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# The Effects of a 4-Week Treadmill Desk Intervention on Motor Control, Tissue Stiffness, Physical Activity and Subjective Health in Office Workers with Non-Specific Lower Back Pain - A Pilot Study

## Master Thesis

M.Sc. Health Science - Prevention and Health Promotion

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# List of Content

LIST OF FIGURES ........................................ 5

LIST OF TABLES ........................................ 6

LIST OF ABBREVIATIONS ........................................ 7

ABSTRACT ........................................ 6

1 INTRODUCTION ........................................ 7

2 BACKGROUND AND STATE OF RESEARCH ........................................ 8

3 RESEARCH QUESTION AND OBJECTIVES ........................................ 12

4 METHODS ........................................ 13

4.1 Sample ........................................ 13

4.2 Measuring instruments and material ........................................ 14

4.3 Study design ........................................ 20

4.4 Intervention ........................................ 21

4.5 Measurement procedure ........................................ 21

4.6 Data processing and statistics ........................................ 23

5 RESULTS ........................................ 24

6 DISCUSSION ........................................ 28

7 CONCLUSION AND OUTLOOK ........................................ 35

BIBLIOGRAPHY ........................................ 36

ACKNOWLEDGMENT ........................................ 45

DECLARATION ON HONOR ........................................ 45

# List of Figures

Figure 1. MCTB – Waiters bow 15
Figure 2. MCTB – Pelvis tilt 15
Figure 3. MCTB – One leg stance 15
Figure 4. MCTB – Sitting knee extension 16
Figure 5. MCTB – Forward Rocking four point kneeling 16
Figure 6. MCTB – Back Rocking four point kneeling 16
Figure 7. MCTB – Prone knee bend 16
Figure 8. Measurement of the tissue stiffness 17
Figure 9. Study design flow chart 20
Figure 10. Treadmill desk by Walkolution 21
Figure 11. Distribution of outcome parameter from pre- to post-measurement in (A) ODI Score, (B) MCTB, (C) Steps per workday and (D) Tissue Stiffness 27
Figure 12. Methodological recommendations 34

# List of Tables

Table 1. Sample anthropometric characteristics ........................................................................................ 13
Table 2: Outcome parameters from pre to post measurement .................................................................. 26

# List of Abbreviations

| | |
|---|---|
| CPM | Counts per minute |
| ICC | Intraclass correlation |
| LB | Low back |
| LBP | Lower back pain |
| LFE | Low Frequency Extension |
| MC | Movement Control |
| MCTB | Movement Control Test Battery |
| MD | Mean absolute difference |
| MET | Metabolic equivalent of task |
| MVPA | Moderate-to-vigorous intensity physical activity |
| NSLBP | Non-specific lower back pain |
| ODI | Oswestry Disability Index |
| PA | Physical activity |
| PSQ | Perceived Stress Questionnaire |
| RCT | Randomized controlled trial |
| SD | Standard deviation |
| TLF | Thoracolumbar fascia |
| VM | Vector Magnitude |
| WHOQOL | WHO Quality of Life Questionnaire |

# Abstract

### Introduction

Prolonged sitting leads to musculoskeletal disorders in muscles, tendons, nerves and other soft tissues, such as the thoracolumbar fascia, causing non-specific low back pain (NSLBP). It leads to inactivity, a loss in motor control and reduced quality of life. Back pain is seen as a global pandemic causing great economic damage due to incapacity to work or productivity loss. While the effectiveness of commonly used standing desks is increasingly being questioned, active workstations such as treadmill desks are gaining popularity. Therefore, this pilot study investigated the effects of a treadmill desk intervention on motor control, tissue stiffness, physical activity (PA) and subjective health in office workers with NSLBP.

### Methods

Six subjects were given a treadmill desk to replace their usual sedentary work for 4 weeks. Subjective health was evaluated using the Oswestry Disability Index (ODI), Perceived Stress Questionnaire (PSQ) and the WHO Quality of Life Questionnaire (WHOQOL). The Movement Control Test Battery (MCTB) provided a measure of motor control in the lumbar spine. Tissue stiffness of the thoracolumbar fascia was assessed with a tissue compliance meter. Those outcome parameters were collected at baseline and after the 4-weeks intervention. PA patterns were recorded over four working days before and during the intervention using an ActiGraph accelerometer.

### Results

Subjective health improved with a decrease in the ODI (64.0%) and PSQ score (9.1%) along with an increase in physical health-related quality of life (8.5%). The average number of sedentary bouts while working decreased by 42.7% and the time spent sitting decreased during the intervention by 30.8%. The number of steps taken during a working day increased by 18.7%. The tissue stiffness of the TLF relatively decreased by 5.8% (left) and 5.6% (right) from pre to post measurement. All subjects showed better motor control after the intervention (median; pre: 2.5 vs. post: 0.5).

### Conclusion

The results may contribute to the body of knowledge on the practical use of treadmill desks in back pain patients. In order to support these findings, further RCTs with a specific research focus should be conducted. The study indicates the value of a treadmill desk as both a rehabilitative and preventive tool in the office setting.

# 1 Introduction

The change from predominantly physical labour into increasingly desk-based jobs over the last 150 years has given rise to a largely sedentary population, especially across developed countries. Self-report data show that the average European adult spends five hours sitting per weekday (Bennie et al., 2013), while objective data indicate way higher numbers with over ten hours sitting on weekdays in the UK (Smith et al., 2015). No wonder that nowadays one can find pictures of a person hunched over in front of a computer at the end of the evolution of man. The threats of prolonged sitting were first highlighted in the 1950s when J. Morris et al. identified a twofold increase in the risk of a myocardial infarction in London bus drivers compared with active bus conductors (Morris, Heady, Raffle, Roberts, & Parks, 1953). In the following 60 years research has focused on studying the relationship between moderate-to-vigorous intensity physical activity (MVPA) and health, while the potentially important association between sedentary behaviour and well-being remained unidentified. With his provocative statement, "Sitting is the new smoking," Dr. James Levine, a professor of medicine at the Mayo Clinic, finally raised higher awareness of this modern sitting disease in the general population. Sedentariness, defined as any waking behaviour characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture, has long been overlooked as an independent risk factor for chronic diseases (Sedentary Behaviour Research Network, 2012). By now, the prevailing view in medical and scientific research has changed drastically. Studies show that sedentary time is associated with an increased risk of diabetes, cardiovascular disease, cancer, dementia and even all-cause mortality (Proper, Singh, Van Mechelen, & Chinapaw, 2011; Wilmot et al., 2012). Despite the emergence of official clinical guidelines to reduce sitting time, the sedentary lifestyle is still pervasive (Gardner, Smith, Lorencatto, Hamer, & Biddle, 2016). The omnipresent convenience of the civilized world, with escalators, elevators and cars, makes it difficult to break habits. Likewise, the social and professional context leaves little room for people to be more physically active. Students and office workers tend to sit on the way to the office, while studying or working, during lunch and even in the evening in front of the TV in order to rest after a hard day. This sedentary lifestyle not seldom ends in a vicious circle of even moving less due to occurring health issues and people not seldom pay an all too high price for that.

# 2 Background and state of research

Besides an increased risk of diabetes, cancer and cardiovascular diseases, sedentariness also carries the risk of suffering from musculoskeletal disorders. The most common consequence in society is back pain, which is nowadays often seen as a global crisis. Back pain comes in all sorts of severity and variation, ranging from mild discomfort to complete immobility. According to the Global Spine Care Initiative, back pain is the main cause of disability in most countries with over 500 million people affected in all age groups worldwide (Hurwitz, Randhawa, Yu, Côté, & Haldeman, 2018). With the rise of inactivity in the older population, an ominous trend is emerging considering the demographic change in most developed countries. While in most cases symptoms resolve within six to eight weeks, up to a quarter of cases lead to chronic conditions. These can have an immense effect on a person's daily life, as well as social and mental well-being (Söhngen, 2018).

According to Andersson (1999), chronic back pain also brings negative economic consequences, as only about half of those suffering from chronic back pain for more than six months return to work. A study showed that around 33 million Americans were absent from workplace in 2005, due to suffering from back and neck ailments (Martin et al., 2008). In 2008, Germany incurred healthcare costs of 3.6 billion euros due to non-specific back pain. The main reason for this was also incapacity to work, which accounted for 135.000 lost working years (Raspe, 2012). But beyond the sheer absence from the workplace, the loss of productivity also contributes to economic losses. A systematic review assessed the direct and indirect costs of back pain in Japan, Sweden, Belgium, Australia, the Netherlands, Korea and the United Kingdom between 1997 and 2007. Accordingly, indirect costs, resulting from lost work productivity represented the majority of overall costs associated with lower back pain (LBP) representing a substantial burden on society (Dagenais, Caro, & Haldeman, 2008). On average, an employee suffering from chronic back pain loses 5.2 hours of productive work time per week (Stewart, Ricci, Chee, Morganstein, & Lipton, 2003). In Brazil, the societal costs between 2012 and 2016 amounted to 2.2 billion US$, while productivity losses represented 79% of these costs (Carregaro et al., 2020).

It is not surprising that professions that require a high amount of sedentary time, such as long-distance drivers and office workers, are at the greatest risk of developing chronic back pain. One study showed that out of 384 full-time bus drivers, over 45% suffered from lower back pain within the past twelve months (Alperovitch-Najenson et al., 2010). Celik et al. (2018) found that out of a cohort of 528 office workers, more than half complained of neck or back pain (52.5% and 53% respectively) within the past year. The critical factors for developing such a medical condition lies in long-lasting loads on the musculoskeletal system. Work-related musculoskeletal disorders arise in muscles, tendons, nerves and other soft tissues from damage-causing enforced repeated actions or holding the body in an improper position (Celik et al., 2018). This includes prolonged sitting and standing, heavy lifting, working overhead, or incorrect upper body and head posture, due to an improperly positioned desk or computer desktop.

Sedentariness weakens the active musculoskeletal system in the long term, leads to muscular imbalances and inhibits primal movement patterns. Active structures such as the core muscles, the gluteal muscles and parts of the hip muscles are particularly affected. This in turn negatively influences passive structures like the spine or the pelvis (Amell & Kumar, 2001; Söhngen, 2018). The term "slouching" relates to the relative position, whereby the head and upper trunk is in a forwards-flexed position, which is also known as postural kyphosis (Hansraj, 2014). This posture deactivates the core muscles, which completely offload the function of upright posture onto the spine (Roussouly & Pinheiro-Franco, 2011). During sitting also, the gluteal muscles are innervated only marginally, which leads to smaller muscle groups trying to keep the hips stable. In the long run, the muscles can get tense, which results in lower back and hip pain (Söhngen, 2018). In addition, the inactivity of the gluteal muscles alters the angle of the pelvis and the hips, which are, together with the spine, originally responsible for a stable upright body posture. This dislocation and the inactivation of the core muscles forces the spine out of its natural s-shape into a hyper kyphosis and a decreased lumbar lordosis. It creates enormous compression and shear forces on critical joints of the cervical and lumbar spine, which in the long run can lead to disc herniations and chronic back pain (Hansraj, 2014).

Another tissue structure that can influence the functioning of the musculoskeletal system is the fascial system. Fascia is a soft collagenous tissue, that pervades the whole body. It is characterized by its three-dimensional, functional structure, which supports the interaction of body systems (Adstrum, Hedley, Schleip, Stecco, & Yucesoy, 2017). Due to the proprioceptive and nociceptive functions of fascial tissue, it might also be a contributing factor to back pain. The thoracolumbar fascia (TLF) is a diamond-shaped area of connective tissue, that covers the thoracic and lumbar parts of the deep fascia enclosing the intrinsic back muscles. In 2017 a study proposed the TLF to represent a possible source of idiopathic low back pain (Wilke, Schleip, Klingler, & Stecco, 2017). Reasons for this may include microinjuries or inflammation of the lumbar fascia, resulting in an irritation of nociceptive nerve endings. Immobility or chronic overloading may also induce a sensitization of fascial nociceptors, which can cause LBP.

The influence on the musculoskeletal system described above and the resulting pain often leads patients to subconsciously adapt their movement patterns and posture. Such relieving posture is accompanied by a loss of movement control (MC) in the lower back (O'Sullivan, 2005). Luomajoki et al (2008) observed a significant difference in lower back movement control among patients with acute or chronic LBP compared to healthy subjects. The study indicates that impaired MC and maladaptive movement patterns perpetuate LBP. Movement control tests are therefore used by many therapists and physicians for diagnosis and risk assessment for chronic LBP.

Sitting for long periods of time and the accompanying lack of physical activity often results in excessive bodyweight, which in turn has a negative impact on one's physical health. Looking only at the orthopedic point of view, overweight increases the pressure on the joints and the spine. Through constant pressure, the degeneration of connective tissue, spinal discs and bones often sets in, resulting in the risk of joint pain, back pain and sciatic nerve irritation. It was shown that bone mineral density in the total body, hip and lumbar spine, is weakly to moderately correlated to body weight, fat mass, and lean body mass (Wardlaw, 1996). A systematic review on twin studies suggest that genetics and early environment are possible mechanisms, underlying the relationship between obesity and LBP. However, there seems to be different findings about a direct causal link between these conditions (Dario et al., 2015; Ferreira, Beckenkamp, Maher, Hopper, & Ferreira, 2013).

People who suffer from chronic pain often engage in less physical activity than those who are pain-free. But it is this inactivity that can exacerbate chronic pain or even cause it in the first place. This relationship was first described around 1984 as the disuse or inactivity syndrome (Bortz, 1984). The disuse syndrome refers to the effects of lack of movement on a physical and mental level and is especially often discussed in connection with back pain. It is characterized by a vicious circle of physical inactivity and chronic pain, which affects not only the physical, but also psychosocial and mental health, as well as overall quality of life. The persistent pain complicates social and professional interaction, which can lead to social isolation and a deterioration of self-image and self-esteem. With the inability to perform everyday tasks, such as cooking, cleaning and personal hygiene, the patient’s quality of life also decreases. Studies show that chronic back pain, especially NSLBP is associated with significant reduced quality of life and depression (Husky, Ferdous Farin, Compagnone, Fermanian, & Kovess-Masfety, 2018; Montazeri & Mousavi, 2010; Stubbs et al., 2018).

The accompanying consequences of a sedentary lifestyle clearly point to the need for preventive strategies for such complaints. According to Celik et al. (2018), it is very important that, in order for office workers not to suffer musculoskeletal pain, the working environment should be ergonomically arranged and various measures should be taken to ensure healthy life behavior. One of these measures was the introduction of height-adjustable desks in offices all over the world. Compared to other wellness benefits, providing employees with a standing desk, had the greatest increase over the past five years. While in 2017 about 44% of employees were provided with a standing desk, in 2013 it were just 13% (Society for Human Resource Manage, 2017). Nevertheless, the effectiveness of standing desks has been increasingly questioned in the recent years. Standing, like sitting, is a very static posture and thus has little impact on energy expenditure (Mantzari et al., 2019). A systematic review, assessing the differences of energy expenditure while sitting versus standing, found only a mean difference of 0.15kcal/min (Saeidifard et al., 2018). Thus, standing desks do not provide a metabolic advantage over sitting and cannot compensate for the adverse effects of inactivity. For this reason, a standing desk seems questionable as a measure against overweight and inactivity at the workplace.

Since many people are not used to standing for long periods of time, they adopt into a slouch posture similar to sitting. In addition, the body weight is often not evenly distributed on both legs and shifted from one side to the other. Due to weak core muscles and gluteal muscles, the hip and pelvis cannot be stabilized, often leading to hyper lordosis in the lower back. This is also confirmed by a study in which most participants complained of muscle fatigue, lower limb swelling and mental state deterioration after only 2 hours of standing work (Baker et al., 2018). Standing posture also showed no significantly less perceived LBP compared to a seated posture (De Carvalho, Greene, Swab, & Godwin, 2020).

The associated discomfort of long standing often causes individuals to stop using standing desks on a regular basis. According to a German study, 16% out of 680 interviewed employees had access to such a desk, but only 50% of these individuals used it while working (Wallmann-Sperlich, Bipp, Bucksch, & Froboese, 2017). In the search for more alternatives to improve ergonomics and activity in the workplace, treadmill desks have become established. Compared to standing desks, these make use of the natural movement of walking. According to a systematic review, treadmill desks have a better effect on physical health and PA levels compared to height-adjustable desks (Torbeyns, Bailey, Bos, & Meeusen, 2014). However, the effect of such active workstations on LBP and overall quality of life needs further investigation before conclusions can be drawn.

# 3 Research question and objectives

Therefore, the research question of this pilot study was

"…what effects do a four-week treadmill desk intervention have on motor control, tissue stiffness, physical activity and subjective health in office workers with non-specific lower back pain. "

The objective was to find out whether the use of a treadmill desk can improve the perception of pain, the restriction caused by LBP and thus the overall quality of life of the subjects. Furthermore, it was to be examined whether the movement behavior at the workplace changes, in order to show a preventive measure against back pain in the office setting. A secondary goal of the study was to establish the basis for further research on the topic and to evaluate the feasibility of a large-scale controlled intervention study on this matter.

# 4 Methods

## 4.1 Sample

Adult male office workers with a predominantly sedentary job of at least six hours sitting per day in an age range from 25 to 50 years were included. Additionally, they had to suffer from nonspecific back pain. Subjects were excluded, if they had any history of an injury or orthopedic surgery on the spine. Subjects suffering from muscular dysfunctions or having a BMI above 30, were also excluded from the sample due to precautionary measures. To avoid the influence of menstruation-related LBP, female subjects were not considered in the study. For the acquisition of subjects, a study advertisement was published at the Faculty of Physics of the Technical University of Munich and at the Technology and Founders Center in Garching Munich. Subjects were informed about the study procedures and screened for exclusion criteria in a telephone appointment. Suitable subjects then received an information leaflet with further details about the study.

In total, 6 male subjects between 26 and 47 years (mean ± SD; age, 36.17 ± 7.44 years; weight, 75.67 ± 11.36 kg; height, 1.79 ± 0.07 m; BMI, 23.64 ± 2.25; sitting hours per day, 7.5 ± 1.0 h) were included in this study. Remarkably, the sitting times of S02 and S03 were more than 10 hours per day. See **Table 1** for individual data.

Table 1. Sample anthropometric characteristics

| Subject | Age [years] | Weight [kg] | Height [m] | BMI [kg/m$^2$] | Sitting/day [hours] |
|---|---|---|---|---|---|
| S01 | 47 | 67 | 1.70 | 23.18 | 7 |
| S02 | 36 | 93 | 1.84 | 27.47 | >10 |
| S03 | 40 | 76 | 1.78 | 23.99 | >10 |
| S04 | 30 | 78 | 1.87 | 22.31 | 7 |
| S05 | 26 | 60 | 1.70 | 20.76 | 9 |
| S06 | 38 | 80 | 1.82 | 24.15 | 7 |
| **Mean ± SD** | 36.17 ± 7.44 | 75.67 ± 11.36 | 1.79 ± 0.07 | 23.64 ± 2.25 | 7.50 ± 1.00 |

Abbreviations: BMI, Body Mass Index; SD, standard deviation

## 4.2 Measuring instruments and material

During data collection, measuring devices and materials were used for the following parameters.

<u>Motor Control</u>

To assess the motor control of the lumbar spine the MCTB described by Luomajoki et al. was used (Luomajoki, 2012; Luomajoki, Kool, De Bruin, & Airaksinen, 2007, 2008). It consists of six directional movement tests designed for screening movement control dysfunctions in the lumbar spine. The first test was the waiters bow with a 50°-70° flexion of the hips in upright standing position, without a movement (flexion) of the low back. Secondly, the participant had to perform an active dorsal tilt of the pelvis in upright standing. In the third test, the lateral movement of the belly bottom from normal standing to a one leg stance was measured on both sides. For the sitting knee extension, the subject was sitting upright with a corrected lumbar lordosis and asked to extend the knee without a movement in the LB. In the rocking four-point kneeling, the subject was in a quadruped position and had to transfer the pelvis backwards and forwards (rocking) without any extension movement in the LB. The last test was the prone knee bend, with a maximum flexion of the knee without an extension movement of the LB. While the waiters bow, sitting knee extension and backwards rocking point out flexion dysfunctions, the pelvic tilt, prone knee bend and forward rocking test for extension dysfunctions. The one leg stance difference show patients with a rotational dysfunction or lateral shift pattern (Luomajoki et al., 2008). The movements were described and then demonstrated by the examiner. The subject had to perform the movement at least three times under observation. When a flexion or extension pattern or any other evasive movement was detected the test was rated as incorrect. All incorrect tests were summed for evaluation. In total a maximum score of 6 represents worst motor control, while 0 shows no movement control dysfunction. Subjects with a score higher than 2 are categorized into “at risk”. Overall the MCTB was found to have substantial intra- and inter-rater reliability [$k > 0.6$](Luomajoki et al., 2007). Furthermore, there was a significant difference between patients with LBP and subjects without back pain [ $d=1.18$, $p < 0.001$]. Patients with LBP had 2.21 [95%CI 1.94-2.48] positive tests, while healthy controls had 0.75 [95%CI 0.55-0.95] (Luomajoki et al., 2008).

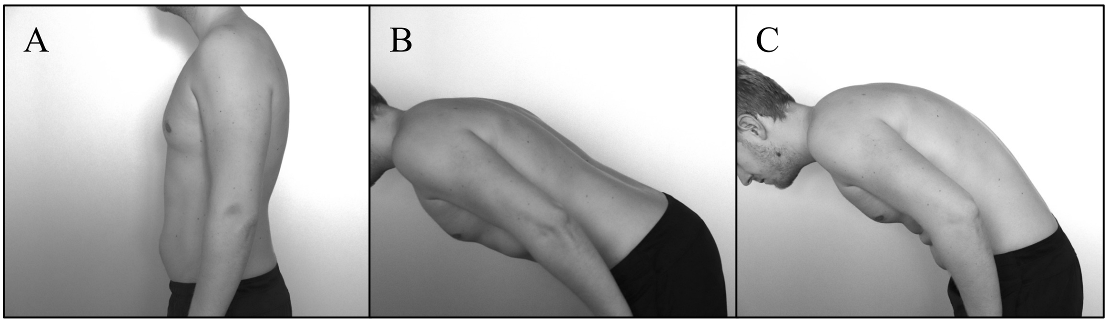

Figure 1. MCTB - "Waiters bow". Flexion of the hips in upright standing without movement (flexion) of the LB. **A**. Starting position **B**. **Correct –** Forward bending of the trunk without movement of the LB (50–70° Flexion in the hips). **C. Not correct –** Flexion in the hip less than 50° or flexion occurring in the LB.

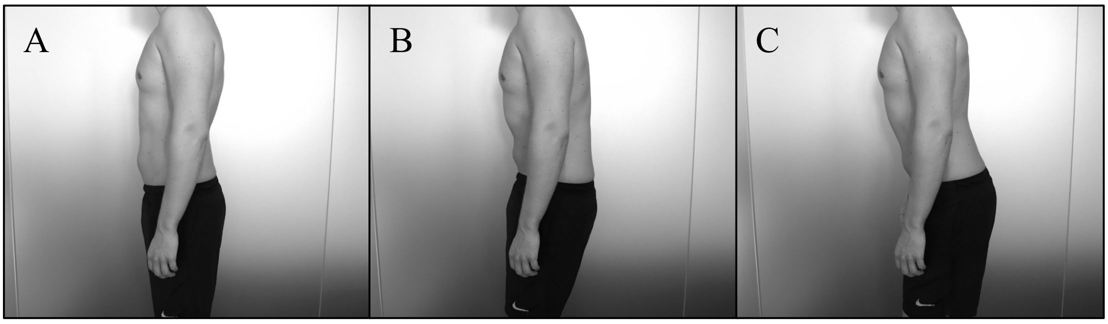

Figure 2. MCTB - “Pelvis tilt". Active dorsal tilt of the pelvis in upright standing. **A.** Starting Position **B. Correct** – Activity in the glutes, while keeping thoracic spine in neutral; lumbar spine moves towards flexion. **C. Not correct –** Pelvis doesn't tilt or the LB moves towards extension; No gluteal activity.

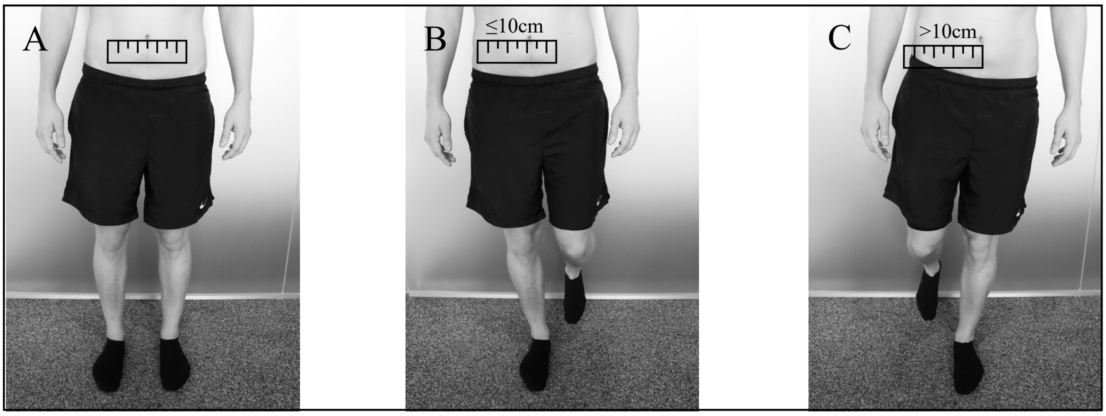

Figure 3. MCTB - “One leg stance“. **A.** From normal standing (feet one third of trochanter distance apart) to one leg stance; measurement of lateral movement of the belly button. **B. Correct** – The distance of the lateral shift is symmetrical right and left; Not more than 2 cm difference between sides. **C. Not correct –** Lateral shift of belly button more than 10 cm; Difference between sides more than 2 cm.

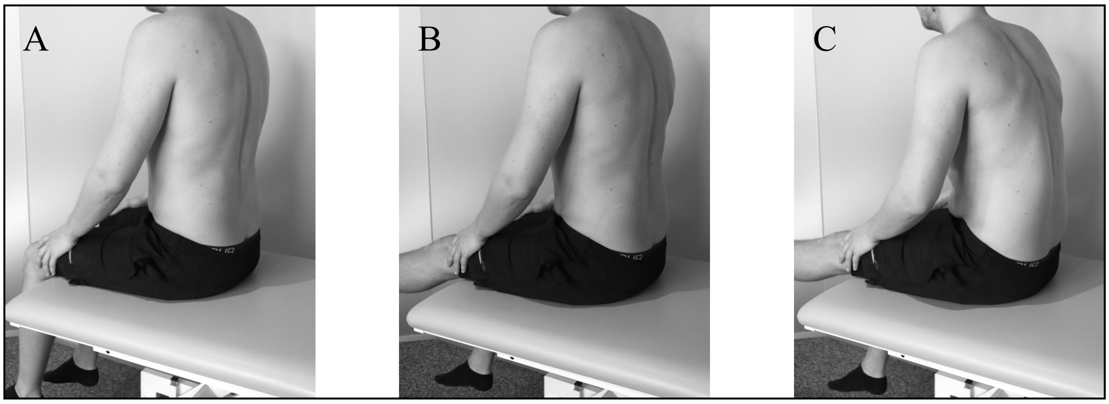

Figure 4. MCTB - “Sitting Knee Extension" **A.** Upright sitting with neutral lumbar lordosis; extension of the knee without movement (flexion) of LB. **B. Correct** – Extension of the knee without movement of LB. **C. Not correct** – LB is moving in flexion; Patient unaware of the change in posture.

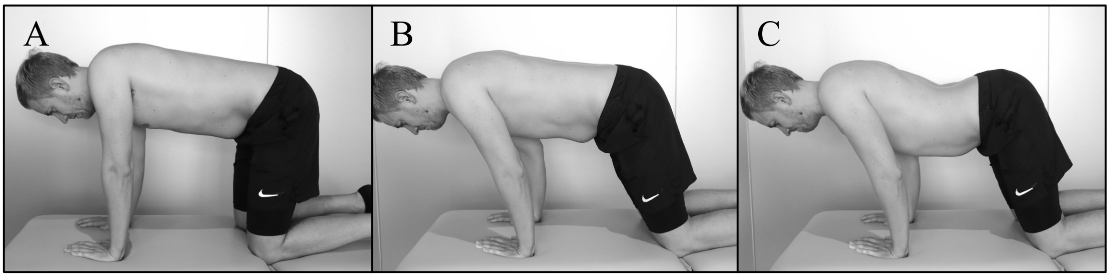

Figure 5. MCTB - “Forward Rocking four point kneeling“. Transfer of the pelvis forwards keeping the LB in neutral. **A.** Quadruped position with 90° hip flexion. **B. Correct** – Rocking forwards to 60° hip flexion without movement of the LB. **C. Not correct** – Hip movement leads to extension of the LB.

Figure 6. MCTB - “Back Rocking four point kneeling“. Transfer of the pelvis backwards keeping the LB in neutral. **A.** Quadruped position with 90° hip flexion. **B. Correct** – 120° of hip flexion without movement of the LB by transferring pelvis backwards. **C. Not correct** – Hip flexion causes flexion in the lumbar spine; Patient not aware of the change in LB

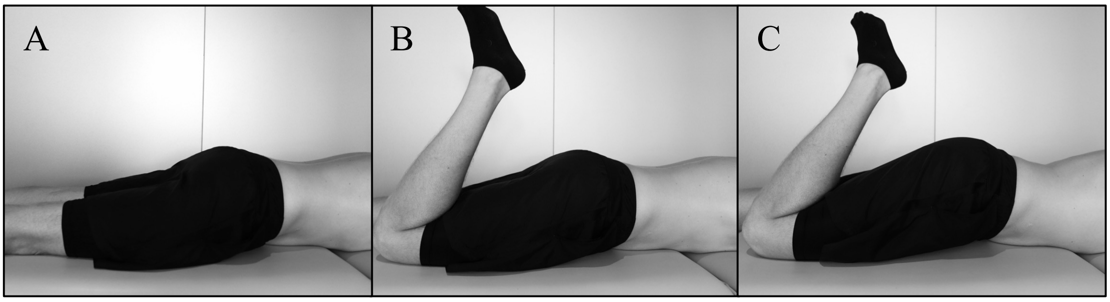

Figure 7. MCTB - “Prone knee bend“. Prone lying active knee Flexion. **A.** Starting position. **B. Correct** – Active knee flexion of at least 90° without movement of the LB and pelvis. **C. Not correct** – With knee flexion the LB moves in extension or rotation in the hips.

### Tissue Stiffness

The parameter of tissue stiffness is generally considered to be the resistance of a tissue against deformation (Wilke, Vogt, Pfarr, & Banzer, 2018). The tissue stiffness of the thoracolumbar fascia was measured using a semi-electronic tissue compliance meter (IndentoPro, Chemnitz University of Technology, Chemnitz, Germany). The handheld device has a build in membrane potentiometer (ThinPot 10kOhm, Spectra Symbol, Salt Lake City, USA) and a load cell (Compression Load Cell FX1901, TE Connectivity, Schaffhausen, Switzerland), which measures the dislocation and force of resistance of a circular indentation probe (Kett & Sichting, 2020). To obtain the stiffness of the fascia, the indentation depth was set to 12mm. The corresponding force of resistance was measured in N/mm. According to Langevin et al. (2011), the indentometer was placed 2cm lateral to the thoracic spine in the area between L2 and L3. One measurement consisted of five consecutive and consistent indentations of the tissue to the defined depth. In order to be able to make predictions about lateral differences, measurements were caried out on both the right and the left side of the spine. Overall, Wilke et al. (2018) showed a intraclass correlation (ICC) for a high test-retest reliability (ICC 0.84, 95% CI: 0.70 to 0.92; p< 0.05) for this non-invasive measurement principle. Inter-rater reliability was also sufficient to good (0.75, 0.56 to 0.87; p< 0.05).

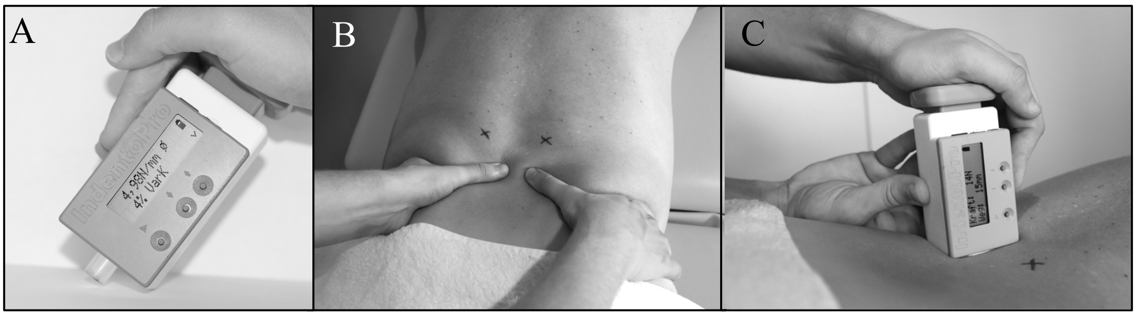

Figure 8. Measurement of the tissue stiffness **A.** Indento Pro indentometer **B.** Palapation of the thoracolumbar fascia **C.** Measurement on the left side of the spine

### Physical Activity

To investigate changes in the subjects' physical activity, the Actigraph GT3X activity tracker (Actigraph, Pensacola, FL, USA) was used. Among the commercially available brands, the ActiGraph accelerometers are the most frequently used by researchers (Wijndaele et al., 2015). The ActiGraph GT3X uses a solid-state tri-axial accelerometer to collect motion data on 3 axes: vertical (Y), horizontal right-left (X) and horizontal front-back axis (Z). Unlike previous models, the GT3X also includes the Vector

Magnitude (VM), which is the vector summed value $\sqrt{(x^2 + y^2 + z^2)}$ (Santos-Lozano et al., 2013). It measures and records time-varying accelerations ranging in magnitude from ~0.05 to 2.5 Gs (ActiGraph Software Department, 2012; Migueles et al., 2017). The output of the accelerometer is first digitized by a 12-bit analog to digital convertor at a rate of 30Hz. After that the signal gets band limited by a digital filter to a frequency range of 0.25 to 2.5 Hz. In the end, each sample is summed over a specific "epoch" and the final output is given in "counts" (ActiGraph Support Center, 2018). According to Migueles et al. (2017) the counts obtained in a given time period, generally counts per minute (CPM), are linearly related to the intensity of the subject's PA during this period. The ActiGraph was placed on the dominant side of the hip and worn over a period of four workdays before and during the intervention. The focus of the activity data was on sitting behavior and steps taken during working hours. A sedentary bout was detected if the ActiGraph deflection was below 100cpm over a period of 10 minutes. Data was recorded with a default sample rate of 30Hz with an epoch length of 60 seconds. The minimum wear time was set to eight hours per day and at least four days of valid wear time (Choi, Liu, Matthews, & Buchowski, 2011; Donaldson, Montoye, Tuttle, & Kaminsky, 2016; Trost, Mciver, & Pate, 2005). Data sets showing a lower wear time were excluded from analysis.

### Subjective Health

In this study subjective health is composed of three main domains. These are back-specific function, perceived stress and overall quality of life, which were assessed by three different questionnaires.

#### *Oswestry Disability Index (ODI)*

The validated German version of the Oswestry Disability Index (ODI) was used to indicate the extent to which a person's activities of daily living are disrupted or restricted by LBP (Mannion, Junge, Fairbank, Dvorak, & Grob, 2006). It is one of the widest used questionnaires in clinical research of back-specific function and recommended by most state-of-the-art reviews (Bombardier, 2000; Deyo et al., 1998). The ODI consists of 10 parts covering Pain, Personal Care, Lifting, Walking, Sitting, Standing, Sleeping, Sex Life, Social Life, and Traveling (J. C.T. Fairbank, Davies, Couper, & O'Brien, 1980). Each part is rated subjectively on a scale from 0 (= no limitation) to 5 (=complete limitation). The sum of the section scores is multiplied by two and given in percent [%]. Lastly, the overall score can be assigned to a degree of functional restrictions, minimal

(0-20%), moderate (21-40%), severe (41-60%), very severe (81-80%) and in need of care (81-100%) (Jeremy C.T. Fairbank & Pynsent, 2000). In previous studies the ODI showed excellent reliability, with an ICC of 0.96 for a maximum time between the repeated measures of two weeks (Gaul, Mette, Schmidt, & Grond, 2008; Mannion et al., 2006). In this study the ODI was assed at baseline and after the four-week intervention. A larger time interval between measurement points tends to minimize the possible memory effect and therefore provides a more realistic view on the degree of score change (Koke, DeVet, Koke, Vanderheijden, & Knipschild, 1995; Mannion et al., 2006).

*Perceived Stress Questionnaire (PSQ)*

The German version of the Perceived Stress Questionnaire was used to survey the extent of subjectively perceived stress experience and stress load on the emotional and cognitive level. While most questionnaires record events and factors for dealing with stress and strain, the focus of the PSQ is on the current extent of the stress experience and individual reaction to it (Fliege, Rose, Arck, Levenstein, & Klapp, 2001). The PSQ is a very suitable instrument, if the stress experience is to be recorded as directly as possible, without deriving it from the recording of control or coping strategies (Fliege et al., 2005). In this study the long version with 30 items was used. Each item can be assigned to one of the following seven domains: Harassment, Overload, Irritability, Lack of Joy, Fatigue, Worries, Tension. Subjects rated each item retrospectively for the past four weeks on a four-point frequency scale from 1 (= almost never) to 4. (= most of the time). An overall score is calculated and ranges from 0 (= no stress) to 1 (= highest stress experience), or from 0 to 100 after factor multiplication. The PSQ is presented as valid and sensitive to change (Fliege et al., 2001, 2005).

*WHO Quality of Life Questionnaire (WHOQOL)*

“Quality of life is defined as individuals’ perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns.” (Orley, 1996)

This definition reflects the view that quality of life refers to a subjective evaluation which is embedded in a cultural, social and environmental context (Harper et al., 1998). In this study the short version WHOQOL-BREF, an abbreviated version of the original WHOQOL-100, was used as a complementary parameter for subjective health. It consists of 26 items, which can be classified into the domains physical health, psychological health, social relationships and environment. For evaluation, the respective domain score is created and then converted to a scale of 0 (= worst health status) to 100 (= best possible health status)(Aigner et al., 2006; Harper et al., 1998). Despite its clear reduction in questions, the WHOQOL-BREF showed strong validity and good to excellent psychometric properties (Gholami et al., 2016; Jang, Hsieh, Wang, & Wu, 2004; Skevington, Lotfy, & O'Connell, 2004; Taylor, Myers, Simpson, McPherson, & Weatherall, 2004). The WHOQOL-BREF was also assessed at baseline and after the four-week intervention. A usage license was obtained prior to data collection by the chair of conservative and rehabilitative orthopedics (TUM, Munich).

## 4.3 Study design

Due to its pilot approach, this study was designed as an uncontrolled prospective intervention study. It was conducted in accordance with the ethical principles of the Declaration of Helsinki. The recruitment of participants started in July 2020 and data was collected between August and December 2020. Informed consent and privacy policy were obtained from each subject before participation. The subjects' physical activity was collected one week before intervention and during the first week of intervention. Baseline measurement of the other parameters took place on the day the intervention started. Measurements took place, either in the subjects' individual office facilities, or at the Prevention Center of the Faculty of Sport and Health Sciences in Munich. All governmental and hygienic guidelines concerning the COVID-19 pandemic were followed during data collection.

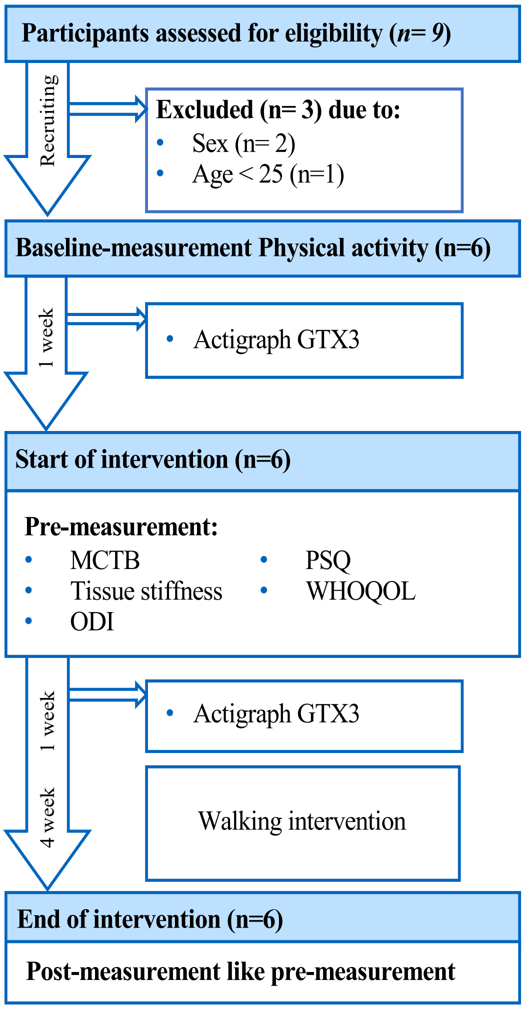

Figure 9. Study design flow chart

## 4.4 Intervention

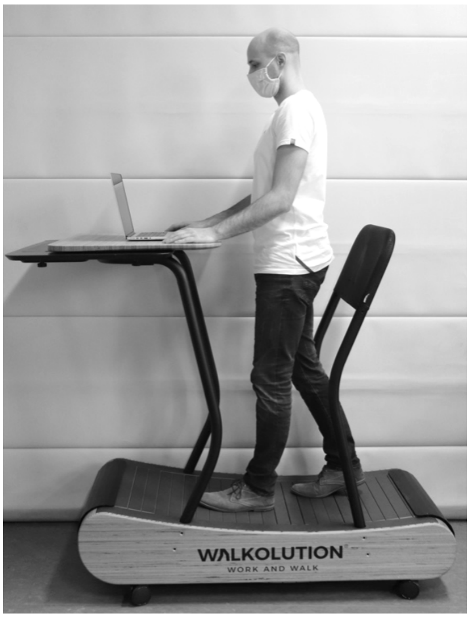
Figure 10. Treadmill desk by Walkolution

The aim of the intervention was to replace the usual sedentary activity during the working day with walking for a period of 4 weeks. Therefore, subjects were supplied with a treadmill desk, which was provided by the company Walkolution. It consists of a non-electronic treadmill, an integrated desk plate and a backrest. In addition to walking upright, the backrest allowed to change into a leaning position from time to time. The subjects were instructed to use the treadmill as often as possible and to refrain from sedentary behavior during the workday. They were allowed to initially supplement the walking activity with occasional sitting breaks for adaptation purposes. The treadmill desks were delivered and installed by the head of study.

## 4.5 Measurement procedure

The measurement procedure started one week before the intervention. Subjects confirmed in written form, that they had read the subject information including the declaration on data protection according to DSGVO. Subsequently, they received an initialized Actigraph GT3X activity tracker, which was set to a measurement duration of 2 weeks. They were instructed in the use of the tracker and on the correct wearing position. Subjects were asked to wear the tracker all day and only to take it off for sleeping periods. In addition, they were supposed to record their exact working hours on a worksheet provided.

The baseline measurement was divided into three parts and was scheduled for 60 minutes. After the welcome, the subjects were asked to fill out the different questionnaires. These were prepared in electronic form on a disinfected laptop. The test supervisor was available to answer any questions of understanding from the subjects and checked for correct completion of the questionnaires.

The second part included the MCTB, which procedure was first explained. As per Luomajoki et al. (2008), subjects received standardized instructions to each movement test. For example, in the waiters bow test the instruction was: “Please bend forward as far as you can while keeping your back straight” – “try not to flex your back or bend your knees”. The movement was then demonstrated once by the examiner. The subjects then had to perform the movement three times under observation and evaluation. The order of the tests was always the same (standing, sitting, quadruped, prone). In order to allow the observation of the entire spine patients were asked to be torso-free for testing. Alternatively, subjects were offered a skintight undershirt. As the subjects did not know the tests, only clear movement dysfunction was rated as “not correct”. If movement control improved with instruction and correction, it was considered not to indicate a relevant movement disorder.

The last part of the measurement procedure was the measurement of tissue stiffness. For this purpose, the subjects remained lying on a treatment bench, proceeding from the previous exercise (prone knee bend). The measurement device was explained and permission was requested to palpate the thoracolumbar fascia, which was marked 2cm lateral to the thoracic spine in the area between L2 and L3. One measurement consisted of five consecutive and consistent indentations of the tissue to the defined depth of 12mm on both sides of the spine. The target variance was set to less than 10%. If this was exceeded, the measurement was repeated. Subjects were encouraged to interrupt the measurement at any time, if pain occurred during the indentation. All data from the MCTB and the measurement of tissue stiffness were recorded on paper and subsequently digitized in MS Excel. This procedure was to protect against data loss and to ensure reproducibility after potential technical failure.

After data collection, the treadmill desk was installed. The subjects were instructed in the handling of the system and informed about possible risks during its use. After that, the intervention period of four weeks started. One week after the start of the intervention, the Actigraph device and the completed data sheet of the working hours were collected. In the course of this, it was also checked whether everything is in order with the handling of the desk. Four weeks after the start of the intervention, a post measurement was carried out, which followed the same procedure as the baseline measurement.

## 4.6 Data processing and statistics

While data from the MCTB and tissue stiffness were evaluated during testing, some data needed further processing after collection.

*Physical Activity*

The data sets from the Actigraph GTX3 were read out and processed in the ActiLife software version 6.11.4 (by Actigraph, Pensacola, FL, USA). A laptop from the Faculty of Sport and Health Sciences was provided for this purpose. After wear time validation with a default algorithm according to Choi et al. (2011) (also see 4.2 p.18), the data was prepared for scoring. In order to assess the influence on physical activity at work, the individual movement data was filtered according to the recorded working hours. The same four working days were used for evaluation. One working day was not included, due to base-line measurement and delivery of the treadmill-desk. Subsequently, sedentary and cut point analysis were performed. The results were directly formatted into Excel by the software. For a better data interpretation, average working hours per day were calculated and supplemented to the results. In addition to the scoring files, the raw data was saved in “.agd” format. This allows future studies to evaluate the movement data based on other aspects.

*Subjective Health*

The different questionnaires (ODI, PSQ, WHOQOL) were evaluated according to given literature as stated in chapter 4.2.

All data sets were backed up in triplicate. In addition to storage on the Head of study's laptop, backup copies were made both on an external storage medium and in a private cloud storage. The data handling was carried out in compliance with data protection according to DSGVO. Due to the study design and research question, only descriptive statistics were used for data analysis.

# 5 Results

All subjects completed the entire intervention period. There were no unintended side effects or adverse events. The effects of the intervention are summarized in individual and overall trends. Detailed values for the results described in the following are shown in **Table 2**. The distribution of specific parameters is illustrated in **Figure 10.**

Subjective Health

The ODI score decreased by 64.0% between pre (mean ± sd: 8.3 ± 6.6) and post measurement (mean ± sd: 3.0 ± 2.7) with an absolute mean difference (MD) of 5.3. All subjects had lower scores after the intervention still showing minimal functional restriction. Perceived stress also slightly decreased by 9.1% (pre: 27.3 ± 7.0 vs. post: 24.8 ± 10.7; MD: 2.5). In two of six subjects PSQ values rose during the intervention. The subscales of the WHOQOL showed different trends. While social relationships and physical health increased by 6.0% (pre: 69.4 ± 22.8 vs. post: 73.6 ± 9.7; MD: 4.2) and 8.5% (pre: 76.8 ± 12.1 vs. post: 83.3 ± 19.7; MD: 6.5) respectively, psychological health (4.3%; pre: 79.9 ± 8.1 vs. post: 76.4 ± 6.3; MD: 3.5) and environment (0.6%; pre: 83.3 ± 5.5 vs. post: 82.8 ± 7.6; MD: 0.5) slightly decreased in mean.

Physical Activity

The data indicate a change in PA during working hours. An average working day lasted 7.9h. The average number of sedentary bouts while working decreased during the intervention by 42.7% (before: 13 ± 6 vs. during: 7 ± 3; MD: 6). In addition, the time spent in a sedentary bout also decreased in all subjects during the intervention by 30.8% (before: 172 ± 39 min vs. during: 119 ± 61 min; MD: 53). The average amount of steps taken during a working day increased by 18.7% during the intervention (before: 3003 ± 787vs. during: 3565 ± 1250; MD: 562).

Tissue Stiffness

The average tissue stiffness of the TLF relatively decreased by 5.8% (left) and 5.6% (right) from pre to post measurement (pre left 3.05 ± 0.49 vs. post left 2.88 ± 0.60; MD left: 0.17; pre right 3.18 ± 0.78 vs. post right: 3.00 ± 0.74; MD right: 0.18). Only two subjects showed an increased value on the right side of the spine.

### Motor Control

Before the intervention, half of the subjects had an MCTB score higher than 2, which classified them as “at risk”. The median score at baseline was 2.5. All subjects showed better motor control after the intervention (median: 0.5). In the post measurement, half of the subjects had no movement limitation at all, while the other half showed a deficit in only one out of six movement tests.

Table 2: Outcome parameters from pre to post measurement

| | | S01 | S02 | S03 | S04 | S05 | S06 | Mean ± SD |
|---|---|---|---|---|---|---|---|---|
| **Subjective Health** | | | | | | | | |
| ODI [%] | pre | 4 | 6 | 12 | 2 | 6 | 20 | 8.3±6.6 |
| | post | 2 | 4 | 8 | 0 | 2 | 2 | 3.0±2.7 |
| PSQ [%] | pre | 24 | 39 | 26 | 18 | 30 | 27 | 27.3±7.0 |
| | post | 29 | 30 | 37 | 6 | 27 | 20 | 24.8±10.7 |
| WHOQOL [%] | | | | | | | | |
| *physical health* | pre | 89.3 | 75.0 | 60.7 | 85.7 | 64.3 | 85.7 | 76.8±12.1 |
| | post | 78.6 | 92.9 | 46.4 | 100.0 | 85.7 | 96.4 | 83.3±19.7 |
| *psychological health* | pre | 75.0 | 75.0 | 79.2 | 75.0 | 79.2 | 95.8 | 79.9±8.1 |
| | post | 75.0 | 75.0 | 70.8 | 79.2 | 70.8 | 87.5 | 76.4±6.3 |
| *social relationships* | pre | 83.3 | 33.3 | 75.0 | 50.0 | 83.3 | 91.7 | 69.4±22.8 |
| | post | 75.0 | 66.7 | 75.0 | 66.7 | 66.7 | 91.7 | 73.6±9.8 |
| *environment* | pre | 81.3 | 84.4 | 81.3 | 78.1 | 81.3 | 93.8 | 83.3±5.5 |
| | post | 71.9 | 87.5 | 78.1 | 81.3 | 84.4 | 93.8 | 82.8±7.6 |
| **Sedentary Analysis** | | | | | | | | |
| Sedentary Bouts [n] | pre | 11 | 14 | 24 | 6 | 10 | 10 | 13±6 |
| | post | 10 | 11 | 9 | 2 | 6 | 5 | 7±3 |
| Time in Sedentary Bouts[a] | pre | 209 | 198 | 103 | 188 | 185 | 151 | 172±39 |
| | post | 199 | 184 | 43 | 87 | 81 | 122 | 119±61 |
| Steps[a] | pre | 3578 | 2722 | 2850 | 3243 | 1686 | 3939 | 3003±787 |
| | post | 4951 | 3142 | 3276 | 1455 | 4014 | 4555 | 3565±1250 |
| **Tissue Stiffness [N/mm]** | | | | | | | | |
| Left Side | pre | 2.92 | 3.59 | 3.41 | 3.37 | 2.33 | 2.70 | 3.05±0.49 |
| | post | 2.65 | 3.54 | 3.32 | 3.32 | 2.07 | 2.36 | 2.88±0.60 |
| Right Side | pre | 3.39 | 2.91 | 4.55 | 3.25 | 2.7 | 2.29 | 3.18±0.78 |
| | post | 3.04 | 4.18 | 3.50 | 2.71 | 2.25 | 2.34 | 3.00±0.74 |
| | | | | | | | | Median |
| **MCTB** | pre | 1 | 2 | 4 | 3 | 1 | 3 | 2.5 |
| | post | 0 | 0 | 1 | 1 | 0 | 1 | 1 |

Abbreviations: **ODI**, Oswestry Disability Index: score given in [%] from 0 (=no functional restriction) to 100 (=in need of care); **PSQ**, Perceived Stress Questionnaire score given in [%] from 0 (=no stress) to 100 (=highest stress experience); **WHOQOL**, WHO Quality of Life Questionnaire: score given in [%] from 0 (=worst health status) to 100 (= best possible health status); **MCTB**, Movement Control Test Battery given in a total score from 0 (=no movement dysfunction) to 6 (=worst motor control);
[a] parameter is given in minutes per working day (Ø 7.90 hours)

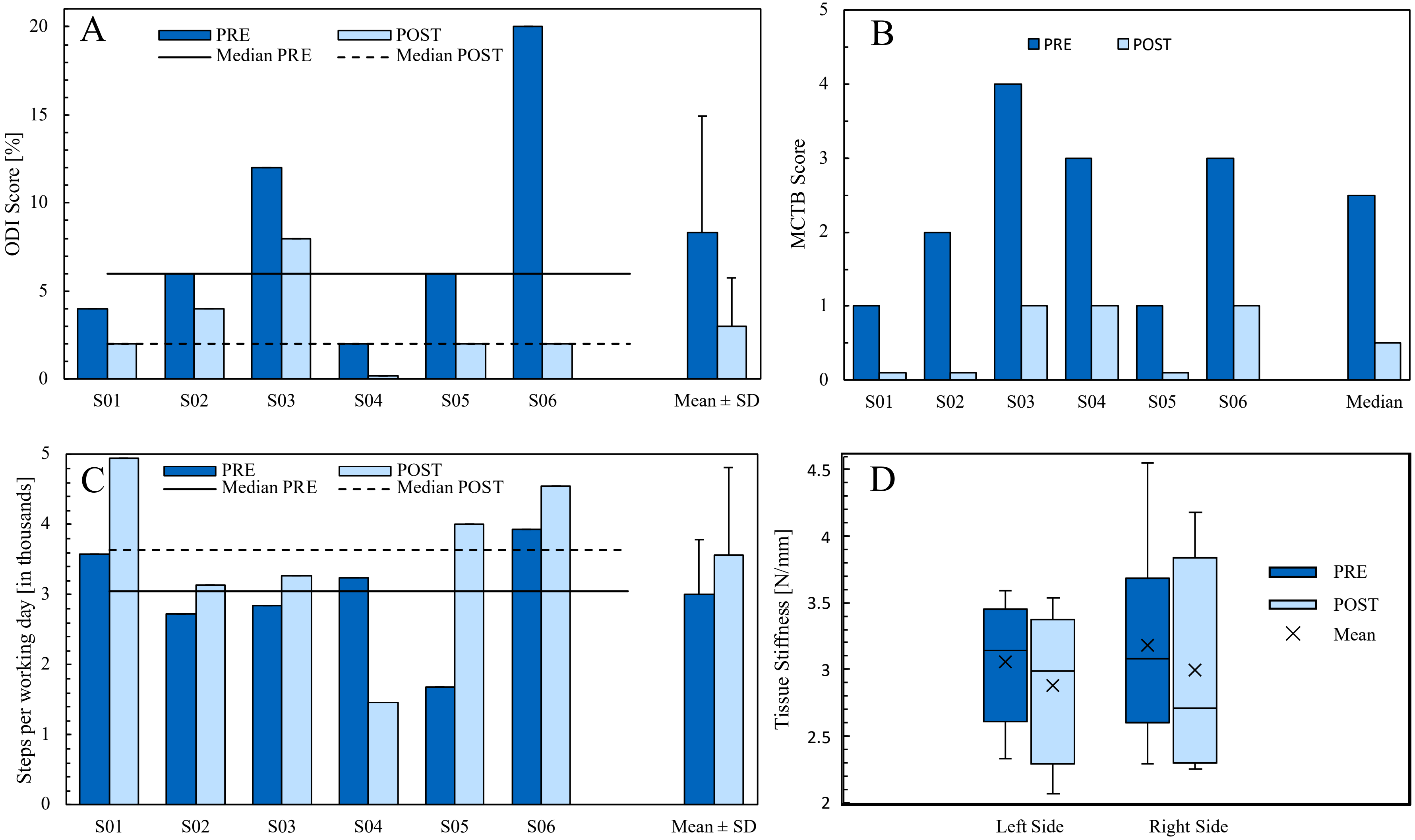

Figure 11. Distribution of outcome parameter from pre- to post-measurement in (A) ODI Score, (B) MCTB, (C) Steps per workday and (D) Tissue Stiffness

# 6 Discussion

The results provide insight into the effects of a treadmill intervention on motor control, tissue stiffness, physical activity and subjective health in office workers with NSLB. In order to further elaborate the findings scientifically, it is necessary to examine the feasibility of a large-scale study in the present design. In the following, the study methodology and results are evaluated for strengths and weaknesses and recommendations for future research in this area are given.

## 6.1 Subjective Health

*ODI*

In the group of subjects, baseline values before the intervention ranged from 2% to 20%. This high range of scores indicates unequal pain intensity and resulting restrictions due to back pain in the sample. Furthermore, all subjects were in the lowest scoring category with "minimal functional restriction" (pre mean ± sd; 8.33 ± 6.62) (Jeremy C.T. Fairbank & Pynsent, 2000). Interestingly, despite the already low baseline scores, all participants were able to further decrease their scores over the intervention period (post mean ± sd; 3.00 ± 2.67). Here, the maximum score was 8% and one subject even showed no restrictions (0%) due to back pain.

In general, when selecting questionnaires for patients, a distinction must be made as to whether it is the restriction of physical functions ("impairment"), the restrictions in the performance of activities and behavior ("disability") or the social restrictions associated with the back pain ("handicap") that are to be recorded (Gaul et al., 2008). With domains of sexuality and participation in social life, the ODI captures more than just the extent of pain and physical disability. Compared to other questionnaires, it does more justice to the multidimensionality of pain in chronic back pain patients. Nevertheless, the ODI is considered to be more suitable for severely affected patients (Roland & Fairbank, 2000). Due to the apparently low degree of back pain in the sample, a comparable questionnaire might have been more suitable for the study. The Roland & Morris Disability Questionnaire (RDQ) is also commonly used in international studies. It measures pain and disability rather than the resulting psychological or social challenges. Since subjective health was also measured with the WHOQOL the psychosocial orientation of the ODI would not have been necessary. In this case the RDQ might have complemented the data better than the ODI.

*PSQ*

The assessment of perceived stress revealed different results. The subjects showed an average baseline value that was in the lower third of the PSQ scoring. On average, the stress level decreased slightly from pre to post measurement. In two subjects, however, the score increased over the intervention, which might explain the high standard deviation of 10.7%. It should be taken into account, that especially in the work context, subjective stress perception is a highly volatile indicator, which is also dependent on individual resilience and coping strategies. Therefore, future studies should complement the subjective perception with objective data such as cortisol measurement. The relationship between stress and back pain has so far mainly been observed in patients with severe post-traumatic stress disorders (Suri et al., 2017). With regard to the fairly low PSQ scores and the individual deviation, stress might be excluded as a contributing factor for back pain in this study.

*WHOQOL*

The study group already showed a fairly high quality of life before the intervention, with average values in the upper quarter of the scoring range in all 4 domains. The greatest change was seen in the physical health domain. The 8.5% increase in physical health after the intervention confirms the results of the ODI. The other domains developed less strongly and in different directions. While the domain of social relationship also improved, the values of psychological health and environmental conditions decreased. In regard of these varied trends, it is necessary to evaluate how much impact the intervention really had on the overall quality of life. Similar to the stress parameter, quality of life is influenced by many different factors. It is questionable whether the WHOQOL with its interpretation of four domains was not too general for the evaluation of the intervention. Especially the domains social relationship and environment should have been only marginally influenced by the intervention, if at all. A more focused assessment of the health related QOL could be useful for future studies. In this case, the SF-36 questionnaire or the Pain and Discomfort Module (PDM) of the WHOQOL, which was designed to assess quality of life (QoL) in adults with chronic pain, would be more suitable alternatives. In general, it can be said that a clear change in QoL is most evident with a worse initial score and is strongly dependent on the health-related change. However, the small changes in quality of life seem to be in line with the literature. A systematic review that examined the effects of active workstations in 32 studies, showed no clear results regarding the impact on quality of life (Torbeyns et al., 2014).

It might also be assumed that the individual situation during the Covid-19 pandemic had an influence on subjective health. Due to the lower disability index and the increased physical health, the positive influence of the treadmill intervention is nevertheless apparent.

## 6.2 Physical Activity

The results show a clear change in sitting behavior in all subjects during the intervention. Not only the number of sitting bouts during the working day decreased, but also the sitting time within the bouts decreased by almost one third. The MD of 53 minutes was even higher than that of a comparable study. Schuna et al. (2014) recorded in their RCT that a treadmill desk plus counseling reduced sitting time at work by 29 minutes per eight-hour workday (95% CI -55 to -2) compared to no intervention. Two other studies also found that the time spent being sedentary was reduced by the introduction of walking workstations (John et al., 2011; Koepp et al., 2013). The average amount of steps taken during a working day increased by 18.7% during the intervention. Five out of six subjects showed an increased number of steps, while one subject even took fewer steps during the intervention than before. This is also reflected in the high SD during the intervention. Since the subject was not ill or on a business trip during the intervention period, the small number of steps might only be explained by a non-use of the treadmill desk. Considering this subject as an outlier and excluding him from the data analysis of steps, the difference in average would increase from 18.7% to 34.9%, which corresponds to a mean absolute difference of 1032 steps. Thompson et al. (2008) confirm the increase in step count, although to a higher extent of 2000 steps per workday on average. This difference could be due to the study design as well as the measuring devices used. Since in their study several treadmills were used at the same time within a department, the use of the treadmill desk could have been increased through competition or motivation among colleagues. In the present study treadmill desks were used in different offices and usage was solely dependent on the subject's own commitment.

A good data quality when measuring PA with activity trackers is always reliant on subject’s compliance. The PA baseline measurement of one subject had to be repeated after a wash-out period of two weeks due to insufficient wearing time of the Actigraph. Insufficient wearing time and a short measurement period reduces the chance of obtaining valid data sets. This gives reason to change the measurement methodology for future studies. Tudor-Locke et al. (2015) found higher wear-time compliance with 24-h protocols compared to waking-hour protocols, with this finding being consistent across different studies (Migueles et al., 2017). As subjects were only instructed to put on the Actigraph after getting up and to take it off before going to bed, this could explain the lack of wear time compliance.

From the data sets, it can be seen that some subjects put on the Actigraph later into the day. Continuous wearing (24h protocol) could counteract this matter and thus improve wear time. The measurement period of four days was at the recommended lower limit (Trost et al., 2005). Extending the measurement period to the full four weeks might have produced more valid data. However, this would also have required longer compliance of the subjects.

The ActiLife software allows users to choose between two different filters when processing the data: normal (default) and low-frequency extension (LFE) filters. For comparison with other criterion devices the default with normal filter was used in this study. However, studies have shown that enabling the LFE filter leads to decreased sedentary time, greater time in PA and a higher number of steps per day (Migueles et al., 2017). Because of the limited movement during desk work, the use of the LFE filter could be considered for future studies unless a cut point analysis to determine individual activity levels is of interest.

## 6.3 Tissue Stiffness

Apart from two subjects, whose values on the right side of the spine were higher after the intervention than before, the tissue stiffness of the thoracolumbar fascia decreased in all other candidates on both sides as a result of the intervention. According to Langevin et al. (2011), inactivity and altered movement patterns can worsen connective tissue adhesions resulting in increased movement restriction. This is especially the case in the presence of pain and inflammation. The researchers found that the thoracolumbar fascia shear strain was ~20% lower in subjects with chronic LBP. Since the dense connective tissue layers within the thoracolumbar fascia are connected to dorsal and ventral trunk muscles, they argue that reduced shear strain results from impaired neuromuscular control and recruitment patterns of these muscles during trunk movements (Langevin et al., 2011). This line of thought can also be applied to this study and may explain the reason for the decreased tissue stiffness of the thoracolumbar fascia after the intervention. It is well known that walking leads to increased activation of the deep trunk muscles (Gordon & Bloxham, 2016). The use of the treadmill desk and the subsequent increased activity improved neuromuscular control as well as recruitment, which is also reflected in the MCTB results. In addition, the activity released connective tissue adhesions, which led to a decrease in tissue abnormalities (stiffness). Furthermore, the baseline measurement of tissue stiffness had to be almost terminated in one subject due to excessive pain sensation. In the post measurement, however, the subject did not feel any pain during the measurement. This also confirms the reduction of back pain and a possible change in connective tissue pathology (stiffness or inflammation) due to the movement intervention. Since chronic LBP alters gait (Müller, Ertelt, & Blickhan, 2015), it can be assumed that an improvement in gait pattern and the associated beneficial effects on motor control and soft tissue pathology will only occur with a decrease in pain over time. This shows how important the recording of long-term intervention effects is for further research.

## 6.4 MCTB

The results of the baseline measurement were in line with those of Luomajoki et al (2008). In their group of patients with LBP, the mean score was 2.2, whereas in this study, the mean score was 2.33 and the median was 2.5. This indicates that, although the group of subjects had low scores in the ODI, they still had impaired motor control in the lumbar spine. In the post measurement, there were clear improvements in motor control, with only half of the subjects still having a score of 1 and the remaining no longer showing any limitation (median: 0.5). The fact that the remaining deficits occurred in different movement tests, suggests that there is not *the one* exercise that patients with LBP find particularly difficult. According to Lamoth et al. (2006), LBP affects the trunk coordination and activity of the musculus erector spinae during walking. This could indicate improved neuromuscular control and coordination of the deep trunk muscles after the movement intervention. Some might also suspect a learning effect as an influence for the change in MCTB scores, since subjects completed the same movement tests within the four weeks. Another potential issue is that the assessor's decision was based solely on his own observation, which was subjective. In addition, the movement assessment was not performed by a certified physiotherapist. Nevertheless, it can be assumed that the assessment was valid, since the assessor was a qualified sports scientist, who was trained in the test methodology. Future studies should consider movement assessment using objective measurement technologies to ensure that the lumbar spine remains neutral during the movement tests. Functional radiography or movement analysis systems such as Vicon® or Optotrac® have proven to be the gold standard in this matter (Luomajoki et al., 2007). However, the use of such measurement systems should be based on a cost-benefit analysis, as the costs would be very high, especially in randomized controlled trials (RCT) with large numbers of subjects.

## 6.5 Research question and objectives

Based on the study results, the effects of a four-week intervention with a treadmill desk on the various study parameters could be shown, thus answering the research question posed. Besides the expected outcomes, such as increased physical activity due to the intervention, there were also some surprising results. In subjective health, against expectations, rather minor changes were observed as a result of the movement intervention. A different priority in the selection of the measurement methodology could provide clearer results. Surprisingly, there were short-term effects even in the tissue stiffness of the TLF. The results show a trend of decreased stiffness and thus a change in connective tissue pathology. Probably the biggest and most substantial change was in motor control of the lumbar spine. After only four weeks, all subjects were able to improve their motor control by walking. Since poor motor control of the lumbar region has been shown to increase the risk of LBP, the results show what a great effect walking can have as a preventive measure. With the analysis of the data, the primary study objectives were met. In addition, the pilot study was able to provide an insight into the comprehensive effects of a treadmill desk intervention. From the data obtained, more specific research questions can be elaborated and investigated in larger studies.

## 6.6 Recommendations

With regard to the research results and their detailed discussion, the following recommendations for future studies can be made:

☐ Accurate selection of the subjects based on medical histories and sample size estimation
☐ Subject groups with a higher severity of LBP
☐ Questionnaire focusing on pain perception and disability (RDQ)
☐ Assessment of health-related Quality of Life (SF-36, WHOQOL-PDM)
☐ For stress measurement, use objective markers such as cortisol in saliva
☐ Functional radiography or movement analysis systems as objective measurement tools for motor control (cost-benefit-analysis required)
☐ 24h-protocol with a longer measurement period for activity tracking
☐ Assessment of individual energy expenditure based on cut-point-analysis
☐ Adding a no-treatment comparison group (RCT)
☐ Expend the intervention period to 12 weeks for long term effects

Figure 12. Methodological recommendation

The given recommendation mainly refers to the research question of the presented study. Since effect trends on different parameters are provided in the findings, it is generally recommended for future studies to focus on a specific outcome parameter. This will give the opportunity to gain even more profound knowledge in the area of walking interventions in LBP patients. In particular, blinded large-scale RCTs could confirm the presented trends and statistically prove associations between variables.

# 7 Conclusion and Outlook

This pilot study showed that a treadmill desk intervention could reduce pain intensity and physical restrictions in daily life in office workers with NSLBP and lead to improved motor control of the lumbar spine. The intervention appears to release connective tissue adhesions and reduce tissue stiffness of the thoracolumbar fascia, which is prone to LBP. Another benefit of the treadmill desk was enhanced physical activity and decreased sitting time during the workday. All of the changes also appear to increase subjective health and quality of life. These outcomes hopefully contribute to the body of knowledge on the practical use of treadmill desks in back pain patients. In order to support the findings of this investigation, further RCTs with specific research focus should be conducted. Future research could include not only physical adaptations but also effects on cognitive performance such as working memory, selective intention or processing speed while using a treadmill desk.

The high prevalence of NSLBP and sedentariness inevitably points out the urgent need for change in the health care system, especially in developed societies. Since people spend almost a quarter of their lives at work, especially employers should be held more responsible for the general health of employees with the aim of a well-structured occupational health management. The study indicates that the supply of a treadmill desk not only has a positive effect on the health of office workers from a preventive point of view, but can also be used as a rehabilitation measure to improve the reintegration management after long-term illness. It is to be desired that in the future companies will provide more ergonomic workplaces and overall, better protect one of their most important resources, employee **health**.

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## Declaration on honor

Hereby I assure that the work

The Effects of a 4-Week Treadmill Desk Intervention on Motor Control, Tissue Stiffness, Physical Activity and Subjective Health in Office Workers with Non-Specific Lower Back Pain - A Pilot Study

has been made by myself and without any unauthorized assistance, that it has not yet been submitted to any other body for examination. The places of the work, including the tables and illustrations, which are taken from other works in terms of their wording or meaning, I have identified in each individual case and proven their origin.

Munich, 12.04.2021 F. Becker
..................................................................................
Place, date and signature