

**SHORT THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
(PHD)**

**Development and impact of an occupational health promotion
programme for the prevention and management of low back pain
among sedentary workers**

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The effects of a workplace program for the prevention and treatment of low back pain among
sedentary employees

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I. INTRODUCTION, PROBLEMS

Sedentary, inactive lifestyles are a major risk factor for musculoskeletal, metabolic and cardiovascular diseases. Today, the vast majority of the global population lead sedentary, sedentary lifestyles, spending a large part of their working and leisure time in a sedentary position. According to the *Eurobarometer 2022* report on Sport and Physical Activity, 45% of Europeans are inactive. The survey also revealed that during the COVID-19 epidemic, half of Europeans reduced their activity levels or even stopped exercising altogether. More than half of Europeans (54%) take part in sport or physical activity to improve their health, far ahead of other reasons such as recreation or leisure. According to the survey, lack of time (41%) and lack of motivation (25%) are the two main reasons preventing Europeans from doing more sport these days. And a survey of sedentary time shows that 44% of the European population spend between 2.5-5 hours, 8% between 5.5-8.5 hours and 11% more than 8.5 hours in a sedentary position per day (1), which has been shown to increase the risk of developing low back pain (2).

Of all musculoskeletal disorders associated with sedentary, inactive lifestyles, low back pain is the most significant problem, with low back pain being the largest contributor to the global burden of disease in terms of years lived with disability. In addition to the increased costs of healthcare and financing, low back pain also has other unpleasant consequences for the individual. These include, for example, lower wages due to sick pay; avoidance of activities such as physical activity and work, or social interactions due to avoidance behaviour because of pain. From a patho-anatomical point of view, low back pain increases the risk of developing various spinal pathologies, which in the long term can significantly reduce the patient's quality of life, activity and productivity (3,4).

The vicious circle of pain can cause irreversible damage to the structure of the spine, making its prevention and reduction an important public health challenge. Previous research has demonstrated that low back pain induces motoneuron reflex-inhibition in the stabilizer muscles of the lumbar spine, resulting in atrophy and reduced strength of muscle fibres, as well as altered physiological patterns of myoelectric activation. Because the muscles responsible for trunk stability and mobility are activated in a specific sequence and at a specific rate during each movement, late and/or differently sequenced weakened contractions do not ensure intervertebral joint stability. For example, m. multifidus is a particularly important stabiliser, with unusually high levels of proprioceptors in its fibres, which are responsible for sensing muscle tension and joint position, and is therefore at risk of intervertebral instability due to its atrophy, contraction delay and reduced proprioceptive capacity. However, once the pain has subsided, the condition of the muscles can only be improved with targeted and very precise exercises, and if it is untreated, irreversible lesions such as fatty infiltration may develop. Instability may lead to intervertebral disc injury, disc protrusion and herniation, osteoarthritis and spondylarthrosis, and nerve root involvement over time, among other consequences (5, 6). On the basis of epidemiological data collected globally by the *World Health Organization (WHO)* from 1990 to 2019, it is important to highlight that low back pain is the first in the rank list of all observed diseases and injuries in terms of years lived with disability and disability adjusted life years (7). In view of the above, there is no doubt that the prevention of low back pain is justified from both a public health and an individual perspective.

The importance of this problem has been recognised by health promotion professionals, and in recent years, the *European Union and the World Health Organisation (WHO)* have sought to address it by implementing various programmes and campaigns and by developing guidelines. In order to reduce musculoskeletal disorders and complaints, the *European Agency for Safety and Health at Work (EU-OSHA)* has also launched a campaign entitled 'Lighten the load' for the period 2020-2022, as the risk of developing these disorders is work-related and there are more opportunities to involve the at-risk group in the workplace (7,8). In recent years, several research studies have been carried out in the workplace to investigate the effects of individual therapies and combined training. Results show that even a 10-minute training session per day can significantly reduce the incidence and intensity of low back pain (9). In terms of interventions, multi-method training is more effective, and studies have shown that core strengthening, proprioceptive and functional training, Pilates, segmental stabilisation, McKenzie therapy, stretching and ergonomics education also significantly reduce pain and functional limitation (10).

The overall aim of our research was to develop and evaluate the impact of a workplace health promotion programme that can prevent or reduce musculoskeletal complaints and improve fitness and coordination among sedentary workers with low back pain. Our preparatory research investigated the physical characteristics of the target population, posture, spinal statics and mobility, and assessed the impact of a minimal intervention to increase theoretical knowledge. Pilot studies were carried out with a small number of participants to analyse the effects of three different movement programmes, and the experience gained led to the final design of the *Multimodal Progressive Functional Training Programme*, adapted to the characteristics of the target group and the workplace. The main objectives of the main study were, on the one hand, to implement and evaluate the impact of the workplace training programme designed by analysing the data collected during the questionnaire and physical fitness assessment of the participants and, on the other hand, to gain experience in the organisation and implementation of the programme.

My thesis presents a cross-sectional study of the physical condition of sedentary workers with low back pain; the results of the theoretical training; and the impact assessment of the intervention implemented during the main study, complemented by the methodology of our studies and the experience of implementing the intervention. This present shortened version of dissertation is limited to the results of the main study.

II. REVIEW OF LITERATURE

II.1. Low Back Pain

II.1.1. Epidemiology of Low Back Pain

Low Back Pain (LBP) has been the focus of public health attention for the last few decades, as preventing LBP and reducing its prevalence and incidence would significantly reduce the significant global burden of disease due to LBP. The most recent results of the *World Health Organization (WHO)*, which monitored global epidemiological studies on LBP are published in the *Global Burden of Disease Study (GBDS) 2019*. The results of the study show that the musculoskeletal disorders (MSDs) group was the largest contributor to the overall

global prevalence with 1.71 billion people and 149 million years lived with disability. Among MSDs, low back pain (LBP) was the health condition with the highest burden of disease, and LBP was the health condition that contributed most to the use of rehabilitation services in 134 of the 204 countries analysed. In 1990, 386 million prevalent cases were observed globally, compared to 568.4 million in 2019, hence a significant increase (47%) can be seen in the total population. The global incidence in 1990 was 149.3 million, compared to 223.5 million in 2019, which is also a significant (50%) increase for the total population. Low Back Pain resulted in 42.5 million *Years Lived with Disability (YLDs)* globally in 1990 and following an increase of almost 50%, this indicator reached 63.7 million YLDs in 2019, thus back pain remains the 'prominent' first cause of years lived with disability in the ranking of studied diseases and injuries (3,4,7,11). Taking into account the epidemiological data and trends over the last three decades, LBP is one of the most important public health problems of our time, placing a significant disease burden on global civilisation.

II.1.2. Definition of low back pain

Low Back Pain is defined as discomfort and pain localised in the region between the lower rib cage and the gluteal skin folds, which may be associated with radiating pain in the lower limb, divided into non-specific and specific subgroups according to aetiology. Non-specific low back pain is pain with no diagnostically verifiable patho-anatomical source, whereas in specific LBP the complaints have a known or specific pathological cause (e.g. infection, malignant tumour, osteoporosis, ankylosing spondylitis, axial spondylarthritis, vertebral fracture, inflammatory process, radicular syndrome, cauda equina syndrome, etc.) (12). The diagnostic triage of LBP aims to exclude non-spinal causes and classify patients into one of three categories: specific spinal pathology (<1% of cases), radicular syndrome (5-10% of cases) or non-specific LBP, which accounts for 90-95% of cases and can be diagnosed by excluding the first two categories. In radicular syndrome, three subgroups of nerve root involvement are distinguished on the basis of clinical features, which are radicular pain, radiculopathy and canal spinal stenosis (13).

II.1.3. Risk factors for the development of low back pain

Putative risk factors for low back pain are grouped into 2 main categories by the *Orthopaedic Section of the American Physical Therapy Association*, namely individual and activity (work and leisure) related factors. Individual factors include demographic, anthropometric, physical and psychosocial factors, among others things. Most research focuses on individual factors, mainly examining the relationship between genetics, gender, age, body composition, muscle strength and flexibility in relation to low back pain. Genetic factors have been clearly linked to certain disorders of the spine, such as disc degeneration. There is considerable evidence that activities involving heavy weight-bearing induce low back pain, and cardio-vascular hypertension and lifestyle (smoking, overweight, obesity) have also been associated with the development of sciatica. However, the results of these studies have shown that psychosocial factors play a greater prognostic role in the development of low back pain than actual physical factors. Anxiety and depression, illness-related behaviours and beliefs play a major role in the development of pain, but fear of pain and avoidance behaviours also play a

significant role, and can both worsen and maintain the patient's adverse state and exacerbate the degree of functional decline. In terms of physical activity, some sports activities such as weightlifting, bodybuilding and rowing are associated with low back pain, but the prevalence of LBP increases significantly in the more inactive, sedentary and more active than average population (14,15).

The above suggests that interventions targeting low back pain can be truly effective if they address the physical and psychosocial well-being of the affected population, taking into account potential risk factors and using a multidimensional approach.

II.1.4. Stability and mobility of the lumbar spine, the "core" muscles

The 'core' is essentially the central part of the body consisting of the trunk, pelvic and shoulder girdle and their muscles, as well as connective tissue and bony structures. The core is intrinsically linked to the body's centre of gravity, a dynamic centre around which the body is balanced and which is always dependent on the body's position at any given moment. The relative position of the centre of gravity is constantly changing as the limbs move or change spatially, and therefore the core is an integrated functional unit that synergistically adjusts the whole body to maintain balance, postural stability and mobility. These abilities are essential to perform the basic activities of our daily lives. There are several possible classifications of core muscles in the literature, so we can talk about anterior, posterior, medial and lateral muscles, moreover local or global muscles in terms of location, and stabilizers or mobilizers in terms of function. The muscles of the core coordinate the position of the spine, ribcage and pelvis, thus ensuring the absorption and controlled, uniform distribution of external static and dynamic forces acting on the body. Adequate activation and timing of the local and global stabilizer muscles is essential to maintain stability, and their coherent action ensures an even distribution of forces. Adverse alteration of the synergistic relationship between the 'core' muscles may have a negative impact on the proprioceptive system or induce degenerative processes in the joint components (16).

In 1989, *Bergmark* categorized the stabilizer muscles of the lumbar spine as either local or global, based on the location and main function of the muscles. Local muscles are defined as those that originate and/or insert to a lumbar vertebra, with the exception of the m. psoas major. Local muscles are involved in the positioning and curvature control of the lumbar vertebrae and provide the sagittal and lateral stiffness necessary for the mechanical stability of the spine. The synergic contraction of the m. multifidus, m. transversus abdominis, m. levator ani and m. diaphragm increases intra-abdominal pressure and stiffness of the "core", providing inter-segmental stability, which allows for an even distribution of external and internal forces acting on the intervertebral joints. Conversely, the transmission of forces on the trunk and body between the pelvis and the rib cage is achieved by the global system of muscles and changes in intra-abdominal pressure. It is important to stress that the origin of these global muscles is typically located in the pelvis and their attachment in the rib cage. The main role of the global system is to balance and transfer external loads and forces so that the resultant forces on the lumbar spine can be properly managed by the muscles that make up the local system. This means that large variations in the distribution of external loads can cause only small changes in the magnitude of the load on the lumbar spine, so that the demands on the local system depend

on the magnitude of the external load, rather than its distribution, and on the current position of the lumbar curve and vertebrae (17).

Faries and Greenwood published a comprehensive analysis in 2007, including the classification by Hodges and Richardson of local and global stabilizers and the muscles responsible for global mobility. The "core" muscles have the primary function of supporting the pelvico-lumbo-hip complex in order to stabilise the spine, pelvis and kinetic chains during functional movements, and therefore knowledge of the specific characteristics of these muscles is essential for therapeutic and preventive activities. An essential prerequisite for spinal stability and injury prevention is adequate muscular strength, endurance and an adequate activation pattern of the trunk muscles, with adverse changes in these abilities being a necessary factor in various spinal complaints and diseases (18).

II.1.5. Possible patho-anatomical consequences of low back pain

Chronic or recurrent low back pain can significantly impair the functional capacity of the muscles stabilising the spine in the short term and induce structural changes in the long term. In the deeper muscle fibres of the m. multifidus, closer to the facet joints, the number of muscle spindles is much higher than in the more superficial fasciculi and therefore plays an important role in proprioception, acting as a "kinesiology monitor", helping to establish appropriate proximal stability during functional activities. In the case of low back or other arthrogenic pain, motoneuron reflex inhibition of the m. multifidus can be expected, leading to an overload of the more superficial muscles, recurrent pain, segmental instability and other inter-segmental complications such as disc protrusion, prolapse or herniation (5,19). The three dominant signs of degeneration due to reflex inhibition of the m. multifidus are reduced radiological density of the soft tissue, reduced muscle cross-sectional area (atrophy) and fatty infiltration, which can be confirmed by diagnostic imaging. Fatty infiltration is highly associated with LBP, since several magnetic-resonance spectroscopy studies have confirmed that the fat content of m. multifidus is significantly higher in individuals affected by LBP compared to asymptomatic controls (20). Hides et al. found that spontaneous regeneration of m. multifidus function is not expected after the symptoms have resolved. In contrast to subjects who received a targeted intervention, subjects who did not receive specific exercises recovered in all other aspects examined, but atrophy of the m. multifidus was still observed 10 weeks after "complete" recovery (21).

A literature review by *Comeford and Mottram* published in 2001 highlighted some additional dysfunctions. Abnormal afferent information from the joints (e.g. pain) can reduce γ -motor neuron excitability, which reduces proprioceptive system function, and joint damage can reduce α -motor neuron excitability, which reduces the ability to contract voluntarily. In addition, simple muscle fatigue can also adversely affect joint proprioceptive reduction and kinaesthetic abilities. Dysfunction of the global system may include agonist-antagonist imbalance; changes in the order of activation of synergistic and antagonistic muscles; and direction- and segment-specific hypermobility. Dysfunction of the local system may be due to abnormal segmental control; altered activation pattern; and/or altered timing (delay) of activation (6,22).

From the physiotherapist's point of view, the mechanisms listed above are of great importance, as the design and content of targeted training programmes must be consistent with the dysfunction that is expected to lead to the progression of pathological processes. In the case of low back pain and other spinal disorders, particular and primary attention should be paid to training local stabilizers, with an emphasis on the sensation and acquisition of voluntary and isolated contraction, correct timing of activation, and increasing muscle strength and cross-sectional area. Based on the above, segmental stabilisation of the trunk can be considered an essential core exercise for the prevention and treatment of low back pain, but other aspects should also be taken into account when designing the training, such as improving posture, muscle flexibility and muscle strength, improving coordination and movement patterns, improving endurance or increasing ergonomic and theoretical knowledge.

II.2. The relationship between back pain and work

According to a WHO analysis, in 2004, 37% of all back pain is attributable to an occupational risk factor, a rate that outweighs many serious diseases and is therefore the most significant work-related problem.

Occupational ergonomic stressors such as lifting and carrying heavy weights and objects, strenuous physical work, frequent bending and twisting of the spine and prolonged uncomfortable, static, incorrect posture play a vital role in the development of LBP. Despite the fact that low back pain is rarely associated with a life-threatening condition, it can be a significant limitation of work and social activity, moreover is also the most common cause of disability and loss of productivity, resulting in substantial direct and indirect economic losses and costs to employers, employees and the health care system (2).

Reports by *EU-OSHA* and *The National Institute for Occupational Safety and Health (NIOSH-USA)* cite prolonged sitting and uncomfortable static postures as major risk factors for low back pain and other musculoskeletal, cardiovascular and metabolic disorders. The main aim of these organisations is to reduce the negative health effects of sedentary work by collecting data on risks and symptoms, prevalence and incidence, absenteeism and health-related expenditure, and to help employers by developing guidelines and publishing and promoting best practices in the workplace environment. Reducing sedentary working hours, shifting to standing and walking meetings, using stairs instead of lifts, sedentary workstations, flexible rest breaks, ergonomics education and providing time for physical activity are among the most recommended methods for preventing LBP (23-25).

Nowadays, many organisations and research groups are working on occupational health, health promotion and prevention strategies. As long-term static sitting is a major risk factor for non-specific LBP (26) and low back pain is the most common MSD resulting from occupational hazards (27), targeted occupational health promotion programmes are needed to engage the most at-risk population. In order to reduce the high work-related risk of back pain, *EU-OSHA* ran a campaign from 2020 to 2022 under the motto "*Healthy Workplaces – Lighten the Load*". The main objective of the campaign was to reduce musculoskeletal disorders and to raise awareness of possible preventive and therapeutic options.

The facts described above, moreover the coordinated efforts of international organisations clearly demonstrate the importance of the prevention of work-related

musculoskeletal disorders, and in particular low back pain According to the objectives of *EU-OSHA* the maintenance of workplace health promotion and prevention programmes at multiple target points of intervention, using a combination of different methods is justified (8).

II.2.1. Prolonged sedentary work and its possible consequences

According to *EU-OSHA's* definition, prolonged sitting is defined as maintaining a static sitting posture for two hours or more, with low energy expenditure and static load (physical effort required to maintain the same position).

According to *2013 Eurobarometer* data, 18% of adults in the *European Union (EU)* spend more than 7.5 hours sitting at work, and a survey in 2022 estimates that 44% of the population will spend between 2.5-5 hours, 8% between 5.5-8.5 hours and 11% more than 8.5 hours in a sedentary position on an average day. According to *Eurostat* data from 2017, 39% of EU workers do their work sitting down. According to the *2015 European Working Conditions Survey*, 28% of workers reported sitting almost all the time, while a further 30% spent between a quarter and three quarters of their working time in a sedentary position. And according to the *2019 European Survey of Enterprises on New and Emerging Risks*, prolonged sitting was the second most frequently cited workplace risk in the EU-27 (by 61% of enterprises on average), while in Hungary it exceeds 70%, the second highest rate among the 27 Member States surveyed. In addition, the proportion of workers sitting in front of a computer also increased significantly, from 52% to 56% on average in the EU-28 between 2010 and 2018, according to *2020 Eurostat* data, while in Hungary it increased from 39% to 49%, and it is estimated that this trend could become even more significant in the future. Teleworking and home-office arrangements, which became widespread during the COVID-19 pandemic, exacerbate the situation, as workers have less incentive to move around at home, no opportunity to participate in workplace programmes and ergonomic conditions in the home are not necessarily ideal for preventing back pain (1,28).

Low back pain is a relatively common complaint that may resolve over time and return later, but it is difficult to determine the extent to which a sedentary lifestyle contributes to its development as there are many known influencing factors and risk factors. However, when estimating the risk, it is worth taking into account the biomechanical forces acting on the spine and soft tissues, which vary considerably in different postures. Both previous research by *Alf L. Nachemson* and more recent research by *Marcel Dreischarf et al.* have shown that intervertebral disc pressures vary significantly in different postures compared to those observed in the standing neutral position. The distribution of forces on the articular surfaces is uniform under ideal biomechanical conditions (standing posture, neutral spinal curves), but significant changes in the magnitude and distribution of forces are expected in the presence of incorrect posture or postures other than standing. While sitting with a backrest inclination of 100-110 degrees, the disc pressure is almost equal to the value measured in the standing position (100%), the pressure in the sitting with a straight trunk is 140%, 190% with trunk flexion ("hunched" position) and almost 400% in combination with trunk flexion rotation in the sitting position, i.e. four times the value measured in the standing, resting position. Computer simulation models have shown that the compression/shear force on the lower spine is significantly increased

compared to the values measured in the standing position (550/200 Newtons) during weight lifting in flexion, dynamic or sudden loading conditions, up to 5000/2000 Newtons (29,30).

This of course has an impact on the condition of soft tissues and other joint components. The relationship between the change in pressure measured in the discus and the development of pain is not necessarily direct, but it is well established that prolonged overloading of the discus induces degenerative processes in the intervertebral joints, the surrounding bridging muscles and ligamentous system. These negative effects are most pronounced when the load is applied continuously or repetitively over a long period of time, or when the above-mentioned structures are subjected to sudden and significant loads, so that the injuries and complaints resulting from prolonged sedentary work are not necessarily due to the magnitude of the forces but to the duration of load.

In addition to the increase in disc pressure, sitting increases the mechanical stress on ligaments, muscles and tendons, resulting in increased pain; discomfort; overuse and injury due to postural stress; and the risk of joint compression and soft tissue injuries. Prolonged sitting is associated with weakening of the extensor muscles of the trunk, as prolonged sitting predisposes to a 'stooped' position, protraction of the shoulder girdle and head (increased cervical curvature or double curvature) and increased kyphosis of the thoracic spine. These adverse positions lead to the shortening of the pectoral muscles and elongation of the back muscles, in other words lead to muscle imbalance. Muscle imbalances are also observed in the abdominal muscles and the extensor muscles of the lumbar spine. The abdominal muscles are generally prone to weakening and therefore the lumbar muscles are subjected to a significant degree of eccentric stress in the sitting position. The sedentary lifestyle is usually associated with a persistent shortening of the ischiocrural muscles, which, in turn results in a weakening of the lumbar muscles, a backward tilt of the pelvis, increased flexion of the lumbar spine, protrusion of the abdominal soft tissues, and eventually the development of further complaints. The complexity of the effects of prolonged sitting is also demonstrated by the fact that the body's energy requirements are persistently low, so that the energy and nutrient requirements (and utilisation) of the lumbar region are significantly below the recommendations for health maintenance. Reduced metabolism and poorer circulation in the soft tissues of the lower back can lead to long-term muscle degeneration and osteoporosis, and lack of exercise can also lead to stiff joints.

II.2.2. Prevention at work

In a systematic review published in 2009, *Bell and Burnett* examined primary, secondary and tertiary prevention methods for low back pain in workplace settings, considering clusters of workers in different job roles. Based on the studies reviewed, there is limited evidence on the overall effectiveness of exercise in reducing the incidence of low back pain or sick leave, but there is evidence that exercise reduces the intensity and severity of LBP and the degree of immobility or functional limitation due to pain. The methodology of the included studies was heterogeneous, with exercise sessions ranging in duration from 5 to 60 minutes, frequency ranging from 6 sessions per month to every working day, and intensity ranging from light to moderate. Among the studies, only two studies used a multidimensional approach, but in these studies gymnastic exercises were only a minimal part of the intervention, which was

predominantly ergonomic and theoretical. In the reviewed articles, the compliance rate, i.e. the cooperation of participants, was about 76% when participation in all training sessions was expected and about 51% when participation in more than 50% of all training sessions was considered, but a common methodological gap in the studies is the lack of assessment of cooperation and adherence. The analysis found that significant improvements in LBP incidence and pain intensity could be achieved with 5-17 minutes (average 10 minutes) of training during working hours every working day. The authors emphasised that the success and effectiveness of workplace programmes are strongly influenced by the motivation and adherence of participants to the programme, with time availability playing a key role, as lack of it was found to be the most common limiting factor. Training sessions of short duration are more appropriate for employees as they do not reduce productivity, and adherence can be further increased if the intervention includes different methods of social cognitive theory (9).

A meta-analysis published by *Sowah et al.* in 2018 found that a workplace exercise programme alone or supplemented with theoretical education was effective in preventing LBP (31).

A 2020 systematic review and meta-analysis by *De Campos et al.* found similar results, examining the subsequent observable effects of prevention strategies on low back pain intensity and associated disability. In their analysis, only randomised controlled trials were selected, with pain and disability as the primary outcome indicators and quality of life test scores as secondary indicators. Their analysis found moderate-strength evidence that physical training alone, as well as interventions combining exercise and education, are effective in reducing future LBP intensity and associated disability (32).

The authors of the above papers agree that, given the paucity of evidence on this topic, further high-quality randomised controlled trials are needed to better explore the effects of prevention programmes.

II.2.3. Applicable practices

In order to prevent the adverse consequences already described in relation to low back pain, it is important to pay particular attention to developing the strength of the m. multifidus and core muscles, and the correct temporal activation of the muscles responsible for stabilisation and mobility. However, many other aspects such as improving posture, muscle flexibility or theoretical and ergonomic training should also be taken into account and should be combined in a targeted and comprehensive multidimensional training. Several previous studies have examined the effectiveness of different types of interventions to prevent or treat low back pain.

A systematic review and meta-analysis published by *Gomes-Neto et al.* in 2017 found that segmental stabilisation exercise was as effective as manual therapy, but was more effective in terms of reducing pain intensity and disability compared with general strengthening exercises for superficial trunk muscles (33).

Sipaviciene and Kliziene's randomised controlled trial analysed the effects of exercise programmes for lumbar segmental stabilisation (n=35) and core muscle strengthening (n=35) in sedentary women with low back pain. Both interventions lasted 20 weeks, with participants training twice a week for 45 minutes. Their results showed that both programmes were effective

in reducing symptoms and functional disability associated with low back pain and in increasing the cross-sectional area of the m. multifidus muscle, but that lumbar stabilisation was significantly more effective than general strengthening (34).

As a consequence of low back pain, the function of the proprioceptive system, i.e. joint position perception and appropriate muscle tone adjustment, may be significantly impaired. After a systematic review of the literature, *Tong et al.* concluded that there is clear evidence of impaired lumbar proprioception in individuals with low back pain, most commonly associated with prolonged sitting in a sloppy posture (35), and that it is worth considering the integration of exercises that affect the proprioceptive system.

In a case-control study, *Areeudomwong et al.* analysed the effects of *Proprioceptive Neuromuscular Facilitation (PNF)* technique on symptoms and changes in balance ability. The physiotherapist-led intervention was delivered over a three-week period, three times a week for 30-40 minutes. The progression of the exercises was determined by varying weekly tasks. Although the training was short and the number of subjects was small, the results showed a small but positive effect on pain intensity, disability and static balance (36).

A comprehensive network meta-analysis was published by *Hayden et al.* in 2021, which ranked the effectiveness of different movement therapy methods for chronic low back pain in comparison with other physiotherapy treatments. In terms of physical training, they considered 'core' strengthening/motor control; combined training methods; general strengthening; aerobic exercises; Pilates; stretching; yoga; functional rehabilitation; McKenzie therapy; and other specific exercise methods, and placebo (no treatment); patient education; manual therapy; spinal school; electrotherapy; combined physiotherapy (without physical training); psychotherapy; anti-inflammatory and analgesic; and relaxation were selected for interventions without movement therapy. Outcome indicators were pain intensity and functional limitation of the lower back. A network analysis of the data was performed using 217 randomised controlled trials with data from 507 treatment groups and 20,969 participants; 10% of the trials were conducted in a workplace setting. In order of distribution by type of intervention, core strength development (30%), mixed or combined exercises - combining three or more types - (26%) and general strengthening exercises (12%) were the most frequently studied methods. In addition, 45% of interventions were "back (waist) specific" and 29% targeted the whole body. Exercise programmes were 19% individual, 19% semi-individual and 45% standardised group training, with most groups using complementary interventions (57%), the most common of which was counselling and education (31%). Exercise programmes examined were mostly delivered in supervised group settings (40%) or under the supervision of an individual health care provider (39%). The median length of training programmes was 8 weeks; the median total treatment time was 12 hours. The results suggest that Pilates, core strengthening, McKenzie therapy and functional rehabilitation and flexibility exercises were effective in reducing pain intensity and functional limitation (10).

II.2.4. Idiag SpinalMouse - Testing the spine in the workplace

During a screening and health assessment in a workplace environment, or for the purpose of assessing the impact of a programme, it is important to collect valid and reliable data on the worker. In designing our programme, we looked for an instrument that could be used to

perform a physical examination of a large number of workers in a workplace environment, simply and quickly, and to process the data to determine the static and mobility characteristics of the spine of the target population. We considered that the *SpinalMouse*® could be a suitable tool to collect relevant data, as several previous studies have already demonstrated the reliability and validity of the tool.

The *SpinalMouse* is a relatively novel non-invasive telemetry device that can assess spinal curvature, mobility and functionality using a Bluetooth connection and computer software, and can therefore be easily used in workplace interventions. The reliability of the device was also investigated by *Kellis et al.* by assessing 81 healthy male children (10.62 ± 1.73 years) in the sagittal plane in standing, flexion and extension positions using three examiners on two different days. Their results showed that the reliability of the measurements of thoracic and lumbar curvatures was strong (37). Similar conclusions were reached by *Post and Leferink* based on a comparison of data from healthy subjects and patients, who had recovered from spinal fracture ($n=111$), but they also questioned the validity and reliability of the measurement of inter-segmental angles (38). *Mannion et al.* had also found similar results in a small healthy population, but their results showed that the instrument could only reliably measure the position and range of motion of the spine and its segments, whereas *Post and Leferink's* position was supported for the measurement of inter-segmental angles. Nevertheless, they strongly recommend the use of *SpinalMouse* in clinical trials, for research purposes in the workplace, and in ergonomics and seating design to measure the overall sagittal profile and regional range of motion of the spine (39).

In addition to evaluating the reliability and validity of the test tool, several authors have reported that *SpinalMouse* is an excellent tool for assessing the impact of interventions in large target populations. This tool was used by *Celenay et al.* to analyse the effects of four different therapeutic methods on spinal statics and mobility in ninety-six university students, in which the position and mobility of the lumbar and thoracic spine in the sagittal plane were assessed. Their measurements showed statistically significant ($p < 0.05$) differences in both sitting and standing positions compared to data collected in baseline studies (40). *Feng et al.* conducted a randomised case-control study involving 164 senior high school students in Beijing. The subjects included had a thoracic spine curvature above 40° and were randomly assigned to intervention and control groups. In each group, spinal position and mobility were measured using *SpinalMouse* to determine the effects of a targeted exercise programme in the target group. Pre- and post-intervention tests were performed in the sagittal plane in the vertical, flexion and extension positions of the trunk, showing a significant ($p=0.002$) change in spinal inclination in the intervention group (41).

Several previous studies have shown that skin surface assessment of spinal position and mobility can be performed quickly and efficiently in a workplace setting, providing reliable data for determining spinal characteristics of sedentary workers, and can be used effectively to evaluate the effects of targeted physical training in workplace health promotion programmes. Based on the literature review, the use of the spinal tap appears to be an interesting new option, as it allows for more precise data acquisition and processing compared to traditional manual physiotherapy examinations. In addition to the accuracy of the device, the speed and

repeatability of the examination may be an important factor, but experience in this area can only be gained through actual use and practice.

II.3. Objectives and hypotheses of the research

The overall aim of the research was to develop and implement an effective, sustainable health promotion intervention programme in a workplace setting, which is suitable for reducing and preventing musculoskeletal complaints and low back pain in workers, as well as improving their fitness and coordination skills and increasing their activity level. In order to achieve the overall objectives, sub-objectives were identified and implemented through a preparatory study and pilot programmes.

The primary aim of our preliminary cross-sectional study was to assess the physical condition, physical activity level and theoretical knowledge of low back pain of the target group that met the inclusion criteria. Secondary objectives were to evaluate the ultra-short and long-term effects of a minimal intervention based on theoretical training; and to test the testing tools and methods, assess feasibility and gain experience with them.

The aim of the pilot programmes was to test and evaluate the feasibility and impact of three different types of workplace physical activity programmes, thus providing an opportunity to collect data and gain experience on the applicability and effectiveness of different practices and methods, as well as on the structure and acceptability of the programmes. The exercise programmes (office-based gymnastics; stretching and trigger massage; functional training) were all conducted for 10 weeks, 2 x 1 hour per week, and the results of the exercise programmes and the baseline and follow-up assessments were reported in a thesis by the physiotherapy students under my supervision, and are therefore not included in this thesis.

The aim of the main study was to implement a 20-week *Multimodal Progressive Functional Training Programme* in a workplace setting, to gain experience of its implementation and to evaluate its impact. Due to space limitations, the shortened version of dissertation is limited to the results of the main study.

Hypotheses from the main study:

We hypothesized that:

- of all the musculoskeletal pains reported in the questionnaire survey, low back pain was the most frequently reported complaint, with the most frequently reported cause being a sedentary posture.
- in the study population the number of hours spent sitting on an average weekday exceeds eight hours on average, and at least half of the respondents do not perform the level of physical activity recommended by the WHO as necessary for good health.
- significant changes in spinal mobility and posture in the frontal and sagittal planes, both sitting and standing, were observed as a result of the programme.
- the programme has resulted in significant improvements in thoracic mobility, trunk and ischiocrural muscle flexibility, coordination and balance, static and dynamic core muscular strength and endurance,

- ischiocrural muscle flexibility and frontal plane mobility of the spine; trunk stabilizer muscle strength and thoracic mobility; and trunk stabilizer muscle strength and balancing ability show significant positive correlations.
- after the intervention, at least three quarters of participants are satisfied with the content of the programme; their complaints are reduced or eliminated; they apply the exercises learned and report noticeable changes in posture, endurance and theoretical knowledge.

III. MATERIALS AND METHODS

III.1. Circumstances of the study

We conducted an intervention cohort study among sedentary workers of *NI Hungary Kft.*, a Hungarian subsidiary of *National Instruments Corporation (Austin, Texas, USA)*, at its Debrecen site. Prior to our main study, we tested three different types of workplace exercise programs of 1 hour twice a week for 10 weeks, which were performed by physiotherapy students under my supervision and guidance, and the results were reported in their thesis. The three programmes mentioned above - office-based exercise programme; stretching and trigger point massage programme; functional training programme - and our experience from the pilot study described above, together with the results of the trials, were used to develop the methods used in the main study. Prior to the intervention programme, we conducted physical examinations (preIFV) among volunteer participants between the 9th of November and 7th of December 2018. The workplace physical activity programme for the target group was implemented at the company's fitness centre over a 20-week period between the 28th of January and 14th of June 2019. After the intervention, a post-intervention physical examination (post-IFV) was conducted between the 17th and 28th June 2019 among employees who met the inclusion criteria of the post-intervention study. From the company's 1,452 employees at the time, we invited employees to participate in our programme who had been suffering from lumbar spine complaints and low back pain over the previous 12 months, and who also performed their daily tasks in a sedentary position. For the workers concerned, we developed a 20-week *Multimodal Progressive Functional Training Programme (MPFTP)*, specifically structured to be delivered in the workplace during working hours.

To identify the target group, in October, we sent several online questionnaires to all employees via the company's electronic newsletter, accompanied by a motivation letter presenting the schedule and content of the physical examinations and the "*New Spine Programme*". In the invitation, we detailed the inclusion and exclusion criteria for the examination; information on the dates, locations and schedule of the physiotherapy examinations; the content and schedule of the training programme; and information on how to apply for the physiotherapy examinations and training. Inclusion criteria were: sedentary work; presence of acute or chronic non-specific low back pain; history of a low back pain episode in the last 12 months; no other known diagnosed musculoskeletal, internal medicine or other conditions; age between 20 and 60 years; willing and able to participate in the Training Programme. Exclusion criteria were the following: the subject did not complete the Pre-Intervention Questionnaire; did not participate in the Pre-Intervention Examinations; attended less than 30 sessions; did not complete the Post-Intervention Questionnaire; and did not sign the Informed Consent Form.

Subsequently, workers who met the inclusion criteria and were willing and able to participate in the physical examinations and the training programme were asked to complete a pre-intervention questionnaire (pre-IK).

During Recognition Week, a series of events for company employees in October, I gave two introductory presentations on the New Spine Programme. Participation in the Training

Program was contingent upon completion of the preIK and attendance at the physical examination, but, in compliance with the employer's request, completion of the preIK was not a prerequisite for attendance at the pre-intervention examinations.

The pre-intervention questionnaire (pre-IK) was distributed among the employees of the company, but the pre-intervention physical examinations (pre-IFV) were made available to a limited number of participants - 250 - due to the location and timeframe made available by the employer. The intake capacity of the Training Programme was set at 160 participants and the post-intervention questionnaire (postIK) (Annex 10) was only sent to those who had participated in the training programme, and the post-intervention physical examination (postIFV) was only organised for those who met the inclusion criteria for the re-selection.

The pre-intervention physical examination was carried out in the company's medical room and fitness room with the help of 18 physiotherapy students. The students practiced the test method delegated to them prior to the tests and performed the same test during both pre- and post-tests. The physical examination of a subject took one hour and was conducted in rotation at ten different examination sites. The order of the examinations was different for each subject arriving at the same time during the hour, as the time needed for the physical examination was short, only by using the 'rotation system'. As the employer's requirement was that workers had a maximum of one hour to complete the examinations, different predefined and printed schedules were used. In order to avoid congestion and speed up the process, the timetable issued helped participants to follow their own examination sequence and complete the examinations within the time interval. The recovery time between each test was defined between a minimum of 2 and a maximum of 5 minutes, taking into account the subject's subjective exhaustion (Rate of Perceived Exertion - RPE), monitored using the Borg CR-10 scale. Subjects were only allowed to start the next physical test if the RPE value marked on the Borg scale (42) was 1-2 or less. A longer recovery time was provided in individual cases where the subject was not able to achieve near full recovery in the available 5 min. The length of the rest interval was determined according to the *American Society of Exercise Physiologists'* recommendation for accurate assessment of muscle strength and performance, as random sequencing of tests and inappropriate rest intervals would have confounded and adversely affected test results (43-45). The pre-intervention physical examination took five days and the post-intervention examination two days. Participants were asked to create their own test code using specific numbers extracted from their ID number, the initials of their first and last name, and their mother's year of birth, thus ensuring anonymity of participation in the study, so that the person's test code was the only way to self-identify. These codes were used by participants during data collection, during physical examinations, and registration for the training programme, when signing the attendance sheets and as passwords to download and open the pre- and post-intervention physical examination results sheets from the online database. Participants signed the "Informed Consent Form" for the handling of their data at the time of the physical examination.

The 20-week exercise programme was conducted with the help of two physiotherapy students at the company's fitness centre. The sessions were available alternately in the morning or afternoon of each working day. Four training sessions were organised daily, each lasting 30 minutes. Up to 20 participants could register online for each session and could choose the day

and specific time in the schedule according to their daily work commitments and workload. Attendance, i.e. adherence, was measured by means of attendance sheets, i.e., subjects signed the document with their own study code. In addition to specific physical exercises, the workers received theoretical training during each session on correct posture, correct performance of exercises and functional tasks, ergonomics of work (sitting, standing, lifting weights and other activities). The progression of the training programme was defined in a training plan with a weekly variation in the training theme and, accordingly, each session in a given week contained exactly the same exercises, number of repetitions and theoretical training material. Participants in the exercise programme were encouraged to attend at least three sessions per week, if possible. A minimum requirement for statistical analysis of the data was set for the impact of the intervention, so only those participants who attended at least 50% of the recommended 60 sessions, i.e. at least 30 sessions, were included.

At the end of the training programme, all participants were asked to answer questions on the post-intervention questionnaire, which focused mainly on participants' subjective experiences and satisfaction. When conducting the post-intervention physical survey, only subjects who had participated in at least 30 or more sessions were invited to participate.

III.1.1. Pre-Intervention Questionnaire

The online questionnaire asked about gender, age, perceived health status, musculoskeletal symptoms and complaints in the past year, painful regions, time spent sitting at work and at leisure, and also assessed willingness to participate in physical examinations and training. A total of 38 questions were included in the questionnaire, of which 26 questions on daily physical activity level were based on the *International Physical Activity Questionnaire* (46).

III.1.2. Physical examination

III.1.2.1. SpinalMouse

The SpinalMouse is a wireless, bluetooth-connected electronic instrument for non-invasive skin surface measurement, suitable for computer imaging and radiation-free examination of the spine. It is recommended by the manufacturer for the assessment of inter-segmental mobility of the spine, the range of motion of the whole spine and individual segments, and the assessment of posture. In our study, instrumental tests were performed in the sagittal and frontal planes, in the sitting and standing postures in upright and full flexion and extension, and in the left and right lateral-flexion end positions. Before the start of the study, all participants were registered in the SpinalMouse software by entering gender, age and randomly assigned test codes. After upper body undressing and palpation of the spinal column and spinous process, an assistant marked reference points on the skin surface, with the spinous process of the C7 and S3 vertebrae as the starting and end points of the test. Workers were tested in standing and sitting postures, with the spine at rest, erect but uncorrected, and during maximal trunk flexion and extension. The test head of the instrument was rolled along the paravertebral line in a distal direction between the C7 and S3 vertebrae along the spinous process, so that the software recorded the spatial position of the skin contour over the vertebral

bodies in the sagittal and frontal planes. The tests were performed only once, according to the verbal instructions of the examiner, and were not preceded by any warm-up or practice (38).

The data collected were used to determine the inter-segmental angles measured in each position and the inclination of the whole and some sections of the spine relative to the vertical axis perpendicular to the ground (47,48).

III.1.2.2. Chest expansion - mobility

Chest expansion was measured at three levels of the thorax using a measuring tape. Measurements were taken during complete inspiration and complete expiration at the level of the axilla (CEA), the level of the xiphoid process of the sternum (CEX) and the level of the tenth ribs (CER). The chest expansion on each level was determined by subtracting the expiration values from inspiration values. The examination was performed only once following 2 or 3 repetitions of forced inhalation and exhalation according to the verbal instruction of the examiner (49,50).

III.1.2.3. Sit and Reach Test

The *Sit and Reach test* for the examination of spinal and hamstring flexibility was performed using a *Sit and Reach Box (SRB)* (*Cartwright Fitness Ltd., Chester, UK*). The SRB was set to the baseline of 15 cm. The participants were asked to sit on the floor in a long-sit position, with full extension of the knees, while the soles of the feet were positioned against the surface of the box with a neutral position (90°) for the ankle. After two repetitions of warm-up practice, two measurements were recorded by the examiner. A ruler was used to mark the “zero” point, from which it was pushed forward on the superior surface of the SRB. The subjects were asked to place the dominant palm on the contralateral one facing downward and bend forward with the trunk as far as possible, with the knees kept extended and sliding the ruler on the SRB with the tip of the fingers. Statistical analysis was performed in relation to both measurements and the average of those as well (51).

III.1.2.4. Y-Balance Test

The instrumented version of the lower quarter *Y-Balance Test (YBT)* (*Functional Movement Ltd., London, UK*) was primarily used to determine the dynamic balance of the lower extremities. The participants were asked to stand on the centre of the equipment with one leg and reach with the contralateral leg toward the anterior, posteromedial and posterolateral directions, while pushing a slider on the bars located on those directions as far as possible. All three bars present the reach distance in cm; hence, the results can easily be registered. The subjects were asked to practice the task three times on each side in each direction prior to the three recorded trials. They were also asked to maintain a single leg squat stance, while keeping their hands on their hips and full contact of their foot on the supporting surface, without touching the ground with their contralateral foot. If the trial failed to meet these requirements, the result was unsuccessful. Practice and recorded trials started with a right foot stance on the YBT platform, and after the completion of three trials for one reach direction, the subjects were

allowed to perform the same reach direction with a left foot stance. The results of the trials were averaged and recorded in each direction without leg length normalization (52).

III.1.2.5. Prone Bridging Test

The *Prone Bridging Test* was used to measure the static, isometric core strength. The participants were directed by one tester via verbal and manual assistance, and were asked to get into a prone forearm plank position and hold it correctly as far as possible: both forearms were placed on the floor, parallel to the midline; the palms were facing the floor, and the elbows were placed under the glenohumeral joints; both humeri were perpendicular to the ground; both scapulae were stabilized on the plane of the dorsal thorax; the head, neck, trunk and lumbo-pelvic-hip complex were in a neutral position; the knees were extended; the toes were placed on the floor, and the ankles were in a neutral position. Another tester inspected the subject and started a digital timer when the correct posture was located. The timer was stopped as soon as voluntary termination of the test occurred due to any reason; the tester noticed or the participant reported signs and symptoms of exhaustion; or the subject repeatedly failed to maintain the proper position—after a first verbal warning from the investigator. The test was conducted only once according to the verbal and visual instructions of the examiner, without warm-up or practice, and the results were recorded in seconds (53).

III.1.2.6. Side Bridging Test

The *Side Bridging Test* was used to measure the static, isometric strength of the left- and right-sided core musculature. The participants were asked to suspend the whole torso, keeping its neutral position from a starting side-lying position on a mat, while only the edge of the foot, the elbow, the forearm and the hand were supported by the floor on the test side, and they were asked to maintain the side bridging as far as possible. The side plank was performed on both sides, with a neutral lumbo-pelvic-hip complex, in line with the trunk, neck and head, with the extension of the knees and a neutral ankle position on both sides. The superior ankle was placed on the inferior one, and the superior arm was beside the trunk. The supporting shoulder was abducted to circa 80–85° without rotation; the elbow was placed just beneath the glenohumeral joint, so the humerus was perpendicular to the ground, and the forearm was supported in a pro-supinated position. The same testing process was used as described above in the Plank Test; the procedure was performed with right-side prior to left-side bridging (54,55).

III.1.2.7. Timed Abdominal Curl Test

The *Timed Abdominal Curl Test* was used to measure the dynamic endurance of the superficial trunk flexor muscles. The subjects were asked to lie down on a mat in a supine position while the lower limbs were supported by a height-adjustable box at 90–90° of flexion in the hip and knees and with arms crossed in front of the chest. The participants were instructed to lift up the head, neck and shoulder until the elbows were touching the thigh while the lumbar spine and pelvis were stabilized on the ground. The pace of the performance was given by the sound of a metronome (50 beat/min), and the cadence was set to 25 repetitions/min; thus, equal time was spent for curling up and down. The recording of the time and repetition number was

started at the beginning of the exercise and ended immediately at the end of the last correct performance. The test was conducted only once according to the verbal and visual instructions of the examiner without warm-up or practice, and the results were recorded in seconds and as the repetition number (56,57).

III.1.2.8. Modified Biering-Sorensen Test

The static, isometric trunk extensor endurance test was performed according to the modified version of the method of *Biering-Sorensen et al.* (58). The participants were positioned on the examination table in a prone position with the lower limbs and the pelvis supported. The trunk was unsupported by the table, but a chair was used to help the subject in manually carrying the trunk while the legs and pelvis were stabilized by three mobilization belts with metal buckles. The subjects were asked to place the elbows laterally, put their hands under the forehead and lift up the trunk to the horizontal plane. As soon as a horizontal position was reached, an inclinometer was placed on the back of the trunk, between the scapulae. At this moment, a digital timer was started, and when the subject failed to further maintain the position, the test was terminated. The test was conducted only once according to the verbal instructions of the examiner, without warm-up or practice, and the results were recorded in seconds (58).

III.1.3. Multimodal Progressive Functional Training Program

Our “*Multimodal Progressive Functional Training Program*” is a newly developed and unique physical exercise program, which was specifically designed for workplaces by addressing the special needs and characteristics of sedentary employees in order to promote their health and to reduce occupational musculoskeletal diseases and non-specific LBP. The training program was structured by a weekly changing progressive schedule. The foundation of the training was the segmental stabilization in order to activate and re-educate the main deep superficial stabilizers of the lumbar spine in a precisely positioned neutral–anatomical position. The exercises built on this basis progressed from a lying through sitting to standing position, from a stable and larger to an unstable and smaller support surface, and from simple to complex tasks; thus, more complicated exercises with multiplanar movements were progressively performed (34,59). The training was multimodal, since ergonomic education, stretching, self-myofascial release, segmental stabilization, the isometric and isotonic strengthening of the muscular system, the stimulation of the proprioceptive system and dynamic functional training exercises were applied.

Every training session started with 5 min mobility and light aerobic exercises. Except for the stretching sessions—which started with a 10 min warm up—every training session ended with a 5 min stretching exercise preferably for the main muscles involved. The performance of the exercises and segmental stabilization were inspected; an inappropriate position was corrected verbally and/or manually if required. The progression of the exercises was determined by increasing the length of the exercise: (a) from the basic 3–5 s gradually up to 30 s during the 3rd–4th week; (b) from the basic 15 s gradually up to 30 s during the 5th–6th week; (c) from the basic 30 s up to 45 s during the 7th–8th week. Breathing exercises were performed during rest periods of (a) 3–5 s, (b) 5–10 s (c) and 10–15 s. The exercises were performed in 4 repetition sets with longer rest periods in between. The numbers of sets during

the sessions were dependent on the given length of each exercise and rest periods. From the 9th week up to the 20th week, the length of an exercise was 45 s with a 15 s rest period in 4 repetition sets, and 4 sets of different exercises were performed during a session. The participants were allowed to have some rest during the exercises according to their subjective sensation of fatigue.

The intervention included two articles supplemented with photos and created by the instructors were distributed to the employees through the company's electronic channels. Our first article covered the most important stretching exercises, while the second piece of written material presented the theoretical background and technical implementation of trigger-point massage. The aim of the materials sent out was to increase the motivation and theoretical knowledge of the participants and to increase their activity.

III.1.3.1. Ergonomic Instructions, Stretching Techniques and Self-Myofascial Release

During the first 2-week period of the intervention we intended to teach and enable participants to practice the active and passive stretching exercises used during the training program, first without and then with tools (e.g., a towel). Pain relief, myofascial compression and self-massage were performed using a self-myofascial release (SMR) foam roller and *TriggerPoint MB5 (12.7 cm)* foam massage balls. The theoretical education was intended to teach and to enable practicing ergonomic aspects related to work and physical activity, which continued throughout the program in line with the theme of physical training.

III.1.3.2. Segmental Stabilization of Lumbar Spine

During the second 2-week period our goal was to teach and enable the practice of conscious, voluntary segmental lumbopelvic stabilization using the abdominal drawing-in maneuver (ADIM) (60). The participants were asked to lie on the mat in a straight but relaxed position and search and feel for the proper neutral position of the pelvis and lumbar spine. Verbal explanations helped in the required positioning, and the subjects had been taught to manually palpate and control the anterior superior iliac spine (ASIS) and symphysis pubis in line with the horizontal plane. After correct positioning, the subject was taught—following *Saliba et al.* (61) to contract the deep core musculature, focusing on the multifidus, abdominal transverse, and pelvic floor muscles, without the contraction of superficial muscles or any movement of the pelvis and spine. The verification of proper contraction was carried out by both the physiotherapist and the subject. Supine bridging was performed with a slow hip extension by raising the pelvis and the trunk in a block by hip extension until reaching the trunk and femur in line.

III.1.3.3. Static Strengthening of Core Musculature

The aim of the fifth week training was to maintain segmental stabilization while performing static, isometric exercises: prone plank and side plank in a kneeling position. The position of the trunk and femur was the same as described above in the Plank and Side Plank Test, with the difference that the knees were bent at 90° and the superior arms were abducted toward the ceiling in side bridging. The position decreases the effect of gravity relative to the

original method due to a shorter lever arm and increases stability due to a larger supporting surface. Only those who were able to complete the task without mistake were allowed to perform the original plank.

III.1.3.4. Segmental Stabilization Combined with Dynamic Exercises on Stable and Unstable Surfaces

During the sixth week focus was placed on an introduction to proprioceptive exercises by gradually decreasing the size of the supporting surface and switching from stable to unstable surfaces. In case of supine bridging, progression was determined according to the following: (1) bilateral stable bridging; (2) bilateral stable bridging with one-sided knee extension; (3) unilateral stable bridging; (4) bilateral unstable bridging; (5) bilateral unstable bridging with one-sided knee extension; (6) unilateral unstable bridging. Instability was created using a foam roller. Unstable support was created by using Swiss balls to make the plank exercises on a stable surface more difficult, but also by using bilateral and then unilateral support.

III.1.3.5. Basic Functional Exercises in Different Positions

The following exercises were used in the seventh and eighth weeks of the program, based on well-established segmental stabilization. A supine leg raise was performed with one-sided lower limb support (hip–knee flexion, with feet flat); supine leg lowering was performed from a bilateral 90 degrees of hip and knee flexion to unilateral and then bilateral hip and knee extension. A Swiss ball was used in sitting exercises for tilting the trunk to the anterior and posterior directions, in supine exercises for abdominal crunches and hamstring curls, and in prone exercises for back extension while maintaining segmental stabilization of the core. The most important standing exercises were lunges, squats and repeated bilateral side-step squats.

III.1.3.6. Functional Training

During the phase (9.-20. week) of Functional Training, the group was divided into two subgroups, and circuit training was performed. One subgroup performed exercises chosen from the previous phases of the training program; the other subgroup used a Suspension Trainer in order to perform unstable, multi-planar, functional exercises. As described above, in this section, 4 sets of different exercises were performed with 4 repetitions of each exercise. One repetition of an exercise lasted for 45 s, followed by 15 s of recovery, and a 1 min recovery time was allowed between the sets. None of the exercises were compulsory to complete; all the participants had the opportunity to ask for a given exercise to be changed to an easier or harder one. The exercises in this phase were chosen from those listed below, taking into account the principle of gradation, progression and individual subjective sensation of exhaustion or capability during the 12 weeks of functional training. Due to the factors listed above, the sequence and weekly progression of the exercises used in this phase cannot be generalized or defined precisely.

III.1.4. Post-Intervention Questionnaire

The post-interventional questionnaire focused on the subjective opinions of the participants in relation to the training program. The questions among the others were focused on perceived health, on changes in previous symptoms and complaints, on changes in posture and endurance, on the adherence rate, on the perceived improvement of knowledge in health-related topics, on the musculoskeletal symptoms during the training program on the usefulness of the content learned during the training program, on the capability of incorporating the content learned during the training program in daily living, and on the exercises that were practiced at home. The *Net Promoter Score (NPS)* was used to assess how much the participants supported and recommended the training program. The score divided the respondents into three subgroups of “detractors” (0–6), “passives” (7–8) and “promoters” (9–10) according to the points (0–10) given by the subjects. To calculate the NPS, we subtracted the percentage of “detractors” from the percentage of “promoters”. The classification of the training program related to the satisfaction and loyalty of the participants can be determined according to the NPS as follows: a need for improvement between –100 and 0%, a good rating between 0 and 30%, a great rating between 30 and 70%, and an excellent rating between 70 and 100% (62).

III.1.5. Statistical Analysis

A priori sample size calculation was performed with a power level of 90% and an α level of 0.05 using means (45.22 and 49.81) and standard deviations (7.21 and 6.99) relating to the flexibility of the spine and hamstring muscles based on the study of Muyor et al. (63).

A Shapiro–Wilk test was used to check the normality of the continuous variables. Since most of the data did not follow normal distributions, non-parametric Wilcoxon signed-rank tests were used. Categorical data were analysed using chi-square tests. Data are presented as medians and interquartile ranges (IQR) in the case of continuous variables and as percentages in the case of categorical variables. The Spearman rho-s were calculated in order to check the correlation between the variables related to the physical examination. The results were considered as significant if the p-values were below 0.05. The data were processed using *Microsoft Excel* and the *Intercooled STATA version 13.0 software*.

III.1.6. Ethical Approval

The study was approved by the *Ethics Committee of the University of Debrecen (5103-2018)*, and the participants gave informed consent.

IV. RESULTS

IV.1. Results of the study

An open call for the study was introduced to the employees of the company. After voluntary application, a total of 236 subjects completed the pre-intervention questionnaire, 247 subjects participated in the pre-intervention physical examination, 91 subjects completed the post-intervention questionnaire, and 76 subjects were eligible for the post-intervention physical examination, which is above our calculated minimal needed sample size ($n = 51$).

IV.1.1.1. Pre-Intervention Questionnaire

For an open-call invitation, a total of 236 persons completed the pre-intervention questionnaire, 109 male and 127 female participants with a mean age of 32.94 ± 7.26 years. More than 80% of the participants had a college or university degree and 95.35% worked in an administrative job. In terms of perceived health, two-thirds rated their own health as good or very good and one-third rated it as "satisfactory", while all respondents felt they could do a great deal for their health. In the one-year period preceding the survey, 88.6% of respondents had experienced some musculoskeletal complaint, with the lumbar spine (73.7%) being the most common, followed by pain localized in the shoulder joint (61.0%) and the thoracic (44.1%) and cervical (39.8%) spines.

Based on the questions of *International Physical Activity Questionnaire* on physical activity, our results show that 94.4% of workers never perform heavy physical work at work, 74.2% do not perform light physical work, while only 11% perform such an intensive activity once a week.

In the week prior to the survey, only one fifth of respondents walked at least 10 minutes every day as part of their work, only 17.4% walked during working hours on 5 days of the week, while 39.4% did not walk at all. In terms of transport, 42.4% of respondents usually travel by car or public transport every day and 31.8% on 5 or 6 days of the week outside working hours, while 69.1% never choose to cycle as an alternative means of transport. Outside of working hours, 17.8% of respondents do not walk for 10 minutes or more on any day, 45.8% do not do any heavy physical work and 25.4% do not do any light physical work around the house. In terms of domestic work, 19.1% of respondents do at least 10 minutes of light physical work every day and only 3.8% indicated that they did not do this activity on any day.

In terms of purposeful physical activity, 13.6% walked at least 10 minutes every day in their leisure time, but 18.2% did not choose this form of physical activity on any day. 39.8% of the participants in the study did not undertake more intense physical activity, i.e. strenuous exercise for at least 10 minutes, and 48.3% did not engage in non-strenuous exercise on any day. 67.8% of respondents sit for more than 8 hours during an average day and 26.7% spend more than 5 hours on average in this position. 99.2% of respondents would like to take part in a fitness assessment at work and 91.9% would like to join a physical activity programme led by a physiotherapist.

During the week prior to the survey, 94.49% of the respondents did not perform any heavy physical work at work, while 5.51% of the study population performed such activities for an average of 72.1 ± 91.11 minutes. 74.15% did not perform light physical work at all, while 25.85% performed light work for an average duration of 39.28 ± 147.53 minutes. As a part of work, 66.53% of the study population spent time walking (86.55 ± 131.8 minutes) during the last week, while 33.47% did not walk at all during working hours.

In the daily breakdown, 89.41% of the respondents spent an average of 55.95 ± 49.72 minutes in a motor vehicle outside work, while 16.95% did not use such means of transport. Half of the respondents did heavy physical work in the household for an average of 19.05 ± 33.91 minutes per day, while 90.68% did light physical work for an average of 47.62 ± 45.7 minutes per day. 78.39% of the respondents spent their leisure time doing daily walking (31.44 ± 38.34

minutes), 56.78% in strenuous physical activity (34.29±39.38 minutes) and 48.31% non-strenuous physical activity (21.43±32.31 minutes). When asked about the average number of hours spent sitting during a weekday, 95.76% of the participants reported some duration, which averaged 502.96±167.52 minutes, or 8.38±2.79 hours. Regarding the number of hours spent sitting on an average weekend day, 94.07% reported back that they sat for an average of 342.48±223.42 minutes, or 5.71±3.72 hours on a day off.

IV.1.2. Results of the SpinalMouse examination

A total of 76 subjects were eligible for the post-intervention physical examination, 45 males and 31 females, with a mean age of 32.78±6.59 years. The following is a comparison of the results of the pre- and post-intervention tests performed using the *Idiag SpinalMouse* measurement tool, i.e., the impact of the exercise program on spinal mobility and posture.

The results of the frontal plane test performed in the sitting position showed slight changes in individual spinal motion segments and in the position and mobility of the whole spine. Significant increases were detected only in the end position of the left lateral-flexion (before -0.85° [IQR -2.65-1.55°] - after -2.15° [IQR -4.15-0.1°]) and the ROM from neutral position to left lateral-flexion (before -1.4° [IQR -3.7-1.3°] - after 2.55° [IQR -4.35-0.11°]). Although adverse changes were observed regionally for the lumbar spine (in positions LE, U and U-L) and thoracic spine (in positions U, RI, U-L and U-R), the total spinal column inclination still showed an increase in all aspects studied except for the neutral position (U). There were also regional improvements in the total frontal plane range of motion (L-R), but these changes were not significant. Neutral inclination of the spine (U) decreased favourably (before 1.45° [IQR 0.5-2.35°] - after 1.35° [IQR 0.45-2.4°]), indicating a favourable change close to physiological, but this change was also not significant.

The results of the frontal plane examination in the standing position showed more significant favourable differences in the position and mobility of individual spinal motion segments and the whole spine compared to the changes observed in the sitting position. The positive increase in spinal inclination was significant ($p<0.05$) for all positions tested, except for the upright position (U), where the increase in degrees showed a slight rightward tilt compared to the neutral position (before 2.3° [IQR 1.15-3.3°] - after 2.4° [IQR 1.3-3.7°]); however, this change was not significant. The active lateral-flexion ROM of the lumbar region also showed a significant ($p<0.05$) increase in U-L (before 20.95° [IQR 15.25-25.9°] - after 22.3° [IQR 18.7-25.15°]) and L-R (before -44.9° [IQR -52.85-36.95°] - after -48.25° [IQR -54.9-42.9°]).

More remarkable results were found for measurements in the sagittal plane. Measurements in the vertical (U) sitting position had a positive and significant effect on posture, as thoracic kyphosis decreased (before 27° [IQR 20.5-36.5°]-after 25° [IQR 18-33°]) and lumbar lordosis increased (before -6.5° [IQR -14.5-0.5°] - after -13° [IQR -18-6°]), anterior pelvic tilt was greater (before 1° [IQR -4-8°] - after 5° [IQR 1-14°]) and anterior spinal inclination was also reduced (before 2.5° [IQR 0-6°] - after 1° [IQR 0-4°]) as a result of the training programme, and therefore posture was closer to the desired ideal neutral position. Significant ($p<0.001$) positive changes were observed in flexion (F) measurements in all regions except the thoracic spine, with a remarkable increase in total spinal inclination (before

49° [IQR 40-60°] - after 65.5° [IQR 51.5-72°]). Extensional position tests showed a significant increase in anterior inclination of the sacroiliac spine and a decrease in kyphosis of the thoracic spine (before 17.5° [IQR 11-26°] - after 13° [IQR 5.5-20°]), but no significant improvement in the lumbar region and in the whole spine inclination. After the training programme, participants performed the extension with increased anterior tilt of the pelvis, a greater degree of lumbar lordosis and a lesser degree of thoracic kyphosis, which minimally increased spinal inclination in extension.

A significant increase ($p < 0.001$) in estimated ROM was observed in U-F in all regions except the thoracic spine, which remained unchanged. In U-E, interesting results were observed for the estimated ROM in extensor ROM, as an increase in posterior tilt of the pelvis and an increase in mobility of the thoracic segment were observed after the intervention, but these differences were negligible. In addition, the lumbar region and the total spine inclination decreased, and the change was significant ($p < 0.01$) for the lumbar segment. Despite the changes observed in the range of motion of extension, the estimated range of motion (E-F) of total flexion-extension showed a significant improvement ($p < 0.01$) in all the regions studied in the sitting position.

The most significant changes were observed in the sagittal plane in the standing position. Based on the values measured in the U, an increased anterior tilt of the pelvis, a decrease in thoracic kyphosis and an increase in lumbar lordosis were observed for the sacroiliac complex as a result of training, with significant changes ($p < 0.05$). The inclination of the whole spine was posterior relative to the vertical axis, which was already more posteriorly displaced before the intervention (before -2° [IQR $-3-0^\circ$] - after -2° [IQR $-4-1^\circ$]). An increase in the angles measured at the end position of flexion (F) was observed in all regions and this improvement was significant for sacrum/hip and total inclination ($p < 0.001$). The values measured in the end position of extension showed a slight decrease in posterior tilt of the pelvis, a significant decrease in the degree of thoracic kyphosis ($p < 0.05$) and a significant increase in lumbar lordosis ($p < 0.001$) and total inclination ($p < 0.05$).

In the standing position, the estimated range of motion in the flexion direction (U-F) was significantly greater in the thoracic and lumbar spine ($p < 0.05$), as well as in the sacroiliac lordosis and total inclination ($p < 0.001$) after the intervention. The inward ROM in the direction of extension decreased for the sacroiliac and lumbar regions, and the range of motion increased for the thoracic region and total inclination, but these changes were not significant. Estimated total flexion-extension range of motion (E-F) showed significant increases in all regions studied, suggesting that spinal mobility and muscle flexibility also improved. Significant ($p < 0.001$) improvements were observed in the mobility of the sacroiliac complex (pre 34.5° [IQR 25-44.5°] - post 40.5° [IQR 30.5-55°]) and total inclination (pre 102° [IQR 92.5-108.5°] - post 111.5° [IQR 101-123.5°]), presumably due to increased flexibility of the ischiocrural and paravertebral muscles.

IV.1.3. Results of the physical examination

Chest expansion increased significantly ($p < 0.001$) at all three heights tested, at the axilla, the xiphoid process and the tenth ribs, which may be related to an improvement in spinal mobility. The results of the *Sit and Reach test* showed a significant improvement ($p < 0.05$), and

the change was highly significant ($p < 0.001$) for the second trials assessed during the tests, indicating increased extensibility of the hamstring and paravertebral muscles and greater flexibility of the spine. The *Y-Balance Test* was used primarily to assess balancing and coordination skills, and secondarily to assess proprioception, lower limb muscle strength and core muscle stabilisation. Although there was no significant improvement in reach or reach distance in the right postero-medial direction, significant improvements ($p < 0.05$) were found in all other reach directions on both sides, with the change in reach distance in the left anterior direction being the most significant ($p < 0.001$). The change in static isometric strength of the trunk muscles showed a spectacular ($p < 0.001$) improvement in both the Prone Plank Test, the Left and Right Side Plank and the *Biering-Sorensen tests*. The dynamic muscle strength of the trunk flexor muscles was assessed using the *Timed Abdominal Curl Test*, which showed significant ($p < 0.01$) improvements in both the time taken to perform the exercise and the number of repetitions. The analysis of the data measured during the physical tests showed excellent results, thus we conclude that the intervention was highly effective on the physical abilities of the participants.

Correlation analysis between variables was performed to examine the relationship between the parameters measured during the physical examination. We compared the changes in spinal inclination measured in the sitting and standing positions, in the frontal and sagittal planes, with differences found in the *Sit And Reach test* and the chest mobility test. We found a significant but negative correlation ($\rho = -0.303$; $p = 0.010$) between total left-to-right lateral flexion ROM recorded in the frontal plane in the sitting position and thoracic mobility measured at axillary level only. In our further analyses, we compared changes in thoracic mobility with changes in the Plank Test, Side Plank Test, *Timed Abdominal Curl Test* and the modified *Biering-Sorensen tests*. Among the variables analysed, only one significant correlation ($\rho = 0.299$; $p = 0.011$) was found, showing a positive correlation between chest mobility measured at axillary height and the results of the right lateral plank test. The most significant results were obtained from correlation analysis of balance tests and isometric muscle strength tests. Positive significant correlations were found between the differences measured during the Plank test and the YBT for right postero-lateral ($\rho = 0.327$; $p = 0.008$) and left postero-lateral ($\rho = 0.260$; $p = 0.032$) stretch directions; for the left Plank test and the YBT for right anterior ($\rho = 0.364$; $p = 0.002$) and right postero-lateral ($\rho = 0.391$; $p = 0.001$) stretch directions; and during the right Plank test and YBT test in the right anterior ($\rho = 0.362$; $p = 0.002$), right postero-lateral ($\rho = 0.373$; $p = 0.002$) and right postero-medial ($\rho = 0.247$; $p = 0.049$) stretch directions.

IV.1.4. Results of the Post-Intervention Questionnaire

The post-intervention questionnaire was completed by 92 participants - 51 men and 40 women - with an average age of 33.52 ± 6.41 years. Employees who had participated in the training programme were asked to complete the questionnaire, but only participation in the training was a prerequisite for responding, without limitation of the number of sessions completed. The main purpose of the questions was to gauge the participants' subjective views on the impact of the training programme. Over three quarters of respondents rated their health as "good" and less than a quarter as "satisfactory" after the intervention. Although more

respondents rated their health as better in terms of perceived health, there was a mixed result in terms of health behaviour, with two thirds of respondents saying they could do a great deal for their health and one third saying they could do little for their health. More than half of the respondents complained of musculoskeletal pain during the training programme and more than 80% indicated that these symptoms had decreased or disappeared. Two subjects had new symptoms and only one reported that their previous symptoms had increased. Adherence to the recommended number of training sessions, i.e. the number of training sessions completed, was not outstanding, with only 19.78% of respondents stating that they attended three training sessions per week and 70.33% indicating "2 training sessions per week". Despite the fact that participants were not always able to complete the recommended 60 sessions over the 20-week programme, the results of the physical assessments showed the training programme to be effective, with the minimum criterion for evaluation being participation in at least 50% of the recommended training sessions, i.e. at least 30 sessions. Lack of time (21.88%) and sickness or posting (46.88%) were the most common reasons for dropout or occasional attendance for the 31 subjects who chose to answer this question. A Likert scale was used to assess satisfaction with the usefulness of the training programme content, with 87.91% of respondents answering 'Very Satisfied', 10.99% 'Satisfied' and 1.10% 'Neutral'. The stretching and myofascial release techniques were incorporated into the daily routine by 93.41% of the respondents and the exercises learnt were regularly practiced at home by 84.62% of the respondents. The most popular techniques and exercises repeated at home were Stretching (54.95%), SMR Trigger-Ball (52.75%), SMR Foam-Roller (51.65%) and exercises without tools (42.86%). Net Promoter Score (NPS) was used to evaluate the success of the training program. Based on the feedback received, it can be said that our programme was rated as excellent by the participants, as none of the respondents were in the 'against' group, 5.5% were in the 'passive' group and 94.51% were in the 'in favour' group. 90% of respondents perceived an improvement in posture, 98.89% of respondents perceived an improvement in stamina, and 95.7% of respondents indicated that the New Spine Programme had helped them to increase their knowledge of how to prevent problems caused by sedentary lifestyles. Based on the results of physical assessments and subjective feedback from participants, the training programme proved to be effective in increasing participants' activity levels, reducing musculoskeletal complaints, improving posture and physical endurance, muscle strength and flexibility, spinal mobility, and balance and coordination.

V. DISCUSSION

V.1. Results of the study

The main objective of our study was to develop and evaluate the impact of a multimodal workplace health promotion programme that can reduce and prevent low back pain and other musculoskeletal complaints in the sedentary population, while increasing the theoretical and practical knowledge of prevention, physical activity levels and significantly improving physical abilities, posture, spinal statics and mobility of the target population. The structure and content of the study protocol and the training programme, as well as the organisation of the training, were determined on the basis of the experience gained from the pilot studies. Despite the large

number of studies in the literature on health promotion and disease prevention in the workplace, comparisons of results are difficult due to the heterogeneity in the structure of the programmes, the composition of the target groups, the inclusion and exclusion criteria, and the content of the testing methods and interventions used. In my review of the literature, I did not find a similar intervention programme with a long duration and complex content, and therefore it is difficult to compare our results on the variables observed in our study.

From the point of view of questionnaire studies, it is important to underline that the participants' willingness to cooperate is influenced by a number of factors. Efforts should be made to minimise the time needed to complete the questionnaire and to time, place and conditions of completion to maximise response rates. There is no gold standard in relation to the above, as many factors in the planned programme can affect these aspects, but I believe that we have been able to carry out the questionnaire surveys as successfully as possible in the given circumstances. As the acute presence of symptoms was not an inclusion criterion, we did not use the *Visual Analogue Scale* for acute pain and the *Oswestry Disability Questionnaire* for current level of functional disability, in contrast to the study protocol of other researchers (10,33,34). For the pre-intervention questionnaire, we were more interested in the duration of sedentary work, locomotor pain localisation, physical activity level and willingness to participate in the programme; whereas for the post-intervention questionnaire, we were interested in perceived changes in symptoms, physical activity and conditioning levels, practical application of the methods learned during the programme and participant satisfaction. Although 236 of the 573 workers who met the inclusion criteria completed the online pre-intervention questionnaire, the response rate of 41.18% cannot be considered low, as the invitation to complete the questionnaire requested that only those who could or would like to participate in the training programme should respond. This caveat was necessary because of the limited capacity and duration of the physical examinations and the inclusion capacity of the exercise programme.

The results of the questionnaire showed that the most common complaint among respondents for musculoskeletal complaints was low back pain (73.7%), with the most commonly reported cause being "sitting posture" (37.9%) or "any posture" (20.7%). The number of hours spent sitting exceeded an average of eight hours on weekdays, with an average of nearly six hours on weekends. Regarding the level of physical activity, it was found that more than 90% of the respondents do not even reach the level of activity recommended by the WHO to maintain health, let alone the intensity and duration of physical activity needed to improve health. The latest WHO 2020 recommendation on sedentary lifestyles recommends a significant reduction in the number of hours spent sitting, and that those who experience the adverse health effects of prolonged sitting should aim to increase their physical activity to moderate or high intensity levels above the recommended levels (64). Our results described above support our hypothesis that a large proportion of sedentary workers lead a physically inactive sedentary lifestyle, with low back pain being the most common complaint in the study group.

The success of interventions in the workplace environment has also been studied by other researchers. *Jakobsen et al.* (65) conducted a comparative study of 200 female health care workers, comparing the effects of a 10-week workplace exercise programme and home-based

training on musculoskeletal pain, trunk extensor muscle strength and self-reported use of analgesics. In addition to practical ergonomic training and education, high-intensity strength training was organised in a workplace setting, led by a qualified instructor, while home training was carried out independently at leisure by participants using posters with illustrations of exercises. Although the length of the intervention and the duration of each session - 5x10 min per week - were shorter compared to the programme we implemented, both forms of training resulted in significant improvements in the indicators tested. By comparing the results of the two groups, the researchers found that the positive effect of the supervised intervention in a workplace setting was more significant ($p < 0.05$) in terms of physical parameters, subjective variables and adherence to the programme. Given that core muscle strength can be improved with relatively short programmes and short training sessions, I believe that a longer programme would obviously result in a larger and more lasting effect. Reduction or elimination of pain was reported by 42% of those who trained at home and 78% of those who participated in the workplace programme, a similarly favourable rate of 82.35% for the programme we implemented. Based on my experience, I believe that workplace interventions can indeed be more effective than individual or unsupervised home-based exercise for the following reasons: the supervision is professional; the intensity of the training can be increased according to a scientifically based schedule; there is greater motivation due to group dynamics; there is a team-building effect; and those who cannot or do not want to exercise outside of work hours cannot be engaged in regular exercise and therefore cannot be activated in any other way.

In examining the effects of the intervention on physical parameters, we found several meaningful results. The vast majority of the data recorded in the frontal plane did not show statistically significant changes in spinal statics and mobility in either sitting or standing positions. However, our hypothesis was partially confirmed, as we achieved significant improvements in the sagittal plane for 70% of the parameters tested, and also a significant improvement in the posture of the participants. We achieved breakthrough success in other physical parameters such as chest mobility, trunk and ischiocrural muscle flexibility, coordination and balancing ability, static and dynamic trunk muscular strength and endurance, as we found significant improvements in all variables, thus fulfilling one of the main objectives of the training programme and confirming our hypothesis.

Correlation analysis was also performed for parameters more closely related to the topic of low back pain. The flexibility of the hamstring muscles and the frontal plane mobility of the spine are two variables that have been the focus of attention of experts in the field of low back pain. A systematic review published by *Sadler et al.* (66) showed that the development of low back pain is significantly correlated with reduced lateral-flexion mobility of the spine, reduced lumbar lordosis arc and limited flexibility of the hamstring muscles. The authors urge caution when interpreting the results, as the studies included involved heterogeneous populations and the vast majority of the measured values were close to the upper limits of the confidence intervals. Although the authors also found that the range of motion of lumbar flexion and extension, finger-to-toe distance, strength and endurance of the trunk flexor and extensor muscles were not significantly associated with the development of low back pain, no definitive conclusion can be drawn due to the low statistical power and lack of representativeness resulting from the small number of meta-analyses. Based on the available data, we were not able to

perform an analysis in relation to low back pain, but we did investigate the relationship between isciocrural muscle extensibility and lateral flexion range of motion of the spine, which, similar to the results of other researchers, showed a weak, non-significant co-movement of these two parameters, and therefore our hypothesis regarding the correlation of these variables is rejected (67,68). In my opinion, further randomised controlled trials with healthy and complaining subgroups are recommended to assess the correlations more accurately.

Another important consequence often observed in low back pain is an altered respiratory mechanism. Several previous studies have already highlighted the relationship between core muscle strength and thoracic mobility and the importance and effectiveness of respiratory training in low back pain (69,70). As the diaphragm plays an important role in lumbar stabilisation, reflex inhibition of the core muscles due to pain may limit thoracic mobility and respiratory function. During the physical tests, we measured the degree of thoracic mobility at three different thoracic heights, which showed a significant increase ($p < 0.001$) as a result of the programme, as well as a significant improvement ($p < 0.01$) in the results of all core muscle strength tests, but a significant correlation was only found for the right lateral plank test and mobility at the axillary height of the thorax. Since, contrary to our hypothesis, we found only a partial correlation for these two variables, further studies are needed to test this hypothesis. In my opinion, direct investigation of variables related to lung function would better characterize diaphragm function, and therefore may be useful to investigate in other studies in addition to thoracic mobility.

We found a remarkable positive correlation between core muscle static strength-endurance and balancing ability measured by the Y-Balance Test (YBT). *Hooper et al.* (71) have shown that the balancing ability of an individual with low back pain becomes limited when using YBT. The researchers did not find a clear association between YBT scores and pain intensity, fear and avoidance of movement, or parameters indicating disability, but did not examine the association with core muscle strength. We argue that the correlation that we have shown can be explained by the patho-mechanism of back pain, as the previously discussed reflex inhibition, m. multifidus atrophy and degeneration together have a negative impact on the proprioceptive system, and therefore less effective motor control impairs the individual's balancing strategies. Weakness, atrophy and inhibition of the stabilizers of the lumbar spine can cause further pain and lead to instability of the intervertebral joints. Based on these patho-anatomical aspects and the relationship between balance and core muscular strength, the use of segmental stabilisation exercises as well as proprioceptive training can be recommended in programmes aimed at preventing or reducing low back pain.

Segmental stabilisation of the lumbar spine was the main basis of our movement programme, which was monitored throughout the training sessions with increased attention during all phases of the programme. *Sipaviciene and Kliziene* (34) analysed the effects of two different 20-week training programmes in patients with chronic low back pain. Participants were randomly assigned to either a lumbar stabilisation ($n=35$) or a lumbar strengthening ($n=35$) exercise programme, and the training sessions were conducted twice a week for 45 minutes. The duration of the interventions was the same as our intervention, but the duration of the sessions was only 30 min in our case. The results of this study showed that both forms of training were effective in reducing functional disability, and improvements in lumbar m.

multifidus *Cross-Sectional Area (CSA)* and maximum isokinetic strength of trunk muscles were also observed; furthermore, these variables were significantly correlated with low back pain symptoms. Although both training modalities proved to be effective, the follow-up study confirmed that segmental stabilisation was more effective than general muscle strengthening, as its effects were still measurable after 12 weeks. Both the researchers' observations and our own results support the importance of using lumbar segmental stabilisation, as our physical examination showed that our programme significantly increased static and dynamic muscle strength in the trunk muscles ($p < 0.001$), suggesting that our exercises may be useful in preventing low back pain and reducing complaints and functional limitation. Based on the data found in the scientific literature, I consider it important to modify the study protocol for future planned studies. The division of subjects into acute, chronic and control subgroups allowing a more accurate data analysis, in which the use of pain questionnaires and scales (e.g. ODI and VAS) can be considered a relevant study method. In addition, the change in the cross-sectional area of the trunk muscles (CSA) is also an important indicator and the use of ultrasound imaging methods should be considered in the future.

In addition to stabilisation and strengthening exercises, the effects of other methods have been investigated previously. *Shariat et al.* (72) randomly allocated office workers ($n=147$) into three intervention and one control group and then organised three sessions per week for 10-15 minutes over 6 months. The main inclusion criterion for the study was the presence of a musculoskeletal complaint in at least one or more body parts. The effects of ergonomic training, stretching exercises in an office environment and interventions combining the two methods were compared with those of the control group. Analysing data on low back pain, the researchers found that after six months, both the office-based stretching and the programme combined with ergonomic training resulted in significant improvements in pain levels compared with the control group, but between months 4 and 6, significant ($p < 0.05$) improvements were only seen in the group that received the self-stretching programme. Unfortunately, the researchers did not examine muscle flexibility, so it can only be assumed that the improvement in flexibility and spinal mobility during our programme contributed to the reduction or prevention of any pain. As the presence of pain was not a criterion in our study and we did not examine the extent of pain, we can only rely on the subjective feedback of the participants regarding pain reduction, as 80% of the respondents to the postIK question after the programme reported a reduction or cessation of musculoskeletal complaints. We have also incorporated the aforementioned methods in our *Multimodal Progressive Functional Training Programme*, as we believe that both ergonomic education and stretching exercises should be an essential part of health promotion programmes adapted to the workplace.

Cortell-Tormo et al. (73) investigated the effects of functional resistance training in their randomized controlled trial using similar testing methods to our program (e.g., static trunk extensor endurance test, side plank and timed abdominal muscle test) and progressively administered exercises (e.g., segmental stabilization, push-ups and squats) in women with nonspecific low back pain. Outcome indicators were changes in pain (VAS), disability (ODI), quality of life (Short Form-36 Health Survey - SF-36) and physical fitness. In the cited study, the number of participants was smaller and the duration of the intervention shorter (12 weeks; two sessions per week for 45-60 minutes) than in our programme, but the study group showed

significant improvements compared to the control group in all variables tested, except for the SF-36 scores. Despite the methodological differences between the studies, it can be concluded that functional exercises are an essential part of both preventive and therapeutic interventions for low back pain or other musculoskeletal disorders. Based on my experience, it is important to emphasise the importance of a professionally sound, adequate and effective progression of exercises to prevent adverse effects, overuse or further injury. Although the results of the “quality of life” questionnaire did not show significant improvement, I believe that the use of the SF-36 questionnaire should be considered in future planned interventions, as the vast majority of participants gave positive feedback to the post-intervention questionnaire’s quality of life question after our programme. One of the open-ended questions asked respondents for their individual and subjective opinions about their experience of pain, activity level, posture and performance. 47% of those who completed the questionnaire described their experience, reporting improvements in pain levels, posture, stamina, well-being, productivity, quality of life and/or activity levels.

In addition to the previously discussed changes to the research methodology for future studies, we believe it is important to adapt the structure of the programme to meet employer and employee requests as the need has arisen to maintain the exercise programme on an ongoing basis. In addition to the progressive nature of the structured training programme, it is necessary to provide the opportunity for employees to join the programme at any time of the year, and therefore, in addition to providing the necessary professional human resources, infrastructure and equipment, and stakeholder support, there is a need to develop a number of sessions running in parallel, with different themes and different skill levels.

Finally, as regards the satisfaction, suggestions and opinions of the participants in the programme, I wish to highlight some important results. It can be considered a significant success that almost 88% of the participants who completed the postIK were very satisfied and almost 11% were satisfied with the training programme; more than 90% were supportive of the programme; more than 80% experienced a reduction or cessation of pain, applied some of the exercises learned during the programme, and also reported an improvement in posture and stamina, as well as an increase in their theoretical knowledge. Our hypothesis regarding participants' subjective feedback was confirmed, with a much higher proportion of participants reporting positive effects than we had previously assumed.

V.1.1.1. Limitations

We have also recognized the limitations of using SpinalMouse, as previously described by *Post and Leferink* (38). It is important to consider that the landmarks representing the spinous processes of the C7 and S3 vertebrae move with the skin during spinal movements and therefore do not follow the spinal column exactly; therefore, we also recommend manual palpation of the landmarks during the test to ensure accuracy of data acquisition. Another possible measurement error is the sharp lumbar angle observed in neutral position and during extension, as the sharp lordosis, due to the upturned soft tissues and the very high degree of sharp lordosis, prevents the examiner from following the spine all the way along the skin surface with the rolling wheels of the instrument. In these special and relatively rare cases, we are unable to collect reliable data on the position of the vertebrae, which may distort our results. Weaknesses of the self-

completion questionnaire included recall bias of the circumstances and events of the past twelve months, and the response rate of the participants, who in our experience were not as interested in completing the questionnaire as they were in the physical examination itself and its results.

Our experience has shown that a health promotion project in a workplace setting has to take into account the difficulties that, due to the specific requirements and possibilities of the employer, require occasional deviations from the basic rules of research methodology. In a workplace programme, it is necessary to carry out studies under real conditions rather than using a theoretically regulated methodology. The schedule and sequence of tests for the training programme were developed in consultation with the company's delegates, taking into account the company's specific requirements and possibilities. Due to the limited time, space and human resources available for the physical tests, we were forced to use a planned but different sequence of tests for each individual in order to be able to assess a large number of employees at the same time in a relatively short time. The different test sequences may lead to a bias in the results, which we have been able to avoid by ensuring adequate recovery time between tests, but it may be an interesting topic for further research to investigate different variations in the test sequence.

Time and infrastructure are two further factors that have a major impact on the implementation of the research. In our case, the employer limited the time available for physical examinations and the length of the training sessions, as the employees participated in the programme during working hours. In order to conduct the tests, several meeting rooms and offices in the company's buildings had to be cleared and freed up at the same time, which was a challenge for both management and employees. The capacity of the training sessions was limited by the size of the fitness room, so we could not increase the number of participants even though we had the capacity. With the committed support of management in terms of time availability and infrastructure needs, reform of work organisation and the development of a suitable venue, these difficulties could be overcome.

The hectic workload had an impact on the adherence of the participants, as the company's operations are typically interspersed with in-person or online meetings at different locations and times in the employees' daily schedules. Despite the fact that the employee had registered in the timetable independently, taking into account their tasks, there were several occasions when they were unable to arrive or attend the meeting on time due to delays or slips in the meeting. In addition, unforeseen duties, sick leave and secondments also played a role in the drop-out rate. By restructuring the training programme, these difficulties could be easily addressed, as in the case of several sessions running in parallel, with different thematic topics and different ability levels, the worker could join or leave the programme at any time and start again, thus having the possibility to choose the training that suits his/her current skills and condition.

We also measured physical activity levels and sedentary time using a validated questionnaire, but it is important to highlight that selective recall bias limits the validity of the data acquired by a questionnaire. Several studies have previously investigated the correlation between data collected by a questionnaire and by an accelerometer or pressure-sensing pads, suggesting that the correlation between the two methods is only weak to moderate. Experts have suggested that the most accurate data can be collected using both questionnaire and instrumental

testing methods, therefore the use of objective measurement tools should be considered in the future (74,75).

With regard to muscle and joint mobility, it is worth noting the negative impact of stress, as it is well known that stiffness due to stress significantly limits range of motion and flexibility (76). By examining the degree of stress, we can obtain a more accurate picture of the participants' current state and have the opportunity to perform statistical analysis adjusted for this confounding factor, and therefore mental state questionnaire testing is definitely worth using in the future.

The selection bias in health promotion programmes may be due to the fact that the majority of the subjects were of tertiary education level, and therefore our results cannot be generalised as the sampling was not representative. Due to the characteristics of the company, it employs predominantly higher educated workers, who are known to lead healthier lifestyles, and this population was over-represented in our study. However, the lack of randomization and control group also limits the generalizability of the results, but non-probability sampling is usually the only option for studies on health promotion programmes.

V.1.2. Conclusions

- Among sedentary workers, low back pain is the most common musculoskeletal complaint, usually caused by a sedentary posture, but also by an inactive lifestyle.
- Based on our own research and the results of other authors, we found that our Multimodal Progressive Functional Training Program significantly reduces pain and functional limitation, improves posture, mobility, muscle strength, balancing and coordination skills, physical activity levels, and increases theoretical and practical knowledge of preventive methods among sedentary workers affected by low back pain.
- Based on our results, we recommend the implementation of the programme among workers in companies and institutions with an increased risk of musculoskeletal complaints, regardless of the type of occupational hazard and the location of the pain.
- Based on the experience of the main study, a revision of the workplace training programme is justified, as health promotion programmes should be made available to all employees on an ongoing basis, regardless of physical condition, in order to ensure equal opportunities and accessibility.

V.2. Recommendations for the design and implementation of workplace health promotion programmes

Based on the results and experiences of the studies presented in this thesis, the following recommendations are made for the effective implementation of health promotion programmes in the workplace:

- Due to the time, resources, infrastructure and specific needs of the employer, the development of programmes should be carried out in cooperation with management members according to the specificities of the company, and it is therefore advisable to develop several programme designs in parallel.

- Based on the experience of the programme implemented and the needs that arise, it is preferable to design long-term programmes, longer than six months, or even ongoing programmes.
- In the case of campaign programmes, a structured, thematic, progressive physical activity programme is appropriate, but for longer-term interventions, it is more appropriate to consider thematic sessions, with parallel training for different skill levels.
- The physical activity programme should be accessible to all employees, and therefore sessions should be organised in the mornings and afternoons, taking into account the specificities of the workplace and any shift patterns.
- Physical activity during working hours is an incentive for the employee, and should therefore be provided preferably in the form of short training sessions of a maximum of 30 minutes, which can be easily integrated into the daily schedule.
- It is important that the employee is free to choose the time of the activities and tests that are suitable for him or her, according to his or her workload and without restrictions.
- Electronic questionnaires are the most effective way of carrying out health assessments, especially if they are a prerequisite for participation in the programme. Face-to-face questionnaires should be used during physical examinations rather than group presentations and training sessions.
- Multidimensional interventions have a vital role to play in the prevention of any occupational musculoskeletal complaint, achieving the preventive aim of the programme in the short term and improving the overall health behaviour and health awareness of the individual in the long term.

V.3. New results of the study

- The use of the *SpinalMouse* spinal examination tool has been the subject of several previous publications by other authors, but our studies have provided new knowledge and experience that has made the performance of the tool and the interpretation of the data more efficient and reliable. Based on our results, we have developed a new workplace testing protocol that builds on the strengths of the tool that we have identified and takes into account its potential weaknesses.
- The integration of theoretical training into a practical programme has emerged as a unique method, which participants subjectively perceived as having significantly improved their theoretical knowledge and helped them to develop long-term lifestyle changes.
- A new finding is that the training programme for the prevention and reduction of low back pain, designed with a multidimensional approach, has complex effects that go beyond musculoskeletal complaints and is therefore suitable for the overall development of an individual's general fitness and health maintenance skills.
- The *Multimodal Progressive Functional Training Programme* is a unique combination of an innovative theoretical training and several therapeutic and training methods, which makes it a new method in the offer of workplace health promotion programmes due to its specific thematic and complex effects.

VI. SUMMARY

According to a review of the *Global Burden of Disease Study 2019* published by the *World Health Organization*, musculoskeletal diseases and, especially, low back pain (LBP) are a major public health problem around the world. During the last three decades LBP has remained the leading cause of the total number of years lived with disability in 126 of 195 countries. Reports made by the *European Agency for Safety and Health at Work* refer to prolonged awkward sitting as a major risk factor for the development of LBP as well as other musculoskeletal, cardiovascular and metabolic disorders.

The aim of our preparatory study was to evaluate the characteristics of spine, and to determine changes in spinal mobility and posture in sitting compared to standing position; to increase the topic related knowledge especially among sedentary workers with a possible risk of developing low back pain; moreover, to determine the applicability and feasibility of the *SpinalMouse*, as a possible examination device in workplace health promotion programs.

The aim of our main study was to perform the impact analysis of a newly developed exercise training program among sedentary workers by examining physical parameters (posture, spinal mobility, muscular flexibility, static and dynamic muscle strength, coordination and balancing abilities) and subjective outcome measures.

Based on our findings and those of previous studies on the posture and mobility of the spine, sitting position has a negative effect on the biomechanics and mechanical load of the spine among sedentary employees affected by low back pain. The *SpinalMouse* device can be used effectively for physical examination in cross-sectional studies and impact analysis of physical exercise interventions in the future. Our study revealed that segmental stabilization, stretching, self-myofascial release and functional training have a significant positive effect on pain, on disability, on posture, on muscle strength and on balance; therefore, these can be effective methods for the prevention and treatment of musculoskeletal diseases and low back pain. The combination of these techniques probably enhances these effects; hence, our *Multimodal Progressive Functional Training* can be recommended to individuals affected by these problems; moreover, as an advantageous intervention, it can be effectively used among sedentary employees in workplace settings.

VII. REFERENCES

- (1) European Commission. Special Eurobarometer 525-Sport and Physical Activity. 2022;NC-09-22-460-EN-N.
- (2) Ezzati M, Lopez AD, Rodgers A, Murray CJL. "Selected occupational risk factors." Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors. 2004;1651-801.
- (3) Wu A, March L, Zheng X, Huang J, Wang X, Zhao J, et al. Global low back pain prevalence and years lived with disability from 1990 to 2017: estimates from the Global Burden of Disease Study 2017. *Ann Transl Med* 2020 Mar;8(6):299.
- (4) Chen S, Chen M, Wu X, Lin S, Tao C, Cao H, et al. Global, regional and national burden of low back pain 1990–2019: A systematic analysis of the Global Burden of Disease study 2019. *Journal of Orthopaedic Translation* 2022 January 2022;32:49-58.
- (5) Masi AT, Nair K, Evans T, Ghandour Y. Clinical, Biomechanical, and Physiological Translational Interpretations of Human Resting Myofascial Tone or Tension. *Int J Ther Massage Bodywork* 2010 Dec 16;3(4):16-28.
- (6) Comerford MJ, Mottram SL. Movement and stability dysfunction--contemporary developments. *Man Ther* 2001 Feb;6(1):15-26.
- (7) Wang L, Ye H, Li Z, Lu C, Ye J, Liao M, et al. Epidemiological trends of low back pain at the global, regional, and national levels. *Eur Spine J* 2022 Apr;31(4):953-962.
- (8) European Agency for Safety and Health at Work. Healthy Workplaces - LIGHTEN THE LOAD - Campaign Guide. 2020.
- (9) Bell JA, Burnett A. Exercise for the primary, secondary and tertiary prevention of low back pain in the workplace: a systematic review. *J Occup Rehabil* 2009 Mar;19(1):8-24.
- (10) Hayden JA, Ellis J, Ogilvie R, Stewart SA, Bagg MK, Stanojevic S, et al. Some types of exercise are more effective than others in people with chronic low back pain: a network meta-analysis. *J Physiother* 2021 Oct;67(4):252-262.
- (11) Cieza A, Causey K, Kamenov K, Hanson SW, Chatterji S, Vos T. Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2021 Dec 19;396(10267):2006-2017.
- (12) Burton AK, Balagué F, Cardon G, Eriksen HR, Henrotin Y, Lahad A, et al. Chapter 2. European guidelines for prevention in low back pain : November 2004. *Eur Spine J* 2006 Mar;15 Suppl 2(Suppl 2):S136-68.
- (13) Bardin LD, King P, Maher CG. Diagnostic triage for low back pain: a practical approach for primary care. *Medical Journal of Australia* 2017 04/01; 2022/10;206(6):268-273.
- (14) Delitto A, George SZ, Van Dillen L, Whitman JM, Sowa G, Shekelle P, et al. Low back pain. *J Orthop Sports Phys Ther* 2012 Apr;42(4):A1-57.
- (15) Simoncsics E, Stauder A. Fear and avoidance beliefs in chronic pain. The translation and validation of the Hungarian version of the FABQ questionnaire. *Orv Hetil* 2017 Jun;158(24):949-955.
- (16) Dougherty JJ. The anatomical "core": a definition and functional classification. *Osteopathic Family Physician* 2011 November–December 2011;3(6):239-245.
- (17) Bergmark A. Stability of the lumbar spine. A study in mechanical engineering. *Acta Orthop Scand Suppl* 1989;230:1-54.
- (18) Faries MD, Greenwood MC. Core Training: Stabilizing the Confusion. *Strength and Conditioning Journal* 2007;29:10–25.
- (19) Hsu SL, Oda H, Shirahata S, Watanabe M, Sasaki M. Effects of core strength training on core stability. *J Phys Ther Sci* 2018 Aug;30(8):1014-1018.
- (20) Faur C, Patrascu JM, Haragus H, Anglitoiu B. Correlation between multifidus fatty atrophy and lumbar disc degeneration in low back pain. *BMC Musculoskelet Disord* 2019 Sep 5;20(1):414-019-2786-7.
- (21) Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine (Phila Pa 1976)* 1996 Dec 1;21(23):2763-2769.

- (22) Studnicka K, Ampat G. Lumbar Stabilization. 2022 Sep 4.; Available at: <https://www.ncbi.nlm.nih.gov/books/NBK562179/>. Accessed Nov 6., 2022.
- (23) Afanuh S, Johnson A, I. Using Total Worker Health® concepts to reduce the health risks from sedentary work. DHHS (NIOSH) 2017.
- (24) Crawford JO, Graveling R, Davis A, Giagloglou E, Fernandes F, Markowska A, et al. Work-related musculoskeletal disorders: from research to practice. What can be learnt? 2020.
- (25) De Beeck LRO, Hermans V. Research on work-related low back disorders. European Agency for Safety and Health at Work 2000;ISBN 92-95007-02-6.
- (26) Bontrup C, Taylor WR, Fliesser M, Visscher R, Green T, Wippert PM, et al. Low back pain and its relationship with sitting behaviour among sedentary office workers. *Appl Ergon* 2019 Nov;81:102894.
- (27) Hartvigsen J, Hancock MJ, Kongsted A, Louw Q, Ferreira ML, Genevay S, et al. What low back pain is and why we need to pay attention. *Lancet* 2018 Jun 9;391(10137):2356-2367.
- (28) European Agency for Safety and Health, at Work, Peereboom K, Langen N, Copsey S. Prolonged static sitting at work : health effects and good practice advice. : Publications Office; 2021.
- (29) Nachemson AL. Disc pressure measurements. *Spine (Phila Pa 1976)* 1981 Jan-Feb;6(1):93-97.
- (30) Dreischarf M, Shirazi-Adl A, Arjmand N, Rohlmann A, Schmidt H. Estimation of loads on human lumbar spine: A review of in vivo and computational model studies. *J Biomech* 2016 11 April 2016;49(6):833-845.
- (31) Sowah D, Boyko R, Antle D, Miller L, Zakhary M, Straube S. Occupational interventions for the prevention of back pain: Overview of systematic reviews. *J Safety Res* 2018 Sep;66:39-59.
- (32) de Campos TF, Maher CG, Fuller JT, Steffens D, Attwell S, Hancock MJ. Prevention strategies to reduce future impact of low back pain: a systematic review and meta-analysis. *Br J Sports Med* 2021 May;55(9):468-476.
- (33) Gomes-Neto M, Lopes JM, Conceição CS, Araujo A, Brasileiro A, Sousa C, et al. Stabilization exercise compared to general exercises or manual therapy for the management of low back pain: A systematic review and meta-analysis. *Phys Ther Sport* 2017 Jan;23:136-142.
- (34) Sipaviciene S, Kliziene I. Effect of different exercise programs on non-specific chronic low back pain and disability in people who perform sedentary work. *Clin Biomech (Bristol, Avon)* 2020 Mar;73:17-27.
- (35) Tong MH, Mousavi SJ, Kiers H, Ferreira P, Refshauge K, van Dieën J. Is There a Relationship Between Lumbar Proprioception and Low Back Pain? A Systematic Review With Meta-Analysis. *Arch Phys Med Rehabil* 2017 Jan;98(1):120-136.e2.
- (36) Areeudomwong P, Butttagat V. Proprioceptive neuromuscular facilitation training improves pain-related and balance outcomes in working-age patients with chronic low back pain: a randomized controlled trial. *Braz J Phys Ther* 2019 Sep-Oct;23(5):428-436.
- (37) Kellis E, Adamou G, Tziliou G, Emmanouilidou M. Reliability of spinal range of motion in healthy boys using a skin-surface device. *J Manipulative Physiol Ther* 2008 Oct;31(8):570-576.
- (38) Post RB, Leferink VJ. Spinal mobility: sagittal range of motion measured with the SpinalMouse, a new non-invasive device. *Arch Orthop Trauma Surg* 2004 Apr;124(3):187-192.
- (39) Mannion AF, Knecht K, Balaban G, Dvorak J, Grob D. A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: reliability of measurements and comparison with data reviewed from the literature. *Eur Spine J* 2004 Mar;13(2):122-136.
- (40) Celenay ST, Kaya DO, Ozudogru A. Spinal postural training: Comparison of the postural and mobility effects of electrotherapy, exercise, biofeedback trainer in addition to postural education in university students. *J Back Musculoskelet Rehabil* 2015;28(1):135-144.
- (41) Feng Q, Wang M, Zhang Y, Zhou Y. The effect of a corrective functional exercise program on postural thoracic kyphosis in teenagers: a randomized controlled trial. *Clin Rehabil* 2018 Jan;32(1):48-56.
- (42) Shariat A, Cleland JA, Danaee M, Alizadeh R, Sangelaji B, Kargarfard M, et al. Borg CR-10 scale as a new approach to monitoring office exercise training. *Work* 2018;60(4):549-554.
- (43) Brown LE, Weir JP. ASEP Procedures Recommendation I: Accurate Assessment Of Muscular Strength And Power. *Journal of Exercise Physiology Online* 2001 August;4(3):1-21.

- (44) Arazi H, Rahmati S, Pashazadeh F, Rezaei HR. Comparative effect of order based resistance exercises on number of repetitions, rating of perceived exertion and muscle damage biomarkers in men. *Revista Andaluza de Medicina del Deporte* 2015 December 2015;8(4):139-144.
- (45) de Salles BF, Simão R, Miranda F, Novaes Jda S, Lemos A, Willardson JM. Rest interval between sets in strength training. *Sports Med* 2009;39(9):765-777.
- (46) Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003 Aug;35(8):1381-1395.
- (47) Cshai É, Nagy AC, Váradi Z, Veres-Balajti I. Functional Analysis of the Spine with the Idiag SpinalMouse System among Sedentary Workers Affected by Non-Specific Low Back Pain. *Int J Environ Res Public Health* 2020 Dec 11;17(24):9259. doi: 10.3390/ijerph17249259.
- (48) Livanelioglu A, Kaya F, Nabiyev V, Demirkiran G, Firat T. The validity and reliability of "Spinal Mouse" assessment of spinal curvatures in the frontal plane in pediatric adolescent idiopathic thoraco-lumbar curves. *Eur Spine J* 2016 Feb;25(2):476-482.
- (49) Bockenbauer SE, Chen H, Julliard KN, Weedon J. Measuring thoracic excursion: reliability of the cloth tape measure technique. *J Am Osteopath Assoc* 2007 May;107(5):191-196.
- (50) Ramiro S, van Tubergen A, Stolwijk C, van der Heijde D, Royston P, Landewé R. Reference intervals of spinal mobility measures in normal individuals: the MOBILITY study. *Ann Rheum Dis* 2015 Jun;74(6):1218-1224.
- (51) Wells KF, Dillon EK. The Sit and Reach—A Test of Back and Leg Flexibility. 1952 03/01;23(1):115-118.
- (52) Powden CJ, Dodds TK, Gabriel EH. The Reliability of the Star Excursion Balance Test and Lower Quarter Y-Balance Test in Healthy Adults: a Systematic Review. *Int J Sports Phys Ther* 2019 Sep;14(5):683-694.
- (53) Bohannon RW, Steffl M, Glenney SS, Green M, Cashwell L, Prajerova K, et al. The prone bridge test: Performance, validity, and reliability among older and younger adults. *J Bodyw Mov Ther* 2018 Apr;22(2):385-389.
- (54) Palmer TG, Uhl TL. Interday reliability of peak muscular power outputs on an isotonic dynamometer and assessment of active trunk control using the chop and lift tests. *J Athl Train* 2011 Mar-Apr;46(2):150-159.
- (55) McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. *Arch Phys Med Rehabil* 1999 Aug;80(8):941-944.
- (56) Gidaris D, Hatzitaki V, Mandroukas K. Spinal flexibility affects range of trunk flexion during performance of a maximum voluntary trunk curl-up. *J Strength Cond Res* 2009 Jan;23(1):170-176.
- (57) Sparling PB, Millard-Stafford M, Snow TK. Development of a cadence curl-up test for college students. *Res Q Exerc Sport* 1997 Dec;68(4):309-316.
- (58) Biering-Sørensen F. Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine (Phila Pa 1976)* 1984 Mar;9(2):106-119.
- (59) Soligon SD, da Silva DG, Bergamasco JGA, Angleri V, Júnior RAM, Dias NF, et al. Suspension training vs. traditional resistance training: effects on muscle mass, strength and functional performance in older adults. *Eur J Appl Physiol* 2020 Oct;120(10):2223-2232.
- (60) Saiklang P, Puntumetakul R, Swangnetr Neubert M, Boucaut R. The immediate effect of the abdominal drawing-in maneuver technique on stature change in seated sedentary workers with chronic low back pain. *Ergonomics* 2021 Jan;64(1):55-68.
- (61) Saliba SA, Croy T, Guthrie R, Grooms D, Weltman A, Grindstaff TL. Differences in transverse abdominis activation with stable and unstable bridging exercises in individuals with low back pain. *N Am J Sports Phys Ther* 2010 Jun;5(2):63-73.
- (62) Krol MW, de Boer D, Delnoij DM, Rademakers JJ. The Net Promoter Score--an asset to patient experience surveys? *Health Expect* 2015 Dec;18(6):3099-3109.
- (63) Muyor JM, Lopez-Minarro PA, Casimiro AJ. Effect of stretching program in an industrial workplace on hamstring flexibility and sagittal spinal posture of adult women workers: a randomized controlled trial. *J Back Musculoskelet Rehabil* 2012;25(3):161-169.

- (64) Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med* 2020 Dec;54(24):1451-1462.
- (65) Jakobsen MD, Sundstrup E, Brandt M, Jay K, Aagaard P, Andersen LL. Effect of workplace- versus home-based physical exercise on musculoskeletal pain among healthcare workers: a cluster randomized controlled trial. *Scand J Work Environ Health* 2015 Mar;41(2):153-163.
- (66) Sadler SG, Spink MJ, Ho A, De Jonge XJ, Chuter VH. Restriction in lateral bending range of motion, lumbar lordosis, and hamstring flexibility predicts the development of low back pain: a systematic review of prospective cohort studies. *BMC Musculoskelet Disord* 2017 May 5;18(1):179-017-1534-0.
- (67) Hori M, Hasegawa H, Takasaki H. Comparisons of hamstring flexibility between individuals with and without low back pain: systematic review with meta-analysis. *Physiother Theory Pract* 2021 May;37(5):559-582.
- (68) Johnson EN, Thomas JS. Effect of hamstring flexibility on hip and lumbar spine joint excursions during forward-reaching tasks in participants with and without low back pain. *Arch Phys Med Rehabil* 2010 Jul;91(7):1140-1142.
- (69) Mohan V, Paungmali A, Sitilerpisan P, Hashim UF, Mazlan MB, Nasuha TN. Respiratory characteristics of individuals with non-specific low back pain: A cross-sectional study. *Nurs Health Sci* 2018 Jun;20(2):224-230.
- (70) Mohan V, Paungmali A, Sitilertpisan P, Henry LJ, Omar FA, Azhar FZ. The effect of core stability training with ball and balloon exercise on respiratory variables in chronic non-specific low back pain: An experimental study. *J Bodyw Mov Ther* 2020 Oct;24(4):196-202.
- (71) Hooper TL, James CR, Brismée JM, Rogers TJ, Gilbert KK, Browne KL, et al. Dynamic balance as measured by the Y-Balance Test is reduced in individuals with low back pain: A cross-sectional comparative study. *Phys Ther Sport* 2016 Nov;22:29-34.
- (72) Shariat A, Cleland JA, Danaee M, Kargarfard M, Sangelaji B, Tamrin SBM. Effects of stretching exercise training and ergonomic modifications on musculoskeletal discomforts of office workers: a randomized controlled trial. *Braz J Phys Ther* 2018 Mar-Apr;22(2):144-153.
- (73) Cortell-Tormo JM, Sánchez PT, Chulvi-Medrano I, Tortosa-Martínez J, Manchado-López C, Llana-Belloch S, et al. Effects of functional resistance training on fitness and quality of life in females with chronic nonspecific low-back pain. *J Back Musculoskelet Rehabil* 2018 Feb 6;31(1):95-105.
- (74) Skender S, Ose J, Chang-Claude J, Paskow M, Brühmann B, Siegel EM, et al. Accelerometry and physical activity questionnaires - a systematic review. *BMC Public Health* 2016 06/16;16(1):515.
- (75) Sabia S, van Hees VT, Shipley MJ, Trenell MI, Hagger-Johnson G, Elbaz A, et al. Association Between Questionnaire- and Accelerometer-Assessed Physical Activity: The Role of Sociodemographic Factors. *Am J Epidemiol* 2014;179(6):781-790.
- (76) Westgaard RH. Effects of psychological demand and stress on neuromuscular function. In: Moon SD, Sauter SL, editors. *Beyond Biomechanics: Psychosocial Aspects of Musculoskeletal Disorders in Office Work*. 1st edition ed. USA: Taylor & Francis Ltd.; 1996. p. 75-90.

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IX. APPENDIX



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List of publications related to the dissertation

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