetrical posture, has been investigated. A fundamental purpose for scoliosis correction is to achieve coronal, sagittal, and regional balance (Zhao et al., 2011). Correcting some postural alterations in the frontal plane improves the trunk imbalance parameter (Park et al., 2016). Accurate measurement of the proportions of trunk imbalance in the frontal plane plays a key role in the process of understanding patients with trunk imbalance, as for example patients with adolescent idiopathic scoliosis (Zhang et al., 2015).

"Researchers should further explore the potential of treatment approaches to reduce progression of trunk imbalance" (Fortin et al., 2016, p. 691). The authors concluded, that the effect of manual correction of trunk imbalance on pain needs to be clarified in order to understand if trunk imbalance is or is not a compensatory mechanism associated with scoliosis.

In this study, data was collected from the trunk imbalance before and after the treatments of the four diaphragms of the transition areas according to Zink. The results of the TG were compared with the results of the CG that received a sham treatment. Analyses of the variance (ANOVA) of the trunk imbalance (mm) with repetition measurement were compared and grouping factor were done. For this goal, the average value of each group and the measurement with each other to identify, if there was a general significant change over time, a general significant difference between the groups, or an interaction effect.

1. Measurement*group: the interaction effect over time. If this value was significant, the results of the treatment group over time from T1 to T2, would be different from those of the control group. The value p: 0.456 demonstrated no difference in the

nature of the change over time between the two groups, there was no interaction between measurement and group. No differences between the two groups were found. The two groups did not differ in the values measured for the general level of trunk imbalance measured values over both measuring points. The alternative hypothesis was not confirmed (see p. 17).

2. Measurement (group): the time effect. The whole group was taken (n: 45) and it was verified, if it had changed over time. There was no significant change (p: 0.444).

The T-test showed no statistical difference (p: 0.970) for both groups. One treatment of the four functional transverse diaphragms according to Zink using osteopathic techniques in patients with back problems in the present study does not influence the trunk imbalance parameter.
Cho (2015) compared the results before and after the intervention on two groups: a group that received a running training (3x/week running in place during 6 weeks) and a control group. The training group presented a significant difference in the trunk imbalance, while the control group revealed no statistical changes (Cho, 2015). For further studies about Zink´s pattern and trunk imbalance, a longer intervention time is suggested in order to detect if there is a homogeneous correction or alteration in the posture of the subjects after the proposed intervention.

For example, in the study of Park et al. (2016) a difference of 1.85 mm in the trunk imbalance in the group that used general insoles was found. The mean value at the beginning of the study in the group that used the insoles was 6.62 mm and after an intervention period of 4 weeks with 3 hours/day it was 4.77 mm (Park et al., 2016).

The **relative change** of the trunk imbalance in mm for the TG was 1.04, around 4% change, and in the CG it was 1.018, around 2% change, between T1 and T2. The standard deviation of 1.57 (TG) or of 2.54 (CG) is high. This means that what happens over time, from T1 to T2, is very different among the subjects. There is a change, but the subject reacts differently in the CG after lying and in the TG after the treatment. There was no significant change (p-value) amongst TG and CG after one treatment of the four diaphragms.

Sometimes no statistical difference is found, because the subjects are not homogenous (gender, age, BMI, sport activities, profession...). Another reason might be that, the patients react differently, sometimes with a positive answer, sometimes with a negative, in other patients nothing happens. The great difference between the reactions of the subjects, i.e. an inhomogeneous effect, is demonstrated by the results of the standard deviation (high values).

In their retrospective study, Zhao et al. (2011) analyzed spine parameters, after a spinal fusion operation in idiopathic scoliosis adolescents over a period of at least 2 years. The preoperative values of the adolescent idiopathic scoliosis patients (n= 62) variable for C7- plumb line and the central sacral vertical line were 1.93 $\pm$ 14.39. Like in the present study, Zhao et al. (2011) reported a high standard deviation. Two weeks after the operation, the values were still high, 9.57$\pm$ 19.43 and two years postoperatively 4.63$\pm$10.35 (Zhao et al., 2011).

Bao et al. (2016) defined coronal balance distance as the horizontal distance between the C7 plumb line and the sacral vertical line. It was measured using Surgimap Software (Surgimap Spine Software, Version 2.0.6, New York). In their study, coronal balance distance <3 cm was defined as coronally balanced patients, Type A, and >3 cm coronally imbalanced patients, Type B patients (C7 plumb line shifted to the concave side of the curve) and Type C ptients (C7 plumb line shifted to the convex side of the curve). The values found for the coronal balance distance were: Type A patients 13.11 (7.94), Type B patients 50.45 (18.18) and Type C patients 45.21 (17.64). The coronally imbalanced patients Type B and C had a high value of standard deviation, but also a higher value of coronal balance distance. The standard deviation was around one third of the coronal balance distance value. In the Type A patients, the coronally balanced patients, the values were smaller, standard deviation was around half of the coronal balance distance value (Bao et al., 2016). In the present study, there were no coronally imbalanced patients as defined by Bao et al. (2016), but the values of the standard deviation in both groups were much higher than the mean value of the trunk imbalance.

Krautwurst et al. (2018) studied the lateral shift in disc prolapse diagnosed patients compared to a control group. Rasterstereography measured the lateral shift in 39 patients with lumbar disc prolapse and low back pain, and the results were compared with 36 healthy controls. The lateral shift had a mean value of 5.6 $\pm$ 6.0 mm in the patient group and 5.0 $\pm$ 7.6 mm in the control group. No significant difference (p= 0.693) was found. “The trunk of the participants with diagnosed disc herniation did not deviate laterally more than the healthy controls” (Krautwurst et al., 2018, p. 4). The standard deviation (patient group: 5.6 $\pm$ 6.0 mm, healthy control: 5.0 $\pm$ 7.6 mm) was in both groups smaller than in the presented study before (TG: 8.5 $\pm$ 15.3, CG: 2.5 $\pm$ 13.6) and in the second test (TG: 8.5 $\pm$ 13.7, CG: 5.7 $\pm$ 13.5).

In the study of Park et al. (2016), the subjects used a custom-made biomechanical foot orthosis for at least 3 hours/day. The measurements were performed before the use of the biomechanical foot orthosis and after 2 and 4 weeks of using the biomechanical foot orthosis. The trunk imbalance at the 2- and 4-week follow-ups and directly after the biomechanical foot orthosis fitting were significantly lower than at baseline ($p < 0.05$). The initial value of trunk imbalance (mm) with biomechanical foot orthosis was 6.62 (SD 4.49), after 2 weeks 5.92 (SD 3.97) and after 4 weeks 4.77 (SD 2.74) (Park et al., 2016). The difference of the trunk imbalance after 2 weeks and 4 weeks of using a biomechanical foot orthosis for at least 3 hours/day, compared with the value of the trunk imbalance at the beginning of the study, was not very expressive – 0.7 mm between initial values and after 2 weeks, and 1.15 mm, between after 2 weeks and after 4 weeks.

In the research of Park et al. (2016), the standard deviation was much lower, compared with the mean value of the trunk imbalance (Park et al., 2016). With high values of the standard deviation, a homogeneous reaction was not found in the present study; both groups (TG and CG) presented very different reactions among the participants.

There is a need for more studies about the trunk imbalance. Not only is there a discrepancy between the results of previous studies but also, among these studies. Fortin et al. (2016) wrote that the difference between their results and previous studies may be explained by the small sample size of their double curves group. This may have led to type 2 error, namely results demonstrating no relationship between the two variables, when in reality a relationship exists (Fortin et al., 2016).

No systematic difference or effect for the treatment group and the control group was found, a heterogeneous outcome. What happened over time is very individual and not uniform within the group.

The interesting data in the results of this study is the correlation between patients who have already undergone surgery and the alteration of the trunk imbalance in the treatment group. Those patients with a history of surgeries prior to data collection and treatment, were the ones who presented the greatest change in trunk imbalance after the osteopathic intervention. There is a **significant correlation** between operations and the change of the trunk imbalance for the treatment group (p: 0.007). A positive correlation (0.545): the higher the number of operations, the higher the value for the change.

The position of the respiratory diaphragm can be altered after a surgery, for example after laparoscopy, through the increase of the abdominal pressure (Buzkova, Muller, Rara, Roubik, & Tyll, 2018). This might be one of the reasons for the correlation found between operations and the alteration in the trunk imbalance after the intervention in the treatment group, repositioning the diaphragm in a more physiological position through the treatment. Another possibility is that "the diaphragm is abundantly innervated by the vagus nerve, and so the mechanical stimulation received by these patients could have activated vagal afferents, thus decreasing somatic perceptions of pain" (Martí-Salvador et al., 2018).

Fortin et al. (2016) excluded subjects who underwent spinal surgery or who had a leg length discrepancy greater than 1.5 cm, as these factors might modify the trunk imbalance and pain level (Fortin et al., 2016). In the present study, it was investigated, if there was an alteration in the trunk imbalance after the treatment of the four diaphragms. Fortin et al. (2016) investigated the trunk imbalance in adolescents with idiopathic scoliosis and the relationship with other factors, but did not treat the patients that participated in the study.

It is possible to compare the change in the trunk imbalance after other intervention methods that are more invasive, such as surgery, than the treatment of the four diaphragms. In the study of Zhu et al. (2011), there was a significant difference among the trunk shift before and after the surgery in adolescents with lumbar disc prolapse. The intervention was a posterior discectomy. The trunk shift was evaluated by radiographs. The mean trunk shift diminished from 3.7 cm (range 0.9 - 7.7 cm) to 1.2 cm (range 0.5 - 2.3 cm). In the 17 participants with a follow-up more than two years later," the coronal balance was well maintained with an average trunk shift of 0.9 (range 0.5 - 1.7)" (Zhu et al., 2011, p. 4)

In the study of März et al. (2016), rasterstereography images were used to investigate the relation between 10 different occlusal positions and the immediate alterations in the posture of the spine of the participants in the standing position. The trunk imbalance was one of the analyzed parameters in all of the 10 different occlusal positions. März et al. (2016) found a high standard deviation and no significant difference in the results of the trunk imbalance, as the present study. These results might reflect the individual neuromuscular compensation of the body (März et al., 2016).

Zhang et al. (2015) wrote that "trunk balance, including global and local balance, refers to the results of coordination of distinct parts (shoulder, spine, pelvis) of the body to achieve the balance". When a person is in upright position straight with the legs in total extension, the head should normally be centered over the pelvis when observed from the front (Zhang et al., 2015, p. 2459).

Changes in the coronal plane are important to analyze the trunk imbalance. In future studies, other parameters, such as the position of the pelvis and the leg- length, can be verified. Park et al. (2016), for example, wrote about the relation between the correction of the rear-foot through biomechanical foot orthosis and the importance of this to the lower extremity function and the coronal plane. The alignment of different body segments in the frontal plane is an important factor for the improvement of the trunk imbalance (Park et al., 2016). The alterations in the posture in the sagittal plane are also relevant.

“Sagittal balance is a state in which an individual is capable of keeping a stable standing position with minimal muscle expenditure” (Liang et al., 2016, p. 1) and in this plane compensations also can occur, as the decrease of the lumbar lordosis, as well as the alteration of the pelvis position and the thoracic back (Liang et al., 2016). Some posture alteration after the treatment might be found in the sagittal plane.

Fischer and Kim (2011) wrote that “preservation of global coronal and sagittal balance is the key to ensure good patient outcomes for all spinal deformity surgery, and coronal balance is at greater risk than sagittal balance in selective thoracic fusion” (Fischer & Kim, 2011, p. 1052). Zhang et al. (2015) concluded that precise measurement of trunk imbalance is greatly significant in treatment decision-making (Zhang et al., 2015).

In a retrospective study with prospectively collected outcome data, Daubs et al. (2013) evaluated 85 patients who presented a coronal imbalance (defined as >4 cm) after surgery to reconstruct the spine to determine the importance of coronal balance. Sixty-two participants had combined coronal (>4 cm) and sagittal imbalance (>5 cm), while 23 subjects had just coronal imbalance. “In patients with coronal imbalance alone improvement in coronal balance was not a factor for predicting improved functional outcomes” (Daubs et al., 2013, p. 142). For further studies, it is suggested to collect the results in both planes: sagittal and frontal. Functional parameters are probably more adequate to measure the alteration after an osteopathic treatment.

Liang et al. (2016) observed another interesting point:

> “In degenerative flat back, sagittal imbalance was more evident when walking, hitting its **dynamic** nature”. “All the patients have the typical symptoms of sagittal imbalance, however in the standing lateral radiographs C7PL sometimes fell behind the posterior superior corner of S1 showing no imbalance. This is because the radiographs only revealed the static status of the spine.“ (Liang et al., 2016, p. 7).

In the presented study, the outcomes also revealed the static status of the spine in the frontal plane. **Dynamic tests** may perhaps reveal more about the trunk imbalance. In their research Liang et al. (2016) performed the following procedure: the patients were asked to walk until they were no longer able to stand erect and precisely at that moment, the radiographs were taken. Those participants only walked a few steps. To some extent, the radiologic images could demonstrate the dynamic characteristics of sagittal imbalance (Liang et al., 2016). For further studies in the area of the four diaphragms and the trunk imbalance, a test similar to the one described by Liang et al. (2016) using the Formetric 4D is suggested. It is possible that the static test of the trunk imbalance could not show the dynamic features of the coronal imbalance or its change (Liang et al., 2016).

It is important to do a complete examination of the patient. As Lazennec et al. (2011) concluded:

> "A comprehensive assessment of each patient and in particular of the complex comprising the spine and the pelvis, is essential for understanding each individual´s adaptation to the imbalance induced by disorders of the spine or lower limbs. Monitoring the course of these patients and planning treatment strategies, surgical or not, can thus be rationalized and optimized." (Lazennec et al., 2011, p. 691).

In osteopathy, the patient is treated as a whole and not only the site of pain. The mechanisms of the body to compensate are many, individual and not only restricted to the back.

A few questions arise: How do subjects without low back pain react to an osteopathic treatment of the four diaphragms? Would they adapt more quickly in the standing position? Would it have been possible even with just a single treatment of these regions to identify changes in the trunk imbalance? These are some of the questions that remain open after this study.

As Bordoni and Marelli (2015) wrote, "working on these interconnected parts of the body in terms of fascial and neurological links, it is possible hypothetically to create an improvement in the patient´s symptoms, due to the improvements of the fascial system" (Bordoni & Marelli, 2015, p. 496) with a longer intervention.

Finally, some considerations about the present study: there are some limitations that require attention. In summary:

1. Sample size was relatively small.
2. Qualitative and quantitative evaluation of pain could have been helpful to analyze the results.
3. Time of intervention was short.
4. Static evaluation with the Formetric 4D: a dynamic evaluation is suggested for further studies.
5. Only one spinal parameter was evaluated, with so many possibilities of compensation in the body.

6. No follow-up was done.

As positive consideration, the material used in this study, the Formetric 4D, has proven in other studies to be useful for the assessment of the trunk imbalance. This was the first study about the relationship between the trunk imbalance and the treatment of the four diaphragms in patients with back pain. The study and the treatment of the four diaphragms involve a global understanding of the compensation mechanisms of the body. This understanding is a part of osteopathy and its development, with the objective to support patients with back pain.

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TABLES

FIGURES

ABBREVIATIONS

TG: treatment group

CG: control group

CCP: common compensatory pattern

CP: compensated pattern

UP: uncompensated pattern

ATTACHMENTS

ATTACHMENT A: information´s email for the patients

INFORMATION´S EMAIL FOR THE PATIENTS: german version

Haben Sie Problem mit ihrem Rücken?

Wir suchen Teilnehmerinnen für eine osteopathische Studie.
Drei OsteopathInnen führen im Juni 2017 in Leibnitz, eine Behandlungsstudie durch. Die kostenlosen Behandlungen werden im Forum Energetix Gesundheits- und Lebensenergiezentrum GmbH im Basta Center (Leopol-Figlstraße 1), 8430 Leinbnitz durgeführt. Sollten sie zeitweise Probleme mit ihrem Rücken und Interesse an einer kostenlosen Behandlung haben, dann melden sie sich als TeilnehmerIn an. Die Teilnahme an der Studie wird ungefähr eine Stunde und 15 Minuten in Anspruch nehmen, dazu zählt die Vermessung der Wirbelsäule vor und nach der Behandlung, die Untersuchung durch zwei Osteopathinnen und die Behandlung selbts.
Die Plätze sind begrenzt.
Für genaure Informationen und Anmeldung erreichen sie uns unter 03452 22 50237.
MSc. Marcia Lima Plank, PT Michael Hansmann, Bakk. PT Andrea Arztmann

Name	Geburtsdatum	Telefonnummer

INFORMATION´S EMAIL FOR THE PATIENTS: english version

Do you have problems with your back?

We are looking for participants for an osteopathic study. Three osteopaths will conduct a clinical research in June 2017 in Leibnitz. The gratuitous treatments will be conducted at the Forum Energetix Gesundheits- und Lebensenergizentrum GmbH in Basta Center (Leopold-Figlstraße 1), 8430 Leibnitz.

If you have problems in your back and are interested in the gratuitous treatment, then apply as a participant. The participation in this research will take approximately one hour and fifteen minutes. This includes the measurement of the spine before and after the treatment, the examination by two osteopaths and the treatment itself.

The places are limited.

For more information and registration, you can reach us by telephone: 03452 2250237

MSc.PT Marcia Lima Plank, PT Michael Hansmann, Bakk.PT Andrea Arztmann

Name	Date of birth	Telephone number

ATTACHMENT B: TERM OF CONSENT SHEET

TERM OF CONSENT: german version

Ich freue mich sehr über Ihre Teilnahme. Herzlichen Dank!

Damit wir die Daten gut auswerten können, brauchen wir noch einige Informationen über Sie:

Name:

Geburtsdatum:

Beruf:

Gewicht:

Körpergröße:

Information zum Ablauf:

1. Füllen Sie nach bestem Gewissen diesen Fragebogen aus. Alle Informationen werden anonym und streng vertraulich behandelt.
2. Sie werden von unserem Mitarbeiter aufgerufen, um die Erstmessung durchzuführen.
   Hierfür bitten wir sie Schmuck und Uhren zu abzulegen. Lange Haare bitte hochstecken.
3. Im Behandlungsraum werden Sie anschließend von zwei Osteopathinnen untersucht.
   Eine der beiden wird Sie danach für ca. 30 Minuten behandeln.
4. Nach der Behandlung nehmen Sie bitte im Warteraum Platz. In Kürze werden Sie aufgerufen um die Zweitmessung durchzuführen.

Generell sind durch eine osteopathische Behandlung kaum oder wenn dann nur geringe Nebenwirkungen zu erwarten. Sollten jedoch während der Behandlung Symptome egal welcher Art auftreten, bitten wir sie diese der Behandlerin sofort mitzuteilen. Sie wird die Intensität der Behandlung anpassen oder gegeben falls ganz abbrechen. Die Teilnahme an der Studie ist freiwillig. Sie können ihre Teilnahme jederzeit ohne Angabe von Gründen beenden.

Durch die Behandlung kann es kurzfristig zu einer Symptomverschlimmerung kommen. Dies stellt eine normale Reaktion auf manuelle Behandlung dar. In diese Gruppe der Behandlungsreaktionen sind auch vorübergehende Beschwerden wie Müdigkeit, Schwindel, Kopfschmerz, Fieber, Veränderung der Körperausscheidungen und/oder des Mensturations-Zyklus oder Schlafstörungen einzuordnen.

Einverständniserklärung

Ich habe alle Informationen über meinen Gesundheitszustand selbstständig ausgefüllt und bin damit einverstanden, dass diese Daten anonymisiert verwendet werden. Ich möchte an der

Studie teilnehmen, bin über alle etwaigen Nebenwirkungen einer osteopathischen Behandlung aufgeklärt worden und habe keine weiteren Fragen.

TERM OF CONSENT: english version

I am very pleased about your participation. Thank you very much!

To be able to evaluate the data, we need some information about you:

Name:

Date of birth:

Profession:

Weight:

Height:

Information about the procedure:

1. Fill in this questionnaire as precisely as possible. All information will be treated anonymously and confidentially.
2. Our assistant will call you to execute the first measurement. We ask you to store your watch and jewelry in a safe place. Please, pin up long hair.
3. In the treatment room two osteopaths will examine you. Afterwards one of them will treat you for about 30 minutes.
4. Please take a seat in the waiting room after the treatment. Our assistant will call you to perform the second measurement.

In general, osteopathic treatment has no or only minor side effects are to be expected. If any kind of symptoms appear during the treatment, we ask you to inform the osteopath immediately. The osteopath will adjust the intensity of the treatment or, if necessary, cancel it completely. The participation in the study is voluntarily. You can stop your participation at any time without giving reasons.

The treatment can cause a short-term worsening of the symptoms. This can be a normal reaction to manual treatment. Among the reactions to the treatment are also temporary complaints like fatigue, dizziness, headache, fever, change of body exudates and/or of menstrual cycle or sleep disorders.

Term of consent

I filled in all the information about my health and I agree that my data will be used anonymously. I would like to participate in the study, have been informed about any side effects of osteopathic treatment and have no further questions.

ATTACHMENT C: questionnaire sheet

QUESTIONNAIRE: german version:

- Haben Sie Beschwerden im Rückenbereich? ☐ nein, keine Beschwerden
- Nackenbereich, Oberer Rücken:
- ☐ Links ☐ Mitte ☐ Rechts
- ☐ weniger als 6 Wochen ☐ seit 6 - 12 Wochen ☐ seit über 12 Wochen
- Mittlerer Rücken:
- ☐ Links ☐ Mitte ☐ Rechts
- ☐ weniger als 6 Wochen ☐ seit 6 - 12 Wochen ☐ seit über 12 Wochen
- Unterer Rücken:
- ☐ Links ☐ Mitte ☐ Rechts
- ☐ weniger als 6 Wochen ☐ seit 6 - 12 Wochen ☐ seit über 12 Wochen
- Wie würden Sie Ihren derzeitigen Gesundheitszustand beschreiben?

sehr schlecht Ihr subjektiver Gesundheitszustand sehr gut

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

gering Ihr durchschnittliches Stress-Level hoch

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

gering Ihr durchschnittliches Energie-Level hoch

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Bitte füllen sie kurz die folgenden Fragen zu ihrer Vorgeschichte aus:

- Vorbefunde inkl. vorherige Therapien:

  ____Keine ☐

- Weitere Erkrankungen: (Lunge, Herz, Magen, Nieren, Blase, Geschlechtsorgane, Hals-Nasen Ohren, Augen, Kopfschmerzen, Schwindel)

  ____Keine ☐

- Frühere Erkrankungen:

  ____Keine ☐

- Operationen:

  ____Keine ☐

- Unfälle, Verletzungen:

  ____Keine ☐

- Medikamente:

  ____Keine ☐

- Sport, wenn ja wie viele Stunden pro Woche?

  ____Keine ☐

- Nikotin, wenn ja wieviel Zigaretten pro Tag?

  ____Keine ☐

- Alkohol, wenn ja wie häufig die Woche?

  ____Keine ☐

- Verdauung (Unverträglichkeiten, Allergien, Verstopfung, Durchfall)

  ____

- Schlaf (Einschlafschwierigkeiten, Durchschlafschwierigkeiten)

  ____

Bitte kreuzen sie an ob diese Symptome bei Ihnen im Moment bestehen:

Blutdruck über 190/110 mit Symptomatik (Kopfschmerzen, Sehstörungen, Lähmungserscheinungen, Sprachstörungen…)

☐ Ja ☐ Nein

Starke Bauchschmerzen mit Abwehrspannung, Übelkeit, Erbrechen

☐ Ja ☐ Nein

Plötzliches, unklares heftiges Erbrechen und/oder Durchfall

☐ Ja ☐ Nein

Kollaps Neigung > niederer Blutdruck, Schwindel, starkes Schwitzen, Übelkeit

☐ Ja ☐ Nein

Belastungsabhängige Schmerzen im Brustkorb ohne vorhergehende vollständige Abklärung

☐ Ja ☐ Nein

Unbehandelte Herzinsuffizienz II-IV

☐ Ja ☐ Nein

Unbehandelte Herz-Rhythmusstörungen

☐ Ja ☐ Nein

Unklare akute Atemnot

☐ Ja ☐ Nein

Stark erhöhte Körpertemperatur und starker körperlicher Beeinträchtigung?

☐ Ja ☐ Nein

Verdacht auf akute Gefäßverschlüsse (unklare Schwellungen, Ödeme, Druckschmerz)

☐ Ja ☐ Nein

Deutliche Blässe einer Extremität

☐ Ja ☐ Nein

Operation in den letzten sechs Wochen

☐ Ja ☐ Nein

Skoliose (Cobbwinkel >20°)

☐ Ja ☐ Nein

Beinlängendifferenz > 12mm

☐ Ja ☐ Nein

Sind sie schwanger?

☐ Ja

QUESTIONNAIRE: english version

- Do you have complaints in the back? ☐ no, no complaints
- Cervical area, upper back:
- ☐ Left ☐ Center ☐ Right
- ☐ less than 6 weeks ☐ for 6 -12 weeks ☐ for over 12 weeks
- Middle back:
- ☐ Left ☐ Center ☐ Right
- ☐ less than 6 weeks ☐ for 6 -12 weeks ☐ for over 12 weeks
- Lower back:
- ☐ Left ☐ Center ☐ Right
- ☐ less than 6 weeks ☐ for 6 -12 weeks ☐ for over 12 weeks
- How would you describe your current health condition?

  very bad your subjective health condition very good

  ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

  low your subjective stress level high

  ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

  low your subjective energy level high

  ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Please fill in the following questions on your previous history:

- Previous findings including previous therapies:

  ____None ☐

- Other diseases (lungs, hear, stomach, kidneys, bladder, genital organs, neck, nose, throat, ears, eyes, headache, dizziness)

  ____None ☐

- Previous diseases:

  ____None ☐

- Operations:

  ____None ☐

- Accidents, injuries:

  ____None ☐

- Medicaments:

  ____None ☐

- Sport, if yes, how many hours per week?

  ____None ☐

- Nicotine, if yes, how many cigarettes per day?

  ____None ☐

- Alcohol, if yes, how often in the week?

  ____None ☐

- Digestion (intolerances, allergies, constipation, diarrhea)

  ____

- Sleep (sleep difficulties, insomnia)

  ____

Please tick, if you have these symptoms at the moment:

Blood pressure over 190/110 with symptomatology (Headache, visual disturbances, paralysis, speech disorders…) ☐ Yes ☐ Not

Severe abdominal pain with defensive tension, nausea, vomiting ☐ Yes ☐ Not

Sudden unclear violent vomiting and/or diarrhea ☐ Yes ☐ Not

Collapse, low blood pressure, dizziness, heavy sweating, nausea ☐ Yes ☐ Not

Stress-related pain in the chest without prior complete clarification ☐ Yes ☐ Not

Untreated heart failure II-IV ☐ Yes ☐ Not

Untreated cardiac arrhythmias ☐ Yes ☐ Not

Unclear acute respiratory distress ☐ Yes ☐ Not

Strongly increased body temperature and severe physical disturbance ☐ Yes ☐ Not

Suspected acute vascular occlusions (unclear swelling, edema, pressure pain) ☐ Yes ☐ Not

Distinct pallor of a limb ☐ Yes ☐ Not

Operation in the last six weeks ☐ Yes ☐ Not

Scoliosis (Cobb angle >20°) ☐ Yes ☐ Not

Leg length difference > 12 mm ☐ Yes ☐ Not

Are you pregnant? ☐ Yes

ATTACHMENT D: documentation´s sheet of the treatment

DOCUMENTATION´S SHEET: german version

Name: Datum:

Zink Pattern:

☐ Links	Kopf	Rechts ☐
☐ Links	Schultergürtel	Rechts ☐
☐ Links	Diaphragma	Rechts ☐
☐ Links	Becken	Rechts ☐

Dokumentation der Behandlung:

DOCUMENTATION´S SHEET: english version

Name: Date:

Zink Pattern:

☐ Left	Head	Right ☐
☐ Left	Shoulder girdle	Right ☐
☐ Left	Diaphragm	Right ☐
☐ Left	Pelvis	Right ☐

Documentation of the treatment:

ATTACHMENT E: data CD-ROM

The following contents were outsourced to a CD ROM

. Appendix 1: patient documentation

. Appendix 2: data trunk imbalance

. Appendix 3: statistical analyses: descriptive statistic, trunk imbalance and correlations