Tampere University

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# Neuromuscular Exercise for Low Back Pain

## Efficacy among female healthcare workers in biopsychosocial framework

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## Efficacy among female healthcare workers in biopsychosocial framework

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To my family

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# ABSTRACT

Low back pain (LBP) is common in physically strenuous work, of which healthcare work is one example. Healthcare work includes nursing duties which are loading for the back: lifting, patient transfer, working in a stooped position, frequent flexion and extension of the spine, hurry and stress. Managing physically heavy work demands certain levels of physical fitness, but it is obviously not enough to protect the back from physical loading. Of equal importance is probably the ability to control one's spine posture and movements both at work and at leisure. With LBP being a multifactorial biopsychosocial problem, other contributing factors are also at play

The thesis and its original publications are based on a randomized controlled trial called NURSE RCT (Effects of Neuromuscular Exercise and Back Counselling on Pain, Movement-control impairment, and Fear-avoidance Beliefs in Working Female Health-care Personnel with Recurrent Non-specific Low Back Pain; NCT01465698), conducted between October 2011 and April 2015 at the UKK Institute for Health Promotion Research, Tampere, Finland. Participants (n= 219) with recurrent or sub-acute LBP were recruited from different workplaces of the social and health services of the city of Tampere (geriatric wards, old people's home, home service, outpatient healthcare, and city hospital), Tampere Heart Hospital, Coxa Hospital for Joint Replacement, and wards of Tampere University Hospital, where the work was known to be physically demanding.

In the original NURSE RCT, participants were allocated to four study groups: 1) combined Pilates-type exercise and back care counselling, 2) exercise only, 3) counselling only and 4) controls. In the current thesis, which is a secondary analysis of the NURSE RCT, groups 1 and 2 were merged to be the exercisers (n = 110) and groups 3 and 4 were merged to be the control group (non-exercisers, n= 109). The purpose was to study the effects of a modified Pilates-type neuromuscular exercise program with the focus on controlling the neutral spine posture on LBP intensity, movement control of the lumbar spine, fear-avoidance beliefs, physical fitness and work-related factors, and to assess the factors associated with exercise adherence. Factors which best explained pain interference with work, physical functioning and work ability were studied at baseline, as well as the repeatability of the measurement methods to assess lumbar movement control and physical fitness.

The overall target of the Pilates-type neuromuscular exercise (NME) program was to reduce pain and pain-induced disturbances in lumbar movement control and to increase the muscular strength and endurance needed in heavy nursing duties. The more specific targets were 1) to increase spinal stability using exercises that minimise the load on spinal structures but induce a high level of muscular activity, 2) to improve the endurance of the trunk musculature, 3) to increase the muscular strength of the lower limbs in functional squatting movements, 4) to improve balance, postural control and light co-contraction of the stabilizing muscles around the lumbar spine, 5) to combine breathing with the movements, and thus take advance of the spine supporting role of the increased abdominal pressure and 6) to achieve a normal range of motion in the spine, especially in the thoracic region and the hip and ankle joints.

The 6-month exercise program was progressive in three stages. The target was to exercise twice a week; during the first two months in supervised groups (stage I), and during the following four months (stages II and III) once a week in a group and once at home with the help of a video or a booklet.

The mean exercise adherence rate in 24 weeks was 26.3 (1.1 times/week) from targeted 48 times. With this exercise adherence, LBP intensity, pain interference with work, lumbar movement-control impairments, difficulties in heavy nursing duties and fear-avoidance beliefs deminished statistically significantly compared to the non-exercisers. Abdominal strength increased among the exercisers, but there were no differences in other fitness components compared to non-exercisers. There was a dose response: those with better exercise adherence (exercising at least once a week) had reduced their LBP intensity by 43% in the six months follow-up, which is also a clinically important result.

The exercise adherence rate was lower than targeted. Associated with the lower exercise adherence rate were shift work, lower education level, fear-avoidance beliefs related to physical activity as well as lower results in fitness components at baseline. Because only exercises that have been performed are effective and produce results, more emphasis needs to be given to factors conducive to improved exercise adherence, alongside carefully planned and instructed exercise programmes, both in intervention studies and in clinical practice. As a result, further research is needed to investigate factors associated with exercise adherence.

# TIIVISTELMÄ

Selkäkipu on yleinen fyysisesti raskaissa ammateissa, kuten hoitotyössä, joka sisältää paljon selkää kuormittavia työtehtäviä: nostoja, potilassiirtoja, kumarassa asennossa työskentelyä, toistuvaa selän koukistus- ja ojennusliikettä, kiirettä ja stressiä. Hyvä fyysinen kunto ei todennäköisesti yksinään riitä suojaamaan selkää fyysisiltä kuormitustekijöiltä. Luultavasti tarvitaan myös kykyä hallita ja kontrolloida selän asentoja ja liikkeitä niin työssä kuin vapaa-ajalla. Lisäksi selän terveyteen vaikuttavat monet muut biopsykososiaaliset tekijät.

Väitöskirja ja sen osajulkaisut perustuvat UKK-instituutissa vuosina 2011-2015 toteutettuun satunnaistettuun kontrolloituun interventiotutkimukseen (NURSE RCT; NCT01465698), jonka tavoitteena oli tutkia 1) 6 kk kestäneen pilatestyyppisen, selän neutraaliasennon hallintaan tähtäävän neuromuskulaarisen harjoittelun, 2) selkäneuvonnan tai 3) näiden yhdistelmän vaikutuksia ja kustannusvaikuttavuutta selkäkivun intensiteettiin, pelko- ja välttämiskäyttäytymiseen sekä sairauspoissaoloihin ja elämänlaatuun verrattuna 4) kontrolliryhmään, johon ei kohdennettu mitään interventiota. Ajoittaista tai sub-akuuttia selkäkipua potevat koehenkilöt (n = 219) rekrytoitiin Tampereen kaupungin terveys- ja sosiaalitoimen toimipisteistä (vuodeosastot, kotisairaanhoito, avopalvelut ja vanhainkoti) sekä Tampereen Sydänkeskuksen, Tekonivelsairaala Coxan ja Tampereen yliopistollisen sairaalan eri osastoilta, joissa työ oli fyysisesti kuormittavaa.

Väitöskirjatutkimuksessa alkuperäisen NURSE RCT:n neljään tutkimusryhmään arvotut yhdistettiin kahdeksi ryhmäksi: Lihaskuntoarjoitteluryhmä (n = 110) koostui sekä pilatesryhmään että yhdistelmäryhmään (pilates + selkäneuvonta) arvotuista. Vertailuryhmä (*n* = 109) muodostui ryhmistä, jotka eivät harjoitelleet (selkäneuvontaryhmä sekä kontrollit, jotka osallistuivat vain tutkimusmittauksiin). Tutkimuksessa arvioitiin selän neutraaliasennon hallintaan tähtäävän, sovelletun pilatestyyppisen lihaskuntoharjoittelun vaikutuksia selkäkivun intensiteettiin, selän liikehallintaan, pelko- ja välttämiskäyttäytymiseen, fyysiseen kuntoon sekä työhön liittyviin muuttujiin, sekä arvioitiin harjoitteluaktiivisuuteen vaikuttavia tekijöitä. Alkutilanteessa analysoitiin myös tutkimusjoukon työtä haittaavaan selkäkipuun, fyysiseen toimintakykyyn ja työkykyyn vaikuttavia tekijöitä, sekä selvitettiin

tutkimuksen interventioiden vaikuttavuuden mittaamiseksi käytettävien fyysisten testien toistettavuus.

Neuromuskulaarisen, sovelletun pilatestyyppisen harjoitteluohjelman tavoitteena oli selän neutraalialueen hallinnan avulla selkäkipujen vähentäminen sekä hoitotyössä vaadittavan lihasvoiman ja –kestävyyden lisääminen. Muita harjoitusohjelman tavoitteita olivat: 1) lisätä selän tukevuutta harjoituksilla, joissa selkään kohdistuva kuormitus on pieni, mutta selkää tukevien lihasten aktiivisuus on suuri, 2) lisätä vartalon lihasten kestävyyttä, 3) lisätä alaraajojen voimaa toiminnallisilla kyykistysharjoituksilla, 4) parantaa asennon ja tasapainon hallintaa vartalon lihasten yhtaikaisen lihasaktiivisuuden (co-contraction) avulla, 5) hyödyntää selän tukemisessa hengityksen avulla saavutettu vatsaontelon paineen lisääntyminen ja 6) lisätä liikkuvuutta rintarangassa, sekä lonkka- ja nilkkanivelissä.

Harjoitusohjelma kesti 6 kk ja siinä edettiin progressiivisesti kolmelle eri vaativuustasolle. Tavoitteena oli harjoitella kaksi kertaa viikossa: intervention kahden ensimmäisen kuukauden aikana ohjatussa ryhmässä (taso I) ja sen jälkeen (tasot II ja III) kerran viikossa ohjatussa ryhmässä ja kerran omatoimisesti harjoitusvideon tai kirjallisen ohjelman mukaan.

Keskimääräisiä harjoittelukertoja 24 viikon aikana oli 26,3 (tavoitellusta 48 kerrasta) eli noin 1,1 kertaa viikossa. Tällä harjoittelumäärällä selkäkivun intensiteetti, työtä haittaava kipu, pelko- ja välttämisuskomukset sekä vaikeudet raskaissa hoitotyön tehtävissä vähenivät tilastollisesti merkitsevästi verrattuna harjoittelemattomien ryhmään. Selän liikehallinta ja vatsalihasvoima paranivat, mutta muissa kuntotekijöissä ei tapahtunut muutosta. Harjoitteluaktiivisuus vaikutti tuloksiin. Vähintään kerran viikossa harjoitelleiden selkäkivun intensiteetti väheni 6 kk:n seurantamittauksissa 43%, mikä on myös kliinisesti merkittävä tulos.

Harjoitteluaktiivisuus oli tavoiteltua matalampi. Vuorotyö, matala koulutustaso, fyysiseen aktiivisuuteen liittyvät pelot ja uskomukset sekä matalampi alkutilanteen kuntotaso olivat yhteydessä alhaisempaan harjoittelumäärään. Koska vain toteutunut harjoittelu voi olla tehokasta ja vaikuttavaa, hyvin suunnitellun ja toteutetun harjoitusohjelman lisäksi suurta huomiota pitäisi kiinnittää niin interventiotutkimuksissa kuin käytännön asiakastyössäkin tekijöihin, joiden avulla harjoitusaktiivisuutta saataisiin kohennettua. Näiden tekijöiden selvittely vaatii vielä lisätutkimuksia.

# CONTENTS

# ABBREVIATIONS

| | |
|---|---|
| 6MWT | 6-minutes-walk test |
| ANOVA | Analysis of variance |
| AP | Abdominal pressure |
| BMI | Body mass index |
| CI | Confidence interval |
| CNS | Central nervous system |
| CNSLBP | Chronic non-specific low back pain |
| CV | Coefficient of variation |
| FAB-PA | Fear-avoidance beliefs related to physical activity |
| FABQ | Fear-avoidance beliefs questionnaire |
| FABs | Fear-avoidance beliefs |
| FAB-W | Fear-avoidance beliefs related to work |
| GLMM | Generalized linear mixed model |
| GLMs | Generalized linear models |
| IAP | Intra-abdominal pressure |
| ICC | Intraclass correlation coefficient |
| ICF | International Classification of Functioning, Disability and Health |
| ITT | Intention-to-treat |
| k | Kappa value |
| LBP | Low back pain |
| MCI | Movement control impairment |
| MCIC | Minimal clinically important change |
| MET | Metabolic Equivalent |
| MF | Multifidus muscle |
| NME | Neuromuscular exercise |
| NRS | Numeric rating scale |
| NSAID | Non-steroid anti-inflammatory drug |
| NSLBP | Non-specific low back pain |
| PHQ-9 | Patient Health Questionnaire; 9 items measuring depression |
| PP | Per Protocol |
| RAND-36 | 36-item health survey, assessing quality of life |

| | |
|---|---|
| RCT | Randomized controlled trial |
| ROM | Range of motion |
| $r_p$ | Pearson's correlation coefficient |
| $r_s$ | Spearman's correlation coefficient |
| s | Typical error |
| SD | Standard deviation |
| SMS | Short message service |
| TrA | Transversus abdominis muscle |
| VAS | Visual analogue scale |
| WAI | Work ability index |

# LIST OF ORIGINAL PUBLICATIONS

| | |
|---|---|
| I | Taulaniemi RPA, Kankaanpää MJ, Tokola KJ, Luomajoki HA, Suni JH. Reliability of musculoskeletal fitness tests and movement control impairment test battery in female health-care personnel with recurrent low back pain. Journal of Novel Physiotherapies 2016;6(1):282. |
| II | Taulaniemi A, Kuusinen L, Tokola K, Kankaanpää M, Suni J. Bio-psychosocial factors are associated with pain intensity, physical functioning, and ability to work in female healthcare personnel with recurrent low back pain. Journal of Rehabilitation Medicine. 2017;49(8):667–676. doi: 10.2340/16501977-2261. |
| III | Taulaniemi A, Kankaanpää M, Tokola K, Parkkari J, Suni JH. Neuromuscular exercise reduces low back pain intensity and improves physical functioning in nursing duties among female healthcare workers; secondary analysis of a randomised controlled trial. BMC Musculoskeletal Disorders 2019; 20: 328. doi: 10.1186/s12891-019-2678-x |
| IV | Taulaniemi A, Kankaanpää M, Rinne, M. Tokola K, Parkkari J, Suni JH. Fear-avoidance beliefs are associated with exercise adherence: Secondary analysis of a randomised controlled trial (RCT) among female healthcare workers with recurrent low back pain. BMC Sport Science, Medicine and Rehabilitation 2020; 12:28; doi: 10.1186/s13102-020-00177-w |

# AUTHORS´ ROLES IN WRITING THE ARTICLES

Annika Taulaniemi drafted all manuscripts and was the corresponding author of them. She conducted the literature search, as well as descriptive and bivariate statistical analysis in all articles. She also participated in the development of the study protocol (NURSE RCT, on which this thesis is based), and in participant recruitment. She planned the exercise intervention, trained the other exercise instructors, produced the exercise videos and booklets, and supervised some of the exercise groups.

Markku Kankaanpää contributed to the concept of the articles and to the interpretation and presentation of the results. He was a supervisor of AT.

Jaana Suni is the principal researcher of the NURSE RCT, on which this thesis is based. She was responsible for the design of NURSE RCT, measurements as well as data collection and management. She contributed to the interpretation and presentation of the results in the articles. She was another supervisor of AT.

Kari Tokola verified the descriptive and bivariate statistical analysis and conducted all the multivariate analyses with figures. He contributed to the presentation of the results of the statistical analysis in all articles.

Jari Parkkari is the responsible medical doctor of the NURSE RCT. He contributed to the interpretation and presentation of the results in articles III and IV.

Lotta Kuusinen was a co-writer in study II. She conducted the descriptive and bivariate statistical analysis and drafted the manuscript together with AT.

Marjo Rinne contributed to the interpretation and presentation of the results in study IV.

Hannu Luomajoki contributed to the interpretation and presentation of the results regarding measurements of lumbar movement-control impairments in study I.

All authors contributed to the draft and read the final version of the particular manuscript.

# 1 INTRODUCTION

Low back pain (LBP) is defined by location of pain, typically between the lower ribs and the buttock creases (Dionne et al. 2008). LBP is common among people in all ages, but disability from LBP is highest in working-age groups (Hartvigsen et al. 2018). The prevalence of LBP varies among occupational groups, and workers in physically demanding jobs are known to have increased risk (Sterud et al. 2013). Nursing is among the top professions at risk of LBP (Yassi and Lockhard 2013).

LBP tends to affect and change motor behaviour (van Dieen, Flor and Hodges 2017). Impairments in postural and movement control of the spine (Pijnenburg et al. 2014) and low performance levels for several components of physical fitness are risk factors for transition from acute to chronic pain (Valdivieso et al. 2018, Goubert, De Pauw et al. 2017) and LBP-related sickness absence (Heneweer et al. 2012, Taanila et al. 2012, Kolu et al. 2017). Risk factors for prolonged and chronic LBP are also closely related to psycho-social factors (Linton 2000).

Interventions focusing on ergonomics or lifting techniques have failed to prevent LBP among nursing personnel (Verbeek et al. 2011). Exercise, which is the most commonly recommended treatment for LBP (Choi et al 2010, Balaque et al. 2012, Falla and Hodges 2017), has shown to cause some positive effects among nurses with sub-acute or chronic LBP, but high-quality studies are few. At present, there is no strong evidence of efficacy for any intervention either in treating or preventing low back pain in healthcare personnel (van Hoof et al. 2017).

Among the general population, most of the exercise intervention studies with focus on motor control have been targeted at chronic LBP patients (Saragiotto et al. 2016). Interventions including Pilates-based exercises, which have gained popularity during recent decades, have also been targeted at people with chronic LBP (Yamato et al. 2015, Byrnes et al. 2018). In exercise interventions among people with musculoskeletal pain, exercise adherence has been only modest at best (Andersen et al. 2008; Van Dillen 2016). Poor exercise adherence compromises the effectiveness of treatment (Jordan et al. 2010).

The impact of LBP on the individual can be measured and evaluated within the biopsychosocial framework of the International Classification of Functioning, Disability and Health (ICF-model; World Health Organisation 2001). LBP can cause loss of health status in the form of symptoms and loss of function, limitation of activities and restricted participation. Loss of function relates to LBP, associated distress and behavioural problems. (Krismer and van Tulder 2007.)

This doctoral thesis is concerned with evaluating the effects and efficacy of a modified, Pilates-type neuromuscular exercise intervention focusing on control of the neutral lumbar spine, on low back pain, lumbar movement-control impairments, fitness components, fear-avoidance beliefs, and work-related factors among healthcare workers with sub-acute or recurrent LBP. Factors associated with exercise compliance are also studied. The thesis also aims to assess, according to the ICF-model as framework, which of the factors at baseline best explain pain interference with work, physical functioning and ability to work among healthcare workers with LBP. Repeatability of the fitness and movement control measurements is also studied in order to determine if they are reliable enough to be used to measure the effects of the Pilates-type exercise intervention.

# 2 REVIEW OF THE LITTERATURE

## 2.1 Low back pain

### 2.1.1 Epidemiology and aetiology of low back pain

Low back pain (LBP) is one of the most common musculoskeletal health problems and a leading course of years lived with disability (Vos et al. 2012). The number of years lived with disability has increased by more than 50% since 1990, and people aged between 25 and 64 years are the most affected by spinal pain. In 2015, the global point prevalence of activity-limiting LBP was 7.3%, implying that 540 million people were affected at any one time. (Global Burden of Disease Study 2015.) The burden from LBP is increasing, particularly in low-income and middle-income countries (Hartvigsen et al. 2018).

Prevalence of LBP increases from youth to adulthood, and most adults (80%) experience spinal pain in some period of their life. The median one-year period prevalence globally in the adult population is around 37%, and women have higher prevalence of LBP than men in all age groups. The prevalence of LBP is highest in the age group of 40–49 years among men and in the age group of 60–69 years old among women. (Hoy et al. 2012.) Approximately 5% to 10% of patients experiencing an episode of LBP will develop chronic low back pain (Meucci et al. 2015), which is an important cause of loss of productivity (work absenteeism) and reduced functional capacity, has a high cost of treatment, and is one of the main reasons for healthcare visits (van Tulder et al. 2002). Because LBP is most prevalent and burdensome in working-aged populations, the economic impact is substantial due to work absences and healthcare cost (Dagenais, Caro and Haldeman 2008). In Finland, 41% of women and 35% of men have experienced LBP during the previous month. A noticeable increase from year 2000 can be detected both in women (37% → 41%) and men (30% →35%). (Koskinen, Lundqvist and Ristiluoma 2011.) On the other hand, the prevalence of chronic LBP, especially among the older age groups, has been found to have decreased during the last decades in Finland (Kaila-Kangas 2007; Koponen et al. 2018).

For the vast majority of people with LBP, it is currently not possible to accurately identify the specific nociceptive source (Hartvigsen et al. 2018). LBP is a biopsychosocial, multidimensional, heterogenous, costly and complex problem with associated co-morbidities (Vos et al. 2012, Nijs et al. 2017) and many factors have been identified as possible causes of LBP, or as being able to affect its development and subsequent course (Balaque et al. 2012; Hodges 2019). Most people with LBP have low levels of disability, but the additive effect of those, combined with the high disability and pain chronicity in minority (10% or less), result in the very high societal burden. In high-income countries, disabling back pain is linked to job satisfaction, socioeconomic status, and the potential financial compensation. (Hartvigsen et al. 2018, Hoy et al. 2012, Choi et al. 2010.) Other factors associated with LBP include heavy physical loads to the spine, comorbidities, psychological factors, and pain-processing mechanisms (Hartvigsen et al. 2018). Different contributors to LBP and its course are presented in Figure 1.

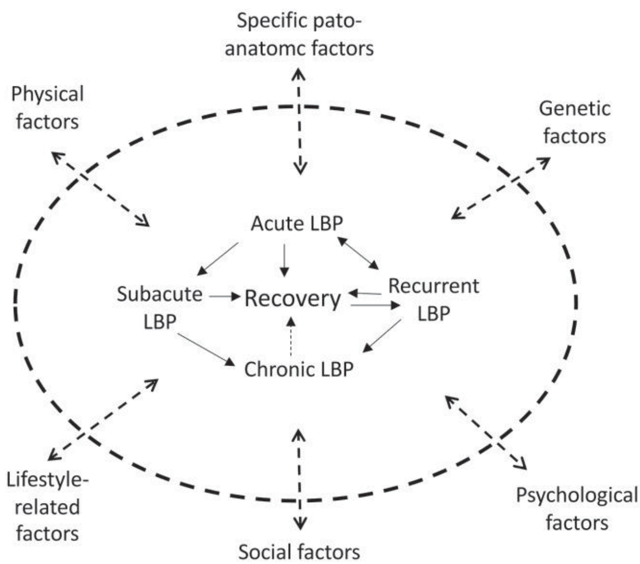


**Figure 1.** Different biopsychosocial factors contribute to low back pain (LBP) and its course. Modified from Hatvigsen et al. 2018.

### 2.1.2 Pain mechanisms in low back pain

Classification of LBP can be made by the source of pain: (1) Nociceptive pain is defined as pain arising from damage to non-neural tissue and is due to the activation of nociceptors, or as pain attributable to the activation of the peripheral receptive terminals of primary afferent neurons in response to noxious mechanical, chemical or thermal stimuli (Smart et al. 2010; Nijs et al. 2015). Nociceptive mechanical low back pain refers to back pain that arises intrinsically from the spine, intervertebral disks, or surrounding soft tissues (Will, Bury and Miller 2018). In (2) neurogenic pain, the nociception arises as a result of irritation to a peripheral nerve root (e.g., lumbar radiculopathy). In (3) central sensitization pain, central mechanisms (e.g. hyperexcitability of the central nervous system) rather than peripheral (lumbar) factors are dominating. (Smart et al. 2010; Nijs et al. 2015.)

In the European guidelines for management of LBP, back pain is classified into three categories: 1) serious or specific back pain due to tumours, anomalies, fracture, or spondylolisthesis with severe syndromes, 2) radicular pain due to nerve irritation, and 3) non-specific low back pain (NSLBP), where the pain is mainly located in the lumbar area without signs of severe pathology or nerve root compression (van Tulder et al. 2006).

In most cases, approximately 90% are classified as non-specific (Hartvigsen et al. 2018). Although clinical tests are unable to accurately identify the tissue source of most non-specific LBP, several structures are innervated and have been shown to produce pain. Accordingly, back pain could rise from spinal structures like intervertebral discs, vertebral endplates, facet joints, joint capsules (Hartvigsen et al. 2018), sacroiliac joint (Vleeming et al. 2012), muscles (Goubert et al. 2018), and connective tissues like ligaments, tendons, and fascia (Wilke et al. 2017). Any of those structures could be affected by injury or disease in order to become painful.

Peter O´Sullivan (2005) proposes a different classification system for NSLBP. According to his work, 90–95% of back pain patients can be classified to be non-specific, and further classified as either centrally or peripherally evoked LBP (Figure 2). The centrally evoked pain is associated with psychological factors like fear avoidance, catastrophizing and depression. The peripherally evoked pain can be further divided into movement impairment (with painful restriction of movement) and movement-control impairment (MCI), which is usually a direction-specific inability or difficulty to control the movement of the lumbar spine. He suggests that up to one third of LBP patients can be classified to each of these three groups (centrally evoked, movement impairment or MCI). (O´Sullivan 2005.)

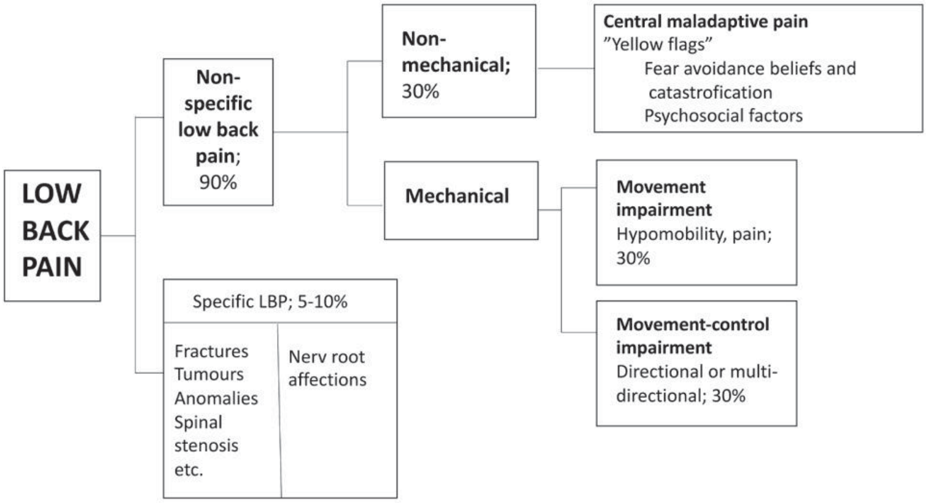


**Figure 2.** Classification of LBP, modified from O'Sullivan 2005, van Tulder 2006, and Luomajoki 2010

Currently, there are many classification systems for LBP; some that are descriptive (diagnostic), some prognostic, and some that attempt to direct treatment. It has been recommended that no single classification system can be adopted for all purposes. (Fairbank et al. 2011.) Owing to the huge heterogeneity of the largest group of LBP patients, sub-grouping NSLBP patients to more specific, diagnostic groups to target a specific treatment, is still a great challenge to current and future research.

### 2.1.3 Non-specific low back pain

Non-specific LBP (NSLBP) is defined as low back pain or discomfort between the lower margin of the twelfth rib and the gluteal folds, not attributable to a recognisable, known specific pathology (e.g., infection, fracture, tumour, osteoporosis, inflammatory disorder, structural deformity, radicular syndrome, or cauda equina syndrome), and lasting for at least one day (Balaque et al. 2012; Hoy et al. 2012). In the literature in general, NSLBP has been categorized according to the duration of pain. Acute LBP has lasted < 4 weeks, sub-acute 5–12 weeks and chronic pain > 12 weeks (Foster et al. 2018). In earlier publications the cut-point between acute and sub-acute LBP was defined to be 6 weeks (van Tulder et al. 2006).

The categorization of NSLBP according to the duration of symptoms has also been criticized. Findings from several reviews suggest, that approximately 65–73% of patients with acute LBP had at least one recurrence of back pain in the following year and most continued to have episodes of significant pain and disability (Pengel, Herbert and Maher 2003; Itz et al. 2013; da Silva et al 2019). These findings challenge the concept of chronicity as a continuous development and the reliance on duration, e.g. the number of weeks since onset of pain (using 4, 6 or 12 weeks as a point for determining risk). The recurrent nature of LBP may make time judgments unreliable because sometimes the point of onset of pain is difficult to determine as is the point of recovery. There is considerable clinical variation, not to mention variation in when help might be sought from primary care providers. (Nicholas et al. 2011.)

Non-specific LBP is generally considered to be short-lasting in most cases and to have a good prognosis (Hartvigsen et al. 2018). However, Itz and colleagues (2013) criticize this widespread belief that spontaneous recovery is common, presenting that patients may still suffer from pain, although many studies have reported "return to work" or "recovery from disability" as evidence for recovery from LBP. They presented that only one third of the LBP patients recovered spontaneously within 3 months. Thus, the traditional assumption that spontaneous recovery occurs in a large majority of LBP patients is maybe not justified. (Itz et al. 2013.)

This thesis focuses on non-specific low back pain.

*Recurrent, non-specific low back pain*

LBP is reported to run a recurrent course in majority of patients. People who have had previous episodes of LBP are at increased risk of a new episode (da Silva et al. 2019). In a systematic review, Stanton and colleagues (2010) presented that there is large variation in literature how the term "recurrent LBP" is defined and that researchers and clinicians use it in a number of different ways. The most common criterion in defining recurrent LBP is frequency of pain episodes (Stanton et al. 2010), and the criteria range from "at least one episode over past year" (Bruce et al. 2005) to "pain twice weekly" (Feuerstein et al. 1987). More recently, Macedo and colleagues (2014) present that differentiation should be made between people with fluctuating pain and those with episodic LBP. The former would be people who have pain at levels that fluctuate over time, while the latter would be those with episodic/recurrent LBP who recover from an episode, but then experience a recurrence. Owing to the different definitions of recurrence and recovery, identifying those with episodic or recurrent LBP is challenging. (Macedo et al. 2014.)

Research using e-mail and SMS answers by mobile phone to record back pain intensity levels on a daily basis has broadened the understanding of the fluctuating nature of LBP: the majority of back pain sufferers experience pain episodes off and on over an extended span of time (Kongsted et al. 2017, Dunn et al. 2013). LBP is actually suggested to be a recurrent, long-term condition such as asthma (which very often can be treated) rather than a self-limiting condition such as the common cold, which comes and goes (Axén and Leboeuf-Yde 2013). According to Axen and Leboeuf-Yde (2013), this means that perhaps we need to look at LBP as a lifelong process, with different causes and modifying factors as life goes on, but always present as an underlying 'trait'. LBP is increasingly understood as a long-lasting condition with a variable course rather than episodes of unrelated occurrences (Dunn et al. 2013). It has also been suggested that more focus should be on distinguishing between fluctuating and episodic LBP (Kongstedt et al. 2017).

Consumers, clinicians, and researchers use various terms to describe the fluctuations of LBP intensity, such as episodes, recurrences and flares. The term "flare-up" was recently defined as "a worsening of the condition that lasts from hours to weeks, that is difficult to tolerate and generally impacts the usual activities and/or emotions" (Costa, Ferreira et al. 2019). Due to such difficulties in definitions, in this thesis the term "re-current LBP" covers both episodic and fluctuating low back pain.

### 2.1.4 Low back pain in healthcare personnel

There is a high risk of cumulative or traumatic spine injury in physically strenuous work like nursing, which is among the top professions at risk of LBP (Yassi and Lockhart 2013). The annual prevalence of LBP among hospital nurses and nursing assistants is between 45% and 77%, respectively, and new high-risk groups include home and long-term care nurses and physiotherapists (Davis and Kotowski 2015, Karahan et al. 2009). Episodes of LBP often begin, and become more frequent, at the nursing school, where studies include practical healthcare training with increased occupational exposure of the low back (Videman et al. 2005, Mitchell et al.2008). Recurrence rates of LBP in nurses exceed 70% (Burdorf and Jansen 2006). Persistent LBP is a strong risk factor for long-term sickness absence and early retirement in healthcare personnel (Andersen et al. 2012, Jensen et al.2012).

## 2.2 Risk factors for non-specific low back pain and pain chronicity

In majority of low back pain cases, a specific pain generator cannot be identified. Hence, non-specific LBP is a symptom, not a disease, and can result from several known or unknown factors, abnormalities or diseases (Hartvigsen et al. 2018). Factors that contribute to LBP and its course can be categorized to 1) physical and biomechanical factors, among them mechanical overloading to spinal structures, lumbar movement control and factors affecting it, as well as physical deconditioning, 2) psycho-social factors e.g. depression, fear-avoidance behaviour, social support, and job satisfaction, and 3) other factors such as genetics and life-style.

### 2.2.1 Biomechanical and physical factors

Alterations in normal lumbar curvature have been detected among patients with LBP. In the spinal column, the weight of the upper body relies on vertebral corpus and facet joints. Normally between the three columns there exists a balanced and modular action for which the posterior facets accept from 0% up to 33% of the load depending on posture. In case of hyper-lordosis, high or prolonged weight loading and disc degeneration, the percentage can rise up to 70%. (Gellhorn, Katz and Suri 2013.) Increased lumbar lordosis may be a risk factor for low back pain development, especially during prolonged periods of standing (Sorensen et al. 2015). On the other hand, reduced lumbar lordosis is also associated with LBP. It can lead to increased postural load and stress on the vertebral corpus and intervertebral discs, which can result in discus degeneration or bulge. (Sadler et al. 2017, Chun et al. 2017.) (Figure 3.) Control of the lumbar neutral spine posture has been suggested to play a key role in maintaining a healthy spine (Suni et al. 2013).

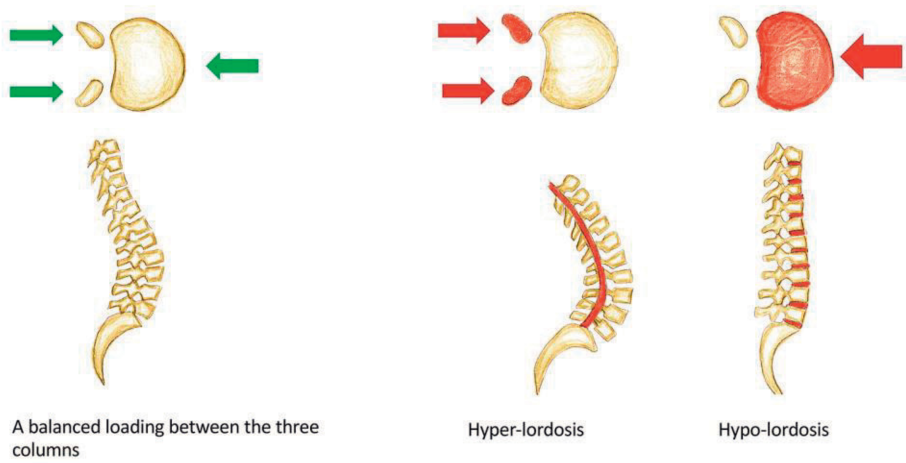


**Figure 3.** Distribution of loads between vertebral corpus, intervertebral discs, and facet joints in neutral lumbar position, hyper-lordosis and hypo-lordosis. Modified from Wallden 2009.

Both hypo- and hyper-lordosis correlate with degenerative joint disease, particularly in women (Murray et al. 2017). The assumption is that postural faults (i.e. a lumbopelvic alignment where people tend to position themselves at outer ranges of the lumbar range of motion) may result in cumulative microtrauma of the structures in the lumbopelvic area (Sahrmann 2002). These assumptions are not, however, consistent. Laird and colleagues (2016) found no differences in the lumbar posture between LBP patients and people with no LBP, measured by wireless, wearable inertial measurement units. Thus, associations between spinal posture and back pain remain somewhat unclear.

*Mechanical overloading to spinal structures*

Mechanical loading is good for the back. The bones, discs, ligaments and muscles of the spine are all capable of adapting to physical exercise by becoming stronger and this makes them less vulnerable to injury. However, all tissues tolerate only a certain amount of loading. Any structure can be damaged by applying a high force to it once, or a smaller force to it many times. (Will, Bury and Miller 2018.) Tissue overload occurs when the load imposed on a tissue exceeds its capacity. Tissue capacity differs between individuals depending on their age, the requirements of their work or leisure time sports, and the condition of their tissues. In any movement or task, several tissues are loaded simultaneously, and the one with the lowest capacity represents the weakest link in the chain and is often the one which gets injured. (Cook and Docking 2015.)

Awkward postures, heavy manual tasks, feeling tired, or being distracted during an activity are all associated with increased risk of an episode of low back pain (Steffens et al. 2015). Exposing the low back to cumulative mechanical loading at work, working in twisted positions and occupational lifting are strongly associated with development of LBP (Coenen et al. 2014; Halonen et al. 2019). Awkward positions are also a risk factor to pain recurrence after recovery from a period of LBP, as is prolonged sitting time (>5 hours) (da Silva et al. 2019). In experimental studies, pain responses have been reported by healthy populations after sitting for longer than one hour (Dunk and Callaghan 2005; Beach et al. 2005). While prolonged sitting increases immediate reporting of LBP no conclusion between sitting and clinical episodes of LBP can be made (De Carvalho et al. 2020).

When joints move to their end range of motion, away from neutral, the tissues surrounding the joints become subject to increased stress and strain. The involved mechanical forces applied to the spine can trigger nociceptive signals via mechanical nociceptors embedded in the tissues (e.g. joint capsule, discs, ligaments, tendons, and muscles). Animal studies show that sustained static or cyclic loading of lumbar viscoelastic tissues may cause micro-damage in the collagen structure, which in turn reflexively elicit spasms in the spinal extensor muscles. (Solomonov et al. 2003, Solomonov et al. 2012.) Sustained activation of erector spinae muscles may result in capillary compression and reduced oxygenation (McGill, Hughson and Parks 2000). Higher muscular activity in erector spinae muscles during walking, detected among people with chronic LBP, leads to a stiffened lumbar-pelvic region (Koch and Hansel 2014). On the other hand, stiffness or restriction in lumbar range of motion due to e.g. intervertebral discs, lumbar facet joints, sacroiliac joints or ligaments can also lead to development of LBP (DePalma, Ketchum and Saullo 2011; Sadler et al. 2017).

When tissue is damaged, due to an acute injury from overload to the tissue, peripheral nociceptors are activated essentially continuously. They produce chemicals in and around the damaged area that leads to the release of cytokines, prostanoids, and growth factors (Khalid and Tubbs 2017). The immune response aims to phagocytose injured cells. An acute inflammatory response is typically short-lived and reversible and involves the release of a range of molecules, including pro-inflammatory cytokines from injured cells and macrophages, along with other substances that sensitize nociceptive afferents and promote immune cell infiltration. (Fedorczyk et al. 2010, Zügel et al. 2018.) If loading is repetitive or prolonged, persistent inflammation may develop, and pain is perceived at lower thresholds when inflammation is present (Barr and Barbe 2004, Gao et al. 2013). That can lead to cytotoxic levels of cytokines and prolonged presence of macrophages in and around tissues, ultimately resulting in ongoing tissue damage and prolonged pain (Zügel et al. 2018). Chronic inflammation increases the production of inflammatory biomarkers and activates pro-inflammatory pathways which may lead to LBP and pain chronicity (Lim et al. 2020).

*Spine instability and mechanical loading*

"Spine stability" is a very popular term when discussing the low back and LBP. The normal function of the spine presupposes its stability. Spine stability is the basic requirement for the transfer of power forces between the upper and lower limbs, the active generation of forces in the trunk, and the prevention of early biomechanical deterioration of spine components (Izzo et al. 2013 a.). White and colleagues (1975) defined clinical stability as "the spine's ability under physiologic loads to limit patterns of displacement in order not to damage or irritate the spinal cord and nerve roots and to prevent incapacitating deformity or pain caused by structural changes".

Spine stability is regulated through three subsystems: passive (vertebrae, intervertebral discs, and ligaments), active (muscles), and neural control (Panjabi 1992). In an unchallenged, rested state, adequate integration of information from these three subsystems allows for effective generation of motor patterns to control spine motion, limit abnormal intervertebral movement, and avoid potential injury when performing dynamic tasks (McGill et al.2003; Panjabi, 1992). However, continuous or prolonged execution of a dynamic task may result in the development of muscle fatigue, which could impair the neuromuscular control of spine stability (Larson et al. 2018). Muscle fatigue negatively impacts the sensorimotor control processes of both the active and neural control subsystems by decreasing force generating capability (Taylor et al. 2000) and proprioceptive reliability of the fatigued muscle (Allen and Proske 2006), respectively. The loss of stability, instability, is suggested to be an important cause of back pain particularly at the lumbar level (Izzo et al. 2013 b).

Strained or failed ligaments and all sorts of tissue damage cause joint laxity and unstable motion under load. A critical role of the musculature is to stiffen the spine in all potential modes of instability and thus prevent the spinal tissues from excessive loading. (McGill et al. 2003.) Trunk muscle activation is adjusted to meet stability demands, and the central nervous system monitors the threats to spine stability.

Terms “stability” and “instability” are relevant concepts when talking about back pain. However, in some people with LBP, the term “instability” may evoke a mental image of fragility. Those individuals may consciously or unconsciously protect the spine by increasing continuous muscle co-activation. (Reeves et al. 2019.)

*Motor control and movement control impairments*

The concept of stability has been affected by modern neuroscience, which explores the control of movement. According to van Dieen and colleagues (2019), people with LBP demonstrate differences in all aspects of trunk motor control compared to healthy individuals. Motor control can be defined as “the way in which the nervous system controls posture and movement to perform a specific motor task”, and it includes consideration of the associated motor, sensory and integrative processes. Differences in muscle activity and kinematics among people with LBP are largely inconsistent. Two phenotypes or possibly the ends of a spectrum of motor deficiencies in LBP, have been suggested. In “tight control”, acute lumbar pain leads to increased muscle activation in spinal muscles. It has been suggested that this happens to protect the spine against tissue strains from uncontrolled movements. This adaptation is likely to provide short-term benefit to enhance spinal protection. In “loose control”, muscle activity is reduced, which might protect against high muscle forces and resulting spinal compression. Both strategies might produce short-term benefits, but they can have long-term consequences for spinal health. For example, whereas “loose control” can cause excessive tensile strain in tissues, the “tight control” may cause high compressive loading on the spine. These phenotypes are still hypothetical, and further research is needed. It is still unclear whether both phenotypes are results of an adaptation process aimed at protecting the low back, or direct interference of LBP and pain-related changes with motor control. (van Dieen et al. 2019.)

Movement changes when an individual is in pain. One mechanism driving non-specific LBP is proposed to be movement-control impairment, defined as an alteration of the spinal alignment and movement pattern in a specific direction (Luomajoki et al. 2018, Sahrmann 2002). This impairment occurs secondary to the presence of pain and can be due to abnormal tissue loading, and lack of proprioceptive awareness. Other circumstances, such as psychological, social and neurophysiological factors, could contribute to reinforce this disorder. (O'Sullivan 2005, Luomajoki et al. 2018.)

Several mechanisms have been described to influence lumbar proprioception and alter it in LBP. Nociception itself impairs somatosensory processing including proprioception (Nijs et al. 2015), but cannot solely explain all changes, especially when taking into account the studies among patients with recurrent LBP during a pain-free period (Brumagne et al. 2008). People with recurrent LBP show reduced back muscle endurance, and this muscle fatigue, maybe in combination with pain, can lead to deficiencies in postural control strategies, meaning that people with LBP rely more on ankle strategy in upright position (Johanson et al. 2011). A higher dependency on ankle strategy means that balance is mainly regulated through ankle movement, whereas the ability to regulate balance through lumbar and hip motion is restricted (Koch and Hänsel 2019). Moreover, excessive foot pronation can lead to an internally rotated tibial and femoral position, which may encourage an anterior pelvic tilt and altered loading of the spinal structures in upright positions, which might contribute to spinal pain (Barwick, Smith and Chuter 2012). Active joint-repositioning sense in sitting is also worse among people with LBP than in healthy controls (Tong et al. 2017).

Movement variability can be defined as variation in motor performance over multiple repetitions of a task (James et al. 2000). Robust movement variability has been detected in acute injury and pain, overuse injury, and injury recurrence (Mottram and Blandford 2020). Those atypical movement patterns have also been detected among people with LBP by using wireless inertial motion and electromyography sensors. The LBP group has smaller trunk, lumbar and pelvic range of motion, lower flexion-relaxation ratio, a greater delay of pelvic movement at the onset of trunk movement, and slower trunk flexion compared to healthy controls. (Laird et al. 2019) People with LBP show less complex and more predictable lumbar movement following fatigue than healthy controls. This may be due to physiological responses to avoid overload of tissues, or a consequence of reduced movement control caused by fatigue. (Bauer et al. 2017) Adequate movement variability of the lumbar spine may in turn lead to a slower development of muscular fatigue by distributing load across adjacent tissues, and thus maintaining task performance (Farina et al. 2012).

*The role of central nervous system in low back pain*

The biological component of back pain is not only in the back, it is also in the brain. During the past two decades, there has been an increased realization that people with LBP might also have extensive neuroplastic changes within the central nervous system (CNS). These include changes related to both the structure and function of the CNS as related to processing of pain and nociception and to motor and somatosensory systems. (Brumagne et al. 2019.)

Nociceptive input is processed throughout the nervous system, including modulation within the spinal cord and supraspinal centers (Hartvigsen et al. 2018). People with LBP have impaired lumbar proprioception compared with healthy controls (Tong et al. 2017). Sensorimotor impairments, e.g. impairments in body perception and spinal control, among people with LBP can also occur specifically due to changes in somatosensory cortex (Goossens, Janssens and Brumagne 2019). Recurrent LBP is also associated with a loss of discrete cortical organization of inputs to back muscles, and there is increased overlap in motor cortical representation of back extensor muscles (deep multifidus and erector spinae) (Tsao, Danneels and Hodges 2011). Patients with chronic LBP show structural brain differences in specific cortical and subcortical areas and altered functional connectivity in pain-related areas (Kregel et al. 2015). Nociceptive drive, but also context, cognition, and emotions can affect the activation and function of these cortical and sub-cortical areas (Hartvigsen et al 2018).

In chronic LBP, several brain changes, including increased activation in the regions of the brain called the "pain matrix" as well as functional connectivity re-organization in several brain regions, can lead to changes associated with the presence of central sensitization, sleep disturbances and fear-avoidance behaviour (Nijs et al. 2017). Because rehabilitation of chronic LBP with possible central sensitization and co-morbities is complicated, it is important to target preventive measures such as exercise or back counselling early to address the risk of prolonged pain, before chronicity.

*Physical inactivity and deconditioning in fitness components*

There is increasing evidence that low performance levels for several components of physical fitness are risk factors for LBP (Heneweer et al. 2012, Taanila et al. 2012), although scientific evidence about those associations is still partly conflicting with respect to revealing whether physical inactivity and deconditioning cause back pain or, alternatively, whether LBP leads to decreased physical activity and deconditioning (Verbunt et al. 2010).

There seems to be a U-shaped relation between physical activity and low back pain: both sedentary lifestyle and strenuous physical activity contribute to increased risk of LBP, particularly in females (Heneweer, Vanhees and Picaver 2009). Being physically inactive (Dunn et al. 2013, Balague 2012) is associated with higher risk of frequent back pain. Physical inactivity and sedentary behaviour are probably risk factors for development of pain and for transition from acute to chronic LBP (Sluka et al. 2018; Valdivieso et al. 2018).

This U-shaped relationship regarding the suggested negative effect of strenuous physical activity on LBP (Heneweer, Vanhees and Picaver 2009) has also been challenged: Lack of vigorous physical activity is associated with chronic LBP (Brady et al. 2018). In a Norwegian 11-year follow-up study, women participating in hard physical activity 1–2 h per week had also a lower risk for chronic LBP compared to those with only light physical activity less than 1 h per week. After adjustment for education, employment, occupational activity, body mass index (BMI) and smoking, significant relationships could be demonstrated only in those aged 50 years or more at baseline. (Heuch et al. 2016)

Individuals with recurrent LBP exhibit reduced lumbar muscle strength compared to healthy individuals (Lee et al. 2020). Deficits in muscle endurance have been found in people with LBP, especially in trunk extensors, hip extensors and quadriceps (Bernard et al. 2008). Majority of the high-quality studies conclude that atrophy of hip muscles is evident in patients with LBP (Pourahmadi et al. 2020). Restriction in lateral flexion of the spine, limited lumbar lordosis, and restricted hamstring range of motion are associated with an increased risk of developing LBP. Abnormal lower limb function is also proposed to reduce absorption of impact force and affect spinal loading, and thus contribute to the development of LBP. (Sadler et al. 2017.)

In physically loading work, it can be speculated that normal alignment in lower extremities, adequate range of motion in ankle and hip joints, and thoracic spine mobility that enable squatting and working in awkward positions without excessive movement and load to the lumbar spine (maintaining the neutral lumbar posture) are needed, but scientific evidence about this is scarce. There is only limited low-quality evidence to support an association between restrictions in hip range of motion and non-specific LBP (Avman et al. 2019).

### 2.2.2 Psycho-social risk factors for low back pain chronicity

The biopsychosocial model of LBP, made prominent by Gordon Waddell in 1987, is currently the recommended model for understanding and managing LBP and its resulting disability (Waddell 1987; Black, Sullivan and Mani 2018). Biological mechanisms are critical in understanding pain and disability (the 'bio' in biopsychosocial), especially in acute LBP, but psychological aspects are not independent from the biological presentation (i.e., trunk mechanical properties) of LBP (Karayannis et al. 2013). The last decades have seen considerable efforts to further understand the role of those factors (Hancock et al. 2011).

Psychological factors associated with prolonged back pain and disability include the perception that LBP will persist, associated with depression, anxiety, stress, low self-efficacy, psychological distress, fear and catastrophizing (Black, Sullivan and Mani 2018). Those factors are known to impact the course of LBP by contributing to the experience of acute LBP, and transition from acute to chronic LBP is known to be catalysed by psychological processes. Psychological processes in pain are highly intertwined and function together as a system. (Linton and Shaw 2011; Nicholas et al. 2011.)

Most of the patients with non-specific acute LBP and high levels of pain intensity and disability, and seeking care in emergency department, can be classified as having a high risk of developing an unfavorable prognosis with high levels of depression (Oliveira et al. 2020). After recovery from LBP episode, individuals with depression have an increased risk of developing a new episode of LBP in the future, with the risk being higher in people with more severe levels of depression (Pinheiro et al.2015). In addition to depression, anxiety also contributes to attentional and emotional pain processing mechanisms and thus, in development of chronic pain (Huber et al. 2010).

Social factors such as work environment, lack of support from superiors, work dissatisfaction and insurance or compensation programs have also been associated with higher levels of disability and increased work absenteeism in LBP (Pincus et al. 2013; Matsudaira et al. 2015). Poor social support, poor collaboration between, and poor support from colleagues are risk factors for back injury and LBP among healthcare workers (Andersen et al. 2019; Bernal et al. 2015). On the other hand, job satisfaction, good mental health and social support have been found to be protective factors against progression from acute/sub-acute LBP to persistent pain (Melloh et al. 2013).

LBP tends to be socio-economically patterned. Scientific evidence supports the hypothesis that people with low education level are more likely to be affected by disabling back pain (Dionne et al. 2001). Both childhood home poverty and own socio-economic position are associated with development of LBP (Lallukka et al. 2014).

*Fear-avoidance beliefs*

Fear avoidance is a belief that activities should be avoided to reduce pain. Fear-avoidance beliefs (FABs) develop as result of a cognitive interpretation of pain as threatening, and this fear affects attention processes (hypervigilance) and leads to avoidance of behaviour, like exercise and other physical activity, which are expected to cause pain (Figure 4). (Linton and Shaw 2011.)

The fear-avoidance model presents that the way an individual with LBP interprets pain leads to two different coping strategies; confronting or avoidance. Confronting is characterized by viewing the pain experience as a temporary setback rather than a life-altering, catastrophic event (Vlayen and Linton 2000). The confronting path echoes most current guidelines for management of non-specific LBP: advice to remain physically active (Foster et al. 2018). In contrast, avoidance is characterized by a path where acute LBP leads to pain catastrophizing, tendency to focus on pain sensation, helplessness, hypervigilance about pain, pain-related fear, avoidance of activities, and ultimately disuse, deconditioning and disability (Vlaeyen and Linton 2000)


**Figure 4.** The fear-avoidance of pain-related fear model (Linton and Shaw 2011). Reprinted with permission from Oxford University Press.

An important construct of the fear-avoidance model is kinesiophobia. It has been defined as an excessive, irrational and debilitating fear of physical movement and activity resulting from a feeling of vulnerability to painful injury or re-injury (Lundberg et al. 2011). Kinesiophobia and pain catastrophizing are strong predictors of prolonged LBP and disability (Picavet, Vlaeyen and Schouten 2002) Catastrophizing is believed to be a precursor for pain-related fear and FAB. However, it has been shown that LBP patients can have FABs without catastrophizing (Pincus et al. 2010), and it is unclear how catastrophizing as a coping strategy and FABs interact (Wertli, Eugster et al. 2014).

The fear-avoidance model suggests that as tissue injuries heal, pain-related outcomes are increasingly determined by psychological factors (Vlaeyen and Linton 2000). FABs influence treatment effects and are prognostic to poor outcome in sub-acute LBP (Wertli, Rasmussen-Barr et al. 2014). The presence of fear-avoidance beliefs is associated with increases in pain levels and reductions in physical activity levels (Nelson and Churilla 2015). Among people with chronic LBP, associations between poor physical fitness and high fear-avoidance beliefs have been presented (Lee and Park 2017).

Rainville and colleagues (2011) suggest classification of FABs into sub-groups of a) misinformed avoiders, who believe that it is common wisdom to avoid painful or strenuous back activities, b) learned pain avoiders, who have a Pavlovian association between making certain movements and experiencing pain, but who express neither elevated affect nor explicit beliefs about risk of injury from physical exposure, and c) affective avoiders, who are distressed about their back pain, who have persistent irrational fear of physical activities, and are strongly committed to their disabilities. Suggested methods to reduce FABs among these three groups are different. Misinformed avoiders probably benefit from FAB-reducing information. Treatment strategies for learned pain avoiders have not been explored, but they might benefit from systematically repeated exposure of quota-based activities in a tolerable way. Interventions for the challenging group of affective avoiders with disabling LBP should systematically challenge irrational beliefs and behaviours. An individually tailored hierarchy of feared physical activities and a gradual exposure are suggested to them, as well as functional restoration. (Rainville et al. 2011.) Those treatment strategies are still hypothetical, and there is no measurement method to classify people with pain to those suggested sub-groups.

### 2.2.3 Other factors associated with back pain

There is an association between back pain and smoking. Back pain is exacerbated with increased smoking exposure and increased number of cigarettes smoked per day (Green et al. 2016). Smoking may induce back pain in many ways, for example through excitatory effects of nicotine on perception and threshold for pain (Brage and Bjerkedal 1996), increasing the level of circulating pro-inflammatory cytogines (Shiri et al. 2010) and aggravating the inflammation process (Chung et al. 2012). Nicotine affects circulation, causing hypertrophy of vascular walls, necrotic changes in endothelial cells, and narrowing of the vascular lumen (Iwahashi et al. 2002). This nicotine-mediated vasoconstriction limits the exchange of nutrients between the discs and their surroundings (Vo et al. 2011), and smoking is strongly linked to degeneration of the intervertebral discs (Elmasry et al. 2015). Moreover, smoking causes carboxy-hemoglobin production, which blocks oxygen transport in plasma (Miller et al. 2000). Smokers also cough, which might cause pressure on low back (Green et al. 2016). Furthermore, smoking is associated with lower physical fitness, which in turn is associated with higher LBP scores (Heneweer et al. 2012).

Overweight and obesity have also shown to increase the risk of LBP (Shiri et al. 2010), especially among nurses with high BMI and shift work (Zhao, Bogossian and Turner 2012). Comorbid obesity is common especially in chronic LBP. The nature of the relationship is not likely to be direct, but many interacting factors appear to contribute, such as mechanical loading to body structures, inflammatory mediators associated with obesity, sleep disturbances, lifestyle (especially reduced physical activity), and depression. (Okifuji and Hare 2015.)

Lack of recovery impacts perception of pain. Sleep disturbances are strongly associated with pain intensity among people with LBP. A night with poor sleep, difficulties in falling asleep, and waking up after sleep onset is followed by a day with higher LBP intensity (Alsaadi et al. 2014). Sleep deprivation, via either a reduction in sleep duration or disruption of sleep architecture, leads to the development of musculoskeletal pain and increased pain sensitivity to noxious stimuli (Lusa et al. 2015; Agmon and Armon 2014). Sleep quality, depression, anxiety and LBP intensity are intimately linked (Parreira et al. 2018; Wang et al. 2016). Poor sleep constitutes a potent risk factor for LBP, and sleeping problems are associated with disabling LBP among healthcare workers (Yoshimoto et al. 2019; Vinstrup, Jakobsen and Andersen 2020).

In fibromyalgia patients, it is suggested that central pain mechanisms can be dependent on abnormal peripheral input for the development and maintenance of chronic LBP (Vierck 2006). Generalized hyperalgesia, hypersensitivity, and enhanced pain facilitation have been detected among patients with fibromyalgia and LBP (Goubert, Danneels et al. 2017).

There is also strong evidence for the associations between LBP, pain in other musculoskeletal sites and other health problems (Dunn et al. 2013). Likewise, people with chronic conditions, including diabetes and headache, are more likely to report low back pain than people in good health (Ferreira et al. 2013). A significant correlation has been reported between LBP and the presence of respiratory disorders, such as asthma and chronic obstructive pulmonary disease (Rasmussen-Barr et al. 2019), as well as dyspnea, different forms of allergy, and respiratory infections (Beeckmans et al. 2016). The mechanism to explain these associations is currently still inconclusive (Beeckmans et al. 2016).

The role of genetic factors in LBP has also been widely discussed, especially in prolonged pain (Hartvigsen et al. 2018). Studies investigating the effect of heritability in LBP have found that genetics accounts for 21–67% of LBP, and the contribution of genetics to LBP appears to be dependent on the severity of the condition (Ferreira et al. 2013). Genetic factors affect structural and anatomical spinal problems such as disc degeneration and narrowing, Modic changes, psychological components such as pain perception and psychological processes, and probably immunity (Freidin et al. 2018, Balague et al. 2012).

### 2.2.4 Healthcare work -related factors associated with non-specific low back pain

Healthcare work is very often both physically demanding and emotionally loading. It includes heavy physical tasks including frequent occupational lifting and /or carrying of heavy and moderate loads with forward bent back, which increases the risk of LBP aggregation among healthcare workers (Jensen et al. 2012; Holterman et al. 2013). Unexpected loading on the spine during patient handling increases the risk of developing acute LBP or other musculoskeletal injuries (Skotte and Fallentin 2008). Physically loading tasks can lead to minor injuries of spinal structures, such as ligaments and fascia, which in turn can lead to muscle fatigue, further injuries, and inflammation (Schleip et al. 2007).

A major challenge for healthcare workers with spinal problems is that their own physical fitness does not always match the physical demands of the work. Women with LBP have lower levels of aerobic fitness than healthy women (Rasmussen-Barr et al. 2008). Even a self-reported low rating of one's own physical capacity is a strong predictor of future LBP among healthcare workers. The risk of LBP is higher when there is an imbalance between the physically laborious and demanding nursing duties and the care worker's own, relatively low strength, aerobic fitness and balance. (Rasmussen et al. 2013.) Back extension endurance in particular is an important physical fitness component in preventing LBP, and the sub-components of physical fitness are related to LBP among healthcare workers in different ways (Stroyer and Jensen 2008). The participants in the NURSE RCT (on which the current thesis is based) were healthcare personnel with sub-acute or recurrent LBP, and among them good cardiorespiratory and muscular fitness were strongly associated with lower sickness-related absences and medical costs (Kolu et al. 2017).

Among female healthcare workers with previous LBP, both the physical workload and high FABs have been shown to be factors associated with new episodes of LBP (Jensen et al. 2009). Those healthcare workers with high FABs were likely to have more sickness absence than those with lower fear avoidance, despite equal levels of LBP intensity (Jensen et al. 2010).

Psycho-social stress and constant time pressures in daily tasks are often common in healthcare work. Nursing personnel is often confronted with life events which cause anxiety, worry and sorrow in patients and their relatives. This, along with the daily time pressures and lack of personnel can also lead to emotional loading. (McHugh et al. 2011.) Among workers in emergency departments, stress and job satisfaction have been found to be associated with low back pain (Rahimi et al. 2015).

Shift work, sleeping problems and problems in recovering from work might influence the perception of pain, as well as lack of support from superiors in a hierarchic working environment, which healthcare workplaces still often are (McHugh et al. 2011).

## 2.3 Treatment options for non-specific low back pain

Recommendations to treat LBP are not always consistent internationally. Oliveira and colleagues (2018) identified discrepancies in treatment recommendations for LBP especially regarding the pharmacological treatment. In the most recent recommendations for treatment of acute LBP, the use of nonsteroidal anti-inflammatory drugs (NSAID) is recommended instead of paracetamol, as well as information and advice to stay active (Oliveira et al. 2018, Schreijenberg 2019). In Danish guidelines for interventions in recent onset (<12 weeks) non-specific LBP, patient education, different types of supervised exercise and manual therapy are recommended, if treatment is needed. Acupuncture, routine use of diagnostic imaging, targeted treatment, glucocorticoid injection, paracetamol, NSAIDs, and opioids are not recommended. (Stochkendahl et al. 2018) Finnish National Guidelines for treating pain (Kipu: Käypä hoito -suositus, 2017) recommend non-pharmacologic treatment as the basis of managing pain. Physical activity, therapeutic exercise, cognitive behavioural therapy, and physical treatments such as cold/heat and electrotherapy for pain are mentioned as primary treatments.

Treatment options for musculoskeletal pain, including LBP, can be depicted graphically according to the grade of evidence as in Figure 5.

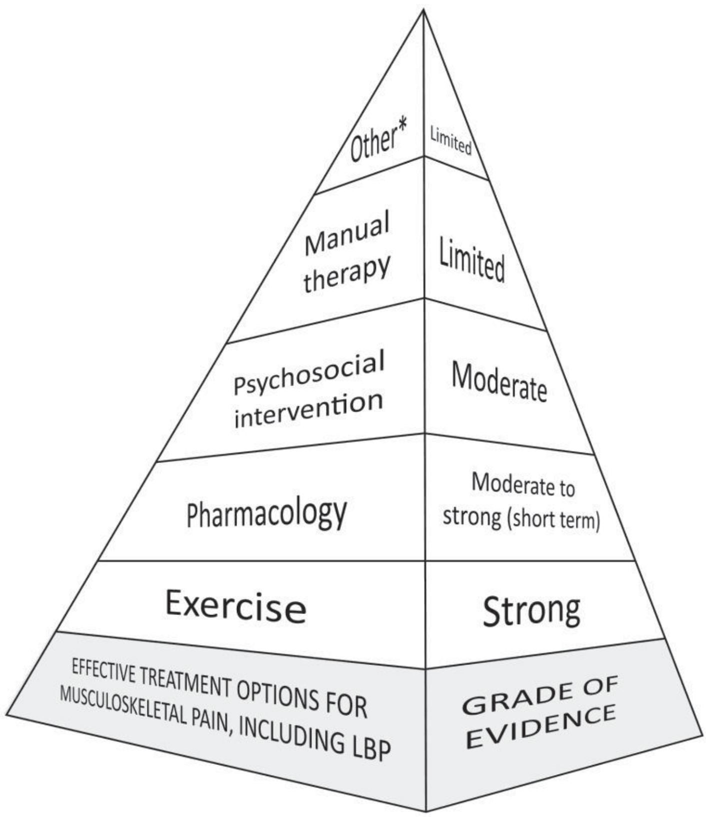


**Figure 5.** Treatment options for LBP and grade of evidence. Modified from Babatunde et al. 2017. Other* = Complementary/alternative therapies, devices and aids. LBP = low back pain

One third of the international guidelines recommend the use of a validated screening tool to identify people with a high risk of pain chronicity (Oliveira et al. 2018). Measurements have been developed to identify risk status based on a short questionnaire. The higher the score of the psychological sub-scale items is, the more serious the psychological problem contributing to the pain experience and possible pain chronicity is. Those with a medium or high risk of prolonged pain are provided more support, advice and patient-centered communication than those with a low risk. (O´Sullivan and Lin 2014.)

In Finnish National Guidelines (Alaselkäkipu: Käypä hoito -suositus, 2017) for treating non-specific low back pain in adults (>15 years), the following treatments are recommended: In acute (defined as less than 6 weeks) LBP, paracetamol is recommended as medical treatment when needed, as well as avoiding bed rest and encouraging patients to retain their usual activity levels. Exercise is not considered to be effective. In sub-acute (6–12 weeks) LBP, an extensive multifactorial examination of the patient's situation should be carried out followed by active, psycho-social and multi-professional rehabilitation. Active therapeutic exercise including both aerobic and muscle strengthening exercises is considered beneficial. As pain medicine, paracetamol, NSAID or a combination of NSAID and a weak opiate can be used, taking into account the side effects and risks. In chronic LBP (>12 weeks), multi-professional intensive rehabilitation is recommended to reduce pain and to improve functional abilities. Graded, supervised therapeutic exercise and cognitive behaviouristic methods in counselling are recommended, along with the pharmacological treatment as in sub-acute LBP. (Alaselkäkipu: Käypä hoito -suositus, 2017.)

## 2.4 Exercise for non-specific low back pain

In the acute phase of LBP, damage to any of the back tissues usually instigates inflammation, where the back tissues are irritable and symptoms easily exacerbated. This is followed by a phase where inflammation leads to tissue regeneration, if the tissue is not re-injured. (Sauaia, Moore and Moore 2017.) Acute LBP is associated with compromised back muscle functions. If the pain continues, in the sub-acute phase changes in muscles can be detected. These include fatty infiltration, fibrosis, and slow-to-fast muscle fiber transformation. (Hodges et al. 2014; Hodges et al. 2015; Hodges and Danneels 2019.) Those changes are unlikely to disappear by themselves, without physical activity or exercise. That has been depicted in Figure 6.

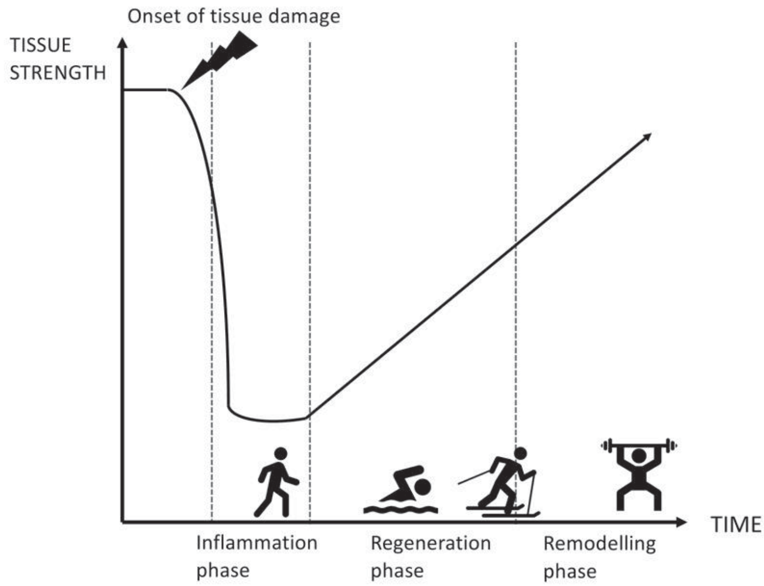


**Figure 6.** Lumbar tissue strength at the onset of LBP and effects of exercise on its course.

After the acute phase, clinical guidelines consistently recommend exercise and physical activity as well as patient education and the patient´s active involvement in the management of their LBP (Oliveira et al. 2018). Exercise can be defined as "planned, structured and repetitive movements that are performed to improve or maintain one or more components of physical fitness" (Daenen et al. 2015). Current evidence suggests that moderate physical activity or exercise is beneficial in reducing chronic back pain: significant reductions in the intensity of pain can be achieved through both aerobic exercise and resistance training (Wewege, Booth and Parmenter 2018). However, the specific content of the exercises and physical activity is often poorly described (Gianola et al. 2016; Kjaer et al. 2018), and there is no consensus on the contents of an effective exercise program, especially among people with non-chronic or recurrent LBP.

### 2.4.1 Existing evidence of the impact of exercise on low back pain

Exercise alone and exercise combined with education can prevent episodes of LBP and LBP- related work absenteeism (Steffens et al. 2016; Huang et al. 2019).

Neuromuscular exercise with focus in controlling the neutral spine proved to be effective in reducing the number of off-duty days due to LBP among conscripts, who had a healthy spine when they started their physically demanding military service (Suni et al. 2013).

Typically in acute LBP, early supervised exercise therapy is generally considered unnecessary – it has not proved to speed up the recovery process (Foster et al. 2018; Alaselkäkipu: Käypä hoito -suositus, 2017), and can instead cause additional loading to injured tissues. According to Danish Guidelines for treatment of patients with recent onset (<12 weeks) low back pain, the advice is to remain active, and supervised exercise is recommended if needed (Stochkendahl et al. 2018). However, the evidence of exercise on acute LBP remains uncertain as evidence from systematic reviews is conflicting. Currently, there is very low to moderate certainty of evidence that exercise of any type may result in little or no important difference in pain or disability, compared with other interventions, in people with acute LBP (Karlsson et al. 2020). There is lack of consensus as to when would be a suitable time to start exercising after the onset of pain or in the case of fluctuating or recurrent LBP. Falla and Hodges (2017) have suggested exercise alone to be insufficient for a multi-factorial problem, such as chronic LBP.

### 2.4.2 Overview of exercise treatment studies for non-specific low back pain

A range of exercise protocols have been used for people with LBP both in exercise studies and in clinical practice. The exact definition of the exercises varies, and consensus is particularly lacking LBP-specific exercise concepts, such as "motor control exercise", "movement control training" or "stabilizing exercises" (Saragiotto et al. 2016).

"Motor control training" or "Motor control exercises" have been portrayed as interventions which involve the isolated training of deep trunk muscles and integrating their activation into more complex static, dynamic and functional tasks. The focus of the motor control exercises is on the function and performance of individual muscles, such as the multifidi (MF) and transversus abdominis (TrA). (Saragiotto, et al. 2016, Luomajoki et al. 2018.) These exercises gained popularity in the late 1990s after the early work by Hodges and Richardson (1996, 1998), who demonstrated a delayed onset of TrA among patients with LBP compared to healthy controls when performing rapid arm movements. It was consequently assumed that the TrA, by means of its connections to the lumbar fascia, is dominant in controlling lumbar stability (Hodges et al. 2003). Although those findings presented correlation between the deficiencies of transversus abdominis and LBP, but not causality, assumptions about the importance of TrA for stabilization of the spine grew out for "a whole industry with gyms and clinics teaching activation of the deep core muscles as a cure for LBP" (Lederman 2010). Later, Gubler and colleagues (2010) found no delay in abdominal muscle feed-forward activation in patients with chronic LBP compared to symptom-free controls, and a systematic review of 15 exercise studies revealed strong evidence that temporal alterations in TrA thickness or feed-forward activation of TrA, following exercise intervention, were unrelated to temporal changes in LBP intensity or LBP-related disability (Wong et al. 2014).

Lumbar multifidus (MF) muscles are considered to be important local muscles in stabilizing the spine, and several studies show structural changes like muscle atrophy, fat infiltration, fibrosis and slow-to-fast muscle transition of MF muscles among people with LBP (Macdonald, Moseley and Hodges 2009; Valdivieso et al. 2018; Russo et al. 2018; Hodges and Danneels 2019). Quite recently, Hodges and Danneels (2019) suggest that gentle, early activation of multifidus muscles in an acute episode of LBP might be beneficial. However, targeted MF exercises are very specific, and many LBP patients are simply unable to perform specific activation of the MF (Russo et al. 2018). For example, LBP participants exhibit higher levels of co-contraction of flexor/extensor muscles and higher antagonistic paraspinal muscle activity than controls in flexion movements (D'Hooge et al. 2013).

In a recent paper, Hides and colleagues (2019) stated that understanding "motor control training" only as activation of isolated deep muscles is not correct. Instead, requiring a balance between movement and stiffness (achieved through appropriately coordinated activation of trunk muscles), maintenance of a neutral lumbar spine posture, initiating movement from periphery (not the trunk), and adequate flexibility and mobility of adjacent joints and muscles attaching to the pelvis are also required (Hides et al. 2019).

The "movement control exercise" approach is differentiated by its aim to change movement behaviour through a combination of physical and cognitive learning processes rather than activating and strengthening isolated muscle groups (O'Sullivan 2005, Luomajoki et al. 2018). Among LBP patients who demonstrate deficiencies in lumbar movement control, exercises aiming at restoring movement control, correcting movement patterns and avoiding pain-provoking postures could be beneficial. (Luomajoki et al. 2018) The approach is based on the idea that for people with movement control impairment, repeated movement patterns and positions might accelerate lumbar tissue stress and trauma. The focus in training is on alignment and movement strategies to normalize trunk movements and positions (Jacobs et al. 2016). There is still very low to moderate evidence of the positive effect of movement control exercises on pain and disability in the short term compared to other interventions (Luomajoki et al. 2018).

Spinal injury, and the associated pain, is characterised by a high complexity of motor re-organization: all the levels of motor abilities are affected. It is probably a matter of an overall control re-organization rather than failure of any particular component. For example, training focused on any single muscle is difficult, because "muscle-by-muscle activation" hardly exists. (Lederman 2010.) No single muscle has proved to be the best stabilizer of the spine, each of the lumbar back muscles is capable of several possible actions, no muscle has a single action and no action is unique to a specific muscle (McGill et al. 2003).

One method to define or determine spinal exercises is according to the objective of the exercise and its intended physical outcomes. Spencer, Wolf and Rushton (2015) defined those targeted spinal abilities in four categories: mobility, motor control, work capacity (muscle endurance), and strength. In sport injury prevention research, exercise interventions to target all those abilities are often called "neuromuscular exercises". Furthermore, neuromuscular exercises typically involve multiple joints and muscle groups performed in functional weight-bearing positions. (Aageberg and Roos 2015.) The emphasis is on the quality and efficiency of movement as well as the alignment of lower limb joints and the trunk. According to Ageberg and Roos (2015), the neuromuscular training method is "based on biomechanical and neuromuscular principles and aims to improve sensorimotor control and achieve compensatory functional stability".

It is rather difficult and unclear to define spinal exercises according to the literature, because definitions have changed over time. Stability of the low back results from highly coordinated muscle activation patterns involving many muscles, and the recruitment patterns of the muscles must continually change, depending on the task (McGill et al. 2003). Thus, in LBP, it is considered to be important to increase spinal stability using exercises that minimize the load on spinal structures (which might be injured or micro-damaged) but simultaneously induce high muscular activity in the core muscles (Kavcic, Grenier, McGill 2003; McGill and Karpovich 2009), especially for people who have strenuous work and low back pain.

### 2.4.3 Exercise-induced hypoalgesia

Basic science studies have only just recently begun to examine the underlying mechanism of exercise-induced hypoalgesia, which is a phenomenon that occurs during and/or after a bout of physical activity and is believed to involve the endogenous pain modulating mechanism. According to animal studies, regular physical activity and exercise prevent development of persistent musculoskeletal pain. (Sluka et al. 2018.) Physical activity prevents hyperalgesia through several mechanisms: 1) Affecting central nervous system by changing the state of central pain inhibitory pathways, especially for cells in brainstem, which modulate pain. Exercising increases the opioid tone in nervous system by activation of opioids and serotonin to produce analgesia. (Sluka et al. 2018; Tour et al.2017.) 2) Physical activity also modulates the immune system locally (at the site of insult), systemically and in the central nervous system by increasing anti-inflammatory cytokines and decreasing inflammatory cytokines (Sluka et al. 2018). Inflammatory cytokines activate receptors on nociceptors to produce pain, whereas anti-inflammatory cytokines reduce activity of nociceptors to prevent pain (Sluka et al. 2018, Dina et al. 2011). 3) Exercising also affects psychological comorbidities, such as depression and anxiety (Carek et al. 2011), as well as fear-avoidance beliefs and pain catastrophizing (Elfwing et al. 2007), which in turn might influence the perception of pain.

### 2.4.4 Modified Pilates-type exercise for low back pain

Over the past decades, the Pilates method has been one of the most popular exercise forms for non-specific LBP in clinical practice (Yamato et al. 2015). The exercise program presented in this thesis is also modified from Pilates exercises.

Pilates is one of so-called body-mind or mindful exercises. Those exercise forms are typically performed at a slow pace, simultaneously integrated with mental focus on muscle and movement sense, and rhythmic diaphragmatic breathing (Zou et al. 2019). The Pilates method was founded by Joseph Hubertus Pilates (1883-1967) in the early 1900s. In the development of his method, Pilates drew inspiration from yoga, martial arts, ancient Greek and Roman exercises, ballet, as well as Zen meditation (Latey 2001).

The Pilates method focuses on core stability, strength, flexibility, muscle control, posture and breathing. This method of body conditioning involves six basic principles: concentration, centering, control, precision, breathing and flow. (Wells et al. 2012, Joyce and Kotler 2017) Traditional Pilates principles and their definitions are presented in Table 1.

**Table 1.** Traditional Pilates principles (Wells et al. 2012, Latey 2002)

| *Principle* | *Definition* |
|---|---|
| 1. Centering | Tightening the musculature between the ribcage and pelvic floor (also called the "powerhouse") during the exercises |
| 2. Concentration | Cognitive attention required to perform the exercises |
| 3. Control | Close management of posture and movements during the exercises |
| 4. Precision | Accuracy of exercise technique |
| 5. Breathing | Breathing in co-ordination with movements |
| 6. Flow | Smooth transition of movements within the exercise sequence |

The Pilates method gained popularity at the end of the 1990s. The exercises of the method can be divided into 2 types and 2 categories: mat Pilates and equipment-base Pilates are the two types and traditional and contemporary are the two categories (Latey 2002; Muscolino and Cipriani 2004). The traditional Pilates mat program called "the classic 34" includes 34 different exercises, which are quite demanding and require muscle strength, flexibility and co-ordination. While the traditional or classic method is physically demanding, the contemporary or modified method can be prescribed to the general population and modified for patients in rehabilitation. It is aimed at spinal alignment and neutral spine posture, and the exercises are adapted to the individual's physical condition, with a gradual and progressive increase in the level of difficulty and complexity according to personal skills and characteristics. (Latey 2002; La Touche et al. 2008)

In a systematic review, Saragiotto and colleagues (2016) present that the principles of Pilates may overlap the principles of motor control exercises, which are based on the concept that individuals with LBP present with changes in the control and coordination of spinal muscles. Motor control exercises focus on the activation of the deep spinal muscles (i.e. TrA and MF), and the inhibition of the superficial muscles (Saragiotto et al. 2016, Falla and Hodges 2017), targeting the restoration of control and coordination of these muscles. That technique has later been followed by many Pilates schools, with the emphasis on recruiting the deep core muscles like TrA during forced exhalation. On the other hand, some Pilates schools focus on conducting the exercises according to the original Pilates method, while others emphasize applying current bio-mechanical knowledge of tissue loading on selecting and modifying specific exercises. Recruiting specific deep muscles in exercises cannot be found in the two books written by Joseph Pilates (Pilates 1934; Pilates and Miller 1945).

Studies show positive effect in favour of the Pilates method vs. usual care or no exercise among people with chronic LBP (Yamato et al. 2015, Byrnes et al. 2018). While some studies did demonstrate better relief on short-term pain and disability along with improved quality of life, there is no conclusive evidence that Pilates is superior to other forms of exercises therapies (Yamato et al. 2015), such as lumbar stabilization exercises (Pereira et al.2012) or general exercise (Wajswelner, Metcalf and Bennell 2012). Research on the Pilates method is further compounded by the fact that there are many different styles of Pilates method exercises (Joyce and Kotler 2017).

### 2.4.5 Breathing technique, exercise and low back pain

One fact that distinguishes Pilates-type exercise from more traditional muscle strengthening exercises is its focus on breathing technique and combining breathing with each movement. The primary function of breathing is the exchange of gases – oxygen and carbon dioxide – between the atmosphere and the human body, but the breathing technique employed also has an effect on intra-abdominal pressure (IAP), core muscle activation and thus, on spinal stability (Calais-Germain 2005). The breathing technique in Pilates method is called lateral breathing (Muscolino and Cipriani 2004).

Spine stability is ensured through muscle activation of surrounding trunk muscles. Those same muscles are contracted rhythmically during breathing (Wang and McGill 2008). The major respiratory muscle, diaphragm also has a role in controlling the spine and in postural control (Hodges and Gandevia 2000). The diaphragm contracts and flattens during inspiration, pushing on the abdomen, while the lower ribs are pushed outwards and upwards (Downey 2011). This action, pushing on the abdomen, increases the IAP, which in turn increases spinal stability (Hodges et al. 2005). The exact role of the diaphragm in trunk stabilization has been under investigation for decades, but the accurate mechanism remains still poorly understood (Kolar et al. 2010). Individuals with LBP appear to show sub-optimal function of the diaphragm: they show a higher diaphragm position and smaller diaphragm excursion during inspiration (Kolar et al. 2012), and they have greater susceptibility to diaphragm fatigue compared to healthy controls (Janssens et al. 2013).

Expiration is generally passive. When breathing effort is increased during physical strain or during forced expiration, expiratory muscles (meaning the abdominal muscles) become active: they pull the abdominal wall inwards when contracted. Decreased abdominal diameter causes increased IAP. (Calais-Germain 2005; Aliverti 2016.) The increase in IAP forces the diaphragm to rise superiorly into the ribcage and deflate the lungs (De Troyer and Bodiek 2011). Active contraction of TrA during forced exhalation also tightens the thoracolumbar fascia, which contributes to spinal stability (Hodges et al. 2003).

In different Pilates schools, breathing with the movements is instructed in different ways. Joseph Pilates himself emphasized active exhalation "by squeezing every atom from the lungs". He considered that this cannot be achieved properly unless the individual is not privately coached. He also had a somewhat careless approach to "lightheadedness" that followed as a side effect of active exhalation, claiming that the feeling will disappear entirely in a few days. (Pilates and Miller 1945, Pilates 1934) Currently, such "lightheadedness" is understood to be a sign of hyperventilation, which can lead to a variety of negative biochemical, psychological, neurological and biomechanical influences, as well as muscular imbalances and motor control alterations (Chaitow 2004; Bradley and Estormes 2014; Ristiniemi et al. 2014; Vidotto et al. 2019).

In the clinical practice of Pilates exercises, forced exhalation through pursed lips during the physically strenuous phase of the movement is often instructed. However, according to Cholewicki, Ivancle and Radebold (2002), this strategy (if not executed properly by active contraction of expiratory muscles) could also reduce intra-abdominal and intra-thoracic pressures and the level of trunk muscle co-contraction resulting in reduced spinal stability. Thus, forced expiration during the heavy phase of a movement is a demanding technique, and it demands proper guidance. Some Pilates schools concentrate more on the execution of the right technique of each movement while breathing "normally" through the nose and utilize the increased IAP during inhalation during the heavy phase of the movement. In conclusion, both inhalation during lateral breathing and/or active exhalation with proper muscle activation may increase IAP during Pilates exercises. There is no scientific evidence as to which one of those breathing techniques during movements is superior.

When each movement sequence is coupled with a specific breathing rhythm, specific movements also help to enhance the breath, and vice versa: breathing supports the movement. For example, expansive movements (e.g., chest openers) facilitate inhalation, whereas contractive movements (e.g., forward bends) facilitate exhalation. (Schmalzl, Powers and Henje Blom 2015.) That kind of technique can be utilized, for example, in flexibility exercises.

There is very little scientific evidence on the effects of combining breathing with movements. In clinical practice, it is, however, considered to be important. In a Delphi study among 30 physiotherapists, who were experienced in treating chronic LBP using Pilates exercises, there was 100% agreement in encouraging breathing with movement (Wells et al. 2014).

### 2.4.6 Summary of existing evidence of the impact of exercise on low back pain

Exercise is the only evidence-based, single treatment for the management of non-specific LBP, and it is also one of the most frequently recommended treatments in spinal pain (Falla and Hodges 2017). Exercise has been proposed to improve not only motor control, strength, endurance, flexibility, range of motion, and general fitness but also mood and alleviate depression among people with chronic LBP (Searle et al 2015). Currently, there is no clear evidence that any particular type of exercise is more effective than another in managing patients with spinal pain (van Middelkoop et al. 2010; Saragiotto et al. 2016; Yamato et al. 2015). Neither have any significant differences been found in reduction of pain and disability between group exercise and individual physiotherapy involving exercise (O'Keeffe et al. 2017).

The summary of non-specific LBP in relation to physical activity and exercise is presented in Figure 7.

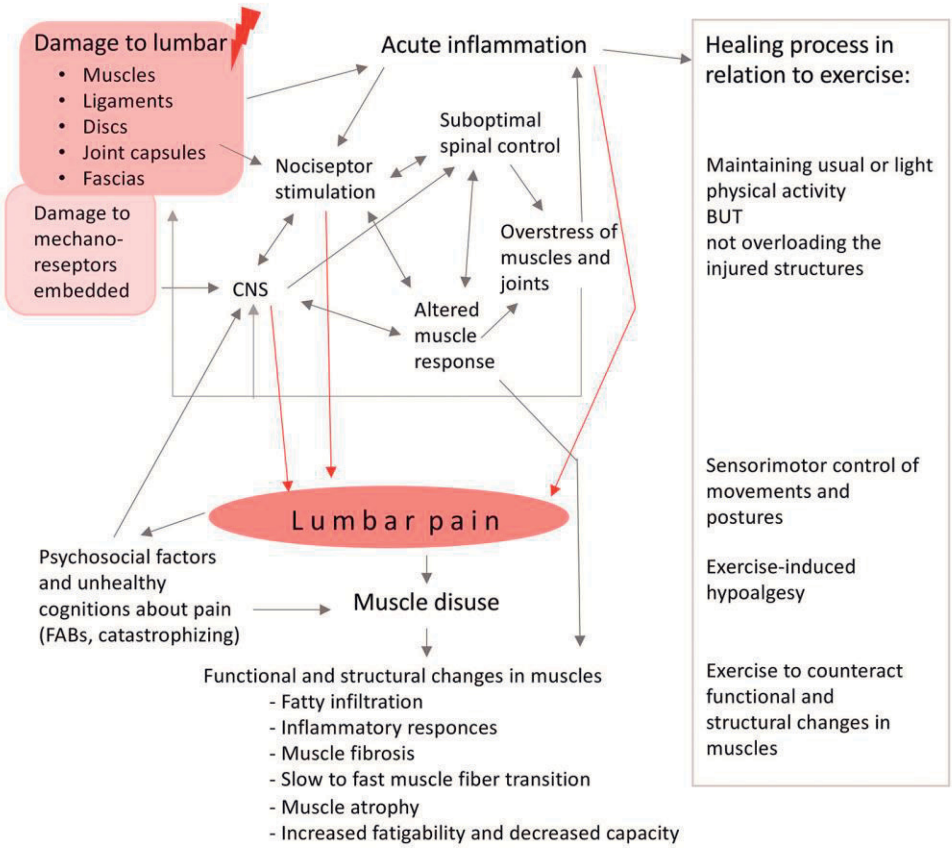


**Figure 7.** Non-specific LBP and its consequences in relation to physical activity and exercise. Modified from Izzo et al. 2013 a) and Hodges and Danneels 2019. CNS = Central nervous system, FABs = Fear avoidance beliefs.

## 2.5 Adherence to exercise in musculoskeletal pain

Exercise adherence is a multidimensional construct, with multiple synonyms used to describe its meaning, such as compliance, concordance, agreement, and cooperation. Adherence and compliance both refer to the patient–healthcare practitioner relationship, but adherence is currently viewed as reflecting a less paternalistic relationship, with the patient/participant as an active decision maker rather than passive recipient. (Bailey et al. 2020)

Achieving and maintaining adherence to exercise in the management of spinal pain is important in order to achieve the beneficial effects of exercising. A common problem in clinical trials, as well as in clinical practice, is the failure of participants to fully comply with the allocated treatment (Knox et al. 2014). Adherence is a key link between the process and outcome of a treatment, and poor adherence compromises the effectiveness of exercise intervention (Jordan et al. 2010).

Exercise adherence among people with musculoskeletal pain has shown to be only modest as best, and several factors are suggested to contribute to poor adherence. Among people with chronic LBP, improvements in functioning are more strongly associated with compliance to exercise than the type of exercise (Andersen et al. 2008; van Dillen et al. 2016). Between 50-70% of people with chronic back pain are non-adherent to prescribed home exercise (Beinart et al. 2013). Thus, factors associated with exercise adherence in LBP need more investigation.

# 3 AIMS OF THE STUDY

Effects of an intervention can be measured only with reliable measurement methods. Thus, the first research question was:

1. Are musculoskeletal fitness tests and the test battery for lumbar movement-control impairments repeatable among healthcare personnel with sub-acute or recurrent low back pain (Study I).

In randomized controlled intervention studies, understanding the characteristics of the study sample is important. The second research question was:

2. In what way are several biopsychosocial factors associated with (i) bodily pain, (ii) physical functioning, and (iii) perceived ability to work, and is there an association between physical fitness and work-induced lumbar exertion at baseline among the study sample of female healthcare workers with sub-acute or recurrent LBP? (Study II)

Exercise is recommended for low back pain, but there is neither consensus about contents of an effective exercise program among people with sub-acute or recurrent LBP, nor strong evidence of any effective treatment of healthcare personnel with LBP. The third research question was:

3. What are the effects, and efficacy, of a modified Pilates-type neuromuscular exercise program with focus on controlling the neutral lumbar spine posture, on pain intensity, pain interfering with work, lumbar movement control, fitness components, work-related factors and fear avoidance believes among healthcare workers with recurrent LBP and physically demanding work? (Studies III and IV)

In sub-acute or recurrent LBP, the intensity of pain fluctuates and changes, and it is difficult to define why that happens. The fourth research question was:

4. Is there an association between a change in LBP intensity and a change in measurement variables in longitudinal measurements: baseline – intervention – 6-month follow-up measurements (Studies III and IV)

Adherence is a key link between the process and outcome of exercise interventions, and poor adherence compromises the effectiveness of an exercise intervention. Thus, the final research question was:

5. Which background and baseline factors of female healthcare personnel with sub-acute, recurrent LBP are associated with exercise adherence in a 6-month intervention (Study IV)

# 4 MATERIALS AND METHODS

## 4.1 Study design

This doctoral thesis and the related original publications are based on the NURSE RCT (Effects of Neuromuscular Exercise and Back Counselling on Pain, Movement-control impairment, and Fear-avoidance Beliefs in Working Female Health-care Personnel with Recurrent Non-specific Low Back Pain; NCT01465698; Suni et al. 2016). The original NURSE RCT aimed to investigate the effects and cost-effectiveness of neuromuscular exercise (NME) and back care counselling, each on their own or both together, on pain intensity and fear-avoidance beliefs among female healthcare workers with recurrent low back pain. In the original NURSE RCT, the 6-month randomized controlled trial (RCT) had 4 experimental groups: 1) modified Pilates-type NME focusing on controlling the neutral lumbar spine posture, 2) back care counselling, 3) combined Pilates-type NME and counselling, and 4) no intervention. (Suni et al. 2016.) The study profile is presented in Figure 8.

This thesis reports effects of the neuromuscular exercise only, as a secondary analysis of the original NURSE RCT. The NURSE RCT study groups were aggregated according to exercise allocation (regardless of receiving back counselling) into:

1. Modified Pilates-type neuromuscular exercise (NME) focusing on controlling the neutral lumbar spine (groups 1 + 3)
2. Controls (= no exercise; groups 2 + 4)

In both study groups, Pilates-type NME and controls, 50% received back care counselling and 50% did not. In investigating effects of the NME program, all analyses were adjusted for counselling.

In study I, the test-retest design (measurements were conducted twice at baseline before the study interventions) was used to analyse the repeatability of certain measurement methods. For study II, a cross-sectional design was used to analyse baseline data of the whole study sample. Effects of the NME intervention at three measurement points (baseline, 6 and 12 months) are reported in studies III and IV, which were based on a secondary analysis of a blinded, randomized controlled trial

(NURSE RCT). The NME group was aggregated into exercise compliers and non-compliers in order to investigate associations of the baseline and background factors on exercise adherence in a retrospective, secondary analysis in study IV.

## 4.2 Participant recruitment and progress off the study

In the NURSE RCT, 3 sub-studies were conducted to reach the adequate sample size. The sub-studies started consecutively in 2011 (sub-study 1), 2012 (sub-study 2), and 2013 (sub-study 3). The participants were randomized within each sub-study, and interventions were carried out identically in each sub-study. (Suni et al. 2016)

The NURSE RCT was carried out in healthcare workplaces, which were known to be physically demanding and include patient work, such as lifting and transferring patients or working in awkward positions. The target population was female healthcare workers with LBP, and engaged in direct patient work: nurses, specialist nurses, nursing assistants, physiotherapists, assistant physiotherapists, radiographers, and midwifes. (Suni et al. 2016)

Sub-study 1 of the NURSE RCT ($n = 56$) was conducted in two geriatric hospitals and an old people's home (Kauppi and Rauhaniemi hospitals, and Koukkuniemi old people's home, Tampere Finland). Recruitment started in October 2011, and baseline measurements were conducted from October to December 2011. In sub-study 1, baseline fitness measurements and movement-control impairment tests were conducted twice in order to confirm the intra-tester test-retest repeatability of the measurements in this study population. Participants completed the interventions between January and June 2012. The 6-month follow-up measurements were conducted immediately after the intervention, with the 12-month follow-up measurements conducted six months later in January–February 2013.

Sub-study 2 ($n = 80$) was conducted in community hospital wards (Hatanpää hospital), and in public healthcare units and home service of the city of Tampere. Recruitment started in October 2012, the interventions were carried out between January and June 2013. The follow-up measurements at 6 and 12 months were conducted in a similar way as in Sub-study 1.

Sub-study 3 ($n = 83$) was conducted in Tampere University Hospital wards, in Coxa Hospital for Joint Replacement, and in Heart Hospital of Tampere. Recruitment started in June 2013, baseline measurements were conducted in September–October, and the interventions were carried out in November 2013–

April 2014. The 6-month measurements were conducted in May-June 2014, followed by the 12-month measurements in November–December 2014.

In the original NURSE RCT with the 4-arm setting, measurements were conducted at baseline and in the follow-ups at 6, 12 and 24 months. Data of the 3 sub-studies was combined, and analysis of the effects of the interventions only started after completion of the final 24-month follow-up measurements of Sub-study 3 in January 2016.

### 4.2.1 Screening, inclusion and recruitment

The head nurses and occupational health services of the work places were first contacted to describe the measurements and planned interventions, and to discuss the nature of work, sickness absence due to LBP in different work places, willingness to participate in the study, and the channels through which to inform the personnel about the NURSE RCT.

Information about the NURSE RCT was delivered to the selected workplaces at in-person information sessions, in the form of handouts and posters, and also via the intranet in the third sub-study. Screening forms were available at the workplaces, and the completed forms were returned to sealed "postboxes". Eligibility of the screening forms filled in by the participants was evaluated by the principle researcher of the study, and, if necessary, the responsible medical doctor of the study was consulted. (Suni et al. 2016)

The inclusion criteria were:

1. Woman aged 30–55 years
2. Current job held for at least 12 months
3. Intensity of LBP at least 2 in Numeric Rating Scale (NRS; 0-10) (Suni et al. 2016)

The exclusion criteria were:

1. Serious former back injury (disc protrusion, surgery, fracture).
2. Chronic LBP defined by a physician or self-reported continuous LBP for 7 months or longer.
3. Pregnant or recent delivery (within 12 months).
4. Disease or symptoms that limit participation in moderate-intensity neuromuscular exercise.

5. Regular engagement in neuromuscular-type exercise more often than once a week. (Suni et al. 2016)

All together, 439 persons filled in the screening form. Some 194 of them were excluded, while 219 persons met the criteria and participated in baseline measurements, 56 in Sub-study 1, 80 in Sub-study 2, and 83 in Sub-study 3. (Suni et al. 2018.) The time span between the screening point and baseline measurements varied from one week to one month. The flow chart with reasons for exclusion is presented in Figure 8.

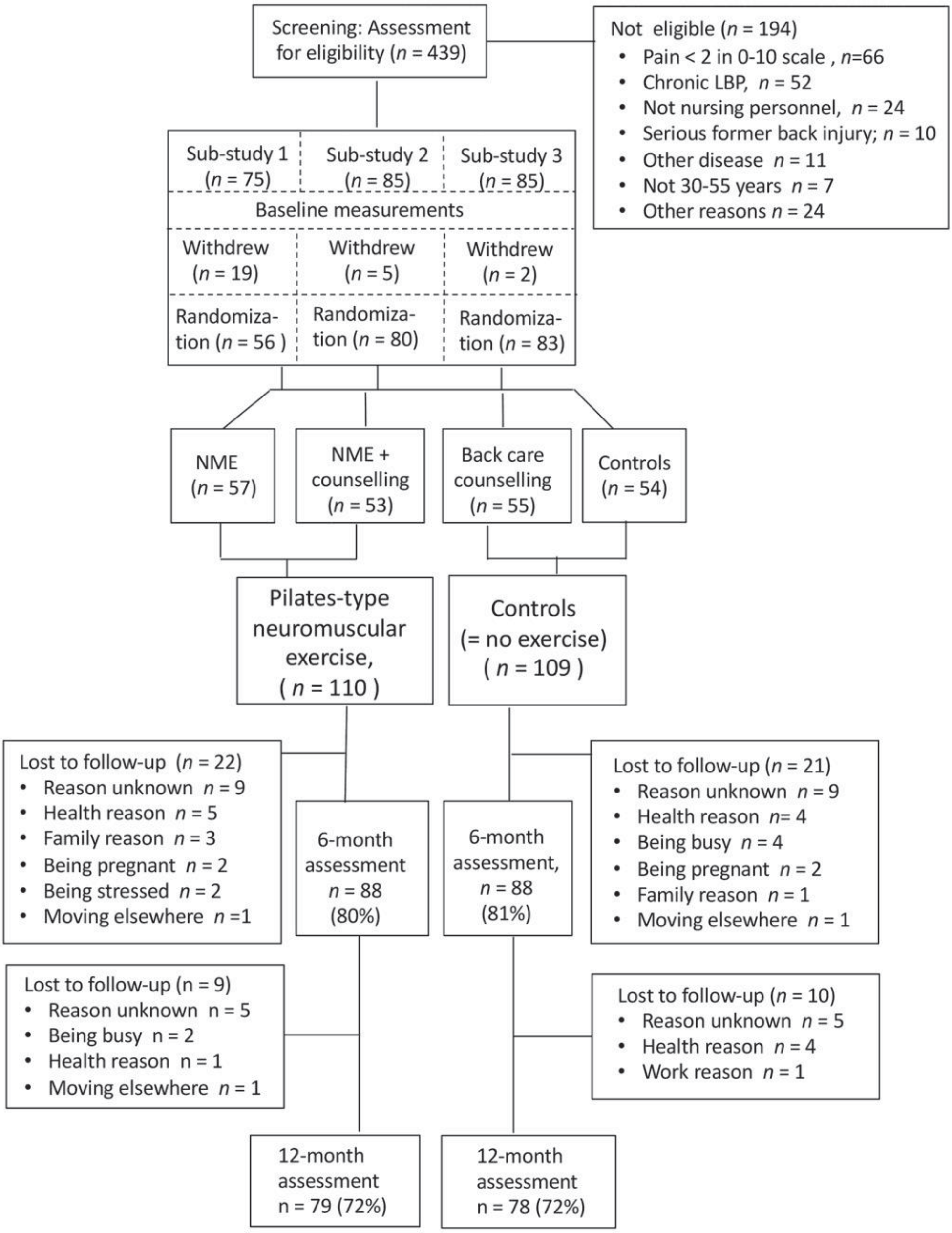


**Figure 8.** The trial profile. NME = neuromuscular exercise

### 4.2.2 Sample size considerations

Sample size was estimated in the 4-arm NURSE RCT for the primary outcome of pain intensity (visual analogue scale, VAS, 0-100mm), with emphasis on the proportion (%) of patients with improved pain intensity on VAS. The minimal important change for VAS is expected to be 15mm. (Ostelo 2008; Dionne et al. 2008) Accordingly, it was expected that there would be a minimal difference of 20% units between the intervention groups in proportions of patients with improved VAS (decrease in pain intensity at least 15mm). The proportion of participants in controls with improved VAS was expected to be 15%. Thus, in order to detect a difference in the main effects (ie, exercisers vs. non-exercisers / back care counselling vs. non-counselling) with a significance level of 0.05 and a power of 80%, at least 160 participants were needed for the original NURSE RCT (40 in each study group in a 4-arm setting). For compensation of probable loss of participants in the follow-ups, the aim was to recruit a total of 240 participants. (Suni et al. 2016.)

### 4.2.3 Randomization and blinding

The randomization was conducted separately in each sub-study. A method of sequentially numbered sealed envelopes (made according to a continuous list for the whole study sample) was used to assign the participants into four study groups. At baseline measurements, once a participant had consented to enter the study, an envelope (next in order) was opened, and the participant was then offered the allocated study group. Accordingly, 57 women were allocated to the NME-group, 55 women to the back care counselling group, 53 women to combined NME and counselling, and 54 women to the control group. (Suni et al. 2018) Accordingly, in the analysis conducted in this thesis, 110 women belonged to the NME group, and 109 to the control group (non-exercisers).

After group allocation, participants received information relevant to practical participation. The assessors conducting the measurements were not involved in the interventions, and they were not aware of the group allocation. Due to the nature of the exercise intervention, it was impossible to blind the instructors and participants involved in the study. In the original 4-arm NURSE RCT, statisticians conducting the analysis were blinded for group allocation (Suni et al. 2018), but those allocation codes were released before the analysis of the effects of the exercise intervention in the present thesis (studies III and IV, which are secondary analyses of the original NURSE RCT).

## 4.3 Interventions

### 4.3.1 Modified Pilates-type neuromuscular exercise intervention with focus on controlling the neutral lumbar spine posture

The exercise program was titled "modified Pilates-type neuromuscular exercise (NME) program with focus on controlling the neutral lumbar spine posture". There is no uniform definition of "neuromuscular exercise", but we justified the use of that term from the description by Ageberg and Roos (2015): "The neuromuscular training method is based on biomechanical and neuromuscular principles and aims to improve sensorimotor control and achieve compensatory functional stability".

Participants randomized into the NME group exercised two times a week for six months, in total 48 times, in three progressive stages. The overall aim of the 6-month NME program was to reduce pain and pain-induced disturbances of movement control, and to increase the muscular strength and endurance needed in heavy nursing tasks. The focus was on controlling the lumbar neutral spine posture in gradually progressive exercises. (Suni et al. 2016.)

During the first 8 weeks, the goal was to exercise twice a week in supervised NME classes (lasting 60 min). During the following four months, the target was to exercise in one supervised class and one home session – with the help of a video (lasting 50 min) or booklet produced for the study (participants received a video disc and a booklet, both of which included the same exercise program). Supervised exercise groups were organized near the workplaces of the participants from Monday to Friday, starting 15 min after the typical work shifts ended. (Suni et al. 2016.)

The learning objectives for the first two months (stage I) were to learn the right performance technique, control the neutral spine posture during low-load exercises, and to combine breathing with each exercise. During the second and third stages (months 3–4 and 5–6, respectively), the exercise program was progressive in terms of the demands for coordination, balance, muscular strength and endurance. (Suni et al. 2016.) Each exercise session included around 25 different exercises. One set with 6–10 repetitions was performed for each exercise (number of repetitions increased progressively at each stage).

More specific aims and training principles were:

1. To increase spinal stability using exercises that minimise the load on spinal structures but induce a high level of core muscular activity (Kavcic, Grenier and McGill 2004, McGill and Karpowicz 2009, Stevens et al. 2007, McGill et al. 2003).

2. To improve endurance of trunk musculature (Cholewicki, Panjabi and Khachatryan 1997; Strøyer and Jensen 2008).
3. To improve postural control (Lee et al. 2010), balance (Taube et al. 2008) and light co-contraction of the stabilizing muscles around the lumbar spine in various upright postures and movements (Suni et al. 2006).
4. To combine breathing with exercises, and thus take advantage of the spine-supporting role of the increased intra-abdominal pressure (Hodges and Gandevia 2000, Hodges et al. 2005). This principle was followed in all exercises.
5. To increase the muscular strength of the lower limbs in functional squatting movements (Distefano et al. 2009).
6. To achieve a normal range of motion in the spine, especially in the thoracic region and the hip and ankle joints (Suni et al. 2016, Hides et al. 2019).

More precise descriptions of the exercises and exercise progressions are presented in Appendix 1. of Study III, and in the Appendix 1. of this thesis.

The traditional key principles of the Pilates method – i.e., concentration, centering, control, precision, breathing, and flow (Muscolino and Cipriani 2004) – were followed, with a special emphasis on intrinsic feedback: to feel of the movement and posture of the spine in each exercise in order to discriminate the movement of the lumbar spine from the movement of the hips and the thoracic spine (Gombatto et al. 2007, Van Dillen et al. 2007).

The instructors of the NME groups were all Pilates instructors with a background education in physiotherapy, a masters' degree in health sciences, or both. Education about the standardized NME program in three progressive stages was organized for the instructors before the intervention and before moving to the next progressive stage in each consecutive sub-study.

In the modified Pilates-type NME program used in the present study, the participants were not instructed to contract or activate isolated deep spinal muscles or to inhibit the superficial muscles, which is a technique used in many Pilates schools. The technique of abdominal hollowing, or isolated deep muscle contraction, is perceived to be quite demanding and requiring time to learn it (McPhee et al. 2017). Controlling the right technique of each individual in a group, or in their home practice, is impossible. Furthermore, motor control exercises with deep muscle contractions have not been shown to be superior to other exercises in reducing NSLBP-related pain or disability (Saragiotto et al 2016). That is why, the technique of a very light abdominal and spinal muscle co-contraction, with focus on control of the position of the lumbar spine (McGill et al. 2003), was chosen in the present study.

In order to motivate and maintain exercise adherence, all participants in the NME group received an information letter at the beginning of the exercise intervention explaining the goals of the exercise programme. In the middle of the first 8-week stage, those who had not participated in any group-based sessions received a telephone call from a research nurse (not involved in the measurements or interventions), who encouraged them to start to exercise. All participants received two material packages (between stages I and II, and between stages II and III), which included an exercise DVD with an accompanying booklet, an exercise diary for home practice along with information about the study and the importance of regular exercise. They also received two e-mails during stage II in order to encourage exercise, and a letter before the 6-month follow-up measurements.

### 4.3.2 Back care counselling

The target number of sessions for back care counselling was 10 in six months. The sessions were conducted within the framework of cognitive behavioural learning theory (Linton and Shaw 2011), and for implementation, problem-based learning was the method used. The main issues discussed in the group counselling sessions were: explaining LBP; how to avoid harmful loading of the lumbar spine in all daily activities by avoiding working with the spine flexed or rotated, or staying for a prolonged time in that position, and  preferring instead a neutral lumbar spine posture; active strategies to cope with LBP; the role of physical activity in LBP, and overall health and well-being. According to the principles of problem-based learning, back-care counselling was anchored to the participants´ working tasks and everyday life in order to reflex the main issues introduced during the counselling sessions and included in the counselling booklet. Among other things, participants were asked to observe their working methods and environment actively throughout the day in the light of how they used their back. To ease the task, the participants were guided with relevant questions to notice key points, such as: ”In which daily tasks might your back hurt?”, “Name three situations in everyday life where your back has been aching, and what might be an adequate way to take care of your back?”.  In addition, safe ways of squatting, emphasizing a neutral lumbar spine posture, were practiced for 5 min during counselling sessions 2–10. (Suni et al. 2016, Suni et al. 2018.)

All longitudinal statistical analyses presented in this thesis were adjusted for back counselling to account for any possible interaction between counselling and exercise (Suni et al 2018).

## 4.4 Study outcomes, measurements and data collection

The measurements of the NURSE RCT were selected and categorized according to the International Classification of Functioning, Disability and Health (ICF) model, which is a biopsychosocial framework that provides an overall view of the different aspects of health (biological, social, and individual). It comprises five main components: (i) body structures and functioning, (ii) activities, (iii) participation, (iv) environmental and (v) individual factors. Each of the main five domains can be subdivided into chapters and further categories. (World Health Organisation 2001.) LBP is characterized by impairments in body functions and structures (biological component) that can lead to activity limitations and/or participation restrictions (functional component). The resulting LBP-related disability, which includes pain and activity limitations and/or participant restrictions, is also under the influence of personal and environmental factors. (Tousignant-Laflamme et al. 2017.) Fear of the recurrence of back pain may also limit activities and restrict participation (Krismer and van Tulder 2007).

The ICF-model aims to provide a scientific basis for understanding and studying health-related states, outcomes and determinants (World Health Organisation 2001).There have been several attempts to classify and define common symptoms, risk factors and consequences of LBP and other musculoskeletal pain to the ICF-model, but classification to different ICF domains is not consistent (Cieza et al. 2004; Delitto et al. 2012; Tousignant-Laflamme et al. 2017). However, measurements used in the NURSE RCT, and presented in this thesis, are categorized to different domains of the ICF-model according to the classification presented by Suni and colleagues (2016). The summary of the measurements according to ICF-model is presented in Figure 9.

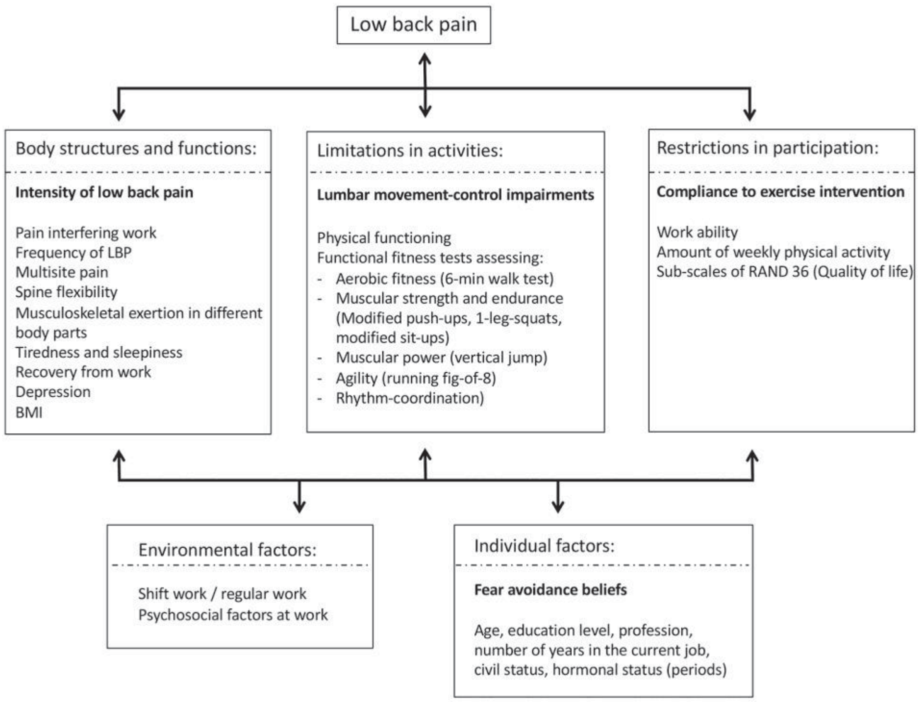


**Figure 9.** Summary of the measurements of the NURSE RCT (Suni et al. 2016), used in the present thesis, and categorized according to the domains of the ICF model. The main outcomes of the different domains are presented on bold letters.

The primary outcome of this doctoral thesis is LBP intensity, which in the ICF-model represents the domain 'Body structures and functioning'. For the three other domains of the ICF model, the following main outcomes were selected: lumbar movement-control impairments for 'Limitations in activities', adherence to modified Pilates-type neuromuscular exercise program for Restrictions in participation' and fear-avoidance beliefs for 'Individual factors'. Secondary outcomes included different fitness components, pain interference with work, physical functioning, managing physically heavy nursing duties, work ability, and tiredness and recovery from work. In the NURSE RCT, a wide range of other measurements was also collected, and those variables were used in this thesis either as background variables or as confounding variables. The variables used for adjustments represented factors that might have an association with the outcome measurements but that had no influence on the neuromuscular exercise intervention carried out in the NURSE-RCT.

All measurements were conducted at the UKK Institute for Health Promotion Research, in Tampere. Specially trained personnel with basic education in health or sport science, and with at least 10 years working experience in the field, conducted all measurements. They were not involved in the study interventions. Health screening was performed before fitness testing in accordance with the safety model of the Health-related Fitness Test Battery for Middle-aged Adults (Suni et al. 1998). The measurement battery consisted of questionnaires, assessment of physical fitness, lumbar movement-control impairment (MCI) tests, and guidance in using the accelerometer for objectively measuring physical activity / sedentary time over one week.

### 4.4.1 Impairments of the body structures and functions

The primary outcome was low back pain intensity, measured by visual analogue scale (VAS 0–100 mm; from 0 = no pain to 100 = worst possible pain) during the past month (Dionne et al. 2008).

The secondary outcomes were:

- Bodily pain interfering with normal work during the preceding 4 weeks, assessed by a sum score from two questions in the validated Finnish version (Aalto et al. 1999) of the RAND-36 Health Survey (Hays et al. 1993). There is one rating on a 5-point-scale (intensity of bodily pain) and one 6-point-scale rating (pain interfering with normal work). Respondent-reported scores were converted into 0-100 scale; scores ranging from 0 = very severe pain and extreme difficulties to 100 = no pain and no difficulties (Ware and Sherbourne 1992).
- Number of musculoskeletal pain sites (1–6; 1 = yes, 0 = no). Pain during the preceding 4 weeks in the 1) low back, 2) upper back and neck, 3) shoulders and upper limbs, 4) hips, 5) knees, and 6) other pain in lower limbs. (Suni et al. 2016.)
- Tiredness and sleepiness (sum score from three questions developed by Finnish Institute of Occupational Health; from 3 = no tiredness or sleepiness to 13 = long-term, daily tiredness and sleepiness (Karhula et al. 2013). The questions concern tiredness in the morning after waking up (1–3; 1 = no tiredness in the morning…3 = has suffered from un-restorative sleep over one month), tiredness during the daytime (1–5; 1 = never or less than once a month…5 = daily or

almost daily), and sleepiness during daytime (1–5; 1 = never or less than once a month…5 = daily or almost daily).

- Perceived recovery from work over the preceding 4 weeks (1 = recovering well…5 = not recovering) (Karhula et al. 2013). Ratings were split into 3 groups (1+2 = recovering well, 3 = some difficulties, 4+5 = not recovering).
- Mental well-being: modified Finnish version of Patient Health Questionnaire (PHQ, 9 items) (Kroenke et al. 2001). Scale 0-27; high values indicate higher levels of depression.
- Perceived musculoskeletal exertion in different body parts after typical working day over the preceding 4 weeks: Numeric Rating Scale (NRS; 1–5; 1 = not exerted at all… 5 = very exerted); assessed for low back, upper back, neck, shoulder, knee, and hip. (Suni et al. 2016)
- Flexibility of the spine. The subject stands feet 15 cm apart with the back against the wall. She bends the trunk laterally to the right and left. The distance between the finger marks in standing and the maximal lateral bending is measured, and the result is the average value between right and left, in cm. (Suni et al. 1996.) (Appendix 2.)

Other factors and measurements, which were measured at baseline or screening, and considered in the analysis were:

1) Body mass index (BMI) calculated by dividing persons' weight (kg) by squared height (m).
2) LBP frequency (daily, most days of the week but not daily, on some days of the week) (Suni et al. 2016).

### 4.4.2 Limitations or restrictions in activities

The main outcome for assessing limitations in activities was movement control impairments (MCI) of the low back, which consisted of four selected tests from the original MCI test battery (Luomajoki et al. 2007), based on descriptions by Sahrmann (2002) and O'Sullivan (2005). The original MCI test battery consisted of six tests: 1) the waiters bow (flexion of the hips in upright standing without movement of the lower back), 2) dorsal tilting of the pelvis, 3) sitting knee extension while maintaining the neutral spine posture, 4) rocking forwards and backwards in quadruped position while maintaining the neutral spine posture, 5) prone-lying active knee flexion without lumbar rotation, and 6) one-leg stance (with feet one third of trochanter distance apart, shifting the weight to one leg; lateral movement of the belly button is symmetrical (≤ 2 cm difference between right and left, and ≤ 10 cm lateral transfer) (Luomajoki et al. 2008). The MCI test results were judged dichotomously by observation from videotapes: the subject was noted either as not having motor control impairment (0) or as having impairments (1). (Appendix 2.)

Two of the MCI tests, namely rocking forward and backwards, and one-leg stance had poor repeatability (Study I), and they were dropped out from the final test battery, assessing effects of the intervention.

The secondary outcomes were:

- Limitations in physical functioning, which was assessed by a sub-scale of validated Finnish version (Aalto et al. 1999) of the RAND-36 Health Survey (Hays et al. 1993). It consists of 10 ratings (for vigorous activity, such as strenuous sport; moderate intensity activity, such as bowling or vacuuming; lifting and carrying groceries; climbing several flights of stairs; climbing one flight of stairs; bending, kneeling or stooping; walking approximately 2 km; walking approximately 500 m; walking one block; and bathing or dressing) on a 3-point scale (limited a lot, limited a little, not limited at all). The respondent-reported scores were converted into scores ranging from 0 = limited a lot to 100 = not limited at all (Ware and Sherbourne 1992).
- Physical functioning in nursing tasks: Ability to manage with heavy, task specific nursing duties including patient transfer: Sum score of NRS 0–10 with eight selection points: 0 = no difficulties … 80 = does not manage at all (Suni et al. 2016).

- Functional fitness tests, assessing aerobic, motor and musculoskeletal fitness:
  - *Aerobic fitness* was assessed by an indoor 6-min-walk test (6MWT), for maximal walking distance (metres), in 6 minutes, around traffic cones placed 15 meters apart (Jenkins et al. 2009; Mänttäri et al. 2018).
  - *Muscular strength* was assessed by:

  (i) Modified push-ups, number of repetitions in 40 seconds (indicating upper-body muscular strength and trunk stabilization). In prone position, person claps her hands behind her back. After push-up, in strait-elbow position, she touches the supporting hand with the other hand. (Suni et al. 1996.)

  (ii) Muscle strength in the lower limbs as assessed by one-leg squats, number of repetitions, with progressively increasing external load (10% of body weight is added after each repetition; no added weight, 10%, 20%, 30% and 40%) using a weight vest system. (Suni et al. 1996.)

(iii) Power of the lower limbs, assessed by vertical jump. Before jumping, one arm is raised to mark the standing height (finger mark of the middle finger on the board). During the jump, the subject touches the board with the same finger at the highest position. The result is the vertical difference between the finger marks. (Suni et al. 1996.)

(iv) Abdominal strength was assessed by dynamic sit-ups in four progressive stages, five repetitions in each stage (The first five sit-ups: Lifting head and shoulders off the mat. The second five: Hands reaching mid-patella with fingertips. The third five: Arms folded over chest aiming to reach thighs with both elbows. The fourth five: Touching back of earlobes with fingertips and reaching thighs with elbows. The final score is the sum of successful sit-ups. (Modified from Engström et al. 1993.)

- *Motor skill assessments* included assessment of agility and gross movement timing (rhythm-coordination)

    - Agilit*y* was assessed by running figure-of-8 test; The person runs a course in a figure of 8, marked with two traffic cones placed 10 meters apart. The stopwatch is started concurrently with the starting signal and stopped when the person passes the starting line after running. (Rinne et al. 2001)
    - Rhythm-coordination was assessed by marching and clapping the hands together to the rhythm of the metronome signal. At first, the subject was asked to march in accordance with a slow pace (92 beats / minute) for 30 seconds, a step for every beat. That was followed by marching for another 30 seconds and clapping hand on every other beat. After the slow phase, marching and clapping was continued at a fast pace (138 beats / minute). The score for each phase is 0–8 points and the sum of the scores is 0–16 points. (Rinne et al. 2001.)

MCI tests and motor and musculoskeletal fitness tests are presented in photographs in Appendix 2.

### 4.4.3 Limitations or restrictions in participation

The main outcome to assess restrictions in participation was adherence to the NME program during the study intervention. The instructors monitored participants' attendance at the supervised group exercise sessions, and study subjects kept an exercise diary for their home practice. Attendance at the supervised exercise sessions and number of home exercise sessions were summed up to describe the total exercise attendance rate.

The secondary outcomes were:

- Work ability index (WAI), short form (Ilmarinen 2009). Sum score from 4 questions, scale 3–27 (from 3 = poor to 27 = the best possible), cover (1) current work ability (0–10; where 0 = unable to work and 10 = the best possible), (2) work ability in relation to physical work demands (1–5; 1 = very poor, 5 = very good), and (3) in relation to mental work demands (1–5; 1 = very poor, 5 = very good), and (4) personal prognosis for work ability in 2 years' time (1 = hardly able to work, 4 = "not sure", 7 = almost certain work ability).
- Amount of weekly physical activity (was used only for adjustments):
    - a) Objectively measured aerobic physical activity (walking hours during one week, using a Hookie AM20 tri-axial accelerometer, from Traxmeet, Espoo, Finland), with re-coding of data on meeting recommendations for physical activity to promote or maintain health (for a total of at least 2h 30 min of moderate activity or 1h 15 min of vigorous activity); at least 3 times a week (Haskell et al. 2007), yes/no.
    - b) Meeting of recommendations for strength training at least twice a week (Haskell et al.2007), yes/no (questionnaire).

### 4.4.4 Individual factors

The main outcome to assess individual factors related to LBP was fear-avoidance beliefs (FABs) with two subscales: FABs related to work (FAB-W, range 0–48 points) and physical activity-related FABs (FAB PA; range 0–30) (Waddel et al. 1993). Three questions considering long-term sick leave were excluded from the original FAB-W questionnaire, because the study subjects were still at work (Suni et al 2016). High values indicate increased levels of FABs.

Other factors and measurements (at baseline), which were considered in the analysis were age, periods (regular periods /unregular periods / periods with hormonal medication /post-menopause with no periods), education level, profession, and current use of medication.

### 4.4.5 Environmental factors

Measurements assessing the effect of environmental factors were used only for adjustments in the analysis of the current thesis. Those factors were 1) psychosocial factors at work (such as work stress), assessed via Finnish work satisfaction questionnaire (Haukka et al. 2010) and 2) shiftwork (in 2 or 3 shifts) / regular work (regular day-time, evening-time or night shifts).

## 4.5 Ethical considerations

The NURSE RCT protocol was approved by the Ethics Committee of the Tampere University Hospital (ETL code R08157), and it is registered in the ClinicalTrial.gov –register (NCT01465698). The NURSE RCT was carried out conforming to the guidelines of good scientific practice and provisions of the Finnish Medical Research Act (Declaration of Helsinki).

Informed consent was obtained in writing form all participants on their first visit at baseline, prior to randomization. The aim of the study, as well as risks and benefits, were clarified in a written information letter to those recruited to the study. They were encouraged to continue their usual physical activity and seek any medical or other treatments when needed (Suni et al. 2016).

## 4.6 Statistical analysis

For the purpose of this thesis, including articles related to it, the four study groups of the NURSE RCT were aggregated according to exercise allocation regardless of they received back care counseling.

Study I was a test-retest repeatability study. Study II was based on the cross-sectional analysis of the baseline data of the whole study sample. For studies III and IV, comparisons were made between the aggregated NME group vs. non-exercisers for effects of the exercise intervention. Study IV is a retrospective study of the effects of baseline and background factors on exercise adherence (exercise compliers vs. non-compliers).

For study I, the test-retest repeatability of the test battery for lumbar movement-control impairment and musculoskeletal fitness tests was studied among the participants of Sub-study 1 before the study interventions started. Estimates of repeatability for interval-scale measurements were calculated in terms of typical error (s) as the standard deviation of the test-retest difference divided by the square root of 2. The relative error measure coefficient of variation (CV) was calculated as typical error divided by the mean of two tests. The percentage changes in mean performance between the first and second test results were calculated, too. Repeatability results of the interval scale measurements were also verified with the calculation of intraclass correlation coefficient (ICC), using the two-way mixed effects model. The repeatability of the nominal-scale measurements in the MCI tests (yes or no) was analyzed by means of Cohen's kappa coefficient (k).

For study II, the objective was to investigate baseline associations of various biopsychosocial factors with (i) pain interference with work, (ii) physical functioning, and (iii) work ability. First, associations between several biopsychosocial variables and dependent variables (bodily pain, physical functioning, and work ability) were first analysed in bivariate setting. Analysis methods were Spearman´s correlation coefficent, one-way analysis of variance (ANOVA), independent-samples t-test, Kruskal-Wallis test and the Mann-Whitney test, when applicable. When statistically significant associations between biopsychosocial factors and dependent variables were found in bivariate analysis, generalized linear models (GLMs) were used to determine which independent factors best explain the dependent variables: bodily pain, physical functioning, and work ability. After calculation of crude β-coefficients, the analyses were adjusted for age, BMI, work type (shift work/regular work), sick leave due to LBP in the preceding 6 months, hormonal status and work satisfaction.

In studies III and IV, differences in time (at the three measurement points: baseline, 6 and 12 months) between the two groups (exercisers vs. non-exercisers) were tested using a generalized linear mixed model (GLMM). All analyses were adjusted to take into consideration the effect of back care counselling. Second, the sub-study was included as a random effect to indicate the possible heterogeneity between the study sites and study time in the three consecutive sub-studies. Other potential confounding factors were background variables (age, hormonal status, BMI, and civil status), work- and health-related factors (shift work/regular work, perceived health, blood pressure, current medication, and tiredness and sleepiness), fitness components, and self-reported and objectively measured physical activity. Only those confounding factors that improved the model in the second stage in the sense of Bayesian information criteria were included in the final GLMM. All those analyses were conducted according to the intention-to-treat principle (ITT).

For the per-protocol (PP) analysis, the study sample was assigned to two groups in order to investigate the effectiveness of the exercise. Those who exercised at least once a week ($\geq$ 24 times in 24 weeks) were assigned to the more exercised group, and the reference group consisted of those who exercised less than once a week and the controls (0-23 times). The same GLMM models were used for the PP and ITT analyses. More accurate analyses of the changes in lumbar movement control according to the baseline results were also analysed with the $\chi^2$ test.

Pearson´s and Spearman´s correlation coefficents were used to analyse associations between change in pain intensity and change in measurement variables in longitudinal analysis (baseline – 6 months) in studies III and IV.

To analyse the effect of baseline and background factors on exercise compliance (study IV), partial correlation analysis was first conducted between all those factors and the compliance rate to determine which of the 60 different factors could have an association with the compliance rate. Those variables showing a statistically significant association with the compliance rate were selected for bivariate analysis with the compliance rate; the analysis methods were Kruskall-Wallis test for the categorical variables and Spearman's correlation for continuous variables.

The median split was used to divide the exercise group into compliers (those who exercised $\geq$24 times during the 24 weeks) and non-compliers (those who exercised 0–23 times). We examined the baseline characteristics of the participants randomised to the exercise group by the compliance status for those variables showing statistically significant associations with the exercise adherence rate in the bivariate analysis. The analytical methods were the independent samples t-test, the $\chi^2$ test, or the Mann-Whitney U test, as applicable.

In studies I and II, all the analyses were conducted with the SPSS statistical analysis package, version 22. In studies III and IV, all the analyses were conducted using SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0 Armonk, NY: IBM Corp.).

# 5 RESULTS

## 5.1 Participants

Table 2. below presents the background and baseline descriptive characteristics of the whole study sample by exercise allocation (groups NME = neuromuscular exercise; controls = no exercise).

**Table 2.** Background and baseline characteristics of the participants by the study group

| | **Pilates-type NME group (n=110** | | **Controls (no-exercise) (n=109)** | | **Miss -ing** | **p-value** |
|---|---|---|---|---|---|---|
| Background characteristics: | % | Mean (SD) | % | Mean (SD) | | |
| Age, years | | 46.2 (6.8] | | 46.6 (6.8) | | 0.69 |
| BMI | | 27.0 (4.7) | | 25.8 (4.0) | 2 | **0.05** |
| Smoking | | | | | | 0.60 |
| daily | 15.5 | | 17.4 | | | |
| occasionally | 10.0 | | 13.8 | | | |
| non-smoker | 74.5 | | 68.8 | | | |
| Civil status: married/cohabiting | 60.9 | | 68.8 | | | 0.22 |
| Education: secondary school or less | 27.5 | | 26.9 | | 2 | 0.50 |
| Occupation | | | | | | 0.31 |
| nurse | 51.0 | | 42.0 | | | |
| nursing assistant | 39.0 | | 42.0 | | | |
| other (PT, midwife, radiographer) | 10.0 | | 16.0 | | | |
| Number of working years | | 11.9 (9.2) | | 10.7 (8.1) | 2 | 0.25 |
| Working times | | | | | 1 | 0.66 |
| regular work | 32.0 | | 29.0 | | | |
| shift work | 68.0 | | 71.0 | | | |
| Perceived health | | | | | 1 | 0.31 |
| average or below average | 41.0 | | 34.0 | | | |
| better or much better than average | 59.0 | | 66.0 | | | |
| Perceived fitness in comparison to persons of the same age and gender | | | | | 1 | 0.71 |
| lower or much lower | 29.0 | | 27.0 | | | |
| similar | 47.0 | | 53.0 | | | |
| higher or much higher | 24.0 | | 20.0 | | | |
| Number of musculoskeletal pain sites | | 3.3 (1.2) | | 3.1 (1.4) | | 0.31 |

| | Pilates-type NME group (*n* = 110) | | Controls (no-exercise) (*n* = 109) | | Miss -ing | *p*-value |
|---|---|---|---|---|---|---|
| | % | Mean (SD) | % | Mean (SD) | | |
| High blood pressure: yes | 15.5 | | 12.0 | | | 0.46 |
| Periods | | | | | 1 | 0.68 |
| normal or irregular periods | 57 | | 59 | | | |
| hormonal therapy or no periods | 43 | | 46 | | | |
| Current use of medication: yes | 52.7 | | 57.9 | | | 0.44 |
| Physical functioning (0-100) * | | 85.6 (12.3) | | 85.3 (14.6) | 8 | 0.88 |
| Meeting recommendations for weekly physical activity | | | | | | |
| for aerobic physical activity: yes | 27.9 | | 24.5 | | 13 | 0.58 |
| for muscle strengthening exercise: yes | 16.4 | | 24.1 | | 1 | 0.16 |
| **Pain-related factors:** | | | | | | |
| VAS: intensity of LBP (0–100) during past 4 weeks at baseline | | 36.3 (22.0) | | 36.0 (23.4) | 1 | 0.94 |
| Bodily pain interfering with work (0–100) * at baseline | | 61.5 (18.7) | | 64.4 (19.3) | 8 | 0.28 |
| LBP intensity at the screening point (NRS 0-10) | | 4.5 (1.8) | | 4.9 (1.8) | | 1.14 |
| Duration of LBP at the screening point | | | | | | 0.40 |
| less than 3 months | 57.4 | | 55.1 | | | |
| 3–6 months | 19.4 | | 23.4 | | | |
| 7 months or more | 23.2 | | 21.5 | | | |
| Frequency of LBP at the screening point | | | | | | 0.93 |
| daily | 17.6 | | 17.7 | | | |
| in most days of the week | 37.3 | | 39.6 | | | |
| in some days of the week | 45.1 | | 42.7 | | | |
| **Lumbar movement control:** | | | | | | |
| MCI sum (0–4) | | 1.0 (1.0) | | 1.1 (1.0) | | 0.94 |
| Deficiencies in MCI test battery | | | | | | 0.91 |
| 0 | 35.5 | | 33.0 | | | |
| 1 | 35.5 | | 35.8 | | | |
| 2–4 | 29.1 | | 31.2 | | | |
| **Health-related fitness components:** | | | | | | |
| 6MWT (meters) | | 619.4 (50.4) | | 624.0 (48.3) | 1 | 0.29 |
| Modified sit-ups (repetitions) | | 17.2 (4.6) | | 18.4 (3.7) | 1 | **0.02** |
| % reaching the maximum of 20 reps. | 61.5 | | 75.2 | | | **0.03** |
| One-legged squats (repetitions) | | 9.4 (2.7) | | 9.5 (2.4) | 3 | 0.72 |
| Modified push-ups (repetitions) | | 9.0 (3.4) | | 9.0 (2.8) | 6 | 0.94 |
| Vertical jump (cm) | | 29.4 (6.0) | | 28.4. (5.8) | 8 | 0.37 |
| Running a figure-of-8 (seconds) | | 7.8 (1.0) | | 7.8 (0.9) | 13 | 0.70 |
| Trunk lateral flexion (cm) | | 18.2 (3.6) | | 17.9 (3.0) | | 0.31 |
| Rhythm coordination (0–16 points) | | 13.9 (2.9) | | 13.7 (2.9) | | 0.75 |

| | Pilates-type NME group (*n* = 110) | | Controls (no-exercise) (*n* = 109) | | Missing | *p*-value |
|---|---|---|---|---|---|---|
| | % | Mean (SD) | % | Mean (SD) | | |
| **Work-related factors:** | | | | | | |
| Difficulties in patient handling (0–80; 0 = no difficulties, 80 = does not manage at all) | | 6.0 (4.9) | | 6.6 (5.2) | 13 | 0.43 |
| Work-induced lumbar exertion | | | | | 3 | 0.45 |
| little exertion | 26.9 | | 31.5 | | | |
| moderate to high exertion | 73.1 | | 68.5 | | | |
| Tiredness and sleepiness (3–13; 3 = no tiredness…13 = daily tiredness) | | 7.6 (2.9) | | 7.4 (2.7) | 1 | 0.61 |
| Perceived recovery from work | | | | | | 0.12 |
| recovering well | 34.9 | | 47.7 | | | |
| some difficulties | 50.5 | | 43.1 | | | |
| not recovering | 14.7 | | 9.2 | | | |
| **Psycho-social factors:** | | | | | | |
| Depression; PHQ-9 (0–27) | | 7.9 [4.9) | | 7.0 (4.3) | 1 | 0.14 |
| FABs-PA (0-30) | | 13.7 (6.5) | | 12.7 (6.1) | 1 | 0.15 |
| FABs-W (0-48) | | 11.4 (8.6) | | 10.4 (7.1) | 9 | 0.36 |
| Work satisfaction: | | | | | | |
| possibilities to exert an influence on one's work | | 2.7 (0.7) | | 2.9 (0.6) | 1 | 0.09 |
| support from one's supervisor | | 3.3 (0.8) | | 3.5 (0.8) | 1 | 0.27 |
| conflicts with one's supervisor | | 2.3 (0.8) | | 2.2 (0.7) | 1 | 0.59 |
| work stress (Siegrist's effort–reward model) | | 1.7 (0.5) | | 1.6 (0.5 | 2 | 0.11 |

6MWT = 6 min walk test, BMI = body mass index, FABs-PA = fear-avoidance beliefs related to exercise, FABs-W = work-related fear-avoidance beliefs, MCI = movement-control impairments of the low back, NME = neuromuscular exercise, PHQ-9 = modified Finnish version of the Patient Health Questionnaire, 9 items measuring depressive symptoms, PT = physiotherapist, VAS = visual analogue scale, * converted scale from RAND36: 0 = extreme pain and difficulties, 100 = no pain, no difficulties

The participants' mean age was 46 years, and they had worked in their current job, for on average, 11 years. Of the participants, 70% did shift work, and 87% were nurses or nursing assistants. Only some 40% were of normal body weight, 42% were overweight and 18% were obese. In the NME group, BMI was higher ($p = 0.05$) and abdominal strength lower ($p = 0.03$) than among the controls. The mean number of musculoskeletal pain sites was 3.2 (SD 1.3).

At the pre-study screening, the mean LBP intensity was 4.7 (SD 1.8), measured on a numeric rating scale of 0–10. Most of the study subjects (82%) experienced LBP on some or most days of the week but not daily, and 18% experienced daily pain. Duration of LBP was less than 3 months for 56%, 3–6 months for 21%, and more than 6 months for 23%. For those 94 persons whose LBP had lasted more than 3 months, 40% experienced pain only in a few days of the week, 42% in most days of the week, and 18% had daily pain. For 48 persons, the duration of symptoms of LBP exceeded 6 months. The majority of them (84%) experienced LBP on a few or most days of the week, but not daily, and 7 persons had daily pain. Only 15% (33 subjects) had been on sick leave due to LBP within the previous 6 months (Kolu et al. 2017).

At the baseline, there was a difference in the fear-avoidance beliefs between occupational groups in the whole study sample ($n$ = 219). Nursing assistants had more physical activity related FABs (FAB-PA, mean 15.5, SD 6.0, $n$ = 89) than nurses (12.0, SD 5.9, $n$ = 102) and other professionals (11.6, SD 6.8, $n$ = 28) (F = 9.5, $p < 0.001$). Some 62% of the participants perceived their health to be better or much better, and 28% perceived their fitness to be lower or much lower compared to persons of the same age and gender.

## 5.2 Repeatability of the musculoskeletal fitness tests and movement control impairment test battery (Study I)

In the first study (I), the motor and musculoskeletal fitness tests and the lumbar movement-control tests (6 tests) were performed twice (test I and test II) before the study interventions started among the participants of Sub-study 1 ($n$ = 47). No feedback, education or training was given to participants between measurements. The mean number of days between test I and test II measurements was 18 (SD 7.9).

All motor and musculoskeletal fitness tests had an adequate repeatability. The lowest within-subject variation was found in the running a figure-of-8 test (s = 0.22 sec, CV=2.8%) and the highest for modified push-ups (s = 1.04 repetitions, CV= 12.2). The results are shown in Table 3.

The results for the nominal-scale measurements of lumbar movement-control impairments are presented in Table 4. The kappa values for the dorsal pelvic tilt, sitting knee extension, waiters bow (anterior pelvic tilt), and lying-prone knee flexion varied between 0.71 and 0.45, but were lower for rocking forwards and backwards (k = 0.31) and the one-leg stance (k = 0.16).

**Table 3.** Test I–Test II repeatability of motor and musculoskeletal fitness tests

| Test | n | Standard error (s) | CV | Change in the means (95% CI) | % | ICC (95% CI) |
|---|---|---|---|---|---|---|
| Running a figure-of-8 | 46 | 0.22 sec | 2.8% | -0.43 (-0.55-0.14) | 5 | 0.88 (0.78-0.93) |
| Trunk lateral flexion | 47 | 1.36 cm | 7.5% | 0.06 (-0.54-0,65) | 0.3 | 0.81 (0.69-0.89) |
| Rhythm coordination | 47 | 1.08 points | 7.7% | 0.36 (-0.86-0.81) | 2 | 0.83 (0.71-0.90) |
| Dynamic sit-up | 47 | 1.9 reps. | 11.2% | 1.02 (0.24-1.80) * | 6 | 0.86 (0.76-0.92) |
| One leg squat | 47 | 1.13 reps. | 11.9% | 0.20 (-2.72-0.68) | 2 | 0.80 (0.67-0.88) |
| Modified push-up | 46 | 1.04 reps. | 12.2% | 1.5 (1.04-1.95) * | 19 | 0.89 (0.80-0.94) |

CI = confidence interval, CV = coefficient of variance, ICC = intraclass correlation coefficient.

**Table 4.** The test I–Test II repeatability (with 95% CI) of the movement control tests of the low back (n = 47).

| Movement-control impairment test | test–retest kappa |
|---|---|
| Dorsal pelvic tilt | 0.71 (0.50–0.92) |
| Sitting knee extension | 0.56 (0.17–0.94) |
| Waiters bow | 0.53 (0.27–0.78) |
| Knee flexion in prone | 0.45 (0.11–0.78) |
| Rocking forwards and backwards | 0.31 (0.03–0.58) |
| One leg stance | 0.16 (-0.11–0.44) |

## 5.3 Factors associated with pain interference with work, physical functioning and work ability at baseline (Study II)

Among the whole study sample (*n* = 219), generalized linear model (GLM) analysis was conducted with factors which had a statistically significant association with a) pain interference with work, b) limitations in physical functioning and c) work ability in bivariate analysis. The purpose was to investigate which of the several factors best explained bodily pain interfering with work, physical functioning and work ability at baseline. Perceived work-induced lumbar exertion, multi-site pain and work-related fear-avoidance beliefs (FAB-W) best explained bodily pain interfering with work. Multi-site pain, work-induced lumbar exertion, FAB-W and physical performance in the test running a figure-of-8 and modified push-ups, best explained the variation in physical functioning. Factors that best explained perceived work ability were FAB-W, lumbar exertion, depression and recovery after work.

As seen in Figure 10, FAB-W and work-induced lumbar exertion were associated with all three dependent variables: levels of pain interfering with work, physical functioning and ability to work.

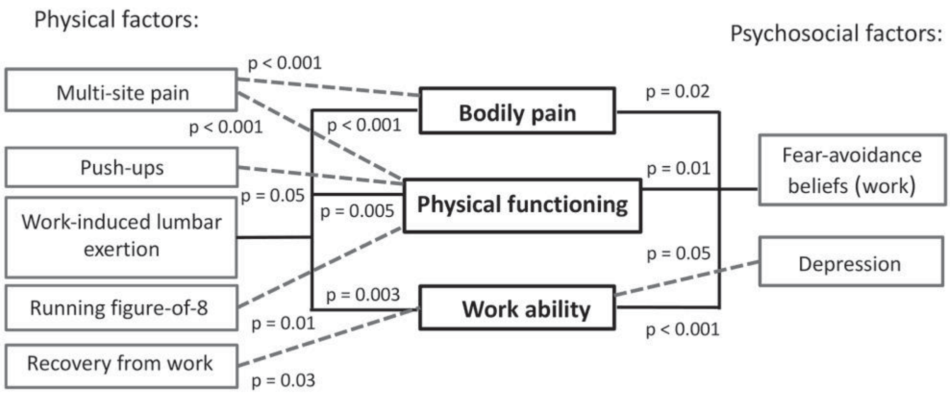


**Figure 10.** Associations of: (i) physical factors and (ii) psychosocial factors with three dependent variables: bodily pain, physical functioning, and perceived work ability, analysed via generalized linear models.

Work-induced lumbar exertion in turn was associated with poor physical performance. Results of the physical fitness tests were consistently lower in those who perceived more work-induced lumbar exertion in comparison with subjects who were less exhausted. The results are shown in Table 5.

**Table 5.** Associations between fitness test results and perceived lumbar exertion after a work shift, analysed via ANOVA and adjusted for age (p-values reflecting statistically significant differences are in boldface)

| | **Mean (SD) test results for various categories of perceived lumbar exertion after a work shift** | | | | |
|---|---|---|---|---|---|
| Fitness test: | little exertion *n* = 62 | some exertion *n* = 78 | high exertion *n* = 70 | mean difference from little exertion to high exertion (95% CI) | *p*-value |
| Six-minute-walk test (meters) | 632.1 (49.7) | 620.7 (44.8) | 602.6 (51.1) | 29.5 (9.5, 49.6) | **0.001** |
| Modified push-ups (reps) | 10.2 (3.2) | 8.8 (2.5) | 8.1 (3.2) | 2.1 (0.8, 3.3) | **<0.001** |
| One-leg squats (reps) | 10.2 (2.3) | 9.7 (2.3) | 8.7 (2.9) | 1.5 (0.5, 2.5) | **0.001** |
| Vertical jumps (cm) | 30.1 (5.5) | 29.3 (5.5) | 27.5 (6.3) | 2.7 (0.2, 5.1) | **0.03** |
| Running a figure-of-eight (seconds) | 7.6 (0.9) | 7.7 (0.8) | 8.1 (1.2) | -0.5 (-0.9, -0.1) | **0.007** |

CI = confidence interval, SD = standard deviation

## 5.4 Effects and efficacy of neuromuscular exercise (NME) intervention (Studies III and IV)

The mean attendance rate in 24 weeks was 26.3 (SD 12.2) exercise sessions. Some 53% of the participants exercised 1–2 times a week. The participants did not report any back-related adverse events, i.e. an increase in back pain during or after the exercise sessions. One participant got a sudden knee pain in a standing exercise – weight shift and standing on one leg – but the pain disappeared by itself in 48 hours.

Of the whole study sample, 80% ($n$ = 176) and 72% ($n$ = 157) participated in the 6-month and 12-month follow-up measurements, respectively. The dropout rate was equal in both groups (NME group, $n$ = 20 and non-exercisers, $n$ =21).

Between the two study groups – exercisers and non-exercisers – there were no other clinically relevant or statistically significant group differences at baseline except BMI (higher in the exerciser, $p$ = 0.05) and results of the modified sit-up tests (lower in the exercise group, $p$ = 0.02) (Table 2). All the longitudinal analyses were adjusted with BMI and baseline fitness results.

### 5.4.1 Low back pain intensity and pain interference with work

At baseline, the mean LBP intensity measured by VAS (0–100) was 36.2 (22.6).

In the ITT analysis, the mean reduction in LBP intensity was −10.7 mm (24.0) at 6 months and −11.3 mm (21.8) at 12 months in the NME group compared to −6.6 mm (26.1) and −6.1 mm (28.1), respectively, in the non-exercise group. The percentage reduction in pain in the NME group was 30.3% at 6 months and 35.7% at 12 months. The corresponding reductions in the non-exercise group were 21.8% and 19.1%, respectively ($p = 0.047$).

In the PP analysis, the difference in the reduction of pain intensity was greater in the more exercised group ($p = 0.029$); the mean reduction at 6 months among the more exercised (once a week or more) was −15.4 mm (21.1), i.e. a reduction of 43.0%. This compares to a reduction of −5.0 mm (26.1) in the less exercised and non-exercisers, i.e. a reduction of 13.7%.

The effects of the NME program on lumbar pain intensity are depicted graphically as the percentage change with 95% confidence intervals at 6 and 12 months in Figure 11.

Pain interference with work decreased in the NME group when compared to the results of the non-exercise group ($p = 0.046$). Exercising more did not improve the result in the PP analysis.

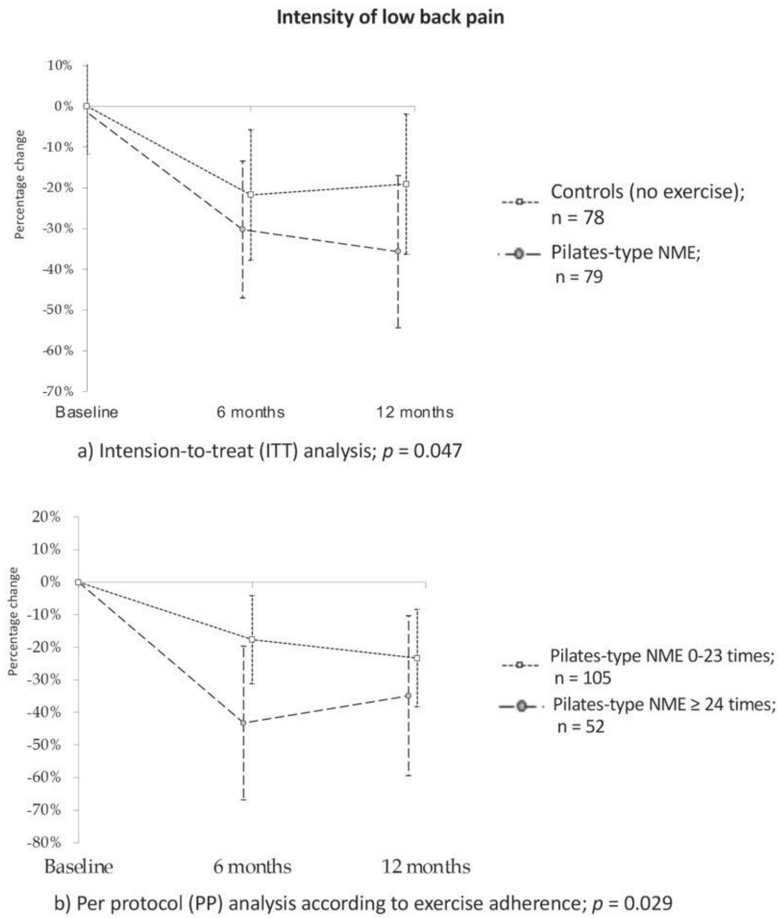


**Figure 11.** Effects of the modified Pilates-type neuromuscular exercise intervention on LBP intensity, measured by VAS (0-100). The mean difference in percentage with 95% confidence intervals analysed by GLMM, and adjusted for civil status, perceived health, and push-ups. NME = neuromuscular exercise.

## 5.4.2 Lumbar movement control impairments

Lumbar MCI decreased more in the exercise group (43%) compared to the non-exercise group (18%) ($p = 0.046$; adjusted for one-legged squats and education level, Figure 12). In the PP analysis, the decrease in lumbar MCI was more obvious in the more exercised compared to the less exercised and the non-exercisers ($p = 0.017$).

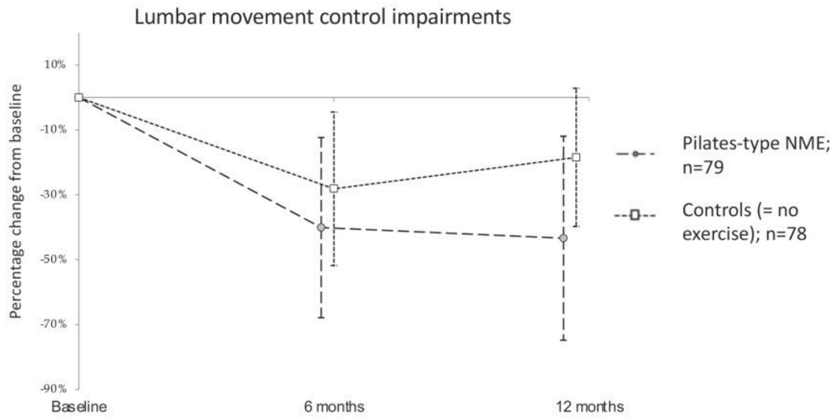


**Figure 12.** Effects of the modified Pilates-type neuromuscular exercise program on lumbar movement-control impairments (MCI) test results from baseline to 12 months. The mean difference in percentage with 95% confidence intervals analysed by generalized linear mixed models ($p$ = 0.046). NME = neuromuscular exercise

At the baseline, 35% of the exercise group had no deficiencies in any of the four MCI tests, 35% had impairments in one test, and 29% had impairments in 2–4 tests. The corresponding percentages in the non-exercise group were 33%, 36%, and 31%, respectively. Of those who had impairments in 2–4 MCI tests at baseline, and who exercised once a week or more, 69% improved their result in 2–3 tests. The corresponding percentage among less exercised was 36% (Figure 13).

The decrease in pain intensity from baseline to 6 months did not correlate with the increase in lumbar movement control ($r_s = 0.03$, $p = 0.75$).

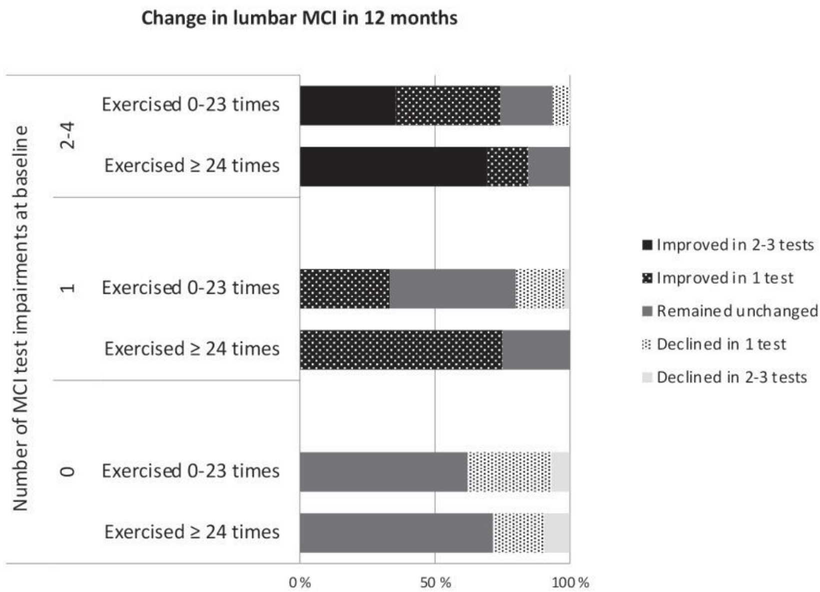


**Figure 13.** Change in lumbar movement control impairment (MCI) test results from baseline to 12 months among exercise compliers (exercised ≥24 times, *n* = 52) and a combined group of less exercised and non-exercisers (exercised 0–23 times, *n* = 105).

### 5.4.3 Fitness components and work-related factors

Compared to the non-exercisers, abdominal strength increased in the NME group ($p = 0.02$) (Figure 14). No significant differences between the study groups were found regarding any other fitness components in the ITT analysis, but in the PP analysis, the more exercised increased their walking distance in the six-minute walk test compared to the less exercised and the non-exercisers ($p = 0.02$). The reduction in pain intensity correlated with the increase in walking distance at 6 months ($r_p = -0.17$, $p = 0.03$).

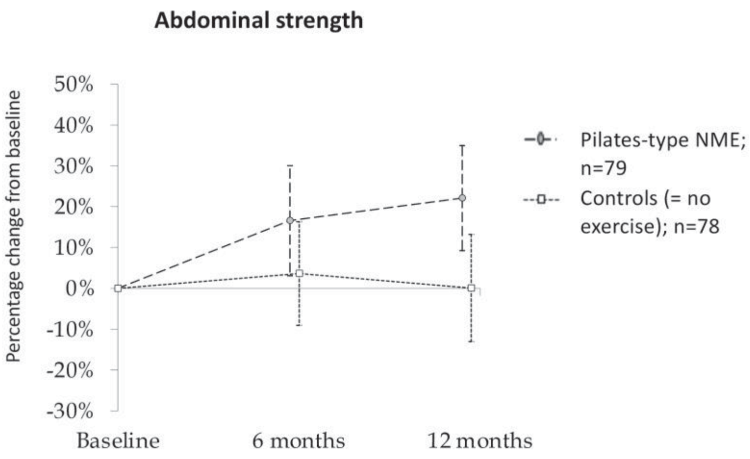


**Figure 14.** Effects of the modified Pilates-type neuromuscular exercise program on abdominal strength. The mean difference in percentage with 95% confidence intervals analysed by generalized linear mixed model, and adjusted for age, BMI, perceived fitness and 1-leg squats ($p$ = 0.016). NME = neuromuscular exercise

In the longitudinal analysis, the NME group perceived fewer difficulties in physical functioning at work ($p$ = 0.007) compared to the non-exercisers (Figure 15.). The change was most obvious at 6 months, when the difficulties decreased in the NME group by 17.1%, while the difficulties increased in the non-exercisers by 10.9%. At 12 months follow up, there were no longer group differences. After adjustments (for age, multisite pain, modified push-ups, self-reported physical activity, and tiredness and sleepiness), the result was not statistically significant. Differences between exercisers and non-exercisers were not statistically significant for other work-related factors, tiredness and recovery from work ($p$ = 0.06), and work-induced lumbar exertion ($p$ = 0.09).

The decrease in pain intensity from baseline to 6 months did not correlate with the increase in abdominal strength ($r_s = -0.10$, $p$ = 0.09), but it correlated with decrease in difficulties in heavy nursing duties ($r_s = 0.27$, $p$ = 0.001).

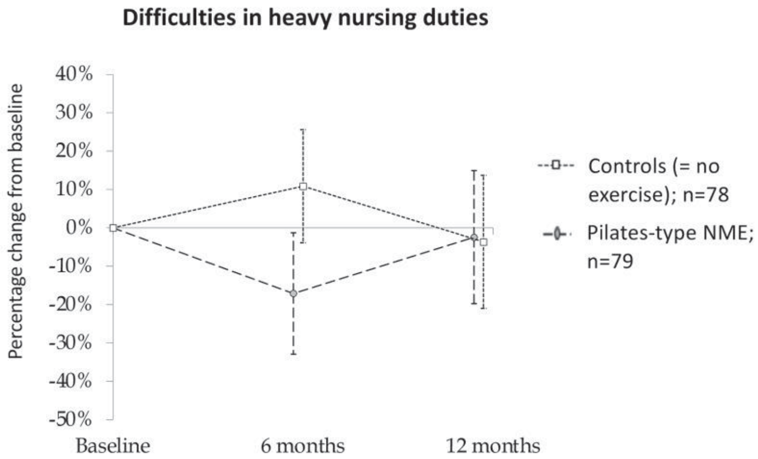


**Figure 15.** Effects of the modified Pilates-type neuromuscular exercise program on difficulties in heavy nursing duties. The mean difference in percentage with 95% confidence intervals analysed by generalized linear mixed model ($p$ = 0.007).

### 5.4.4 Fear-avoidance beliefs

During the exercise intervention, physical-activity related fear-avoidance beliefs (FAB-PA; $p = 0.028$, adjusted for perceived occupational physical loading) and work-related FABs (FAB-W, $p = 0.007$, adjusted for age, perceived health, shift work, fitness and occupational physical loading, and push-ups) decreased in the NME group compared to the non-exercisers (Figure 16; ITT analysis).

There was a dose-response; both FAB-PA ($p = 0.006$) and FAB-W ($p = 0.016$) decreased more in the high exercise-compliance group compared to the less exercised and non-exercisers (Figure 14; PP analysis).

The decrease in pain intensity from baseline to 6 months did not correlate with the reduction in FAB-PA ($r_p = 0.03$, $p = 0.54$), but it had some correlation with decreased work-related FABs ($r_p = 0.16$, $p = 0.05$).

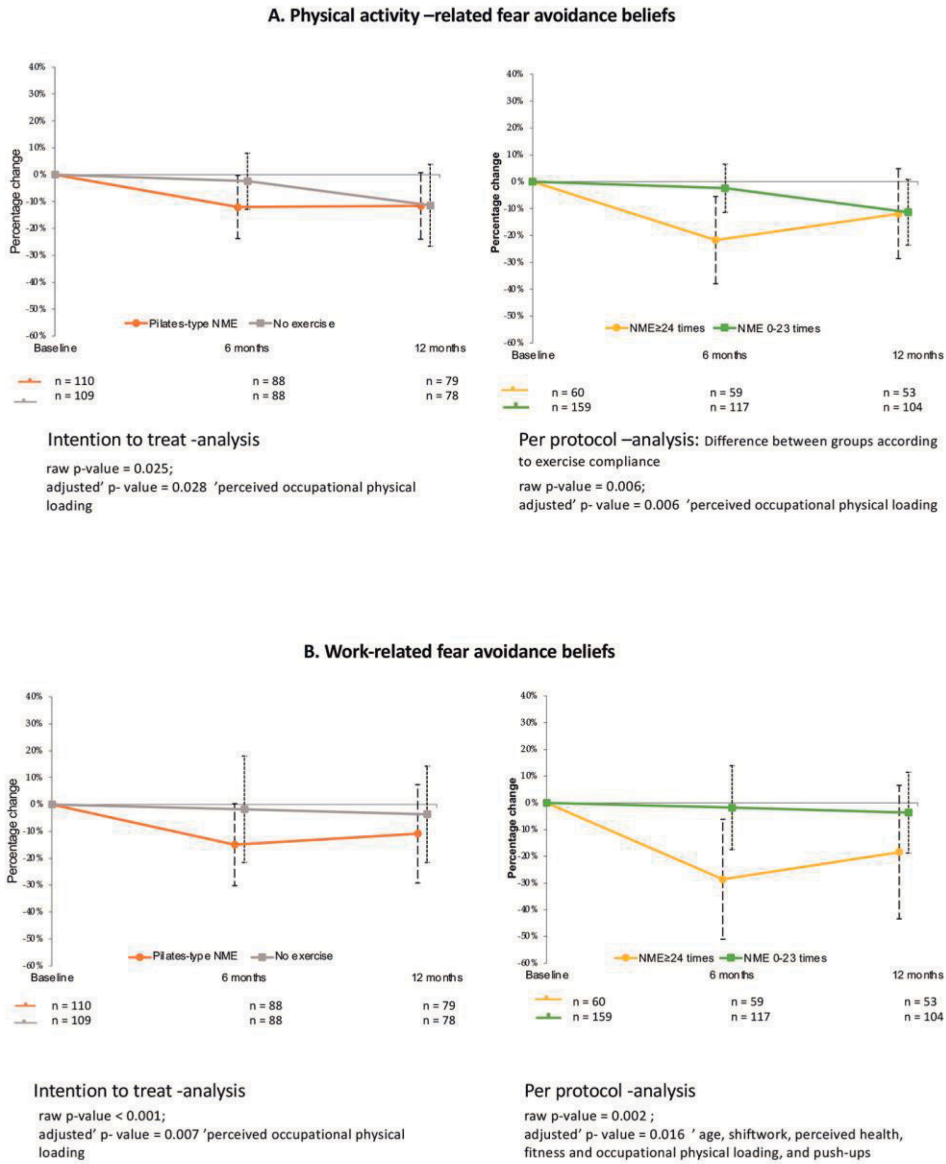


**Figure 16.** Effects of the modified Pilates-type neuromuscular exercise (NME) on a) physical-activity related fear-avoidance beliefs, and b) work-related fear-avoidance beliefs (mean difference in percentage with 95% confidence interval, analysed by generalized linear mixed models).

## 5.5 Exercise adherence (Study IV)

The target was to exercise twice a week – i.e. 48 sessions over 24 weeks. The mean exercise attendance rate was 26.3 (12.2) sessions. Of those who were allocated to the exercise group, 10% did not exercise at all, and another 10% took part in only 1–5 exercise sessions in the 6-month period. Only two people out of the 110 exercised regularly twice a week during the 6-month intervention period.

The exercise group was split to exercise compliers (exercising ≥24 times in 24 weeks, *n* = 58) and to non-compliers (0-23 exercise sessions, *n* = 52) (Table 6).

Exercise non-compliers had more often a lower basic education level (*p* = 0.03), were employed as assistant nurses (*p* = 0.05) and did shift work (*p* = 0.02) compared to the exercise compliers. Exercise adherence was lower in Sub-study I, which was conducted in geriatric wards and an old people's home, where most of the workers were assistant nurses. From the baseline variables, higher fitness test results in the one-leg-squat (*p* = 0.043) and 6-minute walk test (*p* = 0.048) were detected for exercise compliers. Exercise compliers showed lower values for FAB-PA at the baseline compared to non-compliers (*p* = 0.02, Table 6).

**Table 6.** Baseline characteristics of the participants (randomised to the exercise group) by exercise adherence status.

| | Compliers (≥ 24 exercise sessions), *n* = 58 | | | Non-compliers (0–23 exercise sessions), *n* = 52 | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean (SD) | n | % | Mean (SD) | n | % | Missing | *p*-value |
| Education level° | | | | | | | - | **0.026** |
| low (secondary school | | 14 | 24.1 | | 23 | 44.2 | | |
| or less) | | 4 | 75.9 | | | 55.8 | | |
| medium or high | | | | | | | | |
| Work type; ° | | | | | | | - | **0.023** |
| regular work | | 24 | 41.4 | | 11 | | | |
| shift work | | 34 | 58.6 | | 4 | | | |
| Profession; ° | | | | | | | - | 0.052 |
| assistant nurse | | 18 | 31.0 | | 25 | 48.1 | | |
| nurse | | 31 | 53.4 | | 25 | 48.1 | | |
| other (radiographer, PT, midwife) | | 9 | 15.5 | | 2 | 3.8 | | |
| Sub-study; ° | | | | | | | - | **0.042** |
| Sub-study I | | 9 | 15.5 | | 18 | 34.6 | | |
| Sub-study II | | 22 | 37.9 | | 19 | 36.5 | | |
| Sub-study III | | 27 | 46.6 | | 15 | 28.8 | | |

| | Compliers (≥ 24 exercise sessions), *n* = 58 | | | Non-compliers (0–23 exercise sessions), *n* = 52 | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean (SD) | n | % | Mean (SD) | n | % | Missing | *p*-value |
| Perceived health in comparison to others of the same age and sex;° | | | | | | | - | 0.14 |
| moderate | | 20 | 34.5 | | 25 | 48.1 | | |
| good or very good | | 38 | 65.5 | | 27 | 51.8 | | |
| Frequency of LBP ° | | | | | | | 8 | 0.12 |
| on some days of the week | | 21 | 38 | | 25 | 54 | | |
| on most days | | 26 | 46 | | 12 | 26 | | |
| daily | | 9 | 16 | | 9 | 20 | | |
| LBP intensity; (VAS 0–100) □ | 36.9 (19.9) | | | 35.9 (19.9) | | | 1 | 0.79 |
| Running a figure-of-8; seconds □ | 7.7 (1.0) | | | 8.0 (1.2) | | | 9 | 0.20 |
| One-legged squat; (0–12 reps) □ | 9.9 (2.3) | | | 8.9 (2.9) | | | 2 | **0.043** |
| 6MWT; metres □ | 623.0 (43.8) | | | 603.4 (56.2) | | | - | **0.048** |
| Quality of life: | | | | | | | | |
| physical functioning (0–100) □ | 87.3(11.1) | | | 83.4 (13.4) | | | 4 | 0.17 |
| general health (0–100) * | 70.2(16.4) | | | 64.5 (17.5) | | | 4 | 0.08 |
| Work ability (3–27) □ | 22.2 (2.6) | | | 21.9 (2.9) | | | | 0.20 |
| PHQ-9 (0-27) □ | 16.4 (4.5) | | | 17.5 (5.3) | | | 1 | 0.29 |
| Musculoskeletal exertion (7-35) * | 12.2 (3.8) | | | 13.5(4.0) | | | 2 | 0.10 |
| FABs total (0-78) □ | 23.2 (12.9) | | | 27.3(14.5) | | | 7 | 0.07 |
| FAB-PA (0-30) □ | 12.6(6.9) | | | 15.4 (6.4) | | | 1 | **0.019** |

*normal distribution, independent samples t-test, □ Mann–Whitney U test, ° $\chi^2$ test. FAB-PA = physical activity-related fear-avoidance beliefs, LBP = low back pain, PHQ-9 = Nine-item Patient Health Questionnaire measuring depression; PT = physical therapist; VAS = visual analogue scale of 0–100 during the past 4 weeks

# 6 DISCUSSION

In repeatability analysis, all tests assessing musculoskeletal fitness and four of the MCI tests had an acceptable level of long-term repeatability. The two tests for MCI with poor repeatability (rocking forwards and backwards, and one-leg-stance) were eliminated from the final measurements of the later interventions. We investigated which baseline factors of the study sample best explained pain interference with work, physical functioning, and perceived current and future work ability. Work-induced lumbar exertion and work-related fear-avoidance beliefs best explain all three outcomes. Work-induced lumbar exertion was strongly linked with fitness levels in all fitness components.

The modified Pilates-type NME program was feasible and effective in reducing LBP intensity, lumbar movement-control impairments, and fear-avoidance beliefs with dose-response. The NME program also increased abdominal strength and decreased difficulties in heavy nursing tasks, but we did not detect significant changes in improving other fitness components and work-related measurements, maybe due to only moderate exercise adherence. Factors compromising exercise adherence were high FABs-PA, lower basic education level, shift work, and lower fitness levels in muscular and aerobic fitness at baseline.

## 6.1 Repeatability of the musculoskeletal fitness tests and lumbar movement-control impairment test battery

All six tests assessing musculoskeletal or motor fitness (rhythm-coordination, trunk lateral flexion, running a figure-of-8, modified push-up, dynamic sit-up, and one-leg squat) had an acceptable level of repeatability. A learning effect was detected in two of the tests assessing muscular strength, namely dynamic sit-ups and modified push-ups (showing systematic change in mean and 95% CI not including zero number). That must be considered when assessing effects of an exercise intervention on those fitness components. ICC values for test-retest measurements were between 0.80-0.89, which can be interpreted as good reliability (Koo and Li 2016).

Only four of the MCI tests (pelvic tilt, waiters bow, sitting knee extension, and knee flexion in prone) had an acceptable level of repeatability. Wide confidence intervals in Kappa-values for sitting knee extension and knee flexion in prone indicate uncertainty in the results: there might be variation both in performance of the participants and in the visual ratings made by the tester.

The overall target of the present NME intervention was to decrease pain-induced lumbar movement- control impairments and to increase the muscular strength and endurance needed in physically heavy nursing duties. Therefore, the emphasis in selecting and instructing the different exercises in the NME programme was on lumbar movement control and on strength and endurance of core muscles and lower extremities. Thus, it was justified to evaluate the repeatability of certain key measurements assessing those abilities and to drop out those which had a poor repeatability (two MCI tests: rocking forwards and backwards, and 1-leg stance; Study I). Those two tests need to be better standardized than they were in 2011, when the repeatability measurements were conducted among the participants of the Sub-study 1 (Study I). Only reliable and repeatable measurement methods can be used to evaluate effects of an intervention. A measurement will never be valid if it is not adequately consistent in repeated measurements (Atkinson and Nevill 1998).

Physically heavy healthcare work demands certain levels of musculoskeletal fitness and movement control. The motor and musculoskeletal fitness tests assessed muscle strength and endurance (modified curl-up, modified push-ups, and 1-leg squats), spine flexibility (lateral bending) as well as agility and power (running figure-of-8). According to our knowledge, research on fitness levels among workers in other physically demanding jobs such as fire-fighters (Smith 2011) and military professions (Hauschild et al. 2016), has been conducted, but not among healthcare workers.

The test–retest measurements were conducted in October–December 2011. Movement control impairments were assessed visually from videotapes, but visual assessment includes a high risk of bias (Carlsson and Rasmussen-Barr 2013). Standing posture is not always reproducible either (Schmidt et al. 2018). More precise wireless inertial motion and electromyography sensors that measure movement of the spine are capable of providing detailed, precise kinematic information that is not easily measured by visual observation (Laird et al. 2019).

The four MCI tests with acceptable repeatability (waiters bow, pelvic tilt, sitting knee extension and knee flexion in prone) measured lumbar movement control principally in the sagittal plane, not in the horizontal or frontal plane, which are essential in performing nursing duties that are often performed while walking or involve standing in a asymmetric pose. The median walking distance during a working shift on a hospital ward has been measured to be approximately five kilometers (Kwiecień-Jaguś et al. 2019). Thus, it would be beneficial to measure lumbar movement control in the horizontal and frontal plane, because movements occur in those planes in the lumbar spine while walking (Bagheri et al. 2019) or working in an asymmetrical pose.

MCI tests are quick, cheap and easy to perform and thus practical to use in a clinical practice with LBP patients, the majority of whom demonstrate differences in some aspects of motor control (van Dieen et al. 2019). However, repeatability and reliability studies of MCI tests are still scarce. Therefore, final conclusions regarding the clinical and scientific use of these tests can only be drawn when reliability and validity have been studied extensively (Salvioli, Pozza and Testa 2019). The measurement of fitness components in turn is more complicated and time-consuming, and so, according to the present study, it is not possible to define their relevance in the management of LBP.

## 6.2 Factors associated with pain interference with work, physical functioning and work ability at baseline

The main outcomes to be explained at baseline were selected from three different ICF-domains: 1) Body structures and functions (Bodily pain and pain interference with work), 2) Activities (Limitations in physical functioning), and 3) Participation (Perceived current and future work ability). Factors that best explained the levels of bodily pain, physical functioning, and work ability at baseline were work-induced lumbar exertion and work-related FABs. Perceived recovery from work and depressive symptoms explained current and future work ability. Higher musculoskeletal performance level was associated with better physical functioning. Those with poor muscular and aerobic fitness levels perceived more work-induced spinal exertion.

According to definitions made by Kongsted, Hestbaeck and Kent (2017), the majority of the study sample could be described as suffering from mild to moderate non-specific LBP with recurring pain behaviour.

In the bivariate analysis, we detected that performance levels in aerobic, musculoskeletal, and motor fitness tests were systematically lower for those who perceived more work-induced lumbar exertion in comparison with those who were less exhausted. The role of musculoskeletal and aerobic fitness levels among healthcare workers is somewhat unknown. A good general health status and low baseline functional impairment predict recovery from acute LBP (Chou and Shekelle 2010). Physical deconditioning has in turn been suggested to compromise recovery from LBP (Verbunt, Smeets and Wittink 2010); consequently can be hypothesized that nursing personnel with low aerobic and musculoskeletal fitness get tired more easily during a work shift. Fatigue has been reported to be one of the risk factors for LBP among nurses (Ibrahim et al. 2019). Poor endurance leads to exhaustion and fatigue at the end of a work shift, and fatigue, in turn, is known to decrease perception and motor control (Roijezon, Clark, and Treleaven 2015), thereby intrinsically raising the risk of injury in physically demanding tasks. In a study conducted among the participants of the NURSE RCT, regarding their fitness level during the 6 months prior to the baseline measurements, those with good aerobic and musculoskeletal fitness had lower medical costs in terms of visits to healthcare providers, medication and sickness absence than those with low fitness levels (Kolu et al. 2017).

The study sample had pain not only in the low back; the average number of musculoskeletal pain sites was 3.2. Multi-site musculoskeletal pain was associated with higher levels of pain interference with work and lower physical functioning in the study sample. Multi-site pain is a strong predictor of sickness absence (Haukka et al. 2013) and early retirement (Kamaleri et al. 2009). Multi-site musculoskeletal pain is also associated with healthcare workers' perceived ability to work, with the magnitude of association likely to increase with the number of pain sites (Phongamwong and Deema 2015). Multisite musculoskeletal pain is also present in fibromyalgia, which is much more common in females than in males, with a female-to-male ratio of 14:1 (Jones et al. 2015).

High FABs-W were related with high levels of pain interference with work, low perceived current and future work ability, and more limitations in physical functioning. Our results are in line with a recent cross-sectional study showing that kinesiophobia and catastrophising are present among healthcare workers with LBP, involved in patients' manual handling, and they are linked to disability (Lecca et al. 2020). FABs play a central role in chronic LBP when organic pathology is not evident. The role of FABs in non-chronic populations is less clear, but it seems that it is linked to the transition of pain to the chronic stage (Wertli, Rasmussen-Barr et al. 2014) and plays a key role in recovery (Chou and Shekelle 2010). For nursing personnel with previous back pain, both FABs and physical workload are associated with new episodes of LBP (Jensen et al. 2009; Jensen et al. 2010).

Maladaptive pain-coping strategies and presence of psychiatric comorbidities are predictive factors of persistent, disabling LBP (Chou and Shekelle 2010). A systematic review (Wertli, Rasmussen-Barr et al. 2014) summarizes the evidence of catastrophizing as a prognostic factor among patients with acute, sub-acute, and chronic LBP. Associations between catastrophizing thoughts and the future course of pain and disability were conflicting. High scores in catastrophizing were associated with poor outcomes, but no cut-off values can be recommended. Among those with lower baseline catastrophizing the findings were less clear or prognostic. (Wertli, Rasmussen Barr et al. 2014 b.)

## 6.3 Efficacy of the modified Pilates-type neuromuscular exercise program with focus on controlling the neutral spine posture

### 6.3.1 Low back pain intensity and pain interference with work

The modified 6-month Pilates-type NME program was effective in reducing pain intensity and pain interference with work among healthcare workers with sub-acute or recurrent LBP compared to not exercising. In the exercise group, the mean reduction of pain intensity from baseline was -10.7 mm (30.3%) after the intervention. Among those who exercised once a week or more, the mean pain reduction was 15.4 mm, 43% from baseline, which is also a clinically important result. According to Ostelo and colleagues (2008), for patients with LBP, the minimal clinically important change (MCIC) for pain on VAS should be at least 15 mm. In percentage terms, a 30% change from baseline may be considered a clinically meaningful improvement, when comparing before and after measures for individual persons (Ostelo et al. 2008). Because the mean of the LBP intensity was 36 mm in the study sample at baseline (only mild to moderate LBP), it is difficult to draw conclusions of MCIC according to those suggested absolute cut-points, but at least for the more exercised (once a week or more), pain reduction was clinically important.

In reducing pain intensity, there was a dose-response in favour of the more exercised. A corresponding dose-response relationship between training adherence and reduction in lumbar pain intensity has been detected among Danish healthcare workers (Jakobsen et al. 2016).

In a systematic review investigating intervention studies among healthcare personnel with LBP (Van Hoof et al. 2018), only three RCTs including exercise in the interventions and having a low risk of bias were found. Combined strength training and stretching (Jaromi et al. 2012) or stretching alone (Chen et al. 2014) decreased pain among nurses with chronic pain, but an intervention including counselling, segmental stabilization, and general exercise was not superior to general exercise alone in reducing pain among nurses with sub-acute LBP (Ewert et al 2004). Light exercise program has shown to be ineffective in preventing new pain episodes among healthcare workers with recurrent LBP (Chaleat-Valayer et al. 2016). There has been no strong evidence for the efficacy of any intervention either in the prevention or treatment of LBP in nursing personnel (Van Hoof et al 2018).

Among general population, exercise is the most often recommended treatment for chronic LBP. In a recent network meta-analysis, Owen and colleagues (2019) examined the effectiveness of specific modes of exercise training in non-specific chronic LBP, and found low quality evidence that Pilates is the most effective treatment to reduce pain, stabilization / motor control exercises to increase physical functioning , and resistance training and aerobic exercise training for mental health. Heterogeneity among the studies (n=89) and the fact that there were only few studies with low risk of bias limited the results. Because we compared the Pilates-type NME only to non-exercising, we cannot say that it is superior to any other kind of exercise.

### 6.3.2 Lumbar movement control impairments

The modified Pilates-type NME program with focus on controlling the lumbar spine reduced lumbar movement-control impairments with dose-response. Exercise can be used to change motor behaviour, provided that movement-oriented feedback is offered when exercising. Group instructors used both verbal and manual feedback to help the participants to focus on alignment and control of the lumbar spine posture. Currently, the exact effectiveness of extrinsic feedback for the management of patients with non-specific LBP is unknown (Ribeiro et al. 2018). Berglund and colleagues (2018) showed that retraining of the lumbopelvic alignment – both with a hypo-lordotic and hyper-lordotic spine – could be possible for patients with LBP with low-load motor control exercises as well as high-load lifting exercises. Even a single motor skill training session emphasizing intrinsic feedback to decrease early-phase lumbar excursion and to differentiate movement of the spine from movement of the hip joints, can result in better lumbar movement control in functional tasks among people with LBP (Marich et al. 2018).

Frost and colleagues (2015) compared firefighters assigned to a 12-week program of movement-guided fitness training, conventional fitness training, or a control group. Both exercise groups showed significant improvements in all fitness categories, but only the movement-guided group showed spine and knee movement control when performing different occupational tasks. In physically demanding work duties like firefighting or nursing tasks, being physically fit may play a role in the prevention of spinal injuries, but it is likely insufficient for this purpose on its own. (Frost et al. 2015.)

Lumbar movement control was trained by instructing the participants to pay attention to the lumbar spine and pelvic position in all exercise, not by instructing to recruit deeper muscles and relax the superficial muscles, which has been a technique used in many Pilates schools. Instructing "abdominal drawing-in" for people with LBP is still commonly used in the clinic for guiding specific TrA contraction exercises to re-train motor control. This can be questioned since the ability to perform TrA contraction seems simply to be a normal variation independent of LBP (Kaping, Äng and Rasmussen-Barr 2015).

In the study by Bauer and colleagues (2019), effects of the NME program on lumbar movement variability was also assessed with a movement analysis system, which uses wireless inertial measurement units (IMUs) among the participants of Sub-study 3 of the NURSE RCT ($n$ = 83). A positive treatment effect of the NME program on lumbar movement variability was seen at 6 months, but the effect faded at 12 months follow up. Lumbar movement variability worsened in the control group (non-exercisers) over all time periods. These results show that this modified, Pilates-type NME may improve lumbar movement variability in the short term and may indicate improved neuromuscular functional integrity.

### 6.3.3 Fitness components and work-related factors

The only fitness component where we gained positive results in favour of the exercisers was abdominal strength. In the exercise program, the number of repetitions for each exercise varied between 6–10, but several different exercises were targeted to increase the core strength and endurance.

According to Recommendations for exercise training from American College of Sports Medicine, adults should perform resistance exercises for each of the major muscle groups as well as neuromotor exercise involving balance, agility, and coordination on 2–3 days /week. Moderate-intensity cardiorespiratory exercise training for a total of ≥150 min /week, vigorous-intensity cardiorespiratory exercise training for ≥75 min /week or a combination of moderate- and vigorous-intensity exercise is also recommended to gain positive effects on fitness components and health. Flexibility exercises are recommended 2 times /week. (Garber et al. 2011) Physical Activity Guidelines for Americans recommend the same amount of muscle-strengthening exercises, on 2 or more days a week (Physical Activity Guidelines Advisory Committee 2018).

The Pilates-type NME intervention included muscle strengthening, flexibility, coordination and balance exercises, and the target was to exercise twice a week as recommended (Garber et al. 2011, Physical Activity Guidelines Advisory Committee 2018). However, the mean exercise adherence rate was only 1.1 times/week. That exercise dose was not enough to gain positive effects either in flexibility, cardiorespiratory, or muscular fitness. In the PP analysis, the more exercised (once a week or more) increased their walking distance in the six-minute walk test compared to the less exercised and the non-exercisers. The exercise program was not planned to increase cardiorespiratory fitness. Thus, the result can be explained by decrease of pain and potentially increased hip range of motion and thoracic rotation, all of which could have enabled faster walking. Hip and thoracic mobility were practiced in the exercise intervention, but not measured as outcome variables. On the other hand, Fernández-Rodríguez and colleagues (2019) presented in their systematic review that Pilates method also improves cardiorespiratory fitness.

Difficulties in heavy nursing tasks decreased in the exercise group compared to non-exercisers at the 6 months follow up, but at 12 months there were no more group differences. Although fitness is important in physically heavy work, work ability and other work-related factors are probably multicomponent, biopsychosocial factors, on which exercise alone hardly has an effect, especially with an exercise dose lower than targeted.

### 6.3.4 The role of breathing with movements

In the modified Pilates-type NME program, the exercises were conducted at pace of each participant's breathing tempo. We did not have any measurements to measure the effects of that kind of exercise technique and execution. Different breathing exercises (such as focused, mindful breathing, deep or slow breathing, yogic breathing or resisted inspiration) can reduce pain among people with chronic LBP, but the quality of evidence is only low to moderate (Anderson and Huxen Bliven 2017). The underlying mechanism to explain the effects of slow breathing in attenuating pain remains unclear (Jafari et al. 2020).

Combining breathing to movements is not easy. It has been suggested that novice practitioners may only be able to allocate their attention to one single element of the practice at a time, but with time, as their practice advances, they are likely to become increasingly skilled at simultaneously monitoring movement, breath, and any concomitant sensations that may arise (Schmalzl, Powers and Henje Blom 2015). Breathing affects feelings and mental functions. There is a common belief that breathing control has beneficial effects on relaxation, stress and wellness. Nevertheless, science has paid little attention to the investigation of the effects of breathing control and the underlying mechanism of the effects of breathing technique on autonomic and central nervous system. (Zaccaro et al. 2018). Pain is linked to negative emotions, stress, and increased sympathetic nervous system activity (Craig 2003). Exercises combining breathing with movements can affect cardiac autonomic regulation with increased heart rate variability (HRV) and vagal dominance during practice (Tyagi and Cohen 2016), and thus reduce stress and pain (Zautra et al. 2010).

In the present study, the question how combining breathing with the movements effects the reduction of pain remains unclear due to lack of measurements. The typical respiratory rate in healthy humans is within the range of 10–20 breaths per minute. When people put their focus on their breathing, and combine it with their movement, the breathing becomes slower, and slower breathing has shown to reduce ratings of pain intensity and feelings of unpleasantness. (Russo et al. 2017.) Mindful exercise forms that combine breathing with movement have been shown to reduce pain among people with chronic LBP (Zou et al. 2019).

In conclusion, breathing with the movements can reduce pain. The positive effects can be due to several reasons, e.g. enhanced stability, concentration on slow and controlled breathing in co-ordination with movements, activation of the parasympathetic nervous system, reduced stress. The exact mechanism of those effects remains unclear. Different kinds of breathing techniques in Pilates exercises are widely utilized in clinical practice of LBP treatment regardless lack of scientific evidence.

### 6.3.5 Fear-avoidance beliefs

The NME program reduced levels of FABs related to both physical activity and work, and there was a dose response: FABs diminished more in persons with better exercise adherence.

Interventions to lower FABs very seldom include exercise only, but a Pilates-type exercise program has been shown to reduce FABs in the short term more than stationary cycling among people with chronic LBP (Marshall et al. 2013). Graded activity as well as cognitive and psychological interventions are usually considered helpful in the management of FABs and fear avoidance-related pain (Linton and Shaw 2011; Foster et al. 2018). Among French hospital workers who had recently recovered from a period LBP, an intervention including education alongside light exercise was slightly more effective in reducing FABs-PA than the present study (Chaleat-Valayer et al. 2016).

Moderators (or treatment effect modifiers) are baseline characteristics that influence the outcome of treatment, while mediators are factors that change during, or as a consequence of, an intervention and thereby influence outcome (Nicholas et al. 2011). Thus, it might be hypothesized that the reduced LBP intensity among the participants of the present study sample after the NME intervention might have been mediated by a reduction in the FAB-PA. However, there was no correlation between the reduced pain intensity and the reduction of FAB-PA, but exercise adherence was the key factor. Those with lower levels of FAB-PA at the baseline exercised more, and those who exercised more gained more positive results in pain reduction. This modified, slowly progressing Pilates-type neuromuscular exercise program, which was conducted at the pace of each participant's own, calm breathing tempo, might have given the participants positive experiences of movement. They were able to move in a way that they could control, and the movements resulted in reduction of pain. This might explain the diminution of FABs during the exercise intervention.

Fear-avoidance beliefs were measured with a FAB questionnaire (FABQ) developed by Waddel and colleagues in 1993. It has been widely used both in clinical practice and research among people with chronic musculoskeletal pain. However, very recently Aasdahl and colleagues (2020) challenged the predictive property of the FABQ, presenting that it is most likely related to expectations rather than fear among people who are on sick leave due to musculoskeletal complaints. We measured FABs with a modified FABQ, in which three questions considering long-term sick leave had been removed, because the participants were still at work. Thus, interpretations on the clinical significance of the change in FABs cannot be drawn.

## 6.4 Factors associated with reduction in low back pain intensity during exercise intervention

The modified Pilates-type exercise intervention reduced pain intensity with a dose response relationship. The reduction of LBP intensity from baseline to 6 months correlated only with a decrease in FAB-W, a decrease in difficulties with heavy nursing duties and an increase in walking distance at 6MWT, not with changes in other measurements.

It has been suggested that reduction in pain intensity resulting from exercise interventions is unrelated to changes in musculoskeletal fitness, such as improvements in core muscle strength, endurance, and mobility (Steiger et al. 2012, Mannion et al. 2012). This has led to assumptions that changes in psychological factors may be more important drivers of reduction in pain intensity in chronic LBP (Norris 2020).

Pain perception is an interaction between biological, psychological and social factors. Changes in self-reported pain intensity are therefore rarely caused by pure biological changes per se, or by changes in any single, separate factor (Gatchel et al. 2007). With regard to the measurement methods used in the current study, we cannot define which elements of the modified Pilates-type NME program caused the reduction in pain. The reason for the reduction in pain could be in regular exercise in itself, in learning to control the movement of the lumbar spine, in strengthening the musculature of the torso, or in focusing on breathing with the movements – or a combination of all these factors. Maybe the reduction in LBP intensity, the lessening of FAB-PA, and the improvements in lumbar movement control and abdominal strength simply occurred coincidentally, and maybe the diminution of pain was actually mediated by a third factor, such as exercise-induced functional or structural changes in the CNS (Brumagne et al. 2019) or the autonomic nervous system (Weippert et al. 2015), which are affected by exercising and controlled breathing, but not measured in this study.

The correlation between diminution of LBP intensity and 1) the lessening of FAB-W, 2) the decrease in difficulties with heavy nursing duties and 3) the increase in walking distance at 6MWT is easy to understand: It is easier to manage heavy nursing duties and walk faster when pain has decreased. Decreased work-related FABs are maybe a reflection of those experiences.

The treatment of people with non-specific LBP is complex, as the prevention of pain re-currencies and it is challenging to prevent pain from recurring in physically demanding work. People with LBP form a heterogenous group. Sub-groups of patients may respond differently to the same treatment, and some individuals may respond better to one type of treatment than another (Fersum et al. 2010). According to the biopsychosocial model, current opinion emphasizes a multidisciplinary approach, which includes not only biological factors but also psychosocial dimensions (Foster et al. 2018). Given the high prevalence of recurrent and chronic low back pain and the associated costs, a high priority should be placed on interventions that prevent recurrences and the transition to chronic low back pain (Delitto et al. 2012).

## 6.5 Exercise adherence

Those with higher baseline education level, regular working times, better musculoskeletal and aerobic fitness, and lower levels of FAB-PA at baseline had better exercise adherence. We used the median split, 24 times in 24 weeks, to split the exercisers to compliers and non-compliers. Defining "sufficient" exercise adherence is not always done in exercise intervention studies: more than 50% of the exercise studies do not provide any information about the satisfactory value for exercise adherence (Bailey et al. 2020).

Factors associated with exercise adherence among LBP patients can be divided into three categories: physical (e.g. pain intensity), psychological (e.g. fear of pain), and environmental factors (e.g. lack of time) (Boutevillain et al. 2017). Socio-demographic factors, e.g. education level, are also known to affect exercise adherence (Franco et al. 2018; O´Donoghue et al. 2018).

A lack of time is the most frequently reported barrier to leisure-time physical activity or exercise both among people with LBP (Mathy et al. 2015) and among the general population (Carraca et al. 2018). Those working in shifts had a lower exercise adherence than those with regular working hours. Among healthcare personnel, shift work is also associated with sleeping problems, fatigue, and lack of energy (Leyva-Vela et al. 2018), which might compromise exercise adherence, especially attendance at group sessions at certain times.

Higher physical fitness level at the baseline contributed to better exercise adherence. To our knowledge, association between baseline physical fitness and exercise adherence in a later exercise intervention has not been reported previously. We know from practical experience that those with better physical fitness are more prone to take part in exercise programs in workplaces than those with poor fitness, but scientific evidence on that topic is lacking.

Higher educational level has an effect on exercise adherence in general (Scheers, Philippaerts and Lefevre 2013), but also among people with LBP. Those with a higher socioeconomic status are more prone to believing that one should stay active through LBP than those with a lower socio-economic status (Suman et al. 2017), and they have a more favourable prognosis after a group exercise program than those with lower education and a lower socioeconomic status (Steffens et al. 2014).

Increasing adherence to exercise is an important factor for the effectiveness of an intervention. Integrating educational components to exercise sessions, such as goal setting, strategic planning, self-monitoring, encouragement and action planning to overcome barriers to exercise (Nicolson et al. 2017; Mathy et al. 2015), supplementary printed material, motivation strategies, and positive re-enforcement (Kolt and McEvoy 2003) have been suggested to increase exercise adherence. Leadership and organisation skills, appropriate intensity of the training content (Ilvig et al. 2018), favourable environment and pleasure associated with exercise might also help in reducing fear of pain and pain itself and thus increase exercise adherence (Nicolson et al. 2017).

The study interventions were conducted in 2012–2014. Besides supervised group-based NME, the participants also exercised at home with the help of video discs or booklets produced for the study. Following rapid development of technology in recent years, more user-friendly solutions can now be used, such as internet-based exercise programs, which the participants can access from their devices, e.g. mobile phones.

Due to the nature of the original 4-arm NURSE RCT, and in order to not to contaminate the results with the counselling-group, all motivational strategies (except for the telephone call to those who had not attended the group exercise sessions in first 4 weeks) were written information in letters, e-mails and SMS. We could not ascertain if they were reached, read, or understood. No motivational strategies were used to maintain exercise motivation during the 6–12 -months' follow-up time.

## 6.6 Methodological considerations

*Strengths of the study*

The study design of the original 4-arm NURSE study was a randomized controlled trial. The target group was such that the risk of pain chronicity, or of new episodes of LBP, is high. We managed to reach an adequate number of participants with a physically demanding work and with LBP with recurring pain behaviour, who were still at a physically demanding work, and whose pain was not yet chronic. To tackle the risk of pain chronicity is important, but intervention studies among that kind of study population are scarce.

LBP is a multidimensional, complex biopsychosocial problem. We had a large range of reliable measurements, and the repeatability of some physical measurements was also confirmed before the study interventions started. Highly educated personnel with a long working history, blinded to group allocation and not involved in the interventions, conducted all measurements. New measurement methods were also developed in the original NURSE RCT (Suni et al. 2016).

The exercise interventions lasted for six months, which is a long time in comparison with many other exercise studies for LBP. The instructors were also highly educated. Standardized exercise programs with videos and booklets were produced, and regular meetings with the instructors confirmed the same contents of NME intervention throughout all 3 sub-studies.

The exercise program developed for the study was feasible. No back-related adverse events occurred in the NME group. The exercise videos and booklets enabled training at home, when irregular working hours limited attendance at group exercise sessions.

Many factors (reduced muscle function, reduced physical activity, impaired physical fitness, altered breathing, movement control impairments, fear and catastrophizing, depression) are associated with LBP and can maintain a vicious circle, which can lead to prolonged pain. If an intervention is capable of reducing one, or some, of the pain-maintaining factors, at the early phase of pain, the vicious circle can possibly be disrupted or broken before chronicity. We managed to gain dose-dependent, significant reduction in LBP intensity, lumbar movement-control impairments and fear-avoidance beliefs. Positive results in terms of reduction in difficulties with heavy nursing duties and improvements in abdominal strength were gained with lower exercise dose than targeted.

*Limitations*

The main limitation of the study was exercise adherence, which was only moderate. Targeting motivational strategies to those allocated to the exercise group would have contaminated the results of back care counselling intervention in the 4-arm setting of the NURSE RCT.

Another limitation is the somewhat inaccurate criteria for pain duration of the study sample at the screening point. The exclusion criteria for NURSE RCT was LBP duration for longer than six months. However, this criterion was exceeded for 48 persons. In "questionable" cases, the principal researcher or responsible medical doctor made a telephone call to those persons and discussed their pain frequency. If they were not in daily pain, they were included in the NURSE RCT. However, for 7 persons, whose pain had lasted for longer than 6 months and who had daily pain, inclusion process failed for some reason. Thus, calling the participants "people with sub-acute or recurrent LBP" is somewhat complicated. At least 25% of the study sample could have also been called for people with chronic LBP, because their pain had lasted for longer than 3 months, and they had pain in most days of the week or daily.

There are also several limitations regarding the measurements. Although the measurement battery was wide including questionnaires, fitness tests, lumbar movement-control tests and objectively measured physical activity, some additional measurements would have broadened our understanding of these multi-component factors affecting LBP, and of the factors affecting exercise adherence. For example, home environment, previous physical activity (in earlier years), and immediate effects of the exercise sessions (on pain or other bodily sensations) were not ascertained during the study. We also used field tests to measure physical fitness components, which are not sensitive enough to detect smaller changes in muscular strength and endurance. In the screening forms, participants were asked for back surgery, disc bulge, inflammatory back disease, rheumatoid arthritis, and diseases or symptoms that limit participation in moderate intensity neuromuscular exercise, but no other specific diagnosis was asked. Some of the participants with multisite pain might have had fibromyalgia, not only LBP.

In the NURSE RCT, we did not document exercise that the participants may have done alongside participating in the NME program, nor use of any medication, or possible physical treatments and thus they could not be used as confounding factors in the longitudinal analysis. Exercising during the follow-up time (6–12 months) was not documented, either.

In assessing repeatability of the fitness and lumbar MCI tests the main limitation was, that we did not standardize the measurement time in relation to working times. There is a time-of-day effect on muscle fatigue and performance capacity (Nicolas et al. 2007) and working in shifts might also have an effect. Tiredness after work could have caused variation in test results in comparison with measurements which were conducted on the day off or before work-shift. A further limitation is that the mean number of days between test I and test II measurements was 18. In many test–retest studies, the retest time has typically been approximately within one week from the first test. Fitness capacity or movement control of people with LBP seldom changes in a few weeks without any intervention. Given the irregular working hours encountered with irregular shift work, the arrangement of test sessions suitable for participants and the same tester was very challenging.

In study II, the measurement method to assess depressive symptoms was incorrectly named for Beck Depression Scale. The measurement method was a Finnish version of Patient Health Questionnaire (PHQ) (Kroenke et al. 2001), which has not been validated yet. An Erratum was sent to the publisher of study II, Journal of Rehabilitation Medicine, and it was published in the journal (J Rehabil Med 2019; 51: 77)

Due to the nature of the interventions (exercise and/or back care counselling), it was not possible to blind participants to the treatments provided. In addition, all the study participants were females, which limits the generalization of the results to male healthcare workers.

## 6.7 Implementation and implications for further studies

This study showed that a modified, Pilates-type NME program was a low-risk and effective treatment option for reducing pain intensity, lumbar movement-control impairments, and FABs among female healthcare personnel with sub-acute or recurrent LBP and physically demanding work. Future studies may evaluate the benefits of such an exercise program among people with other kind of physically heavy work or implement principles and special targets of this NME program to other type of exercise, for example yoga, tai chi or strength training at the gym. A larger study with several treatment arms comparing multiple exercise regimens to the modified Pilates-type method would be useful to help delineate which types of exercises are most efficacious. With the rapidly changing economics in healthcare and rehabilitation, further evaluation of the cost-effectiveness of the NME program in comparison with other exercise interventions is vital to ensure its availability to patients with limited resources. Furthermore, more studies are needed to establish the optimal frequency, intensity and duration of this kind of NME as treatment for LBP. Finally, there is still a huge need in research. There is call for quality in exercise programs for LBP, both in terms of individual guidance and in how group curricula are put together: what is instructed, how it is instructed, what is measured and when and how, and how are all the results received interpreted for the benefit of the individuals to increase exercise adherence.

Previous exercise studies for LBP have mostly been conducted among people with chronic LBP. Our study showed that exercise adherence is a key factor also among people with sub-acute or re-current LBP. This thesis confirms what has been in focus in LBP research during recent years: We have to get people with LBP to exercise or engage in physical activity!

In intervention studies with people in musculoskeletal pain, exercise adherence has been only low to moderate. Clinicians also struggle with patients' or clients' poor exercise motivation. Behavioural science gives theoretical solutions, but no theory has been proven superior in implementing such behavioural changes in people that would make them in changing the behaviour to more physically active. This is currently a huge challenge in exercise science.

While the thesis is based on the results of a randomized controlled intervention study (NURSE RCT), the participants were not aware of their baseline measurement results nor of the interpretation of the results during the study period. In real life settings, knowing the result of the measurements can be one motivational factor to better exercise adherence. Motivational strategies with a focus on decreasing FABs and FABs-related behaviour, especially among people with a low education level, could be beneficial in future studies. Unfortunately, there is a lack of measurement or screening methods to identify those who would benefit the most from motivational actions for exercising.

The only known effective interventions for secondary prevention of LBP are exercise alone or combined with education (Steffens et al. 2016; Huang et al. 2019). However, it is still unknown when it would be appropriate to start exercising after a period of acute LBP. In Finnish recommendations for treatment of non-specific LBP (Alaselkäkipu. Käypä hoito -suositus 2017), exercise is not recommended in the acute phase, but it is strongly recommended in the sub-acute phase (6–12 weeks). Taking into account the variety of morphological changes in muscles and fascia of what is regarded as 'the core', it can be discussed if an earlier start of low-load exercising might be beneficial. While the majority of incidences of LBP have the tendency to recurrence, and many people have LBP with fluctuating or recurring pain behaviour, there are no clear recommendations as to the quality or quantity of exercise for recurring or fluctuating LBP. There is also ambiguity regarding the roles biological and psycho-social factors play in the course of LBP in physically demanding work. When people with LBP (*n*=130) were asked what triggers their LBP flare-up, 85% identified biomedical triggers, and 15% reported psychological or contextual factors (Costa, Hodges et al. 2019). These findings are in contrast with current pain theories, which suggests that there is a need for a reduced emphasis on biomedical causes of LBP, especially when the pain is persistent.

Musculoskeletal disorders such as LBP are one of the highest global burdens on individuals and health and social-care systems in the future. The burden will only increase due to the current rise in life-expectancy with an increasing ageing population and an increased number of people not taking health, lifestyle, diet and physical activity seriously (Lewis et al. 2019). More and more healthcare professionals are needed to take care of the aging population with decreased physical functioning. That work is physically heavy and managing it demands certain level of physical fitness and spinal control. Attention to this aspect of the work should be paid at nursing schools early on the education period. Worksite programs, such as providing guidance and possibilities to exercise, back care counselling and early rehabilitation to prevent work absenteeism and early retirement due to LBP and other musculoskeletal complaints, might be beneficial for healthcare personnel, especially at workplaces where the work is physically strenuous.

# 7 CONCLUSION

With reference to the main findings of the study, the following conclusions are presented:

1. The modified 6-month Pilates-type neuromuscular exercise program with focus on controlling the lumbar spine was effective in reducing LBP intensity, lumbar movement-control impairments and fear-avoidance beliefs. The training effects were dose dependent.

2. The exercise program was effective in reducing difficulties in heavy nursing duties and in increasing abdominal strength, but we did not detect significant positive changes in other fitness components.

3. The reduction in the intensity of LBP did not correlate with the decrease in fear-avoidance beliefs related to physical activity, the increase in lumbar movement control, or the increase in abdominal strength. With the measurement methods used in the study, we cannot explain which elements of the exercise program produced the pain reduction.

4. The modified, progressive Pilates-type NME program was feasible, and the principles and special targets can be modified to other kinds of exercise training according to client's preferences.

5. The exercise target – exercising twice a week – was hard to reach. The low exercise adherence was associated with, among other things, low education level, shift work, low level of fitness components and high levels of fear-avoidance beliefs related to physical activity. Motivational actions should be targeted particularly at those with low education and high physical activity-related fear-avoidance beliefs.

6. Female healthcare workers with recurrent or sub-acute LBP and a physically heavy work have several risk factors for pain chronicity. Work-induced lumbar exertion and work-related fear-avoidance beliefs best explain pain

interference with work, physical functioning and work ability. In this cohort, the results of the fitness components were systematically lower among those with high work-induced lumbar exertion. Thus, the results support the idea that physical fitness is of importance for spinal health in physically demanding work.

7. Musculoskeletal fitness tests were repeatable, as were four of the lumbar movement control impairments tests. Standardization of two of the movement-control impairment tests, namely one-leg stance and rocking forward and backward in quadruped position, needs to be improved from what it was in 2011.

"Change happens through movement, and movement heals"
Joseph Pilates (1883-1967)

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**Modified Pilates-based neuromuscular exercise programme with focus on controlling the neutral lumbar spine posture**

**Overall target**: to reduce pain and pain-induced disturbances in movement control and to increase the muscular strength and endurance needed in heavy nursing tasks

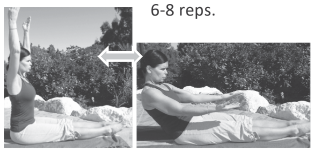
In each exercise the participants were instructed to concentrate on (1) the maintenance of neutral spine posture using light co-contraction of the trunk muscles, and (2) neutral alignment between body parts

In each exercise, the target was to combine breathing with the exercises, and thus take advantage of the spine-supporting role of the increased intra-abdominal pressure.

**In the warm-up**, light so called pre-Pilates exercises were performed along with flexibility exercises presented under Target number 5.

Concentration on lateral breathing and alignment of the body

Upward reach with arms; 6 + 6 reps.



6-8 reps.

Outward rotation of the hip without rotating the spine; 6 + 6 reps.

**Repetitions and progression:**
One set of 6-8-10 repetitions: (each 8-week stage started with 6 repetitions, and the number of repetitions was increased progressively to 8 or 10. Instructions were also given, where applicable, on progressively increasing joint range of motion or the holding time of the posture.

<u>**Specific targets and description of the corresponding exercises :**</u>

**1. To increase spinal stability using exercises that minimise the load on spinal structures but induce a high level of muscular activity**

**Stage I**, weeks 1-8 | **Stage II**, weeks 9-16 | **Stage III**, weeks 17-24

Modified curl-up (”McGill curl-up)

6 – 8 reps.

6 – 8 reps.

6 +6 reps.

”Bird dog”

6 – 8 reps.

6 – 8 reps.

6 – 8 reps. + increasing the holding time with one inhalation + exhalation

Side bridge or Mermaid

Starting position

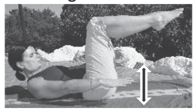
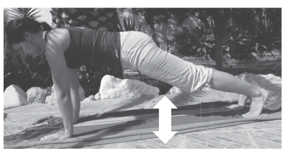
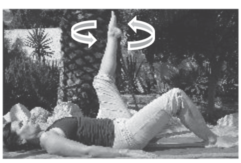
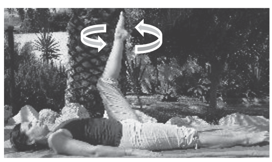
6 reps.

6 reps.

6 reps.

Alternative modification in case of wrist pain or restrictions in hip mobility

**2. To improve the endurance of the trunk musculature**

| | **Stage I** | **Stage II** | **Stage III** |
|---|---|---|---|
| The 100 |  Preparation: Lifting the legs up one after another to 90 degrees; 8-10 reps |  In curl-up postion, quick, small up-and-down movements with straight arms (beginning with 50 reps, increasing to 100) |  In curl-up position , legs in 90 degrees, quick, small up-and-down movements with straiht arms (beginning with 50 reps, → 100 |
| 1 leg stretches |  From constructive rest, stretching one leg after another on the floor, 8-10 reps |  Maintaining the head and shoulders off the floor, changing the position of the legs; 8-10 reps |  As in stage II, but lifting the straight leg off the floor; 8-10 reps |
| Shoulder bridge with 1 leg lifts |  From crook lying, lifting the pelvis up to bridge pose, 6-10 reps |  Maintaining the bridge pose, lifting the heel up one after another, 6-8 reps |  Maintaining the bridge pose, lifting the legs up alternately, 6-8 reps |
| Sidelying 1- and 2-leg lifts were performed on each stage, first with hand support (stage I), supporting with fingers, if needed (stage II) , and without support in stage III. 6-8 reps on both sides. |  |  |  |
| 1-leg kicks |  Preparation: From lying prone, lifting the upper body to cobra: 6 reps |  Bending the knee slowly; 6 + 6 reps |  Bending the knee quickly and kicking 2 times with flexed and pointed foot; 6 + 6 reps |
| Leg pull down with weight withshifts forwards and backwaords in plank pose |  Preparation: From 4-point kneeling, lifting the knees up; 6 -8 reps. |  From 4-point kneeling, lifting the knees up to plank pose 6 - 8 reps. |   Sfifting the weight forwards and backwars in plank pose; 6-8 reps. |
| 1-leg circles in both directions |  Both knees bent; 5 + 5 to both sides |  Stretching the lower leg knee; 5 + 5 to both sides |  Strait legs; 5 + 5 to both sides |

**3. To increase the muscular strength of the lower limbs in functional squatting movements, while controlling the neutral spine posture**

”Tai chi –warrior”. Progression: coordinative demands with arm movements, deeper squat

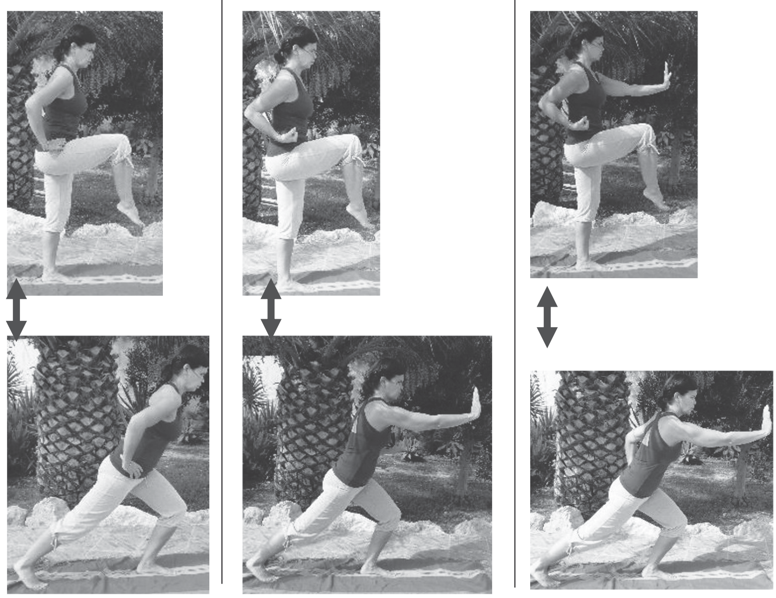
In stage I, lifting the right knee to 90 degrees flexion → streching it back while squatting with the left leg. After 6 reps, repeating the same with the other leg 6 times.

In stage II, adding one-arm movement in cordination with the same leg movement.

In stage III, addng two-arm movements as shown in the pictures.

6+6 repetitions at each stage, progressively deepening the squat with the supporting leg.

Stage I | Stage II | Stage III



Different squats with weight shifts, arm movements or rotation of the upper body

An exercise of ”lifting up an object and reaching it out to the side” was done at every stage, starting with 6+6 repetitions and increasing to 10 repetitions at the end of the program (stage III). Progressively increasing also the range of motion (deeper squat, reaching out with weight shift to one leg)

**4. To improve balance, postural control and light co-contraction of the stabilising muscles around the lumbar spine**

Stage I

Stage II

Stage III

Semi-squat + balance on tip-toes

Controlling the neutral spine while squatting, 8-10 reps

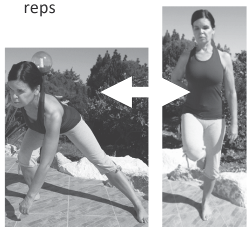
Controlling the neutral spine while squatting + raising on tip-toes, 8-10 reps

Controlling the lumbar spine while squatting and rotating the thoracic spine + raising on tip-toes, 6+6 reps

Weight shift, side lunge and one-leg stance

Wheight shift with one's legs wide apart. 8-10 reps. Deepening the squat progressively

Side lunge 6-8 + 6-8 reps. Deepening the squat progressively



From side lunge to one-leg stance. 6-8 reps in one side, same to the other side. Deepening the squat progressively

**5. To achieve a normal range of motion in the spine, especially in the thoracic region and the hip and ankle joints**

Flexibility exercises were conducted at each stage, progressively increasing joint range of motion

Cat – cow, 6 reps

Dynamic stretcing of the dorsal leg muscles, 6 + 6 times

From 4-point kneeling to downwards-facing-dog. 6 reps

Leg circumductions (rotation in hip joints) 6 + 6 reps.

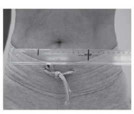
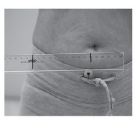
Lying supine and lifting 1 arm over the head, 6 + 6 reps. Repeated with 2 arms simultaneously (6 reps).

Rotation of upper back, 6 + 6 reps

From 4-point kneeling to child's pose. 6 reps.
This pose was also used as a resting pose (for 20-30 secs) in between the back muscle exercises (1-leg kick and bird dog).

Appendix 2.

## Lumbar movement control impairment tests

| **Test** | Correct | Not correct |
|---|---|---|
| Waiters bow |  |  |
| Dorsal tilting of the pelvis |  |  |
| Sitting knee extension |  |  |
| Rocking forwards and backwards |   |   |
| Knee flexion in prone |  |  |
| One-leg stance |  |  |

## Motor and musculoskeletal fitness tests

Modified push-ups, number of repetitions in 40 seconds

One-leg squats,
number of repetitions, with
progressively increasing external load

Vertical jump

Abdominal strength,
5 repetitions in each stage

Running figure-of-8

Flexibility of the spine
(lateral flexion)

Rhythm-coordination, assessed by marching and clapping the hands together to the rhythm of the metronome signal

Photos Marcel Maltcheff

# PUBLICATIONS

# PUBLICATION
# I

**Reliability of musculoskeletal fitness tests and movement control impairment test battery in female health-care personnel with recurrent low back pain.**

Taulaniemi RPA, Kankaanpää MJ, Tokola KJ, Luomajoki HA, Suni JH.

Journal of Novel Physiotherapies 2016;6(1):282.
doi: 10.4172/2165-7025.1000282

Journal of Novel Physiotherapies

Taulaniemi et al., J Nov Physiother 2016, 6:1
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# Reliability of Musculoskeletal Fitness Tests and Movement Control Impairment Test Battery in Female Health-Care Personnel with Re-Current Low Back Pain

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## Abstract

**Background:** Low back pain (LBP) is one of the most important causes of work absenteeism in health-care personnel. Low performance levels for fitness components, and movement control impairment (MCI) of the spine have been posited to be risk factors for persistent LBP. The aims of this study were to examine the long-term reliability (test I – test II) of selected motor and musculoskeletal fitness tests and the standard MCI test battery in female health-care personnel with nonspecific LBP, and to investigate associations between change in intensity of LBP and variation in test results in two measurement points.

**Methods:** The participants (n=47) were workers in geriatric wards. Long-term reliability of six field tests assessing motor abilities, flexibility and muscular strength, and the MCI test battery were studied. Mean test I – test II time-span was 18 days (SD 7.9). The estimates of reliability for interval-scale measurements (fitness) were typical error (s) of measurement and the coefficient of variation (CV). The reliability of nominal-scale measurements was analysed by the kappa coefficient.

**Results:** The lowest within-subject variation was found in running figure of eight test (s=0.22 s, CV=2.8%) and the highest for modified push-ups (s=1.04 repetitions, CV=12.2%). The kappa values for the dorsal pelvic tilt, sitting knee extension, the anterior pelvic tilt, and lying-prone knee flexion varied between 0.71 and 0.45 but were lower for rocking forwards and backwards (k=0.31) and the one-leg stance (k=0.16). Change in the pain intensity was associated only with variation in test I – test II results for modified push-ups (p=0.045).

**Conclusions:** All of the tests assessing musculoskeletal fitness and four of the MCI tests had an acceptable level of long-term reliability. The two tests for MCI that had poor reliability need to be better standardised in order to serve as reliable clinical measurement tools.

**Keywords:** Muscle strength; Motor ability; Movement control; Reproducibility; Repeatability; Patients with pain

**List of abbreviations:** ANOVA: Analysis of Variance; BMI: Body Mass Index; CI: Confidence Interval; CV: Coefficient of Variation; k: Cohen´s Kappa Coefficient; LBP: Low Back Pain; MCI: Movement Control Impairment; NSLBP: Non-specific Low Back Pain; NRS: Numeric Rating Scale; r: Pearson´s Correlation Coefficient; s: Typical (standard) Error of Measurement; VAS: Visual Analogue Scale

## Introduction

The prevalence of LBP varies between occupational groups, with physically demanding jobs known to be a risk factor [1]. Among health-care workers, the one-year prevalence of LBP has been found to be as high as 45% to 77% [2]. Low back problems have often developed already during the nursing-school clinical training period [3]. Among nursing personnel, musculoskeletal disorders are the main cause of work absenteeism and early retirement, LBP being the leading cause. In Finland, only 48% of nursing assistants and 58% of nurses reach the old-age pension point [4].

In most low back patients (85–90%) the pain is classified as nonspecific low back pain (NSLBP). After an acute pain episode, the majority recover, but 50–70% find the pain recurring within the following year, and 10% will become chronic [5]. In the literature there is still some ambiguity in conceptions of the episodic or fluctuating nature of NSLBP [6]. LBP episodes are traditionally regarded as individual events with good prognosis. This opinion has been challenged in longer-term follow-up studies [7-9]. These studies indicate, that majority of people with LBP do experience back pain off and on over long period of time [10]. Preventing new LBP episodes is considered to be of importance for prevention of persistent pain.

Whilst associations found between physical fitness and LBP are partly conflicting, there is increasing evidence that low performance levels for several elements of physical fitness are risk factors for LBP [11-15], and LBP patients tend to be more deconditioned and less physically active than healthy controls [16,17]. Accordingly, sufficient muscular strength and motor abilities might protect the back and prevent back problems whereas poor performance levels might indicate predisposition to persistent LBP especially in physically demanding work such as nursing [18,19]. Health-care workers are exposed to a high physical workload encompassing frequent bending

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and heavy lifting. Therefore, it is conceivable that movement control (i.e. motor skills), ability to stabilize the spine with trunk muscles and muscular endurance/strength are of importance in connection with the risk of developing LBP [5,13,20]. Consequently there is a clear need for reliable measurement methods for evaluation of musculoskeletal fitness and motor abilities in connection with physically demanding nursing work. Repeatability of the field tests for health-related fitness has been studied in healthy populations [21,22], but to our knowledge not in people with NSLBP.

Impairments in postural and movement control of the lumbar spine have been posited to be risk factors for prolonged LBP [23-25]. A significant difference in ability to actively control the movement of the low back has been found between patients with LBP and subjects without back pain, and between acute and chronic LBP patients [26,24], but to our knowledge the test-retest repeatability of the standard movement control impairment (MCI) test battery has not been studied.

Exercise is often recommended for LBP patients [27]. Reliable and valid measurement methods are essential for evaluating the effects of exercises. In addition, methods of measurement for screening the physical performance capacity of people who have a physically demanding job and who may be at risk for LBP are needed.

The standard measure of reliability is the test-retest repeatability within one week [28]. However, long-term reliability (with 2-3 weeks interval between measurements) of measurements for sensorimotor functions [29] and muscle strength and endurance measurements [30] has been studied in patients with chronic LBP, but not in people with minor LBP problems, who are still at work.

The aim of the study reported upon here was to examine the long-term reliability of selected motor and musculoskeletal fitness tests and the MCI test battery for female health-care personnel with recurrent NSLBP. Another aim was to ascertain whether change in pain intensity between two measurement points had any effect on the variation in the test results.

## Materials and Methods

### Participants

The participants (n=47) of the present reliability study were a sub-sample from a larger randomised controlled trial (the NURSE RCT, clinical trial registration NCT04165698). The both measurement sessions (test I and test II) in the present reliability study were conducted before the study interventions started, and no feedback, education or training was given to participants between measurements.

Written information about the NURSE RCT was disseminated by the head nurses to all health-care personnel working in the geriatric wards of two municipal hospitals and an old people's home in late 2011 in Tampere, Finland. Personnel with LBP who were willing to participate in the NURSE RCT filled in the screening questionnaire. To be eligible, personnel had to meet the following criteria:

1) Being a woman aged 30–55

2) Who had worked in her current job for at least 12 months and

3) Experienced LBP intensity of at least 2 on the numeric rating scale (NRS) employed (0–10) [31] within the preceding four weeks.

The exclusion criteria for the study were

1) Serious former back injury (fracture, surgery, or prolapsed disc), 2) Chronic LBP as defined by a physician or self-reporting of daily LBP over the past seven months or longer, 3) A serious other disease or symptoms limiting participation in moderate-intensity neuromuscular exercise, 4) Engaging in neuromuscular-type exercise more than once a week, and 5) Pregnancy or recent delivery (< 12 months). Written informed consent was obtained from all participants.

More than 80% of the study subjects had irregular working hours, in two or three shifts, and 68% of them were assistant nurses. The majority of them perceived their health to be average or good, although 66% reported having at least three musculoskeletal pain sites. Thirty per cent rated their fitness level somewhat worse than that of persons of the same age and gender. Other background characteristics of the participants are reported in Table 1.

### Study design

Long-term reliability was studied by means of test I – test II design. The average interval between pre-study screening and the first measurement point was approximately three weeks, and the mean number of days between the two measurements points was 18 (SD 7.9). The reliability of selected musculoskeletal fitness tests and the MCI test battery were studied in the analysis. Health screening was conducted prior to testing, in accordance with the safety model of the Health-related Fitness Test Battery for Middle-aged Adults [32].

At the first measurement point (test I), an experienced physiotherapist (with master´s degree and 14 years' experience of clinical work) scored the performance of the subjects in six tests of MCI and six field tests of motor and musculoskeletal fitness in set order. At the second measurement point (test II), the same physiotherapist followed the test protocol as used before. The results from the first measurements occasion were not available for the physiotherapist at

| | mean (SD) | n | % |
|---|---|---|---|
| Age (years) | 47.9 (5.9) | | |
| Profession | | | |
| assistant nurse | | 34 | 72 |
| nurse | | 8 | 17 |
| physiotherapist or PT assistant | | 5 | 11 |
| Number of years of work | 11.4 (9.4) | | |
| Work characteristics | | | |
| three-shift work | | 27 | 57 |
| two-shift work | | 13 | 28 |
| regular day shifts | | 5 | 11 |
| regular night shifts | | 2 | 4 |
| Self-reported work ability (0–10 scale, 0=unable to work, 10 = best possible) | 7.9 (1.4) | | |
| Perceived health | | | |
| below average | | - | |
| average | | 23 | 49 |
| good | | 22 | 47 |
| very good | | 2 | 4 |
| Perceived fitness in comparison to persons with same age and gender | | | |
| somewhat worse | | 14 | 30 |
| similar | | 24 | 51 |
| somewhat better | | 8 | 17 |
| much better | | 1 | 2 |
| BMI | 26.7 (4.5) | | |
| Number of musculoskeletal pain sites | | | |
| ≤ 2 | | 16 | 34 |
| 3 | | 13 | 28 |
| ≥ 4 | | 18 | 38 |
| Frequency of low back pain in test I | | | |
| daily | | 3 | 7 |
| in some or most days of the week | | 29 | 71 |
| recovered from the pre-study screening | | 9 | 22 |

**Table 1:** Baseline characteristics of the study sample (n=47).

the second measurement point. The measurements were conducted in the physiotherapy department of the geriatric hospital where most of the study subjects were working.

## Test protocols and measurements

**Motor and musculoskeletal fitness tests:** The field tests of motor and musculoskeletal fitness assessed motor abilities, flexibility and muscular strength. The motor ability tests used included rhythm co-ordination and running a figure of eight [33]. Trunk side-bending [22] was used for assessing the range of motion of lateral flexion of the spine, and dynamic sit-ups [34], modified push-ups and one-leg squats [22] for determination of muscular strength.

**The movement control impairment test battery:** The MCI test battery [26], based on descriptions by Sahrmann [35] and O'Sullivan [36], consists of six tests: 1) the waiters bow (flexion of the hips in upright standing without movement of the lower back), 2) dorsal tilting of the pelvis, 3) sitting knee extension, 4) rocking backwards and forwards in quadruped position, 5) prone-lying active knee flexion and 6) one-leg stance. The MCI test results were judged dichotomously by observation: the subject was noted either as not having motor control impairment (0) or as having impairments (1).

All individual measurements were conducted in standardised order for each study subject: MCI tests before fitness tests, and motor and flexibility tests before measurements of muscular strength. The test instructions, criteria for the MCI test battery, and motor and musculoskeletal fitness tests are described briefly in Supplementary information (1).

**The measurements of LBP intensity:** Intensity of LBP during previous four weeks was measured by NRS (1-10) [31] at pre-study screening, at the baseline (test I) and at the re-test session (test II) in order to get an overview of pain development. To clarify more precisely the intensity of LBP at both measurement points (test I and test II), pain intensity during past seven days was also measured via visual analogue scale VAS (where 0 = no pain and 100 = the worst possible pain) [37].

## Statistical analysis

The mean, standard deviation (SD), and range of the test I–test II measurements of the fitness tests are presented as descriptive statistics in Table 2.

Estimates of repeatability for interval-scale measurements were calculated in a manner suggested by Hopkins [38]. 1) within-subject variation in terms of typical error (s) as the standard deviation of the test–retest difference divided by the square root of 2 $\left(s = sd_{difft} / \sqrt{2}\right)$ and 2) the relative error measure coefficient of variation (CV) as typical error divided by the mean of two tests $\left[CV = s / \text{mean}\left(\text{test}_i + \text{retest}_i\right) / 2\right]$.

Systematic change in the mean is an important issue when subjects perform repeated series of test trials [38,28]. Therefore, the percentage changes in mean performance between the first and second test results were calculated too. The systematic changes in mean between the two measurement sessions, which were considered statistically significant if their 95% confidence interval (CI) did not include value zero, were also calculated.

The repeatability of the nominal-scale measurements in the MCI tests (0 or 1) was analysed by means of Cohen's kappa coefficient (k).

For analysis of the possible effect of change in pain intensity on variation between the test I and test II results, new variables were calculated: 1) change in intensity of LBP, measured by VAS (0-100) during last seven days 2) change between the first and second MCI tests (indicating that performance had deteriorated, remained unchanged, or improved), and 3) change in fitness-test results. Normality of distributions for numerical variables was confirmed. Associations between change in pain and nominal-class variables for change in MCI tests were analysed via the Kruskal-Wallis test. Kruskal-Wallis test was used instead of analysis of variance (ANOVA), because number of cases in some categorical classes was too small for ANOVA. Association between change in LBP and change in interval-scale fitness-test results were examined by means of Pearson's correlation coefficient (r). All analyses were conducted with the SPSS statistical analysis package, version 22.

## The criteria for sufficient reliability

At present, there are no standards delimiting acceptable measurement precision for monitoring physical fitness in healthy populations, nor for monitoring the motor or musculoskeletal fitness levels of people with recurrent or chronic LBP. Altman [39] has rated the kappa coefficient thus: ≤ 0.20=poor, 0.21–0.40=fair, 0.41–0.60=moderate, 0.61–0.8=good, and ≥ 0.80=very good.

# Results

The participants had sub-acute or periodic, but not chronic NSLBP. Mean of their pain intensity (NRS; 1-10 during last four weeks) decreased from 4.5 (SD 1.8) at the pre-screening time to 3.4 (2.4) at the first measurement point and further to 2.8 (2.7) at the second measurement point. At the first measurement point 71% of the study sample had LBP in some or most days of the week, but not daily, 7% had daily pain and 22% had recovered from the screening time and were pain-free (Table 1).

The mean number of days between the test I and test II measurements was 18, and the median LBP intensity, measured on VAS (0–100 mm) during last seven days, decreased from 26 ($Q_1$= 15, $Q_3$ = 51) to 19 ($Q_1$ = 4, $Q_3$ = 36) in that time. The reduction in pain intensity was statistically significant (Z = -2.77, p = 0.006). The change in VAS between two measurement points was less than 15mm for 51% of the study subjects, for 38% the decrease in pain intensity was more than 15mm and for 11% the pain intensity increased more than 15 mm.

Descriptive results from test I and test II measurements of the motor and musculoskeletal fitness tests are presented in Table 2. In general, all subjects were able to perform the rhythm co-ordination,

| Fitness test | n | mean | sd | min | max |
|---|---|---|---|---|---|
| Running figure of eight (seconds) | | | | | |
| 1st measurement | 46 | 8.1 | 0.65 | 6.8 | 9.9 |
| 2nd measurement | 46 | 8.1 | 0.62 | 7.9 | 9.9 |
| Rythm coordination (points) | | | | | |
| 1st measurement | 47 | 13.7 | 2.9 | 6 | 16 |
| 2nd measurement | 47 | 14.1 | 2.8 | 7 | 16 |
| Trunk lateral flexion (cm) | | | | | |
| 1st measurement | 47 | 18.0 | 3.1 | 11.7 | 24.9 |
| 2nd measurement | 47 | 18.1 | 3.3 | 10.6 | 25.7 |
| Dynamic sit-up (repetitions) | | | | | |
| 1st measurement | 47 | 16.4 | 5.3 | 5 | 20 |
| 2nd measurement | 47 | 17.5 | 4.7 | 5 | 20 |
| One leg squat (repetitions) | | | | | |
| 1st measurement | 47 | 9.5 | 2.3 | 2 | 12 |
| 2nd measurement | 47 | 9.6 | 2.7 | 2 | 12 |
| Modified push-up (repetitions) | | | | | |
| 1st measurement | 46 | 7.9 | 2.7 | 0 | 15 |
| 2nd measurement | 46 | 9.2 | 2.6 | 0 | 18 |

**Table 2:** Descriptive results of test I – test II measurements of the musculoskeletal fitness tests.

trunk lateral flexion, dynamic sit-up, and modified one-leg squat tests. On account of musculoskeletal problems other than LBP, one person was excluded from the modified push-up test and one from the running figure of eight.

Results of the test I – test II long-term reliability analysis for interval-scale fitness measurements are presented in Table 3. The least within-subject variation was found for the running figure of eight (s = 0.22 s, CV = 2.8%) and the most for modified push-ups (s = 1.04 reps, CV = 12.2%). Systematic changes in the mean between the two measurement sessions were detected for dynamic sit-ups and modified push-ups, which indicates a slight learning effect.

Results speaking to the level of test I – test II long-term reliability of the MCI tests are presented in Table 4. The best repeatability was found for the dorsal pelvic tilt and poorest for the one-leg-stance.

Associations between change in pain intensity and variation in test I – test II results are presented in Table 5. Only the modified push-up test seemed to be correlated with changes in pain. Lower pain levels implied a higher number of push-up repetitions (r = -0.3, p = 0.045, n = 46), for better test results when the pain had decreased, or on account of the learning effect. The change in pain had no effect on variation in any other test, including the MCI tests.

## Discussion

The main goal for the study carried out was to evaluate the long-term reliability of selected motor and musculoskeletal fitness tests and the MCI test battery for female health-care workers with recurrent NSLBP. Another aim was to ascertain whether change in pain intensity between two measurement points had any effect on the variation in the test results.

Within-subject variation is the most important type of test-retest repeatability measurements: the less within-subject variation there is, the greater the precision of the individual measurements and the better the observation of changes [28,38]. A typical example of a systematic change in results of physical fitness testing is the learning effect (bias). Participants perform better in the second test session than in the first, because they have benefitted from the experience of the first session [28,38].

### Long-term reliability of the motor and musculoskeletal fitness tests

The running figure of eight test requires both agility and power. This test showed the lowest intra–individual variation of all tests (CV: 2.8%)

| Fitness test | n | mean of two tests | Typical error (s) | Coefficent of variation (CV) | Change in the means: | (95% CI) | % † |
|---|---|---|---|---|---|---|---|
| Running figure of eight | 46 | 8.09 | 0.22 s | 2.8% | -0.43 | (-0.55-0.14) | 5 |
| Trunk lateral flexion | 47 | 18.06 | 1.36 cm | 7.5% | 0.06 | (-0.54-0,65) | 0.3 |
| Rythm coordination | 47 | 13.33 | 1.08 points | 7.7% | 0.36 | (-0.86-0.81) | 2 |
| Dynamic sit-up | 47 | 16.93 | 1.9 rep. | 11.2% | 1.02 | (0.24-1.80)* | 6 |
| One leg squat | 47 | 9.52 | 1.13 rep. | 11.9% | 0.20 | (-2.72-0.68) | 2 |
| Modified push-up | 46 | 8.41 | 1.04 rep. | 12.2% | 1.5 | (1.04-1.95)* | 19 |

* learning effect, † percent change in the mean: change in the mean divided by the mean of the first test = mean ($test_i$-$retest_i$)/mean($test_i$).

**Table 3:** Test I – test II repeatability of the motor and musculoskeletal fitness test.

| Movement control impairment test | Test–retest (intra-rater) kappa, n = 47 |
|---|---|
| Dorsal pelvic tilt | 0.71 (0.50–0.92) |
| Sitting knee extension | 0.56 (0.17–0.94) |
| Waiters bow | 0.53 (0.27–0.78) |
| Knee flexion in prone | 0.45 (0.11–0.78) |
| Rocking forwards and backwards | 0.31 (0.03–0.58) |
| One leg stance | 0.16 (-0.11–0.44) |

**Table 4:** The test I – test II repeatability (with 95% CI) of the movement control tests of the low back.

| | Change in pain intensity | | | |
|---|---|---|---|---|
| | n | r | Change in VAS; median (min and max) | p-value |
| **Change in motor and musculo-skeletal fitness tests** | | | | |
| Rhythm coordination | 47 | -0.26 | | 0.15 |
| Running figure of eight | 46 | 0.17 | | 0.27 |
| Trunk lateral flexion | 47 | 0.15 | | 0.32 |
| Dynamic sit ups | 47 | 0.23 | | 0.16 |
| One leg squats | 47 | -0.06 | | 0.7 |
| Modified push-ups | 46 | -0.3 | | 0.045 |
| Change in MCI test results | | | | |
| Waiters bow | | | | 0.34 |
| Deteriorated | 4 | | 3 (-11, 32) | |
| Remained unchanged | 37 | | -7 (-76, 60) | |
| Improved | 6 | | -11 (-38, 7) | |
| Pelvic tilt | | | | 0.41 |
| Deteriorated | 1 | | 6 | |
| Remained unchanged | 41 | | -7 (-76, 60) | |
| Improved | 5 | | -4 (-22, 22) | |
| One-leg stance | | | | 0.55 |
| Deteriorated | 7 | | -2 (-30, 36) | |
| Remained unchanged | 28 | | -7 (-76, 60) | |
| Improved | 12 | | -13 (-38, 56) | |
| Sitting knee extension | | | | 0.89 |
| Deteriorated | 3 | | 1 (-37, 22) | |
| Remained unchanged | 43 | | -7 (76, 60) | |
| Improved | 1 | | -4 | |
| Rocking forwards and backwards | | | | 0.83 |
| Deteriorated | 5 | | -4 (-47, 9) | |
| Remained unchanged | 32 | | -7 (-76, 60) | |
| Improved | 10 | | -7 (-66, 22) | |
| Knee flexion in prone | | | | 0.3 |
| Deteriorated | 2 | | -2 (-11, 7) | |
| Remained unchanged | 40 | | -7 (-76, 36) | |
| Improved | 5 | | 1 (-19, 60) | |

VAS = visual analoque scale 0-100 during past 7 days, MCI = movement control impairment, r = Pearson's correlation coefficient

**Table 5:** Associations between change in pain intensity (VAS in the second test – VAS in the first test) and change in motor and musculoskeletal fitness as well as MCI test results in test I – test II (statistically significant p-value in bold).

and a small change in the mean (5%). The results are in agreement with previous studies [21,40], and the test seems highly repeatable across populations. A high performance level in this test has been linked to high quality of life in elderly women [41], but its relevance in testing of people with LBP has not been studied. That says agility is a capacity that is needed in nursing duties such as transferring patients, who may not behave in the anticipated manner.

Trunk lateral bending assesses spinal mobility in the frontal plane.

The low intra-individual variation (CV: 7.5%), very small change in mean (0.3%), and narrow 95% CI (-0.54–0.65) indicate that the test is repeatable, and there is no systematic change in the mean. A reduced range of lateral bending has been shown to be a risk indicator for LBP among younger health-care workers [42] and adolescents [43].

Testing of rhythm co-ordination assesses ability to simultaneously co-ordinate the movements of the upper and lower limbs at a slower and faster rhythm [44]. The low intra-individual variation (CV: 7.7%) and change in mean (2%) indicate that the test is repeatable. Previous results in healthy volunteers, reported by Rinne et al. [33] seem only modest, and the intra-class correlation coefficient (ICC) was fairly low, 0.70. Changes in the central nervous system, responsible for interpreting sensory stimuli and motor responses, have been found in LBP patients [23,45,46], however, the relevance of rhythm co-ordination in motor ability testing of LBP patients is not known.

The dynamic sit-up test assesses the strength and endurance of the flexor muscles of the trunk. The intra-individual variation was barely acceptable (CV: 11.2%), and there was a small learning effect (change in mean 6%). In a cross-sectional sample [47], persons with LBP were shown to have less abdominal muscle endurance than asymptomatic controls did.

The one-leg squat test assesses the strength of the lower extremities. The intra-individual variation was in the inadequate-reliability margin (CV: 11.9%), but the change in mean was small (2%). No learning effect was detected. Strength of the lower extremities is an important capacity when one is lifting and transferring patients in nursing duties, along with keeping the back in neutral position, although scientific evidence of associations between leg strength and LBP is limited. Individuals with chronic LBP have been shown to have weaker gluteus medius muscles than control subjects without back pain [48].

The modified push-up test requires both upper-body muscular strength and trunk stabilisation. Of the musculoskeletal fitness tests, this one showed the least repeatability, with the highest intra-individual variation (CV: 12.2%). The large change in mean (19%) and 95% CI not including the value zero (1.04–1.95) indicate a learning effect. On the other hand, this was the only test for which we found statistically significant associations between reduced pain and better performance. The test is physically heavy to perform, and might create high compressive forces in the spine. Therefore, the variation in test I – test II results may be due to the learning effect, change in pain intensity, or both. Furthermore, the broad range of results (0–18 repetitions) indicates that performance capacity among nurses varies quite dramatically. A learning effect has been found also in physically active healthy adults [21] and in a less selected population [22]. Low fitness in the modified push-up test has been associated with poor perceived health, low back dysfunction, and pain among middle-aged subjects [49]. Also, poor endurance in the back musculature has been reported to be a risk factor for low back pain [14,50]. The modified push up test requires endurance of the back muscles for trunk stabilisation. Increased risk of low back pain has also been reported in young conscripts with a poor fitness level in trunk muscle endurance and aerobic performance [13].

All three musculoskeletal fitness tests assessing muscle strength and endurance had a CV > 11% and were borderline for having adequate long-term reliability. With the learning effect detected borne in mind, they can be used in intervention studies to evaluate changes in muscular strength.

### Long-term reliability of the movement-control-impairment test battery

Repeatability was good for the dorsal pelvic tilt; moderate for sitting knee extension, waiter's bow, and knee flexion in prone position; fair for rocking forwards and backwards; and poor for the one-leg stance. The results indicate that subjects' performance may vary from day to day. There is a clear need for better standardisation in the two tests yielding the poorest repeatability results (rocking forwards and backwards and the one-leg stance).

Previously, good to excellent intra-observer reliability (k=0.67–0.95) for the same six MCI tests were reported by Luomajoki et al. [26]. The subjects in their study were either LBP patients (n=27) or persons without LBP (n=13). Measurements were videod in a standardized manner, and for the analysis of intra-observer reliability, examiners rated the same videos two weeks apart. In our long-term reliability study, the participants performed the MCI tests in two different measurement points, and all subjects had had back pain within the preceding two months.

Monnier et al. [51] found poor to moderate intra-rater test–retest repeatability for six clinical movement-control tests employed with marines. Their test battery differed from that used in our study, but rating was still dichotomous by visual observation. The only similar test was the waiter's bow (or standing bow), with an intra-rater kappa coefficient of 0.48 for rater A and 0.39 for rater B (0.53 in our study).

Whether it is more appropriate in clinical MCI tests to use quantitative outcome variables or dichotomous ones may be a subject worthy of discussion. Quantifying test results might enable the rater to obtain more information, which may be more useful for diagnosis and evaluation in a clinical setting [52].

Variation in MCI test I – test II repeatability results can be caused by day-to-day variation in test performance or difficulties in rating of the performance. According to Enoch et al. [53], it is difficult to estimate visually how much the lumbar region is moving during MCI tests without using any technical equipment. If the test is rated dichotomously 'yes/no' or 'can/cannot', much information is hidden between the two endpoints. Also, there is no clear consensus on when the test is passed / not passed or on where the dichotomous cut-off points should be [53].

In clear 'yes or no' cases, it is quite easy to place a person in the correct category, but there are many more complicated cases. If, for example, the MCI test performance starts correctly but at the very end of the range of motion the person loses control of the lumbar spine (maybe because of muscle tightness or restricted hip mobility), it is more difficult for the rater to decide whether the performance is correct or not. Two thirds of the study subjects had three or more musculoskeletal pain sites, which may have had an effect on the variation of the results. For instance, pain in the wrists or knees can affect weight transfer when one is rocking forwards and backwards in quadruped position.

For bringing higher reliability to the MCI test battery, we suggest either better standardisation of those MCI tests with poor to fair reliability or adding of a third band between the dichotomous ratings currently used (movement-control impairment and no impairment). This new 'in-between' class could cover all of the less clear cases, which are more difficult to classify without hesitation.

Ability to control the position and movement of the lumbar spine is important for back health. Patients with chronic LBP have more movement control impairments [24], lower tactile acuity in the back region [54], and significantly poorer ability, on average, to sense a change in lumbar position [55] relative to healthy subjects. Measurement of the neuro-motor control of the spine in patients with NSLBP is considered to be important, but there seems to be lack of reliable and feasible measurement methods [56]. Clinical screening tests for assessing MCI in people with NSLBP include a high risk of bias [52].

## Associations between change in pain and variation in test results

Ostelo [37] has evaluated the minimal important change in VAS as 15mm.The change in pain was less than 15mm for 51% and more than 15mm for 49% among our study sample. Pain is often presupposed to influence performance negatively [57]. Our hypothesis was that variation in pain causes variation in test results – i.e., less pain means better performance, and vice versa. The results of our study, however, do not support this hypothesis. Change in intensity of pain in persons with NSLBP had almost no effects in terms of variation of the test I – test II results for motor and musculoskeletal fitness tests, and for MCI tests. Our results are in agreement with results presented by Leitner et al. [29], who found in their long-term reliability study on patients with chronic LBP, that changes in pain intensity are not associated with changes in postural stability measurements.

Long-term reliability is not often analysed in repeatability studies. It has been recommended that for basic repeatability assessment the retest time should be within one week from the first test [28]. Longer periods between measurements are considered to admit more intra-individual changes in fitness, tiredness, and other such factors affecting physical performance. So far, to our knowledge, only two studies [29,30] with interval of 2-3 weeks between tests have investigated long-term reliability of measurements of physical parameters, such as muscular strength and endurance, and sensorimotor functions like postural control in people with LBP. That time interval corresponds the period of time in inpatient rehabilitation program for patients with chronic LBP in central Europe. Fitness or neuro-motor capacity of people with LBP seldom changes without any intervention in a few weeks, but LBP and pain intensity often seems to fluctuate from day to day. The periodic nature of pain in many people with low back trouble might influence patients´ adherence or motivation with the measurements [30,57]. This topic needs further investigation with larger study samples.

## Limitations of the study

The main limitation of the study was, that we did not standardise the measurement time in relation to work shifts. Tiredness after work could have caused variation in test results in comparison with measurements, which were conducted before work-shift or on the day off. Given the irregular working hours encountered with shift work, the arrangement of test sessions suitable for the same tester was very challenging.

## Strengths of the study

All measurements took place twice in the same locations, with same examiner and same equipment. Prior to the first testing session, the written test instructions and criteria were specified, reviewed, and made the subject of drills by two members of the research group and the rater. The statistical methods and outcome measures agree with expert recommendations [28,38]. We showed that selected motor and musculoskeletal fitness tests are reliable, safe and feasible to use in evaluation of motor and musculoskeletal fitness components in female health-care personnel with LBP and having a physically demanding job. We also showed that some of the widely used tests in the MCI test battery need better standardisation.

## Implications

For fitness or MCI tests to be applied in clinical practice, the tests must be reliable and also safe, economical, simple, and easy to administer. All of the musculoskeletal and motor fitness tests studied in the present study fulfil the above-mentioned demands; however, the MCI test battery seems to have some deficits with respect to long-term reliability (for the one-leg stance test and rocking forwards and backwards).

The results provide useful information in selection of measurement methods for intervention studies aimed at reducing LBP and for clinical work in patients with LBP. The results indicate a need for further development of the MCI test battery, which is widely used by physiotherapists in evaluation of patients with LBP.

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## Supplementary information

# Test instructions and criteria for movement control impairment test battery, and motor and musculoskeletal fitness tests

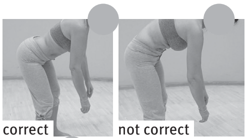
## Movement control impairment (MCI) tests

### (Luomajoki et al. 2007)

The test results are rated dichotomously either correct (0) or not correct (1) based on visual observation

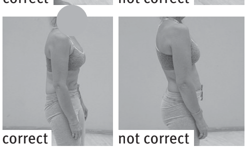
### 1. Waiters bow

Flexion of the hips without movement (flexion) of the low back


correct / not correct

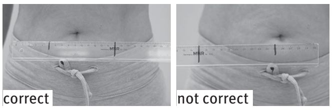
### 2. Pelvic tilt

Dorsal tilt of pelvis actively in upright standing


correct / not correct

### 3. One leg stance:

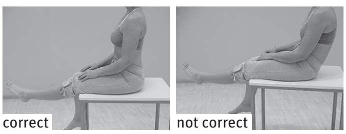
From normal standing (feet one third of trochanter distance apart) to one leg stance. Measurement of lateral movement of the belly button


correct / not correct

**correct:** The distance of the transfer is symmetrical to the right and the left. Not more than 2 cm difference between the sides
**not correct:** Lateral transfer of the belly button is more than 10 cm. The difference between the sides is more than 2 cm.

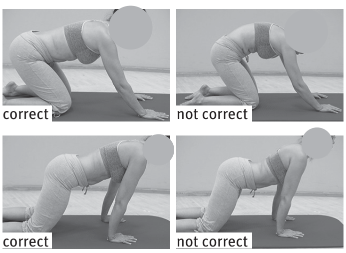
### 4. Sitting knee extension

Upright sitting with neutral lumbal lordosis; extension of the knee without movement (flexion) of the low back


correct / not correct

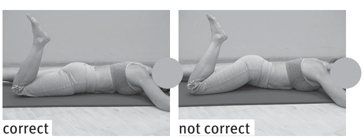
### 5. Rocking backwards and forwards

Transfer of the pelvis backwards (to 120° hip flexion) and forwards (to 60° hip flexion) keeping the low back in neutral position. Starting position 90o hip flexion


correct / not correct
correct / not correct

### 6. Prone lying active knee flexion

Active knee flexion at least 90° without movement of the low back and pelvis


correct / not correct

## Motor and musculoskeletal fitness tests

### a) Motor ability:

**1. Rhythm co-ordination**

The client performs the test by marching and clapping her hands together to the rhythm of the metronome signal. First she is marching with a slow rhythm (92 beats/min) during 30 seconds, then she continues marching for another 30 s and claps her hands together every other step. The same procedure is then repeated at a fast rhythm (138 beats/min). The performances are scored for both rhythms (from 0 to 16 points)

**2. Running figure of eight**

After the starting command the client runs a course in a figure of eight, 20 meters long. One practice trial and 2 test trials with maximal effort are performed with a short resting period between each trial. The result is the fastest time of two trials in seconds.

### b) Flexibility:

**3. Trunk lateral flexion**

The client stands on the marked lines (15 cm apart) with her back against the wall. Arms are kept straight at the sides of the body. The distance the fingertip moves down the leg during maximal side bending is measured in millimeters. The average value of right and left side is calculated.

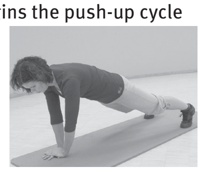
### c) Muscular strength:

**4. Dynamic sit-up**

Five repetitions of sit-ups are performed in four different test levels as follows: The first five sit-ups: Lifting head and shoulders of the mat. The second five: Hands reaching midpatella with fingertips.The third five: Arms are folded over chest. The aim is to reach thighs with both elbows. The last five: Touching back of earlobes with fingertips , and reaching thighs with elbows. The final result is the sum of successful sit ups.

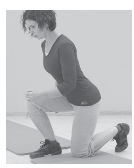
**5. Modified push-up**

The client lies prone on the mat, and begins the push-up cycle by clapping hands behind the back once; this is followed by a normal straight-leg push-up with elbows completely straight in the up-position, so that the client can touch her either hand with the other hand. The client ends the cycle in prone position. The number of correct push-ups in 40 seconds is counted.



**6. One-leg squat**

A step squat is performed in term, with right and left foot ahead, adding 10% of body weight for each pair of squats up to 40%. Each leg is rated separately, and the final result is the sum of successful squats



*photos M. Maltzeff*

# PUBLICATION II

**Bio-psychosocial factors are associated with pain intensity, physical functioning, and ability to work in female healthcare personnel with recurrent low back pain.**

Taulaniemi A, Kuusinen L, Tokola K, Kankaanpää M, Suni JH.

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ORIGINAL REPORT



# BIO-PSYCHOSOCIAL FACTORS ARE ASSOCIATED WITH PAIN INTENSITY, PHYSICAL FUNCTIONING AND ABILITY TO WORK IN FEMALE HEALTHCARE PERSONNEL WITH RECURRENT LOW BACK PAIN

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***Objective:*** **To investigate associations of various bio-psychosocial factors with bodily pain, physical functioning, and ability to work in low back pain.**
***Design:*** **Cross-sectional study.**
***Subjects:*** **A total of 219 female healthcare workers with recurrent non-specific low back pain.**
***Methods:*** **Associations between several physical and psychosocial factors and: (*i*) bodily pain, (*ii*) physical functioning and (*iii*) ability to work were studied. Variables with statistically significant associations ($p < 0.05$) in bivariate analysis were set within a generalized linear model to analyse their relationship with each dependent variable.**
***Results:*** **In generalized linear model analysis, perceived work-induced lumbar exertion ($p < 0.001$), multi-site pain ($p < 0.001$) and work-related fear-avoidance beliefs (FAB-W) ($p = 0.02$) best explained bodily pain. Multi-site pain ($p < 0.001$), lumbar exertion ($p = 0.005$), FAB-W ($p = 0.01$) and physical performance in figure-of-eight running ($p = 0.01$) and modified push-ups ($p = 0.05$) best explained physical functioning; FAB-W ($p < 0.001$), lumbar exertion ($p = 0.003$), depression ($p = 0.01$) and recovery after work ($p = 0.03$) best explained work ability. In bivariate analysis lumbar exertion was associated with poor physical performance.**
***Conclusion:*** **FAB-W and work-induced lumbar exertion were associated with levels of pain, physical functioning and ability to work. Poor physical performance capacity was associated with work-induced lumbar exertion. Interventions that aim to reduce fear-avoidance and increase fitness capacity might be beneficial.**

*Key words:* low back pain; psychosocial factor; physical fitness; work ability.

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Low back pain (LBP) is a bio-psychosocial, multidimensional, complex and costly problem, and is a leading cause of years lived with disability (1). In the majority of people with LBP (85–90%) the pain is classified as non-specific low back pain (NSLBP). Most people recover after an acute pain episode, but in 50–70% the pain recurs within the following year, and in 10% it becomes chronic (2). LBP is often a long-term or recurrent condition wherein individuals experience repeated episodes of pain that are not independent of each other (3), and the majority of people with LBP experience back pain off and on over an extended span of time (4, 5).

The prevalence of LBP varies among occupational groups. Workers in physically demanding jobs are known to have increased risk (6). Among healthcare workers, the 1-year prevalence of LBP is 45–77% (7), which is high in comparison with other occupations. Nursing duties include large amounts of heavy physical work and psychosocial stress, which are known to be risk factors for LBP (8). Among newly qualified female healthcare workers, those with a high physical workload had high risk (78%) of developing LBP (9). Nurses who are engaged in patient-handling also have high risk of chronic LBP (10).

Risk factors for chronic disability from LBP are more closely related to psychosocial factors than to spine condition itself (11). Fear-avoidance beliefs (FABs), job satisfaction, and anxiety are known to be associated with chronicity (12). The concept of FAB refers to the fear-induced avoidance of activities or movements that are expected to be painful. Among healthcare workers with previous LBP, FABs have been shown to be a major risk factor for new episodes of LBP (8).

On the other hand, there is also increasing evidence that low performance levels for several components of physical fitness are risk factors for LBP (13, 14), although scientific evidence about those associations is still partly conflicting with respect to revealing whether physical inactivity and deconditioning cause LBP or, alternatively, LBP leads to decreased physical activity and deconditioning (15). Women with LBP have lower levels of aerobic fitness than healthy women (16). Even self-reported low rating of physical capacity is a strong predictor for future LBP in female healthcare workers (17). Imbalance between physically demanding nursing duties and physical capacity, i.e. demonstrating relatively low strength, aerobic fitness and balance, increases the risk of LBP (17).

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Preventing new episodes of LBP is considered to be important for the prevention of persistent pain. Thus, it is essential to understand links between several biological and psychosocial risk factors influencing the early stages of LBP, before chronicity, especially in a population performing physically demanding work.

The aim of this cross-sectional study was to investigate associations between several bio-psychosocial factors and: (*i*) bodily pain, (*ii*) physical functioning, and (*iii*) perceived ability to work in a sample of female healthcare workers with recurrent NSLBP. Furthermore, we examined the relationship between physical fitness and work-induced lumbar exertion among the study population.

## MATERIALS AND METHODS

*Study design and participants*

This cross-sectional study was part of a randomized controlled trial (the NURSE RCT, clinical trial registration NCT01465698) aimed at reducing pain, movement-control impairment, and fear-avoidance beliefs in working female healthcare personnel with recurrent NSLBP. The study was approved by the Ethics Committee of Pirkanmaa Hospital District, Finland (ETL code R08157).

The target population was female healthcare personnel engaged in lifting and transferring patients and other tasks that are demanding for the lower back. To be eligible for the NURSE RCT, individuals had to meet the following criteria: (*i*) being a woman aged 30–55 years who (*ii*) had worked in her current job for at least 12 months, and (*iii*) experienced LBP of intensity 2 or above within the preceding 4 weeks, measured on the numeric rating scale (NRS; 0–10) (18). The exclusion criteria for the study were: (*i*) a serious earlier back injury (fracture, surgery, or disc protrusion), (*ii*) chronic LBP as diagnosed by a physician or self-reporting of continuous LBP over the past 7 months or longer, (*iii*) a serious other disease or symptoms limiting participation in moderate-intensity neuromuscular exercise, (*iv*) engaging in neuromuscular-type exercise more than once a week, and (*v*) pregnancy or recent delivery (<12 months).

The NURSE- RCT was conducted in the form of 3 identical, consecutive sub-studies. The participants were workers in geriatric wards and old people's homes (in the first sub-study in 2011, $n=56$), in community hospital wards, public healthcare units, and home service (in the second sub-study in 2012; $n=80$) and in university-hospital wards (in the third sub-study in 2013; $n=83$) in the city of Tampere, Finland. Data-sets from the baseline measurements in these sub-studies were combined and analysed in the study reported here. The total sample consisted of 219 healthcare workers. Information about the NURSE RCT was disseminated through information sessions for head nurses and other personnel, hand-outs, posters, and intranet posts. The sample size (at least 160 subjects) was estimated for the primary outcome of pain intensity in the RCT (19). More precise information on recruitment is available in the protocol article on the NURSE RCT (19). Fig. 1 summarizes the recruitment process.

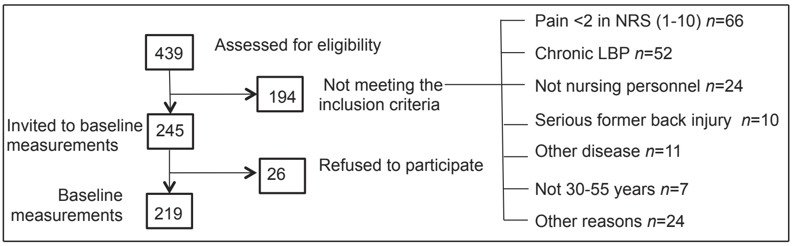


**Fig. 1.** Recruitment process for the NURSE RCT.

*Study procedures and measurements*

The measurements were conducted at the UKK Institute for Health Promotion Research, in Tampere. Informed consent was obtained in writing from all participants on the first visit. Specially educated personnel with a long work history conducted all measurements. Health screening was performed before fitness testing, in accordance with the safety model of the Health-related Fitness Test Battery for Middle-aged Adults (20). The measurement battery, measured in a single 2-h session, consisted of questionnaires, assessment of physical fitness test results, and guidance in using the accelerometer for objectively measuring physical activity/sedentary time over one week.

*Dependent variables*

1. Bodily pain interfering with normal work during the preceding 4 weeks was assessed by a sum score from 2 questions in the validated Finnish version (21) of the RAND-36 Health Survey (22), which measures quality of life in 8 distinct domains. For the bodily pain –domain, there is 1 rating on 5point-scale (intensity of bodily pain) and 1 6-point-scale rating (pain interfering with normal work). Respondent-reported scores were converted into scores ranging from 0 (very severe pain and extreme difficulties) to 100 (no pain and no difficulties) in accordance with the conversion equation presented by Ware & Sherbourne (23). The briefer expression "bodily pain" is used in this article to describe this measurement.
2. Current limitations in physical functioning (sum score from 10 questions from the Finnish version of the RAND-36 survey) (21). The item consists of 10 ratings (for vigorous activity, such as strenuous sport; moderate intensity activity, such as vacuuming or bowling; lifting and carrying groceries; climbing several flights of stairs; climbing 1 flight of stairs; bending, kneeling or stooping; walking approximately 2 km; walking approximately 500 m; walking 1 block; and bathing or dressing) on a 3-point scale (limited a lot, limited a little, not limited at all). The respondent-reported scores were converted into scores ranging from 0=limited a lot to 100=not limited at all (23).
3. Work ability index (WAI), short form (24). Sum score from 4 questions, 3–27 scale (from 3=poor to 27=the best possible), cover current work ability (0–10; where 0=unable to work and 10=the best possible), work ability in relation to physical work demands (1–5; 1=very poor, 5=very good), and in relation to mental work demands (1–5; 1=very poor,

5 = very good), and personal prognosis for work ability in 2 years' time (1 = hardly able to work, 4 = "not sure", 7 = almost certain work ability).

*Independent variables*

*1. Performance tests for physical fitness.*

- Aerobic fitness assessed by a 6-min-walk test (6MWT), for maximal walking distance (metres) in 6 min (25).
- Muscular strength assessed by: (*i*) modified push-ups (26), number of repetitions in 40 s (indicating upper-body muscular strength and trunk stabilization); (*ii*) muscle strength in the lower limbs as assessed by 1-leg squats (26), number of repetitions, with progressively increasing external load (10% of body weight after each performance); and (*iii*) power of the lower limbs, assessed by vertical jump, in cm (26) (measured finger mark distance between standing and the peak of the jump).
- Agility, as assessed by running of a figure-of-eight, running time in s (27).
- Flexibility (trunk side-bending, judged in distance between finger marks in lateral flexion, in cm) (26).
- Body mass index (BMI), in kg/m$^2$.

Repeatability of the motor and musculoskeletal fitness used with this study sample was confirmed in the first sub-study of the NURSE RCT ($n$ = 47) (28). A precise description of the fitness test performances is given in the repeatability article (28).

*2. Physical activity.*

- Objectively measured aerobic physical activity (waking hours during one week, using a Hookie AM20 tri-axial accelerometer, from Traxmeet, Espoo, Finland), with re-coding of data on meeting recommendations for physical activity to promote or maintain health (for total of at least 2h 30 min of moderate activity or 1h 15 min of vigorous activity); at least 3 times a week (29), yes/no.
- Meeting of recommendations for strength training at least twice a week (29), yes/no (questionnaire).

*3. Self-reported physical measures.*

- Number of musculoskeletal pain sites (1–6). Pain during the past 4 weeks in the low back, upper back and neck, shoulders and upper limbs, hips, knees, and lower limbs: yes/no.
- Perceived recovery from work over the preceding 4 weeks (on a 5-point scale: from 1 = recovering well to 5 = not recovering) (30). Ratings were split into 3 groups (1+2 = recovering well, 3 = some difficulties, 4+5 = not recovering).
- Perceived work-induced lumbar exertion (from 1 = no exertion to 5 = high exertion) (31). Ratings were split into 3 groups: 1+2 = no exertion, 3 = moderate exertion, 4+5 = high exertion.
- Tiredness and sleepiness (sum score from 3 questions developed by Finnish Institute of Occupational Health; from 3=no tiredness or sleepiness to 13 = long-term, daily tiredness and sleepiness) (30). The questions concern tiredness in the morning after waking up, and tiredness and sleepiness during the day-time.

*4. Self-reported psychosocial factors.*

- *Fear-avoidance beliefs (FABs)* (32). Two sub-scales of FABs exist: an 11-item work (FAB-W) sub-scale (3 questions considering long-term sick leave were excluded from the original questionnaire; range: 0–48 points) and a 5-item physical-activity (FAB-P) sub-scale (range: 0–30 points). High values indicate increased levels of FABs.

*Depression.* Beck Depression Inventory (BDI), short form (sum score from 9 questions with a 1–4 rating scale) (33), where high values indicate higher levels of depression.

*Psychosocial factors at work* (such as work stress) were assessed via a Finnish work satisfaction questionnaire (34). Those factors were used only for adjustments. Variables used for adjustments represented factors that might have an association with the outcome measurements, but that had no influence on later interventions (neuromuscular exercise and/or counselling) carried out in the NURSE-RCT.

*Statistical analysis*

For the descriptive analyses, the mean and standard deviation (SD), and medians (Md) and quartiles ($Q_1$,$Q_3$) were calculated. Identification of skewed distributions was performed through visual inspection of the histograms, by comparison of means and medians, and by calculation of skewness divided by standard error. Correlations between at least ordinal scale measurements were analysed via Spearman's rank correlation coefficient ($r_s$).

Associations between categorical variables and normally distributed continuous variables were analysed via 1-way analysis of variance (ANOVA) and independent-samples *t*-test. The corresponding statistical tests for non-normal distributions were the Kruskal–Wallis test and the Mann–Whitney test.

When statistically significant associations ($p < 0.05$) between bio-psychosocial factors and dependent variables were found in bivariate analysis, generalized linear models (GLMs) were used to determine which independent factors best explain the dependent variables: bodily pain, physical functioning, and work ability. After calculation of crude β-coefficients, the analyses were adjusted first for age, BMI, and work type (shift work/ regular work), and subsequently also for sick leave due to LBP in the preceding 6 months, hormonal status and work satisfaction.

To enable comparison of the strength of associations between various covariates and dependent variables, standardized β values were calculated for continuous variables (by multiplying the crude β by the SD of the covariate, then dividing the result by the SD for the outcome measurement) (35).

All analyses were conducted with the SPSS statistical analysis package, version 22.

## RESULTS

### Description of the study population

Baseline characteristics of the study sample are reported in Table I. The study subjects had worked in their current position in a mean of 11.4 years. More than 85% of them were nurses or nursing assistants, and 70% had irregular working hours. Most perceived their health to be average or good, but 28% perceived their

**Table I.** Baseline characteristics of the study sample ($n=219$)

| | *n* (%) | Mean (SD) | Median ($Q_1$, $Q_3$) | Missing (*n*) |
|---|---|---|---|---|
| Age, years | 219 | 46.4 (6.8) | 47.0 (42.0, 52.0) | |
| Basic education level | | | | |
| Lower than secondary school | 87 (39.7) | | | |
| High-school or above | 132 (60.3) | | | |
| Profession | | | | |
| Nurse | 102 (46.6) | | | |
| Nursing assistant | 89 (40.6) | | | |
| Physiotherapist (PT) or assistant PT | 14 (6.4) | | | |
| Midwife | 6 (2.7) | | | |
| Radiographer or laboratory technician | 5 (2.3) | | | |
| Head nurse | 3 (1.4) | | | |
| Number of years working in current job | 217 | 11.4 (8.8) | 9.0 (5.0, 17.0) | 2 |
| Work type | | | | 1 |
| Shift work | 152 (69.7) | | | |
| Regular work | 66 (30.3) | | | |
| Smoking | | | | |
| Non-smoker | 157 (71.7) | | | |
| Smoking regularly | 36 (16.4) | | | |
| Smoking occasionally | 26 (11.9) | | | |
| Hormonal status | | | | 1 |
| Regular periods | 91 (41.6) | | | |
| Irregular periods | 30 (13.7) | | | |
| Periods with hormone replacement therapy | 11 (5.0) | | | |
| Post-menopause | 86 (39.3) | | | |
| Body mass index (BMI), kg/m$^2$ | | 26.4 (4.4) | 26.1 (23.0, 28.8) | 2 |
| Normal weight (≤ 24.9) | 88 (40.7) | | | |
| Overweight (25.0–29.9) | 90 (41.7) | | | |
| Obese (≥ 30.0) | 38 (17.6) | | | |
| Perceived health | | | | 1 |
| Below average | 1 (0.5) | | | |
| Average | 81 (37.2) | | | |
| Good | 124 (56.9) | | | |
| Very good | 12 (5.5) | | | |
| Perceived fitness in comparison with persons of the same age and sex | | | | 1 |
| Much worse | 7 (3.2) | | | |
| Somewhat worse | 54 (24.7) | | | |
| Similar | 109 (49.8) | | | |
| Somewhat better | 42 (19.2) | | | |
| Much better | 6 (2.7) | | | |
| LBP intensity (VAS 0–100; past 4 weeks) | 218 | 36.2 (22.6) | 34.0 (17.8, 53.0) | 1 |
| Frequency of LBP at baseline | | | | 27 |
| Daily | 23 (12) | | | |
| Most days of the week | 56 (29) | | | |
| A few days a week | 82 43) | | | |
| Recovered from low back pain episodes | 31 (16) | | | |
| Duration of symptoms of LBP at baseline, months | | | | 2 |
| < 3 | 140 (64.5) | | | |
| 3–6 | 32 (14.7) | | | |
| ≥ 7 | 45 (20.7) | | | |
| Self-reported number of sick-leave days due to LBP in the last 6 months | 207 | 1.9 (7.9) | 0 (0,0) | 12 |
| Work satisfaction | | | | |
| Possibilities to exert an influence on one's work | 217 | 2.8 (0.7) | 2.8 (2.5, 3.3) | 2 |
| Support from one's supervisor | 217 | 3.4 (0.8) | 3.4 (3.0, 4.0) | 2 |
| Conflicts with one's supervisor | 217 | 2.0 (0.8) | 2.0 (1.7,2.7) | 2 |
| Work stress (Siegrist's effort–reward model)* | 217 | 1.6 (0.5) | 1.5 (1.3, 1.8) | 2 |

*Siegrist's effort–reward model refers to mismatch between high workload (and high demand) and low control over long-term rewards (such as salary, other benefits, appreciation for the work contributions, and personal satisfaction).
LBP: low back pain.

fitness to be poor in comparison with that of persons of the same age and sex. Only approximately 40% were of normal body weight, and 60% were considered to be overweight or obese.

At the pre-study screening, the pain intensity for all subjects included in the study was 2 or more (mean 4.7, SD 1.8), measured on the NRS (0–10). Most of the study subjects (82%) experienced LBP on a few or most days of the week, but not daily, and 18% had daily LBP. The corresponding percentages at the baseline measurement were 72% and 12%, and 16% had recovered from pain. Duration of the LBP symptoms was less than 3 months for 65%, 3–6 months for 15% and more than 6 months for 21% of the study population at baseline. For 45 persons, the duration of symptoms of LBP exceeded 6 months during the waiting time between pre-study screening and baseline measurements. The majority of them (84%) experienced LBP on a few or most days of the week, but not daily, and 7 persons had daily pain. The selected study population can be described as nursing personnel with acute or sub-acute NSLBP with recurring pain behaviour. Only 15% (33 subjects) had been on sick leave due to LBP within the previous 6 months (36).

Descriptive data for the measurements (independent and dependent variables) are shown in Table II. Participants perceived themselves as having moderate bodily pain: mean 63.1 (SD 19.0) on a 0–100 scale (from 0 = very severe pain/extreme difficulties to 100 = no pain/no difficulties). The median for physical functioning was 90 ($Q_1$ = 80, $Q_3$ = 95, scale 0–100), and the median for self-assessed current and future work ability was 23 ($Q_1$ = 21, Q = 24, scale 3–27).

**Table II.** Descriptive data for the dependent and independent variables ($n$ = 219)

| | Mean (SD) | Median ($Q_1$, $Q_3$) | *n* (%) | Missing (*n*) |
|---|---|---|---|---|
| *Dependent variables* | | | | |
| Bodily pain (RAND-36) (0–100) | 63.1 (19.0) | 67.5 (55.0, 77.5) | 217 | 2 |
| Physical functioning (RAND-36) (0–100) | 85.5 (13.5) | 90 (80,95) | 217 | 2 |
| Ability to work (3–27) | 22 (2.6) | 23 (21,24) | 217 | 2 |
| *Independent variables* | | | | |
| *Physical factors* | | | | |
| Physical fitness:* | | | | |
| 6MWT (m) | 620 (49.5) | 621 (588, 655) | 199 | 20 |
| Modified push-ups (repetitions) | 9.1 (3.0) | 9 (7, 11) | 199 | 20 |
| One-leg squats (repetitions) | 9.6 (2.5) | 10 (8, 12) | 199 | 20 |
| Vertical jumps (cm) | 29.1 (5.8) | 29 (26, 33) | 199 | 20 |
| Running a figure-of-eight (s) | 7.8 (0.9) | 7.6 (7.1, 8.2) | 199 | 20 |
| Trunk lateral flexion (cm) | 18 (3.3) | 18.1, (15.7, 20.2) | 199 | 20 |
| Physical activity | | | | |
| Aerobic activity | | | | 9 |
| Meeting recommendations | | | 54 (26) | |
| Strength training | | | | 1 |
| Meeting recommendations | | | 44 (20) | |
| Number of musculoskeletal pain sites | 3.2 (1.3) | 3 (2,4) | | |
| Perceived recovery from work | | | | 6 |
| Recovering well | | | 90 (42) | |
| Some difficulties | | | 102 (48) | |
| Not recovering | | | 21 (10) | |
| Work-induced lumbar exertion | | | | 3 |
| Little exertion | | | 63 (29) | |
| Moderate exertion | | | 79 (37) | |
| High exertion | | | 74 (34) | |
| Tiredness and sleepiness | 7.5 (2.8) | 7 (5,10) | 218 | 1 |
| *Psychosocial factors* | | | | |
| FAB-P (0–30) | 13.1 (6.2) | 12 (9, 18) | 217 | 2 |
| FAB-W (0–48) | 10.9 (7.9) | 10 (5,15) | 217 | 2 |
| BDI (9–36) | 16.4 (8.9) | 16 (13,19) | 218 | 1 |

*Main reasons for exclusion of participants from fitness tests were local musculoskeletal problems and high blood pressure. 6MWT: 6-min walk test; FAB-P: fear-avoidance beliefs related to physical activity; FAB-W: fear-avoidance beliefs related to work; BDI: Beck Depression Inventory.

**Table III.** Correlations between various physical and psycho-social factors and (*i*) bodily pain, (*ii*) physical functioning, and (*iii*) work ability (statistically significant correlations in bold)

| | Bodily pain | | Physical functioning | | Workability | |
|---|---|---|---|---|---|---|
| *Physical factors* | $r_s$ | *p* | $r_s$ | *p* | $r_s$ | *p* |
| Physical fitness: | | | | | | |
| 6MWT | **0.17** | **0.02** | **0.28** | **< 0.001** | **0.19** | **0.005** |
| modified push-ups | 0.09 | 0.18 | **0.37** | **< 0.001** | **0.32** | **< 0.001** |
| one-leg squats | −0.03 | 0.68 | **0.28** | **< 0.001** | **0.30** | **< 0.001** |
| vertical jumps | 0.04 | 0.58 | **0.26** | **< 0.001** | **0.23** | **< 0.001** |
| running a figure-of-eight | −0.10 | 0.15 | **−0.34** | **< 0.001** | **0.33** | **< 0.001** |
| trunk lateral flexion | 0.03 | 0.62 | 0.12 | 0.08 | 0.12 | 0.07 |
| BMI | −0.04 | 0.56 | **−0.15** | **0.03** | **−0.15** | **0.03** |
| Number of musculoskeletal pain sites | **−0.29** | **< 0.001** | **−0.29** | **< 0.001** | **−0.21** | **0.002** |
| Tiredness and sleepiness | −0.13 | 0.65 | −0.10 | 0.15 | **−0.25** | **< 0.001** |
| *Psycho-social factors* | | | | | | |
| FAB-P | **−0.18** | **0.01** | **−0.15** | **0.03** | **−0.23** | **0.01** |
| FAB-W | **−0.25** | **< 0.001** | **−0.25** | **< 0.001** | **−0.38** | **< 0.001** |
| BDI | −0.079 | 0.37 | **−0.25** | **< 0.001** | **0.42** | **< 0.001** |

$r_s$: Spearman's rank correlation coefficient; BMI: body mass index; FAB: fear-avoidance beliefs; 6MWT: 6-min walk test; FAB-P: fear-avoidance beliefs related to physical activity; FAB-W: fear-avoidance beliefs related to work; BDI: Beck Depression Inventory. Negative correlation coefficients in relation to pain are explained by coding of bodily pain with descending values: a high score indicates no pain.

### *Bivariate analysis*

The association between physical and psychosocial factors and (*i*) bodily pain, (*ii*) physical functioning, and (*iii*) work ability were calculated. The results are shown in Table III for continuous independent variables and in Table IV for categorical independent variables.

Higher values for physical functioning were detected in those who met recommendations for aerobic exercise ($p$ = 0.05) and strength training ($p$ = 0.02) than in those who did not meet the recommendations (Table IV).

Post-work recovery was associated with physical functioning ($p$ = 0.003) and ability to work ($p$ < 0.001). Subjects who were recovering well had higher scores for physical functioning and work ability than those who had some difficulties in recovering or who did not recover after work.

Perceived work-induced lumbar exertion was associated with bodily pain ($p$ < 0.001). Those who perceived themselves very exerted had more pain than did those who perceived little exertion (mean difference 17.4, 95% confidence interval (95% CI) 9.9, 24.9, $p$ < 0.001) or moderate exertion (mean difference 13.3, 95% CI 6.3, 24.4, $p$ < 0.001). Work-induced lumbar exertion was also associated with levels of physical functioning

**Table IV.** Associations between physical factors, all categorical variables and (*i*) bodily pain and pain interfering with normal work, (*ii*) physical functioning, and (*iii*) perceived current and future ability to work (statistically significant *p*-values in bold)

| | | Bodily pain | | | Physical functioning | | | Work ability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | Mean (SD) | Test statistics | *p*-value | Median ($Q_1$, $Q_3$) | Test statistics | *p*-value | Median ($Q_1$, $Q_3$) | Test statistics | *p*-value |
| Physical activity | | | | | | | | | | |
| Aerobic activity | | | | | | | | | | |
| Meeting recommendations | 54 | 63.0 (19.9) | t=−0.14 | 0.89 | 93 (85, 95) | *U*=−1.96 | **0.05** | 23 (21, 24) | *U*=−2.0 | 0.87 |
| Not meeting recommendations | 156 | 63.4 (15.9) | *df*=197 | | 85 (75, 95) | | | 23 (20, 24) | | |
| Strength training | | | | | | | | | | |
| Meeting recommendations | 44 | 62.6 (18.5) | t=−0.31 | 0.76 | 95 (85, 95) | *U*=−2.26 | **0.02** | 23 (21, 25) | *U*=−1.94 | **0.05** |
| Not meeting recommendations | 174 | 63.6 (20.7) | *df*=208 | | 85 (75, 95) | | | 22.5 (20, 24) | | |
| Perceived recovery from work | | | | | | | | | | |
| Recovering well | 90 | 65.4 (18.8) | F=1.68 | 0.19 | 90 (60, 100) | $\chi^2$=11.94 | **0.003** | 23 (17, 27) | $\chi^2$=22.46 | **<0.001** |
| Some difficulties | 102 | 62.9 (18.7) | *df*=205 | | 85 (15, 100) | *df*=2 | | 22 (15, 26) | *df*=2 | |
| Not recovering | 21 | 57.3 (18.1) | | | 75 (50, 100) | | | 21 (16, 27) | | |
| Work-induced lumbar exertion | | | | | | | | | | |
| Little exertion | 63 | 70.4 (18.8) | F=17.82 | **<0.001** | 95 (60, 100) | $\chi^2$=32.69 | **<0.001** | 24 (15, 27) | $\chi^2$=29.87 | **<0.001** |
| Moderate exertion | 79 | 66.3 (17.4) | *df*=207 | | 90 (15, 100) | *df*=2 | | 23 (16, 26) | *df*=2 | |
| High exertion | 74 | 53.0 (17.0) | | | 80 (45, 100) | | | 21 (12, 27) | | |

F refers to analysis of variance (ANOVA); $\chi^2$ to the Kruskal–Wallis test; t to independent sample *t*-testing; and *U* to the Mann–Whitney test.

($p<0.001$) and ability to work ($p<0.001$); little exertion was linked to higher scores for physical functioning and ability to work.

Physical fitness and work-induced lumbar exertion: results of the physical fitness tests were consistently lower in those who perceived more work-induced lumbar exhaustion in comparison with subjects who were less exhausted ($p<0.05$). The results are shown in Table V.

*Multivariate analysis*

Factors with statistically significant ($p<0.05$) associations with dependent variables in bivariate analysis (see Tables III and IV) were included in GLM analysis. Factors showing a statistically non-significant association with dependent variables were eliminated 1 by 1 in the GLM analysis. The results of the GLM-based analysis with statistically significant associations are presented in Table VI and depicted graphically in Fig. 2.

The factors associated with having bodily pain were perceived post-work lumbar exertion (high exertion vs. little exertion, β=–13.95, $p<0.001$, $n$=206), FABs related to work (β=–0.44, $p$=0.02, $n$=206), and number of musculoskeletal pain sites (β=–3.06, $p<0.001$, $n$=206). Negative β coefficients are explained by coding of bodily pain with descending values: a high score indicates no pain.

When the analyses were adjusted for age, BMI, work type (shift work/regular work), hormonal status, work satisfaction (including work-related stress), and previous sick leave due to LBP, statistically significant associations were found also between work type (β=–10.72, $p<0.001$), previous sick leave (β=0.35, $p$=0.02) and bodily pain.

Lower work-induced lumbar exertion (β=–0.075, $p$=0.005, $n$=174), lower values for FAB-W (β=–0.004, $p$=0.01, $n$=174), a higher number of modified push-ups (β=0.008, $p$=0.045, $n$=174), and shorter times for running a figure-of-eight (β=–0.033, $p$=0.01, $n$=174) were associated with better physical functioning. No significant changes were detected after adjustments.

Lower work-induced lumbar exertion (β=–0.052, $p$=0.003, $n$=192), lower FAB-W (β=–0.004, $p<0.001$, $n$=192), lower scores for depression (β=–0.003, $p$=0.045, $n$=192), and higher scores for perceived recovery after work (β=–0.03, $p$=0.03, $n$=192) were associated with higher scores for work ability. No significant changes were detected after adjustments.

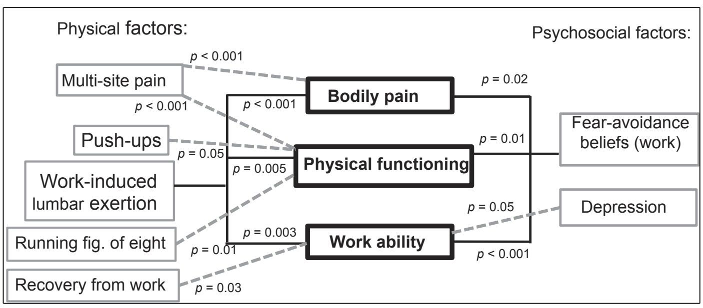


**Fig. 2.** Associations of: (*i*) physical factors and (*ii*) psychosocial factors with 3 dependent variables: bodily pain, physical functioning, and perceived current and future ability to work, analysed via generalized linear models. A solid line indicates factors that were associated with all 3 dependent variables.

**Table V.** Associations between fitness-test results and perceived work-induced lumbar exertion, analysed by analysis of variance (ANOVA) and adjusted for age (*p*–values reflecting statistically significant differences in bold)

| Fitness test: | Little exertion Mean (SD) | Moderate exertion Mean (SD) | High exertion Mean (SD) | Mean difference from little exertion to high exertion (95% CI) | *p*-value |
|---|---|---|---|---|---|
| 6MWT (m) | 632.1 (49.7) | 620.7 (44.8) | 602.6 (51.1) | 29.5 (9.5, 49.6) | **0.001** |
| Modified push-ups (reps) | 10.2 (3.2) | 8.8 (2.5) | 8.1 (3.2) | 2.1 (0.8, 3.3) | **<0.001** |
| One-leg squats (reps) | 10.2 (2.3) | 9.7 (2.3) | 8.7 (2.9) | 1.5 (0.5, 2.5) | **0.001** |
| Vertical jumps (cm) | 30.1 (5.5) | 29.3 (5.5) | 27.5 (6.3) | 2.7 (0.2, 5.1) | **0.03** |
| Running a figure-of-eight (s) | 7.6 (0.9) | 7.7 (0.8) | 8.1 (1.2) | −0.5 (−0.9, −0.1) | **0.007** |

SD: standard deviation; CI: confidence interval; 6MWT: 6-min walk test.

## DISCUSSION

The results of the final regression model indicate that perceived work-induced lumbar exertion and work-related FAB best explained the levels of pain, physical functioning, and work ability. Multi-site musculoskeletal pain was associated with higher levels of pain and lower physical functioning. Higher musculoskeletal performance level (assessed by modified push-ups and figure-of-eight running) was associated with better physical functioning.

### *Bodily pain*

The first dependent variable was bodily pain interfering with normal work. We chose a sub-scale for bodily pain from RAND-36 (22) in preference to a visual analogue scale (VAS) (1–100) (37), because we considered it more informative than VAS in a population performing physically demanding work. Work-induced lumbar exertion, multi-site pain, and FAB-W were all associated with perceived pain in GLM analysis.

The average number of musculoskeletal pain sites was 3.2 in the study sample. Multi-site pain seems quite common in nursing personnel, with 1-year prevalence of 60% among Estonian nurses (38). Multi-site pain is a strong predictor of sickness-related absences (39) and early retirement (40). In a recent cross-sectional study conducted among healthcare providers (41), multi-site musculoskeletal pain was associated with perceived ability to work, with the magnitude of association likely to increase with the number of pain sites.

In the study reported here, shift work was associated with more bodily pain in the GLM analysis. Most of the study subjects performed shift work, which is often associated with sleep disturbances and poor recovery. These, in turn, can affect perceptions of pain (42).

### *Physical functioning*

Higher fitness level in the modified push-up test was associated with better physical functioning in GLM

**Table VI.** Statistically significant associations between different biological and psychosocial factors and (*i*) bodily pain and pain interfering work, (*ii*) physical functioning, and (*iii*) perceived current and future ability to work, analysed via generalized linear models

| | Bodily pain and pain interfering with work | | | Physical functioning | | | Perceived current and future ability to work | | |
|---|---|---|---|---|---|---|---|---|---|
| | Crude β (*p*), and (standardized β) | Adjusted[a] β (*p*) | Adjusted[b] β (*p*) | Crude β (*p*) and (standardized β) | Adjusted[a] β (*p*) | Adjusted[b] β (*p*) | Crude β (*p*) and (standardized β) | Adjusted[a] β (*p*) | Adjusted[b] β (*p*) |
| *Physical factors* | | | | | | | | | |
| Modified push-ups | | | | 0.008 (0.045), (0.0020) | 0.007 (0.08) | 0.008 (0.07) | | | |
| Running a figure-of-eight | | | | −0.033 (0.01), (0.0024) | −0.033 (0.03) | −0.035 (0.03) | | | |
| Number of musculoskeletal pain sites | −3.06 (<0.001), (0.2173) | −2.65 (0.002) | −3.12 (0.001) | −0.28 (<0.001), (−0.0030) | −0.27 (<0.001) | −0.028 (0.001) | | | |
| Recovery from work | | | | | | | −0.03 (0.03) | −0.052 (0.04) | −0.05 (0.06) |
| Work-induced lumbar exertion | −13.95 (<0.001) | −15.31 (<0.001) | −15.48 (<0.001) | −0.075 (0.005) | −0.08 (0.005) | −0.073 (0.01) | −0.052 (0.003) | −0.055 (0.003) | −0.05 (0.002) |
| *Psycho-social factors* | | | | | | | | | |
| Fear-avoidance beliefs related to work | −0.44 (0.02), (0.1751) | −0.59 (0.002) | −0.47 (0.02) | −0.004 (0.01), (0.0022) | −0.004 (0.003) | −0.004 (0.02) | −0.004 (<0.001), (0.0153) | −0.004 (<0.001) | |
| Beck Depression Index | | | | | | | −0.003 (0.045), (−0.0019) | −0.003 (0.08) | −0.004 (0.03) |
| *Factors used in adjustments* | | | | | | | | | |
| Work type | | −10.75 (<0.001) | −10.72 (<0.001) | | | | | | |
| Previous sick leave due to low back pain | | | −0.35 (0.02) | | | | | | |

β: regression coefficient; [a]adjusted for age, BMI, and work type (shift work vs. regular work); [b]adjusted for age, BMI, work type (shift work vs. regular work), hormonal status, work satisfaction, and previous sick leave to LBP during past 6 months. Standardized β is calculated for continuous variables.

analysis, and lower work-induced lumbar exertion in bivariate analysis. The modified push-up test requires both upper-body muscular strength and trunk stabilization, and low performance levels in this test have been associated with low-back dysfunction and pain in middle-aged subjects (43). In a study reported on by Kolu et al. (36), conducted with the same participants as the study reported here, the highest third with regard to aerobic and musculoskeletal performance capacity (measured by 6MWT and by modified push-ups) had lower sickness-related absence rates for the 6 months prior to baseline measurements than did those whose performance capacity was poor (specifically the lowest tertile). Our results are in line with earlier findings indicating that impaired physical functioning predicts development of persisting, disabling LBP (44).

This study indicated that poor results in running a figure-of-eight (which requires agility and power in the lower extremities) were associated with poor physical functioning in GLM analysis, and number of 1leg squats was strongly linked with perceived levels of work-induced lumbar exertion. Previous scientific evidence of this finding is limited. However, it can be assumed that nursing personnel with poor strength and power in the lower extremities are more prone to use their back musculature in lifting and transferring patients, and they might perceive lumbar exertion for this reason.

In the bivariate analysis we found that performance levels in aerobic, motor, and musculoskeletal fitness tests were systematically lower in those who perceived more work-induced lumbar exhaustion in comparison with those who were less exhausted. Poor endurance leads to exhaustion and fatigue at the end of a work shift, and fatigue, in turn, is known to decrease perception and motor control (45), thereby intrinsically raising the risk of injury in physically demanding tasks.

### *Work ability*

Work ability in cases of musculoskeletal disease is affected by several physical, psychosocial, individual-level, and environmental factors (46). In our study, the strongest associations with better work ability were detected in GLM analysis with lower work-induced lumbar exertion, better perceived recovery from work, lower depression, and lower FAB-W.

Managing physically demanding work and having low-back troubles is a challenging combination. Perceived work-induced lumbar exertion depends on exposure to physical loads, the length of the work shift, and personal physical capacities. Handling physically demanding work without incidents of LBP probably requires sufficient physical capacities, but exact cut-off points in fitness-test results are unknown. Therefore, further research is needed.

Depression was associated with levels of perceived current and future ability to work. If one is having negative thoughts about the present, perceived prognosis regarding work ability may also be bleak. In a recent systematic review (47), Pinheiro et al. suggested that depression might also have an effect on LBP prognosis in the acute or sub-acute phase.

Only 15% of the study sample had been on sick leave due to LBP within the previous 6 months. This percentage is surprisingly low, in light of the fact that the mean for pain intensity was 4.7 (on a 0–10 scale) at the point of screening. Perhaps either the participants' perception of minor pain was high on account of difficulties in physically heavy work, or they did not want to go on sick leave in economically hard times, when substitutes cannot be hired.

### *Fear-avoidance beliefs*

In our study, FAB-W was associated with all 3 dependent variables in GLM analysis. All of the participants in the study worked with bedridden patients or carried out other physically demanding nursing tasks, such as lifting and transferring patients. Those tasks are heavy and cause seriously harmful load on the back structures (48). Therefore, it is understandable that nursing personnel's attitudes to some work duties are filled with trepidation.

FABs play a central role in chronic LBP when organic pathology is not evident (49). The role of FABs in non-chronic populations is unclear, but it seems that it is linked to the transition of pain to the chronic stage (50) and plays a key role in recovery (44). For nursing personnel with previous LBP, both FABs and physical work load are associated with new episodes of LBP (8, 51).

### *Clinical implications, limitations, and conclusions*

In this study psychosocial factors and physical performance level were strongly associated with pain, physical functioning and work ability in female nursing personnel with recurrent LBP and physically burdensome work. This association has been widely documented in chronic LBP populations (11, 12, 15), but hardly in people with sub-acute NSLBP with recurring pain behaviour.

Level of work-induced lumbar exertion was assessed with a simple question offering 5 alternatives. This measurement showed strong associations with pain, physical functioning, work ability and level of physical fitness. Therefore, it could be used as a screening tool in assessment of risks for prolonged disability and possible reduced work ability. Those who perceive high work-induced lumbar exertion could benefit from fitness tests and exercise counselling.

Measurement methods to screen people who have a physically demanding job and may be at risk of persistent LBP are needed in occupational health services. The findings of the study reported here might be useful in development of practical tools for screening. For the most part, we used measurements whose reliability and validity have been tested previously. Nevertheless, some limitations of the measurements can be cited: (*i*) the Finnish version of the short form of Beck Depression Inventory has not yet been validated, (*ii*) no reliability studies have been carried out for questionnaires on the site quantity in cases of multiple musculoskeletal pain sites, and (*iii*) interpretations of cut-off-points for several measurements are unclear among people with a physically demanding job.

Another limitation of the study is its cross-sectional design. Interpretations of causality cannot be made. Hence, a prospective study is needed, to explore the causality of the elements propose to be factors in perceived pain, physical functioning, and work ability. In the NURSE RCT, LBP intensity and sick leave due to LBP are asked about at the 12- and 24-month follow-up.

In conclusion, perceived work-induced lumbar exertion and work-related FABs were factors that were associated with bodily pain, physical functioning, and work ability in a sample of nursing personnel with recurrent LBP. Level of physical fitness was related to work-induced lumbar exertion. Therefore, interventions designed to increase levels of fitness capacity and preventive efforts, such as back-related counselling to reduce levels of fear-avoidance, might be of importance for maintaining ability to work in nursing duties.

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*The authors declare no conflicts of interest.*

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# ERRATUM

In J Rehabil Med 2017; 49: 667–676: Taulaniemi et al. ''Biopsychosocial factors are associated with pain intensity, physical functioning and ability to work in female healthcare personnel with recurrent low back pain'' measurement method measuring depressive syndromes was incorrectly named for "short form of Beck Depression Inventory (9 items)". It should have been named for "modified Finnish version of Patient Health Questionnaire (PHQ, 9 items)(1). This mistake can be detected in page 668, column 2, row 8,; p. 675, column 1, row 9; and Tables II, III, and V. The values and results are still correct.

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# PUBLICATION III

**Neuromuscular exercise reduces low back pain intensity and improves physical functioning in nursing duties among female healthcare workers; secondary analysis of a randomised controlled trial.**

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RESEARCH ARTICLE **Open Access**

# Neuromuscular exercise reduces low back pain intensity and improves physical functioning in nursing duties among female healthcare workers; secondary analysis of a randomised controlled trial

Annika Taulaniemi[1*], Markku Kankaanpää[2], Kari Tokola[1], Jari Parkkari[1] and Jaana H. Suni[1]

## Abstract

**Background:** Low back pain (LBP) is common among healthcare workers, whose work is physically strenuous and thus demands certain levels of physical fitness and spinal control. Exercise is the most frequently recommended treatment for LBP. However, exercise interventions targeted at sub-acute or recurrent patients are scarce compared to those targeted at chronic LBP patients. Our objective was to examine the effects of 6 months of neuromuscular exercise on pain, lumbar movement control, fitness, and work-related factors at 6- and 12-months' follow-up among female healthcare personnel with sub-acute or recurrent low back pain (LBP) and physically demanding work.

**Methods:** A total of 219 healthcare workers aged 30–55 years with non-specific LBP were originally allocated to four groups (exercise, counselling, combined exercise and counselling, control). The present study is a secondary analysis comparing exercisers ($n = 110$) vs non-exercisers ($n = 109$). Exercise was performed twice a week (60 min) in three progressive stages focusing on controlling the neutral spine posture. The primary outcome was intensity of LBP. Secondary outcomes included pain interfering with work, lumbar movement control, fitness components, and work-related measurements. Between-group differences were analysed with a generalised linear mixed model according to the intention-to-treat principle. Per-protocol analysis compared the more exercised to the less exercised and non-exercisers.

**Results:** The mean exercise attendance was 26.3 (SD 12.2) of targeted 48 sessions over 24 weeks, 53% exercising 1–2 times a week, with 80% ($n = 176$) and 72% ($n = 157$) participating in 6- and in 12-month follow-up measurements, respectively. The exercise intervention reduced pain ($p = 0.047$), and pain interfering with work ($p = 0.046$); improved lumbar movement control ($p = 0.042$), abdominal strength ($p = 0.033$) and physical functioning in heavy nursing duties ($p = 0.007$); but had no effect on other fitness and work-related measurements when compared to not exercising. High exercise compliance resulted in less pain and better lumbar movement control and walking test results.

**Conclusion:** Neuromuscular exercise was effective in reducing pain and improving lumbar movement control, abdominal strength, and physical functioning in nursing duties compared to not exercising.

**Keywords:** Spinal pain, Recurrent low back pain, Sub-acute low back pain, Pilates, Nursing personnel, Exercise intervention, Movement control impairment

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## Background

In the majority (85–90%) of people with low back pain (LBP), the pain is classified as non-specific low back pain (NSLBP) [1]. The traditional assumption is that after an episode of acute pain, most recover spontaneously within 6 weeks [2]. This assumption has been criticised [3], as LBP is often a long-term or recurrent condition wherein individuals experience repeated episodic back pain that comes and goes over an extended span of time [4, 5]. LBP becomes chronic in 10% of sufferers [6].

LBP is the leading and most costly musculoskeletal disorder among healthcare workers [7, 8]. The one-year prevalence of LBP among nursing personnel varies from 45 to 77% [7, 9–11]. Healthcare workers are exposed to physically heavy work duties, like lifting and transferring patients and prolonged standing or working in a stooped position, which are biomechanical risk factors for LBP and chronic pain [12–15].

Exercise is the most frequently recommended treatment for NSLBP [6, 16, 17]. However, exercise interventions targeted at sub-acute patients are scarce compared to those targeted at chronic LBP patients. There is moderate-quality evidence that post-treatment exercise can reduce the recurrence of back pain [18], and leisure-time physical activity can be beneficial in preventing low back pain [19]. However, the results of exercise treatment studies are conflicting, and it is difficult to specify the content of an effective programme [6].

LBP tends to affect and change motor behaviour [20]. Impairments in postural and movement control of the lumbar spine have been posited to be risk factors for prolonged LBP [21, 22]. A significant difference in the ability to actively control the movement of the low back has been found between patients with LBP and healthy subjects [23]. Female nurses with a recent back injury show more impairments in lumbar control compared to healthy nurses [14]. Both hypo- and hyper-lordosis correlate with degenerative joint disease, particularly in women [24]. Lumbar movement control, especially control of the lumbar neutral spine posture, has been suggested to play a key role in maintaining a healthy spine [25]. However, it is still unclear whether poor lumbopelvic control is a cause for LBP or a consequence of it. Evidence on the effects of movement control exercise interventions on pain intensity is only small to moderate [26, 27].

There is increasing evidence that low performance levels for different components of physical fitness are risk factors for LBP [28, 29], and a self-reported low rating of physical capacity is a predictor for future LBP in female healthcare workers [30]. Evidence about those associations is still partly conflicting with respect to revealing whether physical inactivity and deconditioning cause LBP or, alternatively, LBP leads to decreased physical activity and deconditioning [31]. Among the participants of the present study, high cardiorespiratory and muscular fitness were strongly associated with lower baseline medical costs and sickness-related absences [32].

Spinal stability and control of the spine [33] are considered to be important for back health [34]. Different approaches to exercising have been emphasised to achieve spinal stability; however, no single approach has proved to be superior [6, 35, 36].

Pilates is aimed at spinal alignment and a neutral spine posture [37]. It has been defined as "a mind-body exercise that targets core stability, strength, flexibility, posture, breathing, and muscle control" [38]. The exercises are often considered to be similar to spinal stabilisation / motor control exercises; however, they do not involve conscious activation of specific deep core muscles in the manner often used in spinal stabilisation exercises [39]. However, there is inconclusive evidence that Pilates is superior to other forms of exercise in reducing pain and disability in people with LBP [39]. Studies report a reduction in chronic LBP [39, 40], but to our knowledge, no studies investigating the effects of Pilates for people with non-chronic (sub-acute or recurrent) LBP have been reported. In a blinded four-arm randomised controlled trial (RCT; combined neuromuscular exercise and back care counselling, exercise only, counselling only, and controls), Suni and colleagues [41] found that combined neuromuscular exercise (NME) and back care counselling was effective in reducing LBP and related sickness absence and work-related fear of pain in female healthcare personnel with recurrent LBP. The present study aims to investigate the effectiveness of this 6 months Pilates-type NME with emphasis on control of the lumbar neutral zone of the above RCT in two-arm design i.e. NME and non-NME. More specifically, the study examines the effectiveness of NME on pain intensity and pain interfering with work, lumbar movement control impairments (MCI), fitness components, and work-related factors immediately after the intervention and at a 12-month follow-up in female healthcare personnel with sub-acute or recurrent LBP. We hypothesised that NME reduces LBP intensity and pain interfering with work, and improves lumbar movement control, fitness levels, and work-related factors more than non-exercise [42].

## Methods

### Study design and participants

This study is a secondary analysis of the four-arm randomised controlled trial "Neuromuscular exercise and back care counselling for female nursing personnel with recurrent non-specific low back pain: study protocol of a randomised controlled trial (NURSE RCT, clinical trial registration NCT01465698)", in which healthcare workers with sub-acute or recurrent LBP were randomised to participate in supervised neuromuscular exercise or non-exercise and to receive back care counselling or non-counselling for 6 months [42].

The NURSE RCT was conducted in three consecutive sub-studies to achieve an adequate sample size [41]. The participants were female healthcare workers in physically demanding nursing duties: in an old people's homes and geriatric wards (in the first sub-study in 2011, $n = 56$); in home service, public healthcare units, and community hospital wards (in the second sub-study in 2012; $n = 80$); and on university hospital wards (in the third sub-study in 2013, $n = 83$) in the city of Tampere, Finland. The study protocol and time frame of each identical sub-study are presented in the study protocol [42]. The eligibility criteria, recruitment of participants, and reasons for exclusion have been described in detail previously [41–43]. Briefly, 30–55-year-old female healthcare workers were eligible if they had worked in their current job for at least 12 months and had experienced LBP of an intensity 2 or above on a numeric rating scale (NRS; 0–10) [44] within the preceding four weeks. Age range was set to get a study sample, which participants had been exposed to physically demanding work, and would still be working during the 24 months' follow up (in NURSE RCT). The exclusion criteria were a serious earlier back injury (disc protrusion, fracture, surgery), chronic LBP as diagnosed by a physician or a self-report of continuous LBP over the past seven months or longer, pregnancy or recent delivery (< 12 months), and engaging in a neuromuscular type of exercise more than once a week.

At the pre-study screening, the mean LBP intensity, measured on a numeric rating scale of 0–10, was 4.7 (SD 1.8) [43]. Most of the study subjects (82%) experienced LBP on some or most days of the week but not daily, and 18% experienced LBP daily [43]. Duration of LBP was less than 3 months for 65% [43]. According to definitions made by Kongsted et al. [4], the majority of the study sample could be described as suffering from sub-acute, mild to moderate, recurrent, or fluctuating non-specific LBP. Although term "recurrent LBP" lacks consensus [45], we use it to describe the study subjects, most of whom had a recurring pain behaviour [43] .

The sample size of at least 160 subjects was estimated for the primary outcome of intensity of LBP on Visual Analog Scale 0–100 [42]. The present study is a secondary analysis of the NURSE RCT. The aim is to investigate in detail the effects of the neuromuscular exercise programme on LBP intensity, pain interfering with work, lumbar movement control, physical fitness, and work-related factors in participants randomly assigned to an exercise group or non-exercise control group, regardless of receiving back care counselling in the NURSE RCT (50% of each group, exercise or non-exercise, received counselling). The study design and grouping of the participants are shown in Fig. 1.

## Measurements

Measurements were taken at the baseline, immediately after the intervention at 6 months, and at 12 months from the baseline at the UKK Institute for Health Promotion Research in Tampere, Finland. Experienced, specially educated personnel who were blinded to group allocation and not involved in the interventions conducted all the measurements. The outcome measurements are presented in Table 1.

The repeatability of the physical fitness tests and lumbar MCI tests used with this study sample was confirmed in the first sub-study ($n = 47$) [49]. From the original MCI test battery of 6 tests [48], two tests with poor repeatability (rocking forwards and backwards and 1-leg stance) were removed (Table 1.). A precise description of those tests is given in the repeatability article's supplement [49].

## Randomisation

A method of sequentially numbered sealed envelopes was used in all three sub-studies of the NURSE RCT to assign the participants to the four study groups. Once a participant had consented to enter the study at the baseline measurement, the next envelope in order was opened and the participant was then offered the allocated study group (exercise + counselling, exercise only, counselling only, and controls) [41, 42]. In the analysis of the present study, the first two mentioned groups (exercise + counselling, and exercise only) were merged to be the "exercisers". The latter two groups (counselling only and controls) were merged to be the "non-exercisers", i.e. the control group.

## Exercise intervention

The overall aim of the 6-month exercise programme was to reduce pain-induced disturbances of movement control and increase the muscular strength and endurance needed in heavy nursing tasks [42]. The focus was on controlling the neutral spine posture in gradually progressive exercises. The learning objectives for the first two months were to learn the right performance technique, control the neutral spine posture during low-load exercises, and combine breathing with each exercise [42]. During the second and third stages (months 3–4 and 5–6, respectively), the programme was progressive in terms of the demands for coordination, balance, and muscular strength and endurance [42]. The aims and content of the NME programme are presented in the protocol article's Additional file 1 [42]. Briefly, the general training principles and objectives were: 1) to increase spinal stability using exercises that minimise the

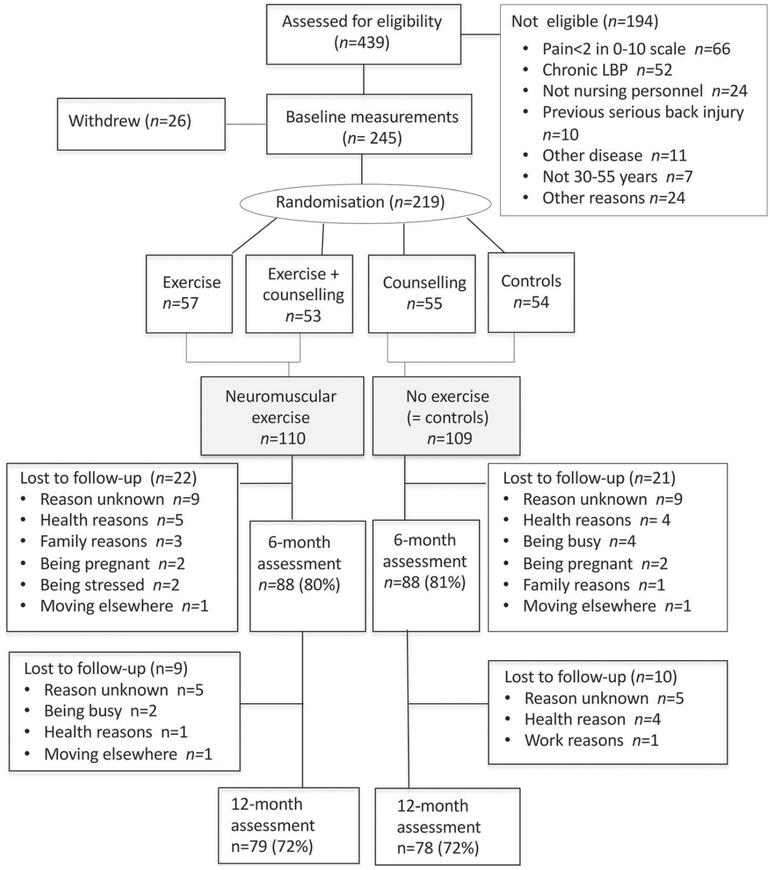


**Fig. 1** Trial profile (CONSORT flow chart)

load on spinal structures but induce a high level of muscular activity [54–59]; 2) to improve the endurance of the trunk musculature [58]; 3) to improve balance [60], postural control [61], and light co-contraction of the stabilising muscles around the lumbar spine in various upright postures and movements [62]; 4) to combine breathing with exercises, and thus take advantage of the spine-supporting role of the increased intra-abdominal pressure [63, 64]; 5) to increase the muscular strength of the lower limbs in functional squatting movements [65]; and 6) to achieve a normal range of motion in the spine, especially in the thoracic region and the hip and ankle joints [42]. The exercises are presented in Additional file 1.

The goal was to exercise twice a week in supervised NME classes (lasting 60 min) for the first two months, and in one supervised class and one home session – with help of a DVD (lasting 50 min) or booklet produced for the study – per week for the following four months. Supervised exercise groups were organised near the workplaces of the healthcare workers from Monday to Friday, starting 15 min after the typical work shifts ended [42].

The instructors of the NME groups were all certified Pilates instructors with a background education in physiotherapy, a masters' degree in health sciences, or both. Education about the standardised exercise programme in three progressive stages was organised for the instructors by AT before the intervention and before moving to the next progressive stage in each consecutive sub-study. The traditional key principles of the Pilates method – i.e., concentration, centering, control, precision, breathing, and flow [66] – were followed, with a special emphasis on intrinsic feedback of the posture of the spine in each exercise in order to discriminate the movement of the lumbar spine from the movement of the hip joints and thoracic spine [67, 68]. To avoid any

**Table 1** Outcome measurements of the study

| | Measurement |
|---|---|
| *Primary outcome:* | |
| Low back pain | Pain intensity: Visual analogue scale (VAS; 0–100 mm) during past month [46] (0 = no pain, 100 = worst possible pain) |
| *Secondary outcomes:* | |
| Pain interfering with work | Subscale from the RAND 36 Health Survey [47]; 0–100 (0 = worst pain and extreme difficulties, 100 = no pain and no difficulties) |
| Movement control of the low back | MCI test battery [48] consisting of four tests: 1) the waiter's bow (flexion of the hips in the upright standing position without movement of the lower back), 2) dorsal tilting of the pelvis, 3) sitting knee extension, and 4) prone-lying active knee flexion [49] |
| Physical fitness: | |
| Aerobic fitness | 6MWT; maximal walking distance (metres) in 6 min [50] |
| Muscular strength and endurance | Modified push-ups [51], dynamic sit-ups [52], one-legged squats [51] |
| Work-related factors: | |
| Work-induced lumbar exertion | Perceived exertion in the low back after a typical working day [53]. NRS 1–5; 1 = no exertion … 5 = high exertion. Ratings were split into two groups: 1 + 2 = no exertion, 3–5 = moderate to high exertion |
| Physical functioning in nursing tasks | Ability to manage with heavy, task-specific nursing duties, including patient transfer: Sum score of NRS 0–10 with eight selection points: 0 = no difficulties … 80 = does not manage at all [42] |
| Tiredness, sleepiness, and difficulties in recovering from work | Sum score from four questions: 4 = no tiredness or sleepiness and recovering well from work … 18 = long-term, daily tiredness and sleepiness, and not recovering from work [53] |

*6MWT* six-minute walk test, *MCI* movement control impairment, *NRS* numeric rating scale, *VAS* visual analogue scale

contamination with back care counselling intervention (in the original 4-arm setting of the NURSE RCT), the instructors were advised to follow the standardised exercise programme, and to avoid other kind of counselling (like physical activity and other lifestyle). Individual modifications to the standardised NME program were sometimes needed because of musculoskeletal problems other than LBP. The participants were asked to report any increase in back pain during or after the exercise sessions.

Two instructed exercise sessions were provided to the participants of the exercise group during the follow-up time (from 7 to 12 months).

### Statistical analysis

Power calculations were conducted based on the original NURSE RCT four-arm study design [42]. The sample size was estimated for the primary outcome of pain intensity (on a visual analogue scale; VAS), with an emphasis on the proportion (%) of patients with improved LBP on the VAS (0–100) [42]. It was expected that there would be a minimal difference of 20% between the intervention groups in the proportion of patients with an improved VAS (at least 15 mm, which indicates the minimal clinically important change) [46]. In order to detect a difference in main effects between groups with a significance level of 0.05 and a power of 80%, at least 160 participants were needed for the study. For the compensation of the probable loss of participants in the follow-up, the aim was to recruit a total of 240 participants [42].

The descriptive results at baseline are presented as means with standard deviations (SD) or proportions. The differences between the two groups at the baseline were analysed by the Independent samples $t$-test, $\chi^2$ test, or Mann–Whitney $U$ test as applicable. The results of the intervention were analysed according to intention-to-treat (ITT) principle. Differences in time (at the three measurement points) between the two groups (exercisers vs non-exercisers) were tested using a generalised linear mixed model (GLMM). All analyses were adjusted to take the effect of counselling into consideration. Other potential confounding factors were background variables (age, hormonal status, BMI, sub-study and civil status), work- and health-related factors (shift work/regular work, perceived health, blood pressure, tiredness and sleepiness, and current medication), fitness components, and self-reported physical activity. Only those confounding factors that improved the model in the second stage in the sense of Bayesian information criteria were included in the final GLMM.

For the per-protocol (PP) analysis, the study sample was assigned to two groups in order to investigate the effectiveness of the exercise. Those who exercised at least once a week were assigned to the exercise group, and the reference group consisted of those who exercised less than once a week and the controls. The same GLMM models were used for the PP and ITT analyses.

The correlation between the change in LBP intensity and the change in the results of other measurements after the intervention period were calculated by Pearson ($r_p$) or Spearman's correlation coefficient ($r_s$) as applicable. More accurate analyses of the changes in lumbar movement control according to the baseline results were analysed with the $\chi^2$ test. All statistical analyses were conducted using IBM SPSS statistics software (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.).

## Results

A total of 219 women underwent randomisation from October 2011 to August 2013. Of the 219 women, 80% ($n$ = 176) participated in the 6-month follow-up measurements immediately after the intervention period and 72% ($n$ = 157) participated in the 12-month follow-up measurements [41]. The drop-out rate was equal in both study groups (Fig. 1).

The participant characteristics are presented in Table 2. The participants' mean age was 46 years, and they had worked in their current job on average for 11 years. Of the participants, 87% were nurses or nursing assistants, and 70% did shift work. The descriptive results of the outcome measures are presented in Table 3. At baseline, the BMI was higher ($p$ = 0.05) and the results of the modified sit-up tests were lower ($p$ = 0.02) in the exercise group (Tables 2 and 3). There were no other group differences.

### Compliance with exercise

The target was to exercise twice a week for 24 weeks, i.e. to complete 48 sessions. The instructors monitored participation in the supervised group exercise, and study subjects kept an exercise diary for their home practice. The mean attendance rate was 26.3 (12.2) exercise sessions, and 53% of the participants exercised 1–2 times a week.

### Effectiveness of the neuromuscular exercise programme

The results of the exercise intervention according to the ITT analysis are presented as the mean difference with SD, or as percentages at 6 and 12 months in relation to the baseline (in Table 4). The main results are depicted graphically as the percentage change with 95% confidence intervals at 6 and 12 months in Fig. 2. Changes in lumbar movement control from the baseline to 12 months are described graphically in Fig. 3. The results of the effectiveness of the exercise programme according to the PP analysis are presented in Table 5; we decided not to show statistically non-significant results.

### Pain intensity and pain interfering work

At the baseline, the mean pain intensity measured by VAS (0–100) was 36.2 (SD 22.6) [43]. The mean reduction in the exercise group was – 10.7 mm (24.0) at 6 months and – 11.3 mm (21.8) at 12 months compared to – 6.6 mm (26.1) and – 6.1 mm (28.1), respectively, in the non-exercise group (Table 4). The percentage reduction in pain in the exercise group was 30.3% at 6 months and 35.7% at 12 months. The corresponding reductions in the non-exercise group were 21.8 and 19.1%, respectively ($p$ = 0.047; Fig. 2).

In the PP analysis, the difference in pain reduction was greater in the more exercised group ($p$ = 0.029); the mean reduction at 6 months among the more exercised was – 15.4 mm (21.1), i.e. a reduction of 43.0%. This compares to a reduction of – 5.0 mm (26.1) in the less exercised and non-exercisers, i.e. a reduction of 13.7% (Table 5).

When compared to the results of the non-exercise group, pain interfering with work decreased in the exercise group ($p$ = 0.035; Table 4 and Fig. 2). Exercising more did not improve the result in the PP analysis. The participants did not report any adverse events, i.e. an increase in back pain during or after the exercise sessions.

### Lumbar movement control impairments

After the intervention, lumbar MCI decreased more in the exercise group compared to the non-exercise group ($p$ = 0.046; adjusted for education level and one-legged squats; Table 4). At the baseline, 35% of the exercise group had no deficiencies in any of the four movement control impairment tests, 35% had impairments in one test, and 29% had impairments in 2–4 tests (Table 3). The corresponding percentages in the non-exercise group were 33, 36, and 31%, respectively. In the exercise group, of those who had any impairment at the baseline, 68% improved their result, 30% remained unchanged, and 2% were more impaired at 12 months (Fig. 3). The corresponding percentages in the non-exercise group were 46, 39, and 15%, respectively. In the PP analysis, the decrease in MCI was more obvious in the more exercised compared to the less exercised and the non-exercisers ($p$ = 0.017; Table 5 and Fig. 3).

The increase in lumbar movement control did not correlate with the decrease in pain intensity at either 6 months ($r_s$ = 0.03, $p$ = 0.75) or 12 months ($r_s$ = 0.07, $p$ = 0.42).

### Fitness components

Compared to the non-exercisers, abdominal strength increased in the exercisers ($p$ = 0.02). No significant differences between the study groups were found regarding any other fitness components in the ITT analysis (Table 4). The increase in abdominal strength did not correlate with a decrease of pain at either 6 months ($r_s$ = – 0.10, $p$ = 0.09) or 12 months ($r_s$ = – 0.15, $p$ = 0.07).

In the PP analysis, the more exercised increased their walking distance in the six-minute walk test (6MWT) compared to the less exercised and the non-exercisers ($p$ = 0.02; Table 5). The reduction in pain intensity correlated with the increase in walking distance at 6 months ($r_p$ = – 0.17, $p$ = 0.03), but not at 12 months ($r_p$ = – 0.06, $p$ = 0.46).

**Table 2** Background characteristics of the participants by the study group

| | Pilates-type NME group (*n* = 110) | | Controls (no-exercise) (*n* = 109) | | Missing | *p*-value |
|---|---|---|---|---|---|---|
| | % | Mean (SD) | % | Mean (SD) | | |
| Age, years | | 46.2 (6.8] | | 46.6 (6.8) | | 0.69 |
| BMI | | 27.0 [4.7) | | 25.8 [4.0] | 2 | 0.05 |
| Smoking | | | | | | 0.60 |
| daily | 15.5 | | 17.4 | | | |
| occasionally | 10.0 | | 13.8 | | | |
| non-smoker | 74.5 | | 68.8 | | | |
| Civil status: married/cohabiting | 60.9 | | 68.8 | | | 0.22 |
| Education: secondary school or less | 27.5 | | 26.9 | | 2 | 0.50 |
| Occupation | | | | | | 0.31 |
| nurse | 51.0 | | 42.0 | | | |
| nursing assistant | 39.0 | | 42.0 | | | |
| other (PT, midwife, radiographer) | 10.0 | | 16.0 | | | |
| Number of working years | | 11.9 [9.2) | | 10.7 [8.1) | 2 | 0.25 |
| Working times | | | | | 1 | 0.66 |
| Regular work | 32.0 | | 29.0 | | | |
| shift work | 68.0 | | 71.0 | | | |
| Perceived health | | | | | 1 | 0.31 |
| average or below average | 41.0 | | 34.0 | | | |
| better or much better than average | 59.0 | | 66.0 | | | |
| Perceived fitness in comparison to persons of the same age and gender | | | | | 1 | 0.71 |
| lower or much lower | 29.0 | | 27.0 | | | |
| similar | 47.0 | | 53.0 | | | |
| higher or much higher | 24.0 | | 20.0 | | | |
| Number of musculoskeletal pain sites | | 3.3 (1.2) | | 3.1 (1.4) | | 0.31 |
| Depression; PHQ-9 (0–27) | | 7.9 [4.9) | | 7.0 (4.3) | 1 | 0.14 |
| High blood pressure: yes | 15.5 | | 12.0 | | | 0.46 |
| Current use of medication: yes | 52.7 | | 57.9 | | | 0.44 |

*BMI* body mass index, *NME* neuromuscular exercise, *PHQ-9* modified Finnish version of the Patient Health Questionnaire, 9 items measuring depressive symptoms [69]

## Work-related factors

In the longitudinal analysis, the exercise group perceived fewer difficulties in physical functioning at work ($p$ = 0.007) compared to the non-exercise group (Table 4 and Fig. 2). The change was most obvious at 6 months, when the difficulties decreased in the exercise group by 17.1%, while the difficulties increased in the controls by 10.9%. At 12 months, there were no longer group differences (Fig. 2). After adjustments (for age, multisite pain, self-reported physical activity, modified push-ups, and tiredness and sleepiness), the result was not statistically significant. The decrease in difficulties correlated with a decrease in pain intensity at 6 months ($r_s$ = 0.27, $p$ = 0.001). The exercise group seemed to perceive less tiredness and better recovery from work ($p$ = 0.06), and less work-induced lumbar exertion ($p$ = 0.09) compared to the non-exercisers (Table 4), but the differences were not statistically significant in either the ITT or PP analyses.

## Discussion

The novel finding of the present study was that the modified 6-month Pilates-type NME with focus on controlling the neutral spine posture in gradually progressive stages was effective in reducing LBP intensity, pain interfering with work, and impairments in lumbar movement control among female health care workers with sub-acute or recurrent NSLBP measured at 6 and 12 months from the baseline. The NME intervention also decreased difficulties in physical nursing duties, but it was ineffective in improving fitness components other than abdominal strength compared to the results for

**Table 3** Baseline characteristics of pain, movement control of the low back, physical fitness, and work-related factors

| | Pilates-type NME group (n = 110) | | Controls (no exercise) (n = 109) | | Missing | *p*-value |
|---|---|---|---|---|---|---|
| | % | Mean (SD) | % | Mean (SD) | | |
| VAS: intensity of LBP (0–100) | | 36.3 (22.0) | | 36.0 (23.4) | 1 | 0.94 |
| Bodily pain interfering with work (0–100)[a] | | 61.5 (18.7) | | 64.4 (19.3) | 8 | 0.28 |
| MCI sum (0–4) | | 1.0 (1.0) | | 1.1 (1.0) | | 0.94 |
| Deficiencies in MCI test battery | | | | | | 0.91 |
| 0 | 35.5 | | 33.0 | | | |
| 1 | 35.5 | | 35.8 | | | |
| 2–4 | 29.1 | | 31.2 | | | |
| Fitness components: | | | | | | |
| 6MWT | | 619.4 (50.4) | | 624.0 (48.3) | 1 | |
| Modified sit-ups | | 17.2 (4.6) | | 18.4 (3.7) | 1 | 0.02 |
| % reaching the maximum of 20 | 61.5 | | 75.2 | | | 0.03 |
| One-legged squats | | 9.4 (2.7) | | 9.5 (2.4) | 3 | 0.72 |
| Modified push-ups | | 9.0 (3.4) | | 9.0 (2.8) | 6 | 0.94 |
| Work-related factors: | | | | | | |
| Difficulties in patient handling (0–80) | | 6.0 (4.9) | | 6.6 (5.2) | 13 | 0.43 |
| Work-induced lumbar exertion | | | | | | 0.45 |
| little exertion | 26.9 | | 31.5 | | 3 | |
| moderate to high exertion | 73.1 | | 68.5 | | | |
| Tiredness and recovery from work (4–18) | | 10.4 (3.4) | | 10.0 (3.2) | 1 | 0.20 |

*6MWT* six-minute walk test, *MCI sum* sum score of movement control impairment tests, *NME* neuromuscular exercise. [a]0 = worst possible pain and extreme difficulties, 100 = no pain and no difficulties

non-exercisers. However, the more exercised did gain better results in the reduction of pain intensity, lumbar movement control, and 6MWT.

Although nursing is among the top risk professions for LBP, and although exercise is commonly recommended as treatment for people with LBP, only a few high-quality intervention studies considering exercise for healthcare workers with LBP have been published. In a recent systematic review [70] investigating intervention studies among nursing personnel with LBP, only three RCTs including exercise in the interventions and having a low risk of bias were found. Stretching [71] or combined strength training and stretching [72] decreased pain among nurses with chronic pain, but a programme including counselling, segmental stabilisation, and general exercise was not superior to general exercise alone in reducing pain among nurses with sub-acute LBP [73]. At present there is no strong evidence for the efficacy of any intervention in the prevention or treatment of LBP in nursing personnel [70].

The contents and length of our NME programme focusing on control of the lumbar spine posture differed from the above-mentioned exercise programmes. On the other hand, our results are in line with previous studies emphasising control of a lumbar neutral spine posture in both exercise and counselling conducted among people with strenuous work [25, 62].

Among general population with LBP, lumbar movement control exercises appear to be more effective in reducing pain in short term, and in improving disability in long term. However, the quality of evidence varies from very low to moderate. Based on the available studies, it is difficult to assess the relative effectiveness of lumbar movement control exercises compared to other interventions offered to people with LBP [27].

Exercise is the most effective treatment for the management and prevention of spinal pain [17]. However, knowledge regarding how and why exercise programmes work is somewhat limited. Physical activity and exercise have been shown to activate endogenous pain inhibitory mechanisms and lead to a reduction in sensitivity to noxious stimuli (termed "exercise-induced hypoalgesia") regardless of the type of physical activity [74–76]. Protective effect of practising regular exercise on developing LBP has recently revealed among healthcare workers [11].

Two common assumptions about LBP are 1) that motions, postures, and loads are responsible for tissue damage or irritation that leads to pain [77] and 2) "risky" movements both during work and also during physical training can eventually result in cumulative tissue damage [78, 79].

Many people with LBP have altered lumbar proprioception [61, 80], and they are probably less "movement

**Table 4** Difference between the groups at the 6- and 12-month follow-ups in relation to baseline, adjusted for age, perceived health, multisite pain, blood pressure, current use of medication, fitness, and civil status

| | Baseline | | | | | Difference in relation to baseline | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 6 months | | | | | 12 months | | | | | | |
| | Pilates-type NME $n = 110$ | | Controls $n = 109$ | | M | Pilates-type NME $n = 88$ | | Controls $n = 88$ | | M | Pilates-type NME $n = 79$ | | Controls $n = 78$ | | M | *p*-value | *p*-value, adjusted |
| | % | Mean (SD) | % | Mean (SD) | | % | Mean (SD) | % | Mean (SD) | | % | Mean (SD) | % | Mean (SD) | | | |
| VAS (0–100) | | 36.3 (21.9) | | 36.1 (24.0) | 1 | | −10.7 (24.0) | | −6.6 (26.1) | 14 | | −11.3 (21.8) | | −6.1 (28.1) | 8 | 0.076 | 0.047 |
| Pain interfering with work (0–100) | | 61.5 (18.7) | | 64.4 (19.3) | 8 | | 11.0 (18.0) | | 2.6 (19.3) | 14 | | 7.2 (18.1) | | 1.3 (25.5) | 9 | 0.035 | 0.046 |
| MCI (0–4) | | 1.1 (1.0) | | 1.1 (1.0) | – | | −0.5 (1.0) | | −0.3 (1.0) | – | | −0.5 (1.0) | | −0.2 (1.1) | – | 0.036 | 0.042 |
| *Fitness components:* | | | | | | | | | | | | | | | | | |
| 6MWT (metres) | | 614 (50.8) | | 620 (48.8) | 1 | | 21.5 (35.4) | | 8.9 (34.4) | 2 | | 22.7 (32.5) | | 13.7 (36.4) | 6 | 0.075 | 0.273 |
| Modif. push-ups | | 9.1 (3.4) | | 9.0 (2.8) | 6 | | 1.7 (2.0) | | 1.6 (1.9) | 10 | | 2.4 (2.6) | | 2.5 (2.2) | 13 | 0.862 | 0.979 |
| Sit-ups; % reaching 20 repetitions max. | 62 | | 75 | | 1 | 74 | | 76 | | 1 | 77 | | 77 | | 2 | 0.016 | 0.033 |
| One leg squats (0–12) | | 9.4 (2.7) | | 9.5 (2.4) | 4 | | 0.4 (1.5) | | 0.6 (1.4) | 10 | | 0.3 (1.7) | | 0.5 (1.3) | 20 | 0.631 | 0.420 |
| *Work-related factors:* | | | | | | | | | | | | | | | | | |
| Work-induced lumbar exertion | | | | | 3 | | | | | 16 | | | | | 10 | 0.086 | 0.138 |
| little | 27 | | 32 | | | 51 | | 44 | | | 48 | | 36 | | | | |
| moderate to high | 73 | | 68 | | | 49 | | 56 | | | 52 | | 64 | | | | |
| Physical functioning in nursing tasks (0–80) | | 6.1 (4.9) | | 6.6 (5.2) | 11 | | −0.9 (4.4) | | 0.3 (4.9) | 26 | | −0.3 (4.8) | | −0.6 (4.7) | 27 | 0.007 | 0.061 |
| Tiredness and recovery (4–18) | | 10.4 (3.4) | | 10.0 (3.2) | 1 | | − 0.7 (2.5) | | − 0.3 (2.3) | 13 | | −0.3 (3.2) | | 0.4 (2.3) | 7 | 0.061 | 0.180 |

*6MWT* 6 min. Walk test, *M* missing, *MCI* movement control impairment, *NME* neuromuscular exercise, *VAS* visual analogue scale

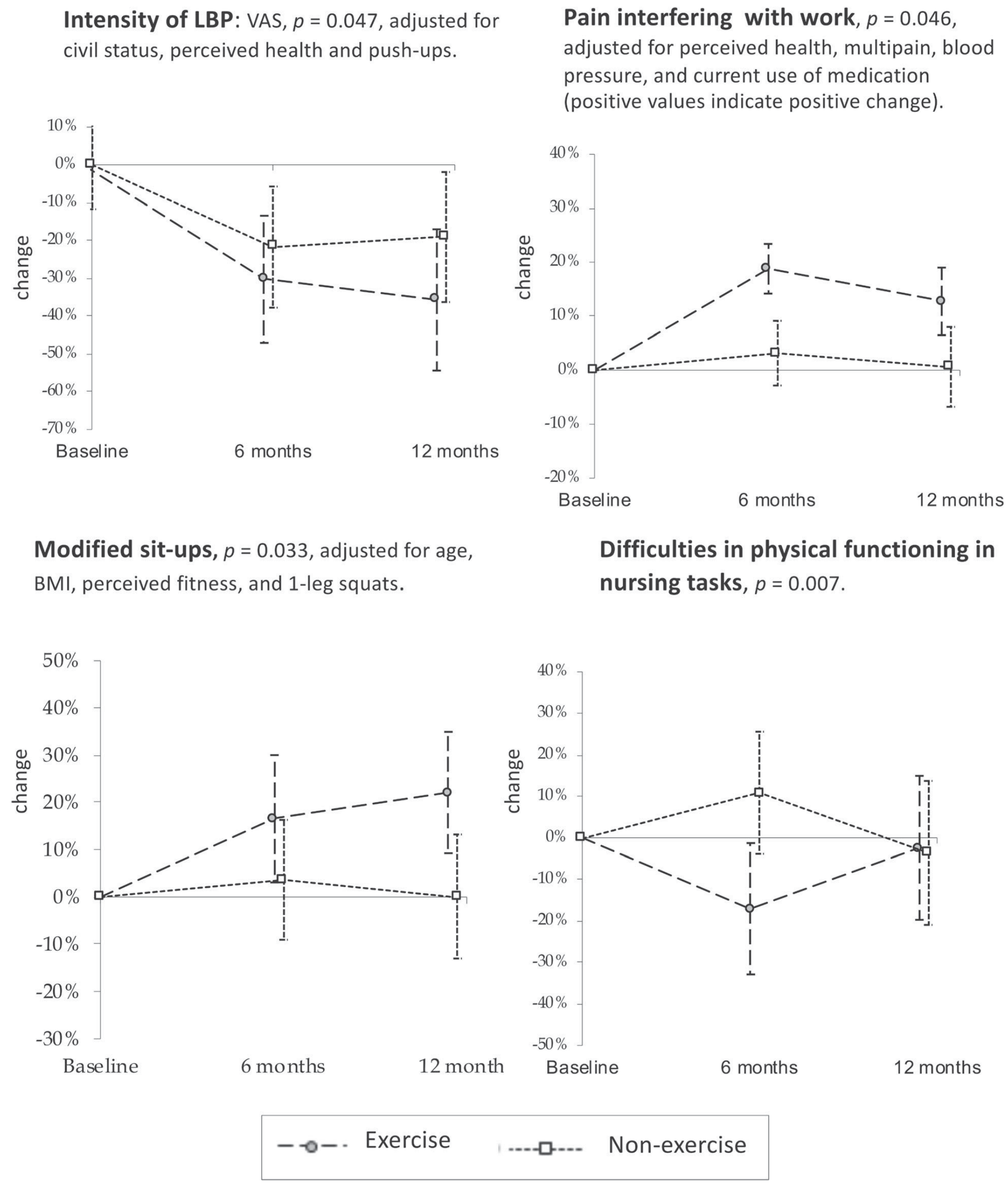


**Fig. 2** Mean percentage change (95% confidence interval) at 6 and 12 months from baseline

aware", with reduced postural control [80] and altered spinal movement patterns [81]. Placing an emphasis on how participants move (i.e. posture and movement control, performance technique, and alignment) may be an effective training strategy to transfer desirable movement patterns to occupational tasks [78, 82]. Frost et al. [78] compared firefighters assigned to a 12-week programme of movement-guided fitness training, conventional

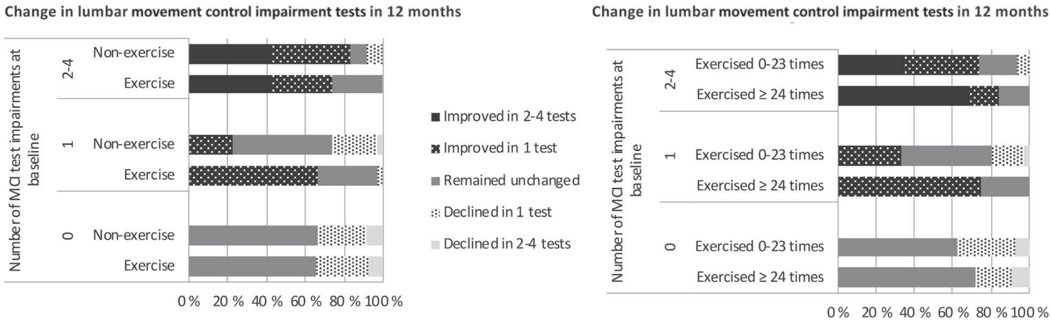


**Fig. 3** Change in lumbar movement control (MCI) test results from baseline to 12 months. **a** Changes among exercisers (*n* = 79) and non-exercisers (*n* = 78), and (**b**) among exercise compliers (exercised ≥24 times, *n* = 52) and a combined group of less exercised and non-exercisers (exercised 0–23 times, *n* = 105)

fitness training, or a control group. Both fitness-training groups showed significant improvements in all fitness categories, but only the movement-guided group showed spine and knee motion control when performing different occupational tasks [78]. In addition, a single motor skill training session emphasising intrinsic feedback to decrease early-phase lumbar excursion can result in better lumbar movement control in functional tasks among people with LBP [83]. These results support the argument that exercise can be used to change motor behaviour, provided that movement-oriented feedback is offered when exercising. In a physically demanding job like firefighting or nursing, being physically fit may play a role in the prevention of future injuries, but it is likely insufficient for this purpose on its own [78]. The way in which movements are controlled and coordinated influences musculoskeletal loading [78].

The exercise programme in the present study included exercises targeted at increasing the strength and endurance of the torso muscles, but we detected significant changes only in abdominal muscle strength. In the PP analysis, the more exercised improved their walking distance in the 6MWT compared to the less exercised and the controls. The exercise programme was not targeted at improving aerobic fitness. Thus, the result can be explained by either the reduction of pain or increased hip and/or thoracic spine mobility (which were practiced in the exercise group, but not measured in the study).

In the exercise programme, special emphasis was placed on movement control, posture, and breathing, which are considered important when applying Pilates exercises for people with LBP [84]. A focus on breathing is one special feature that distinguishes Pilates-type exercise from conventional exercise programmes. There is low to moderate evidence that breathing exercises can reduce pain in chronic NSLBP [85]. In the practice of Pilates, the breathing technique is called lateral breathing, and the exercises are conducted at the pace of each participants' calm breathing tempo [66]. This technique was also followed in the present study. The possible effects of this kind of technique on pain remain unclear due to the lack of measurements.

In the literature, standardised exercise programmes for people with LBP are criticised for presenting the idea that a "one size fits all" approach is appropriate for a multifactorial problem like LBP [17]. The current

**Table 5** Efficacy of the Pilates-type neuromuscular exercise programme: difference in relation to baseline between once a week or more exercised (≥24 exercise sessions) and a combined group of less exercised and controls (≤23 exercise sessions + controls), adjusted for perceived health, BMI, fitness, education, and civil status

| | Baseline | | Difference in relation to baseline: 6 months | | Difference in relation to baseline: 12 months | | | |
|---|---|---|---|---|---|---|---|---|
| | More exercised *n* = 58 | Less exercised + controls, *n* = 161 | More exercised, *n* = 58 | Less exercised + controls, *n* = 118 | More exercised, *n* = 52 | Less exercised + controls, n = 105 | | |
| | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | *p*-value | *p*-value, adjusted |
| VAS (0–100) | 36.8 (20.0) | 35.9 (23.6) | −15.4 (21.7) | −5.0 (26.1) | −12.7 (22.6) | −6.67 (26.1) | 0.057 | 0.029 |
| MCI (0–4) | 1.0 (1.1) | 1.1 (1.0) | −.05 (1.0) | −0.3 (0.9) | −0.5 (1.0) | −0.2 (1.0) | 0.016 | 0.017 |
| 6MWT (metres) | 623 (43.8) | 615 (51.8) | 27.3 (32.9) | 9.3 (35.2) | 25.9 (36.5) | 14.5 (33.3) | 0.020 | 0.065 |

*6MWT* 6 min. Walk test, *BMI* body mass index, *MCI* movement control impairment, *VAS* visual analogue scale opinion emphasises the bio-psychosocial nature of LBP, where comorbidities and lifestyle factors also play an important role [86]. In the original NURSE RCT with the four-arm setting, the back-care counselling intervention was more concerned with psycho-social and lifestyle factors [41, 42]. The combined exercise and back-care counselling intervention was also more effective in reducing LBP intensity and sickness absence than exercise alone [41].

In general, the NME programme used in the present study was feasible and the biomechanical principles can be modified into other kind of exercise training. This NME program can be recommended specially for those who are interested in Pilates- or yoga-type NME, but the exercises can be tailored according to patient's preferences to improve exercise adherence. The NME program improved several measurement variables and reduced pain compared to no exercise in the early rehabilitation of a sample who had non-chronic low back troubles and were at risk for chronic pain due to physically burdensome work [12, 87]. Many European countries are facing shortages of healthcare workers, and decreased work ability is an important determinant of leaving the nursing profession [88]. Therefore, interventions targeted at risk factors causing LBP and the early rehabilitation of LBP among healthcare workers are needed. In this study, we presented one type of effective, feasible exercise programme, but we cannot say that it is superior to any other exercise type.

### Limitations of the study

The main limitations of the study relate to the measurement methods and only moderate exercise compliance.

Lumbar movement control was assessed by a battery of four, repeatable MCI tests [49], (waiter's bow, pelvic tilt, sitting knee extension, prone knee flexion), but the test battery is probably not sensitive enough to detect all (or the smaller) changes in movement control. The four tests measure lumbar movement control principally in the sagittal plane, not in the frontal or horizontal plane, which are essential in both walking and performing nursing duties that often involve standing in asymmetric poses.

We used field tests to measure physical fitness. Smaller changes in muscular strength and endurance cannot be detected with the tests used. With the measurement methods used in the study, we cannot define which elements of the exercise programme caused the reduction in pain. The reason for the pain reduction could be regular exercise in itself, learning to control the movement of the lumbar spine, strengthening the musculature in the torso, or focusing on breathing with the movements – or a combination of all these factors.

Compliance with the exercise regimen was only moderate, which is usual in exercise intervention studies for people with musculoskeletal pain [89]. A training programme of 6 months is quite long in comparison to the duration of 6–12 weeks used in several other studies [39]. Needless to say, only those exercise programmes that are performed can be effective. Thus, a more accurate analysis of the compliance rate and the possible association with baseline factors will be investigated with this study sample in the future. On the other hand, positive changes in several measurement variables were detected with a dose lower than targeted. The compliance rate was probably too low to affect fitness or work- related measurements. A supervised exercise programme of 6 months is also expensive [41], and we do not know if a shorter programme would have been as effective.

## Conclusion

The 6-month modified Pilates-type NME intervention was effective in reducing pain, lumbar movement control impairments, and pain interfering with work; it also improved abdominal strength and physical functioning in nursing tasks among healthcare workers with subacute or recurrent LBP compared to not exercising. There was a dose-response for effects on pain intensity and lumbar movement control. The exercise programme was feasible, and its principles can be applied to other kinds of exercise programmes.

## Additional file

**Additional file 1:** Modified Pilates-based neuromuscular exercise program with focus on controlling the neutral lumbar spine posture (PDF 1593 kb)

### Abbreviations

6MWT: Six-minute walk test; BMI: Body mass index; GLMM: Generalised linear mixed model; ITT: Intention-to treat; LBP: Low back pain; MCI: Movement control impairment; NME: Neuromuscular exercise; NRS: Numeric rating scale; NSLBP: Non-specific low back pain; PP: Per protocol; RCT: Randomised controlled study; $r_p$: Pearson correlation coefficient; $r_s$: Spearman's correlation coefficient; SD: Standard deviation; VAS: Visual analogue scale

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### Authors' contributions

AT is the corresponding author, and she drafted the manuscript. She planned the exercise intervention, trained the other exercise instructors, produced the exercise videos and booklets, and supervised some of the exercise groups. She is responsible for the descriptive and bivariate statistical analysis, tables, figures, and interpretation and presentation of the results. MK contributed to the design of the present study, and the interpretation and presentation of the results. KT verified the descriptive and bivariate statistical analysis, and he conducted all the multivariate analyses, including figures. He contributed to the presentation of the results of the statistical analysis. JP is the responsible medical doctor of the study. He contributed to the interpretation and presentation of the results of the present study. JS is the principal researcher of the NURSE RCT. She is responsible for the study design and measurement selection for the present study. She contributed to planning the exercise intervention and presentation of the results. All authors read and approved the final manuscript.

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**Availability of data and materials**
The datasets used and analysed during the current study are available from the principal researcher (JS; jaana.suni@ukkinstituutti.fi) of the NURSE RCT upon reasonable request.

**Ethics approval and consent to participate**
The participants gave their informed consent at their first visit to the research centre (i.e. at the baseline measurement of the study), and the trial was conducted according to the Declaration of Helsinki. The study was approved by the Ethics Committee of Pirkanmaa Hospital District, Finland (ETL code R08157).

**Consent for publication**
The individual depicted in the images in Additional file 1. provided her written informed consent for the publication of these identifiable images.

**Competing interests**
The authors declare that they have no competing interests.

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Additional file 1.

## Modified Pilates-based neuromuscular exercise program with focus on controlling the neutral lumbar spine posture

**Overall target**: to reduce pain-induced disturbances of movement control and increase the muscular strength and endurance needed in heavy nursing tasks

In each exercise the participants were instructed to concentrate on (1) the maintenance of neutral spine posture using light co-contraction of the trunk muscles, and (2) neutral alignment between body parts

In all exercises, the target was to combine breathing with exercises, and thus take advantage of the spine-supporting role of the increased intra-abdominal pressure.

**In warm-up**, light so called pre-Pilates exercises were performed. Also flexibility exercises, presented under the Target number 5, were included.

**Repetitions and progression:**

6-8-10 repetitions. During progression, increasing the range of motion (deeper squats; flexibility exercises) or increasing the holding time were instructed as applicable.

**<u>Specific targets and description of the corresponding exercises :</u>**

### 1. To increase spinal stability using exercises that minimise the load on spinal structures but induce a high level of muscular activity

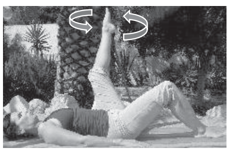
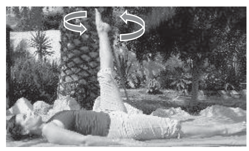
Stage I | Stage II | Stage III

Modified curl-up
(”McGill curl up)

Bird dog

Side bridge or
Mermaid

**2. To improve the endurance of the trunk musculature**

| | Stage I | Stage II | Stage III |
|---|---|---|---|
| The 100 |  |  |  |
| 1 leg stretches |  |  |  |
| Shoulder bridge with 1 leg lifts |  |  |  |
| 1- and 2-leg lifts |  |  |  |
| Kobra → 1-leg kicks |  |  |  |
| Lifting the knees in 4-point kneeling ; weight shifts forwards and backwaords in plank pose |  |  |  |
| 1-leg circles to both directions |  |  |  |

**3. To improve balance, postural control and light co-contraction of the stabilising muscles around the lumbar spine**

**4. To increase the muscular strength of the lower limbs in functional squatting movements**

”Tai chi –warrior”. Progression: coordinative demands with arm movements, deeper squat

| Stage I | Stage II | Stage III |
|---|---|---|
|  |  |  |
|  |  |  |

Different squats with weight shifts, arm movements or rotation of upper body

**5. To achieve a normal range of motion in the spine, especially in the thoracic region and the hip and ankle joints**

# PUBLICATION
# IV

**Fear-avoidance beliefs are associated with exercise adherence: Secondary analysis of a randomised controlled trial (RCT) among female healthcare workers with recurrent low back pain**

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RESEARCH ARTICLE **Open Access**

# Fear-avoidance beliefs are associated with exercise adherence: secondary analysis of a randomised controlled trial (RCT) among female healthcare workers with recurrent low back pain

Annika Taulaniemi[1*], Markku Kankaanpää[2], Marjo Rinne[1], Kari Tokola[1], Jari Parkkari[1] and Jaana H. Suni[1]

## Abstract

**Background:** Exercise is recommended for the treatment and management of low back pain (LBP) and the prevention of chronicity. Exercise adherence has been only modest in intervention studies among people with musculoskeletal pain. Fear-avoidance beliefs (FABs) are known to affect exercise adherence.

**The purpose** was twofold: to examine which bio-psycho-social factors contributed to exercise adherence during a 6-month neuromuscular exercise intervention among female healthcare workers with recurrent LBP, and to investigate how exercising affects FABs at 6 and 12 months' follow-up.

**Methods:** Some 219 healthcare workers aged 30–55 years with mild-to-moderate re-current non-specific LBP were originally allocated into: 1) exercise, 2) counselling, 3) combined exercise and counselling, and 4) control groups. In the present secondary analysis, groups 1 and 3 (exercise only and exercise+counselling) were merged to be exercisers and groups 2 and 4 were merged to be non-exercisers. Baseline variables of the exercise compliers (≥24 times over 24 weeks; $n = 58$) were compared to those of the non-compliers (< 1 time/week, 0–23 times; $n = 52$). The effects of the exercise programme on FABs were analysed by a generalised linear mixed model according to the intention-to-treat principle (exercisers; $n = 110$ vs non-exercisers; $n = 109$) at three measurement points (baseline, 6, and 12 months). A per-protocol analysis compared the more exercised to the less exercised and non-exercisers.

**Results:** A low education level ($p = 0.026$), shift work ($p = 0.023$), low aerobic ($p = 0.048$) and musculoskeletal ($p = 0.043$) fitness, and high baseline physical activity-related FABs ($p = 0.019$) were related to low exercise adherence. The exercise programme reduced levels of both physical activity- and work-related FABs, and there was a dose response: FABs reduced more in persons who exercised ≥24 times compared to those who exercised 0–23 times.

(Continued on next page)

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(Continued from previous page)

**Conclusion:** Healthcare workers who had lower education and fitness levels, worked shifts, and had high physical activity-related FABs had a lower adherence to the 6-month neuromuscular exercise programme. Exercising with good adherence reduced levels of FABs, which have been shown to be linked with prolonged LBP. Motivational strategies should be targeted at persons with low education and fitness levels and high FABs in order to achieve better exercise adherence.

**Keywords:** Exercise compliance, Neuromuscular exercise, Pilates, Fear of pain, Lumbar pain, Exercise intervention study, Nursing

## Background

Low back pain (LBP) is common among people in all ages, but disability from LBP is highest in working-age groups [1]. Among healthcare workers, LBP is the leading musculoskeletal disorder [2] and it has been reported to be the most costly and common self-reported disease [3]. Major contributors to the high incidence of LBP among healthcare workers are physically heavy nursing duties, such as lifting and transferring patients, and working in awkward positions [2, 4, 5].

In physically demanding work duties, maintaining a healthy back requires adequate aerobic and musculoskeletal fitness level [6–8]. Low ratings of self-reported physical capacity have been shown to be a predictor for future LBP in female healthcare workers [9]. Female nurses with a recent back injury also show more impairment in lumbar movement control [10], which has also been suggested to play an important role in maintaining a healthy back [11, 12]. A systematic review on efficacy of interventions for LBP in nursing personnel [13] revealed no strong evidence of efficacy for any intervention in preventing or treating LBP in healthcare workers.

Exercise is the most often recommended treatment for increasing fitness levels [14], lumbar movement control [12], and for the management and prevention of LBP [15–19]. Thus, in the management of spinal pain exercise adherence is important to realise the beneficial effects of exercising. Adherence is a key link between the process and outcome of exercise interventions among people with musculoskeletal pain, and poor exercise adherence compromises the effectiveness of treatment [20].

Barriers to exercise adherence, such as pain with exercise [21], fear of movement and pain aggravation [22], low self-efficacy [21], psychological dysfunction [21], poor social support [21], lack of time [23], and uncertainty about the benefits of exercise [24], have been reported among people with musculoskeletal pain [21, 22, 24, 25]. Aforementioned studies have been conducted among older adults [25], people with chronic LBP [26] or other chronic musculoskeletal pain [22, 24] or among people receiving physiotherapy [21]. To our knowledge, similar studies which concern exercise adherence among people with heavy physical work and non-chronic LBP have not been conducted.

Fear avoidance is the belief that activities should be avoided to reduce pain [27]. Fear of pain develops as a result of a cognitive interpretation of nociseption as something threatening, and this fear affects attention processes (hypervigilance) and leads to the avoidance of behaviours, like physical activity and exercise, which are expected to cause pain [27]. Fear-avoidance beliefs (FABs) influence treatment effects and are prognostic to poor outcomes in subacute LBP [28]. Cognitive behavioural therapy is recommended to reduce FABs among people with LBP [29, 30], but effects of exercise interventions on FABs among people with sub-acute or recurrent LBP are less clear.

Besides FABs, there are probably several other internal factors (like a lack of interest [31], and low self-efficacy [32]) that compromise adherence to exercise among people with LBP. Exercise might be avoided, because it is believed to cause pain, one is uncertain about the benefits of exercising, and one's capabilities to perform and manage the instructed exercises [32]. If those internal factors are combined with external barriers (like lack of time, environment, and transfer), exercise adherence might be challenging.

Among people with chronic LBP, improvements in physical functioning are more strongly associated with adherence to exercise than with the type of exercise [26]. Some 50–70% of people with chronic LBP are non-adherent to prescribed home exercise [33]. Thus, factors associated with adherence to exercise in LBP require more investigation [33]. Exercise adherence among people with musculoskeletal pain in general is a poorly studied subject [20].

In a previously reported study, we found that a 6-month modified Pilates-type neuromuscular exercise intervention, which focused on controlling the neutral lumbar spine posture and developing the muscle strength and endurance needed in heavy nursing tasks, was effective in reducing lumbar pain and lumbar movement control impairments among a sample of nursing personnel with sub-acute or recurrent LBP [34]. In the 6-month intervention, the target was to exercise twice a week, i.e. 48 times in 24 weeks. Exercise adherence was only modest; the mean attendance rate was 26.1 (of the targeted 48). The reduction of LBP intensity and lumbar movement control impairment was significantly better in those who exercised once a week or more compared to the less exercised and non-exercisers [34]. Thus, factors affecting exercise adherence needed more investigation. Our hypothesis was that pain intensity, psychological, and environmental factors compromise exercise adherence, and that the modified Pilates-type exercise reduces FABs-PA.

The purpose of this study was to (1) investigate the effects of baseline bio-psychosocial factors on exercise adherence among female healthcare personnel with sub-acute or recurrent LBP. Furthermore, we sought to (2) examine the effects of the exercise intervention on the development of FABs over time (at 6 and 12 months' follow-up).

## Methods

### Study design

This study is based on the data of a four-arm randomised controlled trial (RCT) among female healthcare personnel (NURSE-RCT, clinical trial registration NCT01465698) [35], in which healthcare personnel with sub-acute or recurrent LBP were randomised to participate in neuromuscular exercise/non-exercise and to receive/not receive back care counselling for 6 months [36]. In the secondary analysis, those receiving exercise (combined exercise + counselling, and exercise only) were merged to be exercisers, and non-exercisers (counselling only and controls) were merged to be the controls [34].

The study was conducted in the form of three identical consecutive sub-studies. The participants were female healthcare workers in physically demanding duties: in old people's homes and geriatric wards (in the first sub-study in 2011, $n = 56$); in home service, public healthcare units, and community hospital wards (in the second sub-study in 2012; $n = 80$); and in university hospital wards (in the third sub-study in 2013; $n = 83$) in the city of Tampere, Finland. The protocol and time frame of each sub-study are presented in the study protocol [35]. The recruitment of participants, eligibility criteria, and reasons for exclusion have been previously described in detail [36]. Briefly, 30–55-year-old female healthcare workers were eligible if they had worked in their current job for at least 12 months and had experienced LBP of an intensity of 2 or above on a numeric rating scale (NRS; 0–10) [37] during the previous 4 weeks. The exclusion criteria were a specific or serious earlier back condition (disc protrusion, fracture, surgery), chronic LBP (pain duration ≥7 months), pregnancy or recent delivery (< 12 months), and engagement in a neuromuscular-type exercise (NME) more than once a week.

The power calculations, recruitment process, randomisation, and ethical issues of the NURSE-RCT have been presented previously [35], as have the contents of the exercise intervention [34].

The study design and flow of the participants are shown in Fig. 1.

### Participants

The participants were female healthcare workers who engaged in physically demanding work (including lifting, patient transfer and working in awkward positions) and suffered from sub-acute or recurrent LBP. The mean age of the participants was 46 years, and they had worked in their current job on average for 11 years [7]. Some 87% were nurses or nursing assistants, and 70% did shift work [7]. In the pre-study screening, most of the study subjects (82%) experienced LBP on a few or most days of the week, but not daily, while 18% had LBP daily [7]. At the baseline, the mean of the pain intensity measured on a visual analogue scale (VAS; 0–100) [38] during the previous 4 weeks was 36.2 (SD 22.6) [7]. The majority (77%) of the study sample can be described as having sub-acute, mild-to-moderate, recurrent or fluctuating non-specific LBP (4). Among those with daily pain (18%), the pain intensity was higher the mean in VAS being 55.7 (25.3).

### Measurements

A wide range of measurements was taken at the baseline. In addition to background factors (age, education level, marital status, occupation, number of working years in the current job, working hours, smoking, perceived health and perceived fitness in comparison to persons of the same age and gender, current use of medication, high blood pressure (yes/no), and hormonal status); LBP intensity (VAS; 0–100) during the previous 4 weeks [38]; the frequency of LBP; the number of musculoskeletal pain sites [7]; quality of life (RAND 36) with eight subscales [39, 40]; depression (using the modified Finnish version of the Patient Health Questionnaire; PHQ-9) [41]; the short form of the workability index [42]; physical functioning in nursing tasks [35]; tiredness, sleepiness, and difficulties in recovering from work [43]; work-induced exertion in different body parts [44]; and psychosocial factors at work (Finnish work satisfaction questionnaire) [45] were investigated by questionnaires. FABs were measured with a questionnaire assessing FABs related to work (FAB-W) and physical activity (FAB-PA) [46]. Three questions considering long-term sick leave were removed from the original FABs questionnaire, because the participants were still in work [35].

Physical measurements included body mass index (BMI), movement control of the low back [47, 48], and performance tests for physical fitness, namely aerobic

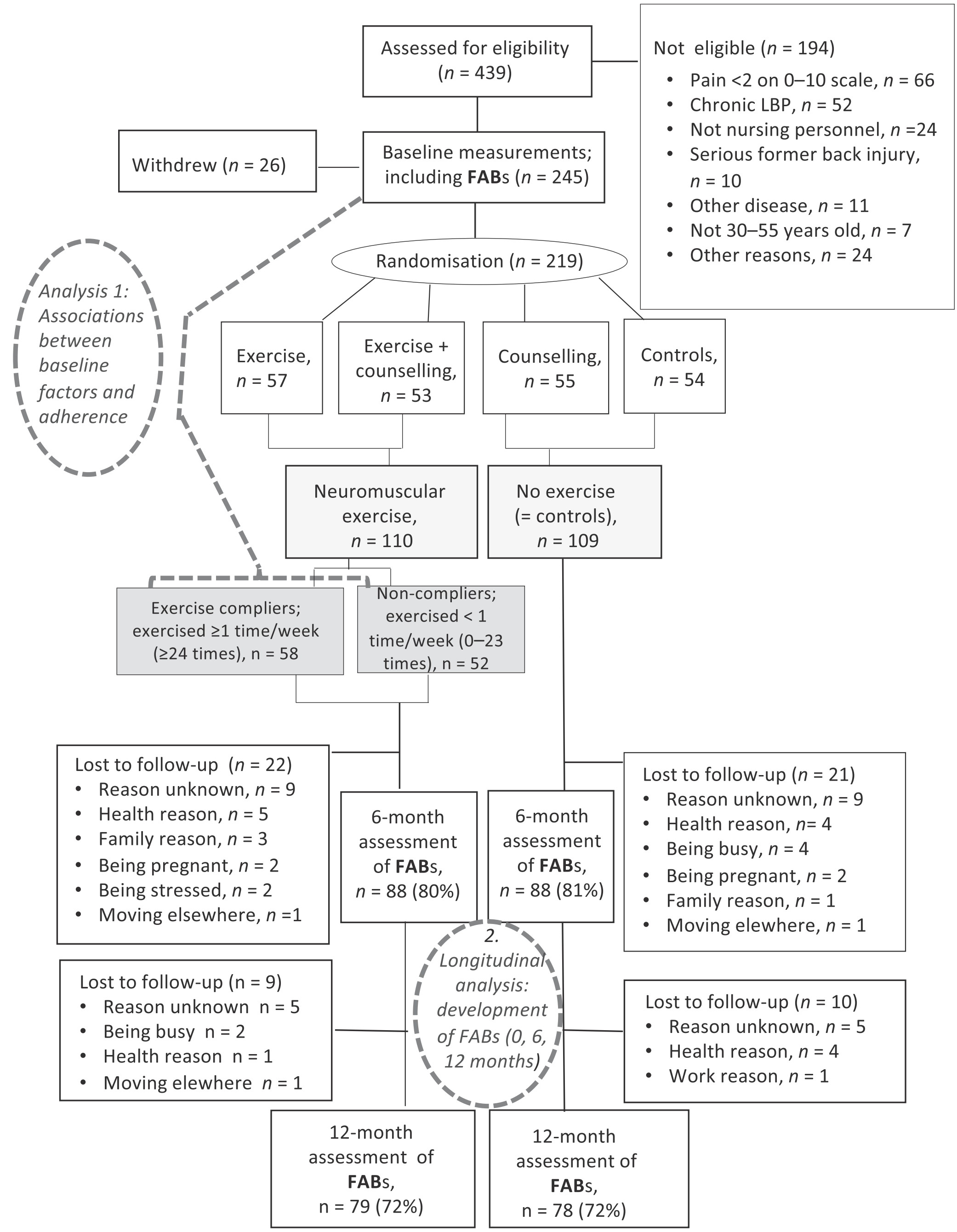


**Fig. 1** Trial profile (CONSORT flow chart). Footnot to Fig. 1: Analysis methods for studying (1) the associations between baseline factors and exercise adherence rate, and (2) the effects of the exercise intervention on fear-avoidance beliefs (FABs)

fitness by the 6-min walk test [49], muscular strength (modified push-up [50], one-legged squat with progressively increasing external load (10% of body weight after each performance up to 40%) [50], vertical jump [50], modified sit-ups [51]), agility by running a figure-of-eight [52], flexibility by trunk lateral side bending [50], and rhythm coordination [52]. More precise information on the measurements is given in the study protocol article [35], the article on the repeatability of the physical measurements [48], and the baseline analysis of the study sample [7].

### Exercise interventions in the NURSE-RCT

The contents of the 6-month exercise intervention have been described previously [34]. The modified 6-month Pilates-type exercise intervention programme, which focused on controlling the neutral spine posture, started with light and easier exercises, and it was progressive in terms of demands for coordination, balance, and muscular strength over three stages. The goal was to exercise twice a week; during the first 2 months (stage I) in supervised neuromuscular exercise (NME) classes (lasting 60 min) and during the next 4 months (stages II and III) in one supervised class and one home session with the help of a DVD (lasting 50 min) or booklet produced for the study [34]. During stages II and III, the participants were also allowed to exercise in supervised group sessions more than once a week if exercise at home was inconvenient, and also only at home if the group sessions were difficult to attend. During the progression (stages II and III), the participants were allowed and/or advised to do easier exercises from the previous stage if the more challenging exercises proved too demanding.

The leaders of the neuromuscular exercise groups were all certified Pilates instructors with a background in physiotherapy, a master's degree in health sciences, or both [34]. Supervised exercise groups were organised in facilities near the workplaces of the healthcare personnel. Group sessions were provided on weekdays starting 15 min after the typical work shifts ended. The exercise classes, videos, and booklets were free for the participants, but they exercised in their own time [36].

### Adherence to exercise

The instructors monitored the participation of supervised group exercise, and study subjects kept an exercise diary of their home practice. The structured exercise diaries were returned at the end of stage II (week 16) and stage III (week 24). Attendance of the supervised exercise sessions and the number of home exercise sessions were added together to determine the total exercise attendance rate.

### Motivational strategies

All participants in the exercise group received an information letter at the beginning of the exercise intervention about the goals and principles of the exercise programme. During the 4th week of the first-stage exercise period, those who had not participated in any group-based exercise sessions received a telephone call from a research nurse (not involved in the exercise intervention or measurements), who encouraged them to start to exercise. All participants received two material packages (between stages I and II, and between stages II and III), which included an exercise DVD, exercise booklet, exercise diary for home practice, and a letter including information about the study and the importance of regular exercise. They also received two e-mails during stage II in order to encourage exercise, and a letter before the 6-month follow-up measurements from the principal investigator (JS).

To avoid any contamination to the back care counselling intervention (in the original four-arm setting), and to ensure exactly the same information to all who were allocated to the exercise group, the exercise instructors focused on instructing the standardised exercise programme (individual modifications due to musculoskeletal problems other than LBP were allowed). All other kinds of counselling (e.g. lifestyle, pain management, and ergonomics) were avoided in the exercise classes.

### Statistical methods

Power calculations (at least 160 subjects needed) for the original NURSE-RCT have been reported previously [35], as has the randomisation of the participants [36].

Partial correlation analysis was conducted between all background and baseline variables and the adherence rate to determine which of the 60 different variables could have an association with the exercise adherence. Those variables showing a statistically significant association with the exercise adherence rate were selected for bivariate analysis with the adherence rate; the analytical methods were Spearman's correlation for continuous variables and the Kruskall–Wallis test for the categorical variables.

The median (24 times) was used to split the exercise group into the compliers (those who exercised once a week or more; ≥24 times during the 24 weeks) and non-compliers (those who exercised 0–23 times) We examined the baseline characteristics of the participants randomised to the exercisers by the adherence status for those variables showing statistically significant associations with the adherence rate in the bivariate analysis. The analytical methods were the independent samples *t*-test, the $\chi^2$ test, or the Mann–Whitney *U* test as applicable.

To analyse the effects of the exercise programme on FABs, the mean differences in time (at three measurement points: baseline, 6 months, and 12 months) between the two groups (exercisers vs non-exercisers) were tested using a generalised linear mixed model (GLMM) (Fig. 1). To take the interaction between back counselling and exercise into consideration, all analyses were first adjusted for counselling. Second, the sub-study was included as a random effect in all the GLLM analysis models to indicate the possible heterogeneity between the study sites and study time in the three consecutive sub-studies. Other confounding factors were background variables (age, civil status, education), work-related factors (shift work/regular work, psycho-social factors at work [45], perceived work-induced lumbar exertion [44]), and health-related factors (BMI, hormonal status, perceived health, perceived fitness, blood pressure, current medication, self-reported physical activity and fitness components). Only those confounding factors that improved the model in the second stage in the sense of Bayesian information criteria were included in the final adjusted model.

After analysis according to the intention-to-treat (ITT) principle (Fig. 1), the study sample was assigned into two groups in order to investigate the effectiveness of the exercise on FABs, based on a per-protocol (PP) analysis. The mean difference in time (0, 6, 12 months) of exercise compliers (≥24 exercise sessions) were estimated and compared to the results of a combined group of non-compliers and non-exercisers (0–23 exercise sessions + controls).

The correlation between the change in LBP intensity from the baseline to 6 months [34] and the change in the results of the FAB measurements after the intervention period were calculated by Spearman's correlation coefficient ($r_s$). Associations between professional status and fear avoidance at the baseline were analysed by analysis of variance (ANOVA).

All the analyses were conducted using SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0 Armonk, NY: IBM Corp.).

## Results

### Exercise adherence

The target was for the participants to exercise twice a week – i.e. 48 sessions over 24 weeks. The mean attendance rate was 26.3 (12.2) exercise sessions. Some 53% of the participants exercised 1–2 times/week. The mean attendance rate was 1.1 times/week during the whole intervention. During the last 8 weeks, the mean attendance rate of the group-based exercise decreased, but the home-based exercise rate increased (total amount remaining 1.1 times /week). Only two people out of the 110 exercised regularly twice a week during the 6-month intervention period.

Of those who were allocated to the exercise group, 10% did not exercise at all, and another 10% took part in only 1–5 exercise sessions in the 6-month period. Of the whole study sample ($n = 219$), 80% ($n = 176$) and 72% ($n = 157$) participated in the 6-month and 12-month follow-up measurements, respectively [36]. At 6 months, 22 persons had dropped out, and 91% of them ($n = 20$) belonged to the least exercised group (0–5 exercise sessions). At 6 months, the dropout rate ($n = 21$) was equal among non-exercisers (Fig.1).

### Baseline variables associated with exercise adherence

The bivariate associations between exercise attendance rates and continuous background and baseline variables is presented in Table 1. The associations for categorical variables are shown in Table 2. Between-group differences for those variables that had statistically significant correlations with adherence rates in the bivariate analysis are presented in Table 3 for the exercise compliers vs non-compliers.

Exercise non-compliers more often had a lower education level ($p = 0.03$) and did shift work ($p = 0.02$) compared to the exercise compliers (Table 3). From the baseline variables, higher fitness results in the one-legged squat ($p = 0.043$) and 6-min walk test ($p = 0.048$) were detected for exercise compliers (Table 3).

**Table 1** Bivariate correlation between baseline continuing variables and exercise adherence rate

| | Correlation with adherence ($r_s$) | Missing | *p*-value |
|---|---|---|---|
| Running figure-of-eight | −0.27 | 9 | 0.006 |
| One-legged squat | 0.19 | 2 | 0.048 |
| 6MWT | 0.28 | | 0.003 |
| Quality of life | | | |
| Physical functioning | 0.19 | 4 | 0.045 |
| Energy | 0.15 | 4 | 0.12 |
| Social functioning | 0.18 | 4 | 0.06 |
| General health | 0.23 | 4 | 0.019 |
| Workability index | 0.26 | | 0.006 |
| Depression; PHQ-9 | −0.20 | 1 | 0.038 |
| Musculoskeletal exertion | 0.25 | 2 | 0.009 |
| FABs (total) | −0.26 | 7 | 0.009 |
| FAB-PA | −0.32 | 1 | 0.001 |
| Intensity of LBP | −0.06 | 2 | 0.54 |

6MWT = 6-min walk test, *FAB* fear-avoidance beliefs, *FAB-PA* fear-avoidance beliefs related to physical activity, *LBP* low back pain, *PHQ-9* Patient Health Questionnaire, 9 items

**Table 2** Association between baseline categorical variables and exercise adherence rate, analysed by the Kruskall–Wallis test

| | *n* | Exercise adherence; median | Range of adherence; min, max | Missing | *p*-value |
|---|---|---|---|---|---|
| Education level | | | | 1 | 0.040 |
| low (secondary school or less) | 30 | 18 | 0, 40 | | |
| medium (high school) | 74 | 28.5 | 0, 55 | | |
| high (university) | 5 | 16 | 0, 29 | | |
| Work type | | | | | 0.001 |
| regular daytime work | 30 | 31.5 | 5, 55 | | |
| shift work | 72 | 21.4 | 0, 44 | | |
| other working time | 8 | 33 | 2, 43 | | |
| Occupation | | | | | 0.003 |
| assistant nurse | 43 | 16 | 0, 41 | | |
| nurse | 56 | 28 | 0, 55 | | |
| other (radiographer, PT, midwife) | 11 | 35 | 4, 50 | | |
| Sub-study | | | | | 0.012 |
| Nurse I | 27 | 12 | 0, 39 | | |
| Nurse II | 41 | 24 | 0, 50 | | |
| Nurse III | 42 | 29 | 0, 55 | | |
| Perceived health in comparison to others of the same age and gender | | | | | 0.037 |
| moderate | 45 | 22 | 0, 55 | | |
| good or very good | 65 | 28 | 0, 50 | | |
| Perceived fitness in comparison to others of the same age and gender | | | | | 0.06 |
| worse | 32 | 23 | 0, 55 | | |
| equal | 52 | 22 | 0, 44 | | |
| better | 26 | 31 | 0, 55 | | |
| Frequency of LBP | | | | 8 | 0.051 |
| on some days of the week | 46 | 22 | 0, 43 | | |
| on most days | 38 | 29 | 0, 55 | | |
| daily | 18 | 40 | 0, 42 | | |

*LBP* low back pain, *PT* physiotherapist

### Fear-avoidance beliefs

At the baseline, there was a difference in the levels of FABs between occupational groups in the whole study sample ($n = 219$). Nursing assistants had more FABs related to physical activity (FAB-PA, mean 15.5, SD 6.0, $n = 89$) than nurses (12.0, SD 5.9, $n = 102$) and other professionals (11.6, SD 6.8, $n = 28$) ($F = 9.5$, $p < 0.001$).

Exercise compliers showed lower values for FAB-PA at the baseline compared to non-compliers ($p = 0.02$, Table 3). During the exercise intervention, both FAB-PA ($p = 0.028$, adjusted for perceived occupational physical loading) and also FAB-W ($p = 0.007$, adjusted for age, shift work, perceived health, fitness and occupational physical loading, and push-ups) decreased in the exercise group compared to the non-exercisers (Fig. 2; ITT analysis). There was a dose-response; both FAB-PA ($p = 0.006$) and FAB-W ($p = 0.016$) decreased more in the high exercise adherence group compared to the less exercised and non-exercisers (Fig. 2; PP analysis). At 12 months follow-up, there were no more group differences in FAB-PA. A reduction in FAB-PA (from the baseline to 6 months) did not correlate with a reduction in LBP intensity ($r_p = 0.03$, $p = 0.54$), but there was a correlation between a reduction in FAB-W and a reduction in LBP intensity ($r_s = 0.16$, $p = 0.05$).

## Discussion

In this 6-month modified, Pilates-type exercise study for female healthcare personnel with sub-acute or recurrent, non-specific LBP, those possessing a lower basic education level, working shifts, and having lower levels of fitness and higher levels of physical activity-related FABs at the baseline had a lower exercise adherence. Exercising during the intervention reduced levels of FAB-PA and FAB-W, and there was a dose-response: the levels of

**Table 3** Baseline variables of the participants (randomised to the exercise group) by exercise adherence status

| | Compliers (≥24 exercise sessions), *n* = 58 | | | Non-compliers (0–23 exercise sessions), n = 52 | | | Miss-ing | *p*-value |
|---|---|---|---|---|---|---|---|---|
| | Mean (SD) | *n* | % | Mean (SD) | n | % | | |
| Running figure-of-eight; seconds | 7.7 (1.0) | | | 8.0 (1.2) | | | 9 | 0.20 |
| One-legged squat; (0–12 reps) | 9.9 (2.3) | | | 8.9 (2.9) | | | 2 | 0.043 |
| 6MWT; metres | 623.0 (43.8) | | | 603.4 (56.2) | | | – | 0.048 |
| Quality of life | | | | | | | | |
| Physical functioning (0–100) | 87.3(11.1) | | | 83.4 (13.4) | | | 4 | 0.17 |
| General health (0–100) * | 70.2(16.4) | | | 64.5 (17.5) | | | 4 | 0.08 |
| Workability index (3–27) | 22.2 (2.6) | | | 21.9 (2.9) | | | | 0.20 |
| PHQ-9 (0–27) | 7.4 (4.5) | | | 8.5 (5.3) | | | 1 | 0.29 |
| Musculoskeletal exertion (7–35) * | 12.2 (3.8) | | | 13.5(4.0) | | | 2 | 0.10 |
| FABs total (0–78) | 23.2 (12.9) | | | 27.3(14.5) | | | 7 | 0.07 |
| FAB-PA; (0–30) | 12.6(6.9) | | | 15.4 (6.4) | | | 1 | 0.019 |
| LBP intensity; (VAS 0–100) | 36.9 (19.9) | | | 35.9 (19.9) | | | 1 | 0.79 |
| Education level | | | | | | | – | 0.026 |
| low (secondary school or less) | | 14 | 24.1 | | 23 | 44.2 | | |
| medium or high | | 44 | 75.9 | | 29 | 55.8 | | |
| Work type | | | | | | | – | 0.023 |
| regular work | | 24 | 41.4 | | 11 | 21.2 | | |
| shift work | | 34 | 58.6 | | 41 | 78.8 | | |
| Profession | | | | | | | – | 0.052 |
| assistant nurse | | 18 | 31.0 | | 25 | 48.1 | | |
| nurse | | 31 | 53.4 | | 25 | 48.1 | | |
| other (radiographer, PT, midwife) | | 9 | 15.5 | | 2 | 3.8 | | |
| Sub-study | | | | | | | – | 0.042 |
| Sub-study I | | 9 | 15.5 | | 18 | 34.6 | | |
| Sub-study II | | 22 | 37.9 | | 19 | 36.5 | | |
| Sub-study III | | 27 | 46.6 | | 15 | 28.8 | | |
| Perceived health in comparison to others of the same age and sex; ° | | | | | | | – | 0.14 |
| moderate | | 20 | 34.5 | | 25 | 48.1 | | |
| good or very good | | 38 | 65.5 | | 27 | 51.8 | | |
| Frequency of LBP; ° | | | | | | | 8 | 0.12 |
| on some days of the week | | 21 | 38 | | 25 | 54 | | |
| on most days | | 26 | 46 | | 12 | 26 | | |
| daily | | 9 | 16 | | 9 | 20 | | |

*normal distribution, independent samples *t*-test, Mann–Whitney *U* test, ° $\chi^2$ test. *FAB-PA* physical activity-related fear-avoidance beliefs, *LBP* low back pain, *PHQ-9* Nine-item Patient Health Questionnaire measuring depression, *PT* physical therapist, *VAS* visual analogue scale of 0–100 during the past 4 weeks

FAB-PA and FAB-W decreased more in more exercised persons.

In exercise interventions, levels of exercise adherence usually drop over time; approximately 50% reduction in 12 months has been presented [26, 53]. In the present intervention, participation in the supervised groups decreased across time, but the amount of home-based exercise increased commensurately. The exercise videos, booklets, supportive e-mails and letters probably helped in maintaining the same exercise adherence level throughout the 6-month intervention. While we knew that exercise adherence is usually only modest at best among people with musculoskeletal pain [20], and that shift work makes attending regular group-based exercise demanding [54], the exercise adherence rate in the present study was lower than we expected. In 2012–

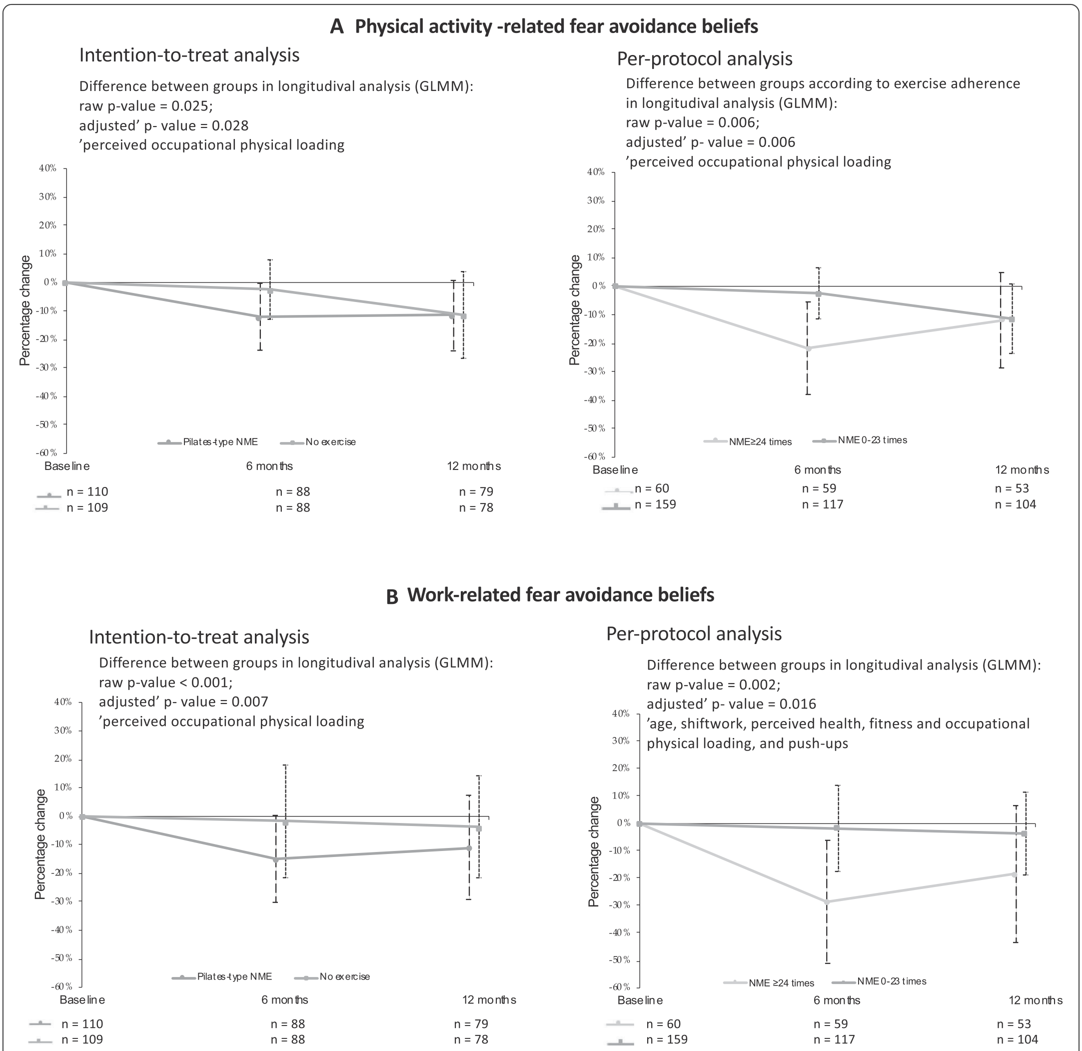


**Fig. 2** Effects of the exercise program on fear avoidance beliefs. Footnote to Fig. 2: Effects and effectiveness of the modified Pilates-type neuromuscular exercise (NME) with a focus on controlling the neutral spine on **a** physical activity-related fear-avoidance beliefs, and **b** work-related fear-avoidance beliefs (the mean difference in percentage with 95% confidence intervals analysed by generalised linear mixed models)

2014, when the study interventions were conducted, Pilates was quite a popular exercise type in Finland, and for that reason it was expected to be more attractive than a typically conventional/traditional neuromuscular exercise form.

It has been suggested that factors associated with exercise adherence among LBP patients can be divided into three categories [55]: 1) physical factors like pain [55] and perceived health status [56]; 2) psychological factors such as the fear of pain [23], diagnostic uncertainty [22], low self-efficacy [21], and depression and anxiety [21]; and 3) environmental factors, such as difficulty in integrating exercise into daily life [22, 55], lack of time [22, 23, 55], and intervention-related variables [33]. This classification is partly insufficient: it is difficult to place education level, which is a socio-demographic background factor, into any of those categories. Socio-economic status is associated with back-related beliefs: those with high socio-economic status are more prone to believe that one should stay active regardless LBP [57].

Education level has been shown to affect adherence to exercise progression among people with chronic LBP [58], strength training [56], and leisure-time physical activity [59]. In the present study, lower basic education level was also associated with lower exercise adherence, even though healthcare workers are a fairly homogenous group, and socio-demographic differences are generally small in Finland [60].

In previous studies, LBP intensity [55] and older age [58] compromised adherence to exercise or exercise progression. Contradictory to earlier studies, they had no effect in the present study, perhaps because in most participants the intensity of LBP was mild to moderate, they were still working, and the age range was set to 30–55 years. Higher physical fitness level at the baseline contributed to better exercise adherence. To our knowledge, association between baseline physical fitness and exercise adherence in later intervention has not been reported previously.

FABs-PA results at baseline in the current study were comparable to those detected among French hospital workers with recurrent LBP [61], but lower than among LBP patients seeking medical care for their pain [62]. FABs related to physical activity are known to affect exercise adherence [22]; activities or exercises are avoided for fear of increasing pain [23]. Cognitive and psychological interventions [27] and graded activity [63] are usually considered helpful in the management of fear avoidance-related pain. An intervention including education in addition to exercise was slightly more effective in reducing FABs-PA among French hospital workers with LBP than the present study [61]. Interventions to reduce FABs very seldom include exercise only, but a Pilates-type exercise has shown to reduce FABs more than stationary cycling in short term among chronic LBP patients [64]. We hypothesise that this modified, slowly progressing Pilates-type exercise programme, which was conducted at the pace of the participant's calm breathing tempo, might have given the participants positive experiences of movement. They could move in a way that they could control; the movements were not harmful or dangerous and could even release pain. This might explain the reduction of FAB levels during the exercise intervention.

*Moderators* (or treatment effect modifiers) are baseline characteristics that influence the outcome of treatment [65]. *Mediators* are factors that change during or as a consequence of an intervention and thereby influence outcome [65]. Thus, it might be hypothesised that the earlier reported reduction of LBP intensity among the present study sample after exercise intervention [34] might have been mediated by a reduction in the fear of movement. Nevertheless, there was no correlation between the reduction of LBP intensity and the reduction of FAB-PA, but exercise adherence was the key factor. Those with a lower FAB-PA at the baseline exercised more, and those who exercised more gained more positive results in pain reduction [34]. While we measured pain intensity only at the baseline and after the 6-month exercise intervention – i.e. not during the intervention period – we cannot say anything about causality. Exercising more might have reduced the pain levels due to exercise-induced hypoalgesia [66–68], or a potential rapid reduction of pain intensity at the beginning of the exercise intervention might have decreased the levels of FAB-PA, and thus increased the motivation to exercise. In exercise intervention, both FABs [69] and exercise adherence [26] can mediate the outcome, i.e. LBP intensity. Identification of the mechanisms through which different treatments affect outcomes is complicated, and there is a clear need for further research that investigates plausible mediators [69].

The reduction of FABs during the intervention was statistically significant, but we do not know its clinical relevance (three questions related to returning to work were removed from the original FAB Questionnaire). Among hospital workers with recurrent LBP, an intervention combining education and exercise reduced FABs-PA, but did not reduce LBP recurrence episodes in two-year follow up [61]. For those healthcare workers with previous LBP, both the physical workload and FABs are important in the development of new episodes of LBP [70].

A lack of time is the most frequently reported barrier to leisure-time physical activity or exercise, both among the general population [31, 71] and among people with LBP [23]. Those working shifts had a lower exercise adherence than those working at regular times. Among nursing personnel, shift work is also associated with sleeping problems, fatigue, and lack of energy [72, 73], which might compromise exercise adherence.

Increasing adherence to exercise is an important factor for the longer-term effectiveness of an intervention. Integrating educational components to exercise sessions, like strategic planning [23], self-monitoring [56], goal-setting [25, 74], supplementary printed material, motivation strategies and positive re-enforcement [74], encouragement and action planning to overcome barriers to exercise [23] have been suggested to increase exercise adherence. Also leadership and organisation skills [21], favourable environment and pleasure associated with exercise [23], and appropriate intensity of the training content [75] might help in reducing fear of pain and pain itself [23] and thus increase exercise adherence. Identification of especially those who have a low education level, and targeting motivating efforts at them [56] might be effective.

Understanding the causality and reasons for exercise adherence is complicated, multidimensional, and difficult to study. People do not always behave in the way they intend to behave. Motivation alone is not sufficient to trigger an action, and one is often confronted with obstacles [23]. In the present study, exercise adherence was lower among those with a lower level of basic education. The levels of baseline FABs were also higher among assistant nurses. In clinical practice, motivational strategies with a focus on decreasing FABs especially among people with a low education level could be beneficial. Unfortunately, there is a lack of measurement methods to identify those who would benefit most from motivational actions.

### Limitations

This study was a secondary analysis of the NURSE-RCT. Investigating associations between individual factors at the baseline and exercise adherence was not planned simultaneously with planning the RCT, and it was not written into the study protocol [35]. We arrived at the idea for the study after we detected the dose response of exercising on LBP intensity and movement control impairments [34]. Due to the four-arm setting of the original NURSE-RCT (combined exercise + counselling, exercise only, counselling only, controls), targeting motivational strategies at exercisers (exercise only and the combined group) would have been difficult without contaminating the back care counselling intervention.

Several additional measurements might have been beneficial: the immediate effects of the exercise sessions (to pain or other bodily sensations), home environment, previous physical activity (in earlier years), and the number and ages of the participants' children were not ascertained in the study. This might have broadened our understanding of the factors affecting exercise adherence. We measured only the number of exercise sessions, which were either supervisor-documented (for group sessions) or self-reported (for home practice). The research calls for standard validated measures of exercise adherence [20].

## Conclusion

Participants with lower education and fitness levels who worked shifts and had high physical activity-related fear-avoidance beliefs at the baseline had a lower adherence to the 6-month neuromuscular exercise programme. Exercising with good adherence reduced levels of FABs, which are known to be linked with prolonged LBP. In exercise interventions, motivational strategies should be targeted at those with low education and fitness levels and high fear-avoidance beliefs to achieve better exercise adherence. In exercise intervention studies, strategies to enhance and/or maintain exercise adherence need to be taken more seriously, because adherence is a key link between intervention and outcomes.

#### Abbreviations

ANOVA: Analysis of variance; BMI: Body mass index; DVD: Digital video disc; FABs: Fear-avoidance beliefs; FAB-PA: Fear-avoidance beliefs related to physical activity; FAB-W: Work-related fear-avoidance beliefs; GLMM: Generalised linear mixed model; ITT: Intention to treat; LBP: Low back pain; NME: Neuromuscular exercise; NRS: Numeric rating scale; 0–10; PHQ-9: Patient health questionnaire, 9 items; PP: Per protocol; RCT: Randomised controlled trial; SD: Standard deviation; VAS: Visual analogue scale; 0–100

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#### Authors' contributions

All authors have read and approved the final manuscript. AT is the corresponding author, and she drafted the manuscript. She planned the exercise intervention, trained the other exercise instructors, produced the exercise videos and booklets, and supervised some of the exercise groups. She conducted the literature search and the bivariate statistical analysis. MK contributed to the design of the present study and the interpretation and presentation of the results. MR contributed to the interpretation and presentation of the results. KT verified the bivariate statistical analysis, and he conducted all the multivariate analyses. He also contributed to the presentation of the results of the statistical analysis. JP is the responsible medical doctor of the study. He contributed to the design of the study and the interpretation and presentation of the results. JS is the principal researcher of the NURSE-RCT. She is responsible for measurement selection and development, and for data collection and management. She contributed to the design of the study and the interpretation and presentation of the results of the present study.

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#### Availability of data and materials

The datasets used and analysed during the current study are available from the principal researcher (JS; jaana.suni@ukkinstituutti.fi) of the NURSE RCT and from tommi.vasankari@ukkinstituutti.fi upon reasonable request.

#### Ethics approval and consent to participate

The participants gave their informed consent in written form at their first visit to the research centre (i.e. at the baseline measurement of the study), and the trial was conducted according to the Declaration of Helsinki. The study was approved by the Ethics Committee of Pirkanmaa Hospital District, Finland (ETL code R08157).

#### Consent for publication

Not applicable.

#### Competing interests

The authors declare that they have no competing interests.

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