MECHANICS, FUNCTION, PAIN AND EFFECTS OF EXERCISE INTERVENTION AMONG NURSES WITH LOW BACK PAIN IN HOSPITAL UNIVERSITI SAINS MALAYSIA

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UNIVERSITI SAINS MALAYSIA

2024

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by

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Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy

April 2024

ACKNOWLEDGEMENT

My deep gratitude goes first to Associate Professor Dr. Shazlin Shaharudin, who expertly guided me in writing this dissertation, shared her knowledge and experience, and was patient with me. I am also thankful to all my co-supervisors Professor Dr. Mohd Imran Bin Yusof, Dr. Azlina Yusuf, and Dr. Rizal Bin Mohd Razman, for their assistance and suggestions throughout my study. I would also like to thank Tenaga Nasional Berhad (TNB) for supporting part of the study. My appreciation also extends to Puan Raudah and Matron Saridah, who have been assisting me tirelessly since the first day of data collection. Not to forget, all the nurses and Exercise & Sports Science laboratory personnel. To my parents, Haji Abd Rahman Bin Abd Jamil and Hajah Mas Ayu Binti Mohd Noor, my uncle Abdul Rahim, and my siblings, they mean the world to me. I would have never been here and been able to finish my study without their tremendous love and support. To my seniors, Lau Jiun Sien and Cheah Pei Yi thank you for your time and help, regardless of your busy schedule. Last but not least, to my best friend, Iffah Binti Zapri, who always support, encourage, and help me in times of need, I thank you with all my heart.

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LIST OF ABBREVIATIONS

CNLBP	Chronic non-specific low back pain
DLSU	Dominant leg length in supine
DLST	Dominant leg length in standing
NDLSU	Non-dominant leg length in supine
NDLST	Non-dominant leg length in standing
BMI	Body mass index
VGRF	Vertical ground reaction force
COP	Centre of pressure
RMDQ	Roland Morris Disability Questionnaire
SLSU	Symmetry of dominant and non-dominant leg length in supine
SLST	Symmetry of dominant and non-dominant leg length in standing
LSE	Lumbar stabilization exercise
LMSE	Lumbar muscles strengthening exercise
IC	Initial contact

LIST OF APPENDICES

MEKANIK, FUNGSI, KESAKITAN DAN KESAN INTERVENSI SENAMAN DALAM KALANGAN JURURAWAT YANG MENGALAMI SAKIT BELAKANG DI HOSPITAL UNIVERSITI SAINS MALAYSIA

ABSTRAK

Sakit pinggang (LBP) diklasifikasikan sebagai penyakit muskuloskeletal yang menjejaskan semua populasi di seluruh dunia dan kejururawatan adalah pekerjaan berisiko tinggi yang dikaitkan dengan LBP. Walau bagaimanapun, kajian terdahulu berkaitan LBP dalam kalangan jururawat tidak mengukur biomekanik berkaitan tugas jururawat merentasi subjenis. Ini menyebabkan ketidakfahaman tentang bagaimana tugasan tersebut boleh mengakibatkan LBP. Selain itu, kajian terdahulu mengenai kesan senaman pada individu yang mempunyai sakit pinggang kronik (CNLBP) hanya tertumpu pada skor kesakitan, kekuatan otot dan fungsi. Ianya tidak menumpukan pada kesan jangka panjang senaman terhadap mekanik seluruh badan dalam kalangan jururawat wanita yang mempunyai CNLBP. Kepentingan kajian ini berbanding dengan kajian terdahulu adalah perbandingan mekanik seluruh badan dalam kalangan jururawat wanita yang mempunyai CNLBP. Penyelidikan ini terdiri daripada dua kajian yang bertujuan: 1) untuk membandingkan biomekanik keseluruhan badan di antara kumpulan sihat dan kumpulan CNLBP dan 2) untuk menilai kesan intervensi senaman terhadap CNLBP dalam kalangan jururawat wanita. Dalam kajian 1, terdapat 26 jururawat wanita yang menyertai (Kumpulan Sihat, n=13 dan Kumpulan CNLBP, n=13) dan perbandingan biomekanik seluruh badan, fungsi ketidakupayaan dan skor kesakitan telah dilakukan. Berdasarkan keputusan, peserta CNLBP menggunakan fleksi lumbar yang lebih besar semasa berjalan ($p<0.05$) dan duduk bangun (STS) ($p<0.05$), fleksi lumbar yang besar dan penurunan daya tindak balas menegak (VGRF)

(p=0.01) semasa mengangkat serta memindahkan beban (CNT) berbanding peserta yang sihat. Pergerakan ini menyebabkan bahagian atas badan bergerak ke arah beban dan mengurangkan daya tindak balas. Secara tidak langsung menggunakan teknik pemindahan yang lebih dekat. Tambahan pula, peningkatan fleksi lumbar semasa berjalan dan STS di kalangan peserta CNLBP adalah perkara biasa kerana corak ini digunakan sebagai mekanisme untuk mengelakkan kesakitan yang disebabkan oleh peningkatan ketegangan otot. Bagi kajian 2, 54 orang jururawat wanita telah dibahagikan kepada tiga kumpulan secara rawak (Kumpulan Kawalan, n=18, Kumpulan Latihan Penstabilan Lumbar (LSE), n=18 dan Kumpulan Latihan Pengukuhan Otot Lumbar (LMSE), n=18). Kumpulan LSE dan LMSE bersenam dua sesi dalam seminggu selama 8 minggu manakala, kumpulan kawalan diberi diari untuk merekodkan aktiviti harian mereka dan mencatat diet 24 jam. Peserta menyelesaikan empat penilaian iaitu pra- (sebelum), - pertengahan- (semasa minggu ke-4), – pasca- (selepas lapan minggu) intervensi dan ujian susulan selepas satu bulan. Kinematik dan kinetik seluruh badan tiga dimensi (3D) semasa berjalan, STS dan CNT, kekuatan otot ekstensor, jangkauan melunjur, fungsi ketidakupayaan, intensiti kesakitan dan ketahanan otot fleksor telah diuji. Susulan satu bulan menunjukkan LMSE mempunyai sedikit peningkatan dalam fleksi lumbar ($p<0.05$), pusat tekanan (COP) ($p=0.01$) dan abduksi buku lali ($p=0.04$) semasa berjalan, fleksi lumbar ($p<0.05$), VGRF ($p=0.02$) dan fleksi lutut ($p=0.04$) semasa CNT dan fleksi lumbar ($p=0.01$) semasa STS berbanding selepas intervensi. Kesimpulannya, LMSE lebih berkesan dari segi kesan jangka panjang untuk mengurangkan LBP dalam kalangan jururawat berbanding LSE.

Kata kunci: Kinematik, kinetik, tulang belakang, kesihatan, jururawat

MECHANICS, FUNCTION, PAIN AND EFFECTS OF EXERCISE INTERVENTION AMONG NURSES WITH LOW BACK PAIN IN HOSPITAL UNIVERSITI SAINS MALAYSIA

ABSTRACT

Low back pain (LBP) is classified as a leading disabling musculoskeletal disorder that affects all range of the population globally and nursing is a high-risk group profession associated with LBP. However, previous studies on LBP among nurses did not quantify the mechanics during nurses-related tasks across subtypes which hinders the understanding of how these tasks cause LBP. Besides that, previous studies on exercise therapy in individuals with chronic non-specific LBP (CNLBP) were focused on pain score, muscle power and function but none on the long-term effects of exercise on full body mechanics among female nurses with CNLBP. The significance of this study compared with previous studies was the comparison of full body mechanics among female nurses with CNLBP. This research comprised of two studies that aim: 1) to compare the full body mechanics between healthy nurses and those with CNLBP and 2) to evaluate the effects of exercise intervention on CNLBP among female nurses. In study 1, 26 female nurses were recruited (Healthy Group, n=13 and CNLBP Group, n=13) and their full body mechanics, functional disability outcomes and pain score were compared. Based on the results, CNLBP participants employed greater lumbar flexion during walking ($p<0.05$), greater lumbar flexion during sit-to-stand (STS) ($p<0.05$), greater lumbar flexion ($p=0.01$) and decreased vertical ground reaction force (VGRF) ($p=0.01$) during carry and transfer (CNT) compared to healthy participants. This motion caused the upper body to move towards the load and decreased the VGRF, hence, indirectly applied narrow base transfer

technique. Furthermore, increase in lumbar flexion during walking and STS among CNLBP participants was common as this pattern was manifested as the compensatory mechanism to avoid pain caused by increasing of trunk stiffness. For study 2, 54 female nurses were randomised into three groups (Control Group, n=18, Lumbar Stabilisation Exercise (LSE) Group, n=18 and Lumbar Muscles Strengthening Exercise (LMSE) Group, n=18). LSE and LMSE groups exercised for two sessions in a week for 8 weeks whereas, control group was given a diary to record their daily activities and 24 hours diet recall. Participants completed four assessments which were pre- (before), middle- (during 4th weeks), post- (after eight weeks) intervention and one month follow up measurements. Three dimensional (3D) full body kinematics and kinetics of walking, STS and CNT, trunk muscle power (extensor), sit-and-reach, functional disability, pain intensity and trunk flexor endurance were tested. One month follow up showed LMSE had slightly increased in lumbar flexion ($p<0.05$), centre of pressure (COP) ($p=0.01$) and ankle abduction ($p=0.04$) during walking, lumbar flexion ($p<0.05$), VGRF ($p=0.02$) and knee flexion ($p=0.04$) during CNT and lumbar flexion ($p=0.01$) during STS than post-intervention. We concluded that LMSE is more effective in long-term effects than LSE in reducing LBP among nurses.

Keywords: Kinematics, kinetics, spine, health, nurses

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Low back pain (LBP) has become a common public health problem and classified as a leading disabling musculoskeletal disorder that affects all range of the population globally (El-Soud *et al*., 2014). LBP affect nurses' daily life activities, interpersonal relations, psychological problems and quality of life adversely (El-Soud *et al*., 2014). Moreover, LBP also affects the economy of the countries adversely due to labour loss of nurses, reduction in work efficiency and other financial costs (El-Soud *et al*., 2014). Nurses may be forced to quit their jobs or change their workplaces because of LBP (Moussa, El-Ezaby & El-Mowafy, 2015).

Generally, LBP is determined as pain and discomfort below the costal margin and above the inferior gluteal folds, with or without referred leg pain (Duthey, 2013). Most common symptoms of LBP are aching, burning, stabbing, sharp or dull, well-defined, or vague pain with intensity ranging from mild to severe. Will, Bury & Miller (2018) stated that LBP can be divided into mechanical and non-specific. Mechanical LBP refers to back pain that occur from the surrounding soft tissues, intervertebral discs or the spine (Will, Bury & Miller, 2018). The pain may arise from acute or chronic traumatic injury, disk herniation, lumbosacral muscle strain, vertebral compression fractures, spondylolysis, spondylolisthesis and lumbar spondylosis. Meanwhile, non-specific LBP refers to the back pain that not being caused by known specific pathology for instance fracture, inflammatory process, osteoporosis, tumour, infection, radicular syndrome, cauda equina syndrome or ankylosing spondylitis (Duthey, 2013).

Another classification of LBP is based on subtypes (i.e., acute, subacute and chronic) and each subtype differs according to the duration of pain (Duthey, 2013). Acute LBP is defined as LBP lasting for less than 6 weeks. Subacute LBP is defined as back pain between six weeks and three months and chronic LBP is defined as low back pain persisting for longer than three months, or after the period of healing or recurring back pain (Deyo *et al*., 1990; Duthey, 2013; Hüllemann *et al*., 2018). Due to wide variation of LBP causes and symptoms, we select a homogenous group of patients to study the mechanics of chronic non-specific LBP (CNLBP).

The concept of biomechanics involve kinematics and kinetics. Generally, kinematics is the study of motion without considering the cause of motion. For example, range of movement (ROM) during lumbo-pelvic movement (Laird *et al*.,2014). Meanwhile, kinetics is the study of forces that caused motion for examples, muscle activation patterns and ground reaction force during walking or lifting (Nicholson, 2020). Biomechanics is used to study the mechanisms of movement and improve our understanding regarding skill acquisition (Nicholson, 2020). Nurses were reported as the most occupation with work-related back injuries (Samer *et al*., 2014). There are many factors associated with CNLBP such as gender (Laird *et al*.,2014), age (Smith *et al*., 2018), work-related ergonomics load (Catena & Xu, 2015), however studies that applied mechanics to understand the causes of pain in CNLBP are scarce especially in nurses. Standing up from sitting and lifting the patients are the two tasks which commonly affect the nurses who suffer from chronic LBP (Gim, 2017). Therefore, this work focused on the associated motions namely sit-to-stand and transferring load.

Nursing is a high-risk group profession associated with LBP. In previous study conducted by Ibrahim *et al*. (2019), there was a total of 989 nurses working in the public hospitals of Penang, Malaysia suffered from LBP. This is because, nurses job scopes involve helping, turning, lifting and moving patients from chair or bed, helping patient to ambulate, moving the bed, frequent standing, forceful exertion during handling obese or overweight patients and awkward posture consists of deep bending and twisting of the trunk during patient-handling tasks (Ibrahim *et al*., 2019). Similarly, nurses may be exposed to numerous physical risk factors that will affect their low back health such as long working hours, excessive workload, insufficient breaks, shift related disruptions that affect sleeping cycle, eating habits and social life (El-Soud *et al*., 2014; Ibrahim *et al*., 2019).

At Hospital Universiti Sains Malaysia (HUSM), nurses have three working shifts (i.e., morning, evening and night) with total working hours between 31-40 hours per week. Most nurses who work in shift had LBP (Horneij *et al*., 2002). Those working on morning shift are more likely to experience back pain compared to those working on evening or night shift (June & Cho, 2011). In addition, working experience at current ward and total years of nursing experience were associated to LBP among nurses whereby nurses with more than 20 years of working experience reported the highest LBP cases compared to nurses working less than one year (Adachi *et al*., 2002).

Statistics in Hospital Universiti Sains Malaysia (HUSM) showed that number of patients with back pain including nurses fluctuate every year. For example, there were 37 LBP patients in 2007, 31 LBP patients in 2008 and 26 LBP patients in 2009 in physiotherapy records (Gim, 2017). The prevalence of LBP in the nurses were

87.5% in Sudan (Al-samawi & Awad, 2015), 65% in Nepal (Rustøen, 2016), 72% in Taiwan (Shieh *et al*., 2016), and 50-80% worldwide (Al-samawi & Awad, 2015), with about 67% to 84.2% of them were nurses at intensive care unit (Ovayolu *et al*., 2014; Petersen & Marziale, 2014). The findings have shown that nurses are under a greater risk of LBP compared to other health professionals.

Taking necessary precaution such as exercising ensure the protection of nurses against mechanical traumas especially at the waist, during care practices (Tosunoz & Oztunc, 2020). Previous studies (Al-samawi & Awad, 2015; Moussa, El-Ezaby & El-Mowafy, 2015) on LBP and coping strategies among nurses have demonstrated that exercise improves and strengthens the back muscles, protects the waist from trauma and also reduces risk of LBP. Minimal intervention for reducing pain was less effective than motor control exercise (MCE) in patients with nonspecific LBP, but MCE probably does not have an important effect on disability among chronic LBP patients (Saragiotto, Maher, Yamato, Costa, Costa, *et al*., 2016). Besides that, there was no difference between MCE and other forms of exercises as well as manual therapy for acute and chronic LBP (Saragiotto *et al*., 2016). Common investigated outcomes on exercise intervention programmes from previous studies involved exercise aiming to activate, train, or restore the stabilisation of specific deep muscles. None of the previous studies evaluated the effects of exercise interventions on full body mechanics during functional tasks among female nurses with CNLBP.

The exercise interventions included in this study were lumbar stabilisation exercise (LSE) and lumbar muscles strengthening exercise (LMSE), which were adopted from Sipaviciene & Kliziene (2020) and Moon *et al*. (2013). As we are dealing with clinical population, it is imperative to modify a proven safe intervention rather

than developing a new intervention programme. Therefore, in this study, we modify exercise intervention done by Moon *et al*., (2013) and Sipaviciene & Kliziene, (2020) by combining both exercise protocol, increase number of repetitions, include one month follow-up and four assessments (pre-. middle, post and follow-up). The differences between previous studies and this study were progression (increment of number of repetitions) and post-intervention assessment (after one month follow-up). Additionally, both studies did not include the follow up session after cessation of exercise intervention, which is important to analyse effects of exercise intervention either the results can be maintained or back to pre-exercise state.

To the best of our knowledge, studies that evaluate full body mechanics comparison, functions and pain score of CNLBP, and effects of exercise intervention on CNLBP among female nurses are scarce. Therefore, the current work was conducted to understand the full body mechanics (kinematics and kinetics) of healthy and CNLBP and how exercise intervention may alter these mechanics to reduce pain and functional disability score. Besides that, the impact of this study was nurses with CNLBP able to apply and practice the correct technique especially during nurses work-related tasks. The study consisted of two parts which are comparison of the mechanics (kinematics and kinetics) of healthy and CNLBP nurses and effects of exercise intervention on full body mechanics, functional disability and pain score among female nurses with CNLBP.

1.2 Objective of the study

1.2.1 General objective

To study full body mechanics between healthy nurses and those with CNLBP and effects of exercise intervention on CNLBP among female nurses.

1.2.2 Specific objectives

Non-interventional Study

Study 1:

1) To compare full body mechanics between healthy nurses and those with CNLBP.
2) To compare functional disability outcomes between healthy nurses and those with CNLBP.
3) To compare pain score between healthy nurses and those with CNLBP.

Interventional Study

Study 2:

1) To compare the effects of exercise interventions (lumbar stabilisation exercise (LSE) versus lumbar muscles strengthening exercises (LMSE)) on full body mechanics among female nurses with CNLBP.
2) To compare the effects of exercise interventions (lumbar stabilisation exercise (LSE) and lumbar muscles strengthening exercises (LMSE)) on functional disability outcomes among female nurses with CNLBP.
3) To compare the effects of exercise interventions (lumbar stabilisation exercise (LSE) and lumbar muscles strengthening exercises (LMSE)) on pain score among female nurses with CNLBP.

1.3 Research Questions

Study 1:

1) What are the differences in full body mechanics between healthy nurses and those with CNLBP?

2) What are the differences in functional disability outcomes between healthy nurses and those with CNLBP?

3) What are the differences in pain score between healthy nurses and those with CNLBP?

Study 2:

1) How exercise intervention affects full body mechanics among female nurses with CNLBP?

2) How exercise intervention affects functional disability outcomes among female nurses with CNLBP?

3) How exercise intervention affects pain score among female nurses with CNLBP?

1.4 Research hypotheses

The following hypotheses were formulated to achieve the objectives.

Study 1

Alternative Hypothesis (H_A)

1) There are significant differences in full body mechanics between healthy nurses and those with CNLBP.
2) There are significant differences in functional disability outcomes between healthy nurses and those with CNLBP.
3) There are significant differences in pain score between healthy nurses and those with CNLBP.

Null Hypothesis (H_O)

1) There are no differences in full body mechanics between healthy nurses and those with CNLBP.
2) There are no differences in functional disability outcomes between healthy nurses and those with CNLBP.
3) There are no differences in pain score between healthy nurses and those with CNLBP.

Study 2

Alternative Hypothesis (H_A)

1) There are significant differences in the effects of exercise intervention on full body mechanics among female nurses with CNLBP.
2) There are significant differences in the effects of exercise intervention on functional disability outcomes among female nurses with CNLBP.
3) There are significant differences in the effects of exercise intervention on pain score among female nurses with CNLBP.

Null Hypothesis (H_O)

1) There are no differences in the effects of exercise intervention on full body mechanics among female nurses with CNLBP.
2) There are no differences in the effects of exercise intervention on functional disability outcomes among female nurses with CNLBP.
3) There are no differences in the effects of exercise intervention on pain score among female nurses with CNLBP.

1.5 Problem statement

LBP is the most common musculoskeletal disorder among nurses compared to other health care personnel (Hofmann *et al*., 2002; Lorusso, Bruno & L'abbate, 2007).

Common manual patient-handling tasks consist of lifting, repositioning, and transferring a patient from a bed to another location such as to another bed, wheelchair, bathtub, or toilet may lead to various work-related musculoskeletal disorders associated with physical risk factors (Nagavarapu, Lavender & Marras, 2017; Zhou & Wiggermann, 2017). Detailed mechanics among nurses with CNLBP will provide the insight of clinical practice to differentiate the abnormal movement from the normal movement particularly during tasks related to their job (Laird *et al*., 2014). However, previous studies on LBP among nurses did not quantify the mechanics during nurses-related tasks which hinders the understanding of how these tasks causes LBP. Additionally, previous studies on exercise therapy in individuals with CNLBP were focused on pain score, muscle power and function (Hides *et al*., 2012; Macedo *et al*., 2012) but none on the long-term effects of exercise on full body mechanics among female nurses with CNLBP.

1.6 Significance of the study

The present study investigated full body mechanics between healthy nurses and those with CNLBP and its adaptations following exercise intervention. The reason of investigating full body mechanics between healthy nurses and those with CNLBP is because CNLBP requires different solution in treating LBP. Hayden *et al*., (2005) concluded exercise is not recommended for treating an episode of acute LBP. Instead of treating an episode of acute LBP, they suggested patients to seek for a treatment such as physiotherapy. Meanwhile Choi *et al*., (2010) stated for LBP recurrence at one year (sub-acute and chronic), exercise (such as MCE) is recommended and able to decrease the risk of chronic LBP. Moreover, exercise can reduce pain and disability function (Saragiotto, Maher, Yamato, Costa, Costa, *et al*., 2016), decreasing the risk

of chronic LBP, and increase work attendance. Additionally, Menzel, Lilley & Robinson, (2006) stated that having LBP can be a financial burden towards individual and organisations due to high cost of workers' compensation, insurance to be paid to injured workers, and long recovery time. Therefore, it is important to carry out this study because the results of this study may reduce the number of nurses having CNLBP and improve their quality of life. Moreover, by identifying motions related to LBP, preventive measures can be conducted at early stage in order to avoid recurrent or chronic LBP in the future.

1.7 Operational definitions

(a) Low back pain (LBP)

In this study, the type of LBP being investigated were CNLBP.

(b) Healthy

Healthy refers to nurses without any LBP conditions.

(c) Nurses

The nurse can be defined as a person who received authorisation by the appropriate regulatory authority to practice nursing in his/her country. The nurse must has completed a program of basic, generalised nursing education for examples, providing a broad and sound foundation in the behavioural, life, and nursing sciences for the general practice of nursing. In this study, we only recruited nurses who are registered with Malaysia Nursing Board and have nursing work experience as for at least two years. Female nurses were recruited from three specific wards (i.e., adult intensive care unit, adult high dependency unit and general operation theatre).

(d) Exercise intervention

Lumbar stabilisation exercises (LSE) and lumbar muscle strengthening exercises (LMSE) were chosen in this study and conducted for 8 weeks.

(e) Full body mechanics

This study focused on both kinematic (i.e., joint angle) and kinetics (vertical ground reaction force (VGRF), moment and centre of pressure (COP)).

(f) Motor control exercise (MCE)

Specific stabilization exercise is commonly used to manage CNLBP by enhancing the function of specific muscles of the lumbopelvic region and the control of posture and movement.

CHAPTER 2

LITERATURE REVIEW

2.1 Biomechanical factors of low back pain

Globally, LBP prevalence is 12% momentarily, 23% monthly and 38% annually (Tosunoz & Oztunc 2017). According to the Global Burden of Disease 2010 Study, LBP ranked sixth highest burden disease, which was followed up with the more recent Global Burden of Disease 2019 Study whereby LBP ranked fourth from the perspective of the disability-adjusted life year. LBP became a top 10 disease over the past 10 to 24 years among 25 to 49 years age group (GBD 2019 Diseases and Injuries Collaborators, 2020). LBP is one of the examples of musculoskeletal diseases associated with disability continued increasing in 11 countries which was categorised as low-income countries and low Socio-Demographic Index (SDI) scale. Vujcic *et al*., (2018) stated more than 80% of working people experience LBP at least once in a lifetime. In fact, it is estimated that 18% of the population experience LBP at any given moment (Vujcic *et al.*, 2018). Furthermore, LBP is the main cause of disability of which leading to non-attendance from work in 187 countries (Hoy *et al.*, 2014). Apart of LBP prevalence records, up to 84% was chronic LBP (Airaksinen *et al.*, 2006). Almost 85% of LBP cases were diagnosed as non-specific chronic LBP with variety of movement dysfunction in which one of it is gait (Steele *et al.*, 2014). LBP was classified as the second most common cause for consulting a doctor the fifth for inpatient treatment and the third among diseases that require a surgery (Carneiro & Rittenberg, 2010).

United Nations Educational, Scientific and Cultural Organization (UNESCO)'s introduced the 17 Sustainable Development Goals (SDGs) in order to achieve the 2030 Agenda for Sustainable Development. Two of the 17 SDGs are to

ensure healthy lives and promote well-being for all at all ages and to promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. However, LBP affects various areas of life such as, economic, psychologically, work attendance and also public health issues. Work attendance associated with reduction in productivity and loss of labour force and these conditions caused medical and economic burden on individuals, families and employers (Ibrahim *et al.*, 2019). Hüllemann *et al*., (2018) stated the prevalence of LBP had increased from the past ten decades causing tremendous economic cost for treatment, sick leave and early retirement. In term of psychosocial aspects, LBP resulted in a lack of supportive and encouraging culture, and passive coping skills among nurses. Meanwhile, psychologically, LBP resulted in stress and anxiety causing dissatisfaction about the job (El-Soud *et al.*, 2014; Shieh *et al.*, 2016). According to Mousazadeh *et al*., (2019), increasing job dissatisfaction will lead to medical and nursing errors, and other undesirable functioning. Mousazadeh *et al*., (2019) stated job satisfaction is an essential component in health care settings. This concept associated to conditions and relationships that govern the workplace, the organizational system of employment and social, cultural and economic factors. Besides that, individuals suffered from LBP easily burnout. Daraiseh *et al*., (2003) found that LBP was able to weaken the quality of nursing care due to complex interaction of working conditions.

For the past 30 years, motion analysis on trunk activity of the upper extremities has been developed on a large scale compared to lower extremities. Nevertheless, both upper and lower extremities movement play an important role in numerous human activities as the trunk provides stability to the limbs, allowing them to function properly (Negrini *et al.*, 2016). Basic component of the physical examination for people with LBP is by observing lumbo-pelvic movement and posture (Laird *et al.*,

2014). This is because identifying and correcting movement and postural aberration is a common belief to improve pain and activity limitation (O'Sullivan, 2005; Ikeda & McGill, 2012). Therefore, basic kinematics assessments obtained from motion analysis such as range of motion (ROM), joints angle and posture are typically used to assess lumbo-pelvic movement (Laird *et al.*, 2014). Biomechanical factors such as kinematics (i.e., joint angle) and kinetics (i.e., ground reaction force, joint moments), and muscle activity in population with LBP were vigorously studied in diverse motions including walking (Lamoth *et al*., 2006; Prins *et al*., 2016; Hemming *et al*., 2019), sit-to-stand (Verlaan *et al.*, 2018) trunk flexion-extension (Milosavljevic *et al.*, 2008) trunk circumduction (Cheng *et al.*, 2013), weight lifting (Bouilland, Loslever & Lepoutre, 2002; Bourigua *et al.*, 2014), carrying and transferring a standard load (Catena & Xu, 2015) and single leg squat (Graci, Van Dillen & Salsich, 2012).

Sung & Maxwell, (2017) conducted a study based on kinematic chain reactions on trunk and dynamic postural steadiness in subjects with recurrent LBP. This study was conducted on 34 control subjects (18 female, 16 male) and 29 subjects with recurrent LBP (17 female, 12 male) to compare the standing time, spine range of motion (ROM), and dynamic postural steadiness index (DPSI). They compared the visual conditions (i.e., eyes-open and eyes-closed condition) between subjects with and without recurrent LBP during upright one leg standing. The result indicated that LBP group demonstrated shorter standing times in the eyes-open condition could be due to the motor learning. Their motor learning associated with functional daily activities was altered by proprioceptive sensitivity in order to avoid pain while maintaining postural steadiness (Brumagne, Cordo & Verschueren, 2004). LBP group also avoid pain and minimize trunk rotation by decreased thorax and lumbar spine rotation during the eyes-closed condition. These results suggested that LBP group

avoid pain or protect the connective tissues from further injury by altered load sharing strategies for coordination within the spine regions (Sung & Maxwell, 2017). Although the VAS score results reported as mild pain intensity and the level of pain might not be severe, participants with recurrent LBP were still unable to adapt postural control strategies because they suffered acute muscle fatigue or pain. Besides that, LBP group showed DPSI significantly correlated with the medio-lateral steadiness index (MLSI), anterior-posterior steadiness index (APSI), and vertical steadiness index (VSI) during eyes-closed condition. Chain reaction between DPSI and ROM of spine region proved the use of DPSI in this study was a sensitive measure for three-dimensional examination of postural stability (Wikstrom, Tillman & Borsa, 2005; Meardon, Klusendorf & Kernozek, 2016). Therefore, the results of this study could provide the insight on how CNLBP group response to surrounding in any visual conditions while maintaining postural steadiness.

Hasegawa *et al*., (2018) conducted cross-sectional case-control study to investigated association of low back load with LBP during static standing among 67 university students with and without LBP. This study examined kinetic and posture angle features of habitual standing posture. They stated that habitual poor standing posture may be a risk factor of LBP in the workplace due to large mechanical load on the low back that increased the intervertebral disc compressive force when the lumbar vertebrae are in a flexed or an excessively extended position. In the same vein, Hasegawa *et al*., (2018) reported that the group with LBP had greater intervertebral disc compressive force and the low back moment than group without LBP. Even though there was a small intervertebral disc compressive force during static standing but a large magnitude of this force appeared to contribute to LBP. Besides that, LBP group tend to alter their standing posture hence increased the intervertebral disc

compressive force. This analysis revealed that the risk of LBP will increase about two to three times higher for every 1 N/kg increase in intervertebral disc compressive force. They concluded the intervertebral disc compressive force as the most strongly associated factor with LBP during static standing. However, the results are not generalizable to other populations for instances, middle-aged women or elderly individuals.

Müller *et al*., (2015) conducted three-dimension (3D) motion analysis of walking and running on the unperturbed flat track and an elevation of 10 cm of uneven walkway to compare gait parametric (i.e., speed (m/s) and step length (m)), trunk as well as lower limb kinematics (i.e., thorax, pelvis, knee and ankle touch down angle (°)) and kinetics such as ground reaction force (GRF) between 11 (five males, six females) CNLBP and 11 healthy participants (five males, six females). They found that during walking on level and uneven ground, CNLBP participants had lower early peak GRF compared to healthy participants. Meanwhile there was slight changes of early peak GRF during running on uneven ground whereby the CNLBP participants peak GRF (1.73bw ± 0.31bw and 2.43bw ± 0.25bw) was lower at first contact and second contact compared to healthy participants respectively (1.85bw ± 0.18bw and (2.58bw ± 0.23bw).

LBP is commonly accompanied by decreased walking velocity. Previous study conducted by Lamoth *et al*., (2002) has shown that chronic LBP patients walk slower than normal velocity to reduce pain by restricting movements of the erector spine (ES) activity. However, they found that acute LBP patients did not alter the trunk coordination and muscle activity during walking even at different velocities (Lamoth *et al*., 2004). Lamoth *et al*., (2006) then expended their study on the effects of chronic LBP on trunk coordination and back muscle (i.e., ES) during various walking velocity.

The study included 19 CNLBP patients (eight males, 11 females) and 14 healthy participants (nine males, five females). Supposedly, normal gait should have transverse thorax–pelvis coordination changes from more in-phase (synchronous pelvis and thorax rotation in the same direction) to more antiphase (synchronous counter-rotation) as walking velocity increases (Lamoth *et al*., 2002). However, they found that CNLBP patients' pelvis-thorax coordination changes from more in-phase to more antiphase was decreased (less transverse counter-rotation) at higher walking velocity. Besides that, CNLBP patients demonstrated rigid and less variable kinematic coordination in the transverse plane, more variable coordination in the frontal plane, slower walking velocity, shorter stride length, and poorly coordinated activity of the lumbar ES compared to healthy participants. They concluded that conservative gait training therapy should be considered as well as exercises aimed at improving muscle coordination.

Hemming *et al*., (2019) investigated the trunk muscle activity in CNLBP group with motor control impairment (MCI) (27 Flexion Pattern patients, 23 Active Extension Pattern patients) and 28 healthy individuals during functional tasks (i.e., reaching upwards, step-down, step-up, lifting and replacing a box, stand-to-sit, sit-to-stand and bending to retrieve (and returning from retrieving) a pen from the floor. CNLBP patients with flexion pattern MCI were unable to activate lumbar multifidus due to pain during flexion activities, whereas extension pattern MCI individuals showed hyperextended lower lumbar postures and reported pain during more extended or upright activities (O'Sullivan, 2005). Hemming *et al*., (2019) found that flexion pattern group had increased activity on the left side of transversus internal oblique compared to controls during stand-to-sit. Meanwhile extension pattern group had greater right side of external oblique activity compared to controls during box lift.

Active extension pattern group reported greater activity of right superficial lumbar multifidus during step up, reach up and box replace compared to controls. Flexion pattern group reported greater activity of left superficial lumbar multifidus during stand-to-sit compared to controls. Active extension pattern group and flexion pattern group reported no activity differences of longissimus thoracis during any task. Hemming *et al*., (2019) concluded that muscle activity in CNLBP subgroups appeared to be highly variable during functional tasks with no clear pattern of activity identified due to inconsistencies and variability in trunk muscle activity. However, intervertebral motion may be restricted in order to increase local spinal stability and at the same time to protect dysfunctional passive spinal structures from pain provocative movement. This was considered a protective mechanism of the neuromuscular system because patients who reported pain during extension activities may adopt motor strategies to protect the spine especially in extension activities.

People with chronic LBP had reduced ROM at the lumbar spine and speed of lumbar (Laird *et al*., 2014). Hidalgo *et al*., (2012) observed that the mean ROM of lower lumbar spine during flexion from a seated position for CNLBP patients and healthy subjects were 53.8° (16.3) and 73.1° (15.8) respectively. Whereas the mean ROM upper lumbar spine during flexion from a seated position for CNLBP patients and healthy subjects were 60.9° (16.8) and 81.9° (15.9) respectively. This discrepancy occurred due to loss of flexibility in the lumbar spine coupled with stiffness which led to reduce lumbar spine ROM. Besides that, Hidalgo *et al*., (2012) found that the mean speed of lower lumbar spine during flexion from a seated position for CNLBP patients and healthy subjects were 88.1°/s (32.1) and 120.7°/s (42.4) respectively. Meanwhile the mean speed of upper lumbar spine for CNLBP patients and healthy subjects were 101.1°/s (31.8) and 139.6°/s (40.9) respectively. It means that LBP patients typically

exhibited slower lumbar movement speed and reduced ROM due to fear of movement which persisted even after recovery (Laird *et al*., 2014). Additionally, excessive spinal flexion together with trunk rotation may be associated with increased mechanical stress at the spine in CNLBP patients (Taniguchi *et al*., 2017). Laird *et al*., (2014) found that lordosis angle did not differ between LBP individuals (23° to 56°) and healthy individuals (19° to 53°).

LBP can be observed during dynamic movements such as walking, sit-to-stand, step up, forward bending and so on using two-dimensional (2D) kinematic analysis or three-dimensional (3D) analysis. Studying the kinematics itself helps us to understand the mechanism of LBP and how its affect joints kinematics. Abd Rahman *et al*., 2023 conducted a systematic review regarding biomechanical factors associated with non-specific low back pain in adults. They reported LBP patients walked with lower amplitude of trunk and pelvis residual rotation (van den Hoorn *et al*., 2012), increased trunk and knee rotations and trunk-flexed posture and a higher level of extended knee joint angle at touchdown (Müller *et al*., 2015) and deficits in the lower lumbar and thoracic ROM (Christe *et al*., 2017). Meanwhile, in kinetics, Farahpour *et al*., (2016) reported LBP patients walked higher ground reaction force (GRF). Abd Rahman *et al*., 2023 elaborated the result of GRF can be influenced by speed of walking and also foot pronation. Faster walking speed with pronated foot will increase the results of GRF. These situations happened due to increase in stiffness during walking, accompanied by a protective strategy to prevent painful motion and further injuries (van den Hoorn *et al*., 2012).

2.2 LBP among Nurses

Overall, studies on biomechanical factors of LBP among nurses are lacking and existing studies among nurses with LBP focused on educational program with clinical training (Samer *et al*., 2014) and role of job satisfaction in the relationship between job performance and organizational commitment components (Otoum *et al*., 2021) Previous studies in 2.1 recruited university community (students and employees) (Sung & Maxwell, 2017), sedentary university students (Hasegawa *et al*., 2018), patients and volunteers from University of Jena (Müller, Ertelt & Blickhan, 2015), recreational runners (Seay, Van Emmerik & Hamill, 2011) local volunteers in Amsterdam region (van den Hoorn *et al*., 2012), university employees from Medical Centre of the Free University (Lamoth *et al*., 2006), patients and healthy volunteers in physiotherapy department from Cardiff and Vale University Health Board (Hemming *et al*., 2019) patients and volunteers from Saint-Luc University Hospital (Hidalgo *et al*., 2012) recreational university students (Taniguchi *et al*., 2017). Among personal healthcare around the globe, nurses are the most affected by work-related musculoskeletal problems such as LBP.

There are two reasons that cause nurses to leave their job which are physical and mental demands. Ibrahim *et al*., (2020) identified that 898 out of 1292 (76.5%) nurses in the public hospitals of Penang suffered from LBP in 2016 and 17% to 39% of nurses wanted to quit their job due to their nature of job which required physical and mental commitments. The prevalence of LBP among nurses has been reported to be six times higher than other health professionals.

Meanwhile, in a developed country such as United State (US), it was reported 82% nurses had LBP within a year (Videman *et al*., 2005). In Japan, the prevalence of nurses had LBP was 85.5%. In developing country such as Turkey, the prevalence of back pain among turkey nurses was 77.1% within a year. However, prevalence of LBP

among nurses in Turkey not as high as in US and Japan. Videman *et al*., (2005) showed LBP prevalence among nurses increased from 31% at entry of nursing school to 72% at the end of the school and further to 82% after 5 years working as a nurse. Prevalence of LBP varied according to working unit and years of experience. Gim, (2017) reported 84.5% nurses in critical care units, Hospital Universiti Sains Malaysia complained they had LBP after working as a nurse due to working experience at ward and total years of nursing experience. In addition, nurses with more than 20 years nursing experience reported had higher risk of LBP compared to nurses working less than one year. It shown that occupational back pain and seniority level were related (Gim, 2017). Also, a report had shown 70% nurses working in the orthopaedic unit had the same prevalence rate as well as nurses working in intensive care unit (ICU) (Vieira *et al*., 2006).

Nurses play a major role in hospital in term of patient management especially for warded patients. Nurses who work actively led them exposed to LBP due to the nature of their work. On a daily basis, nurses deal with occupational hazard including physical hazards such as patient handling tasks and ergonomic hazards. El-Soud *et al*., (2014) explained that improper body posture and carrying of objects and patients are the contributing factors for LBP. There are several motions related to nurse's job that increased risks of LBP for example, positioning patients on the bed, carrying, lifting and transferring patients or carrying medical equipment of various weights and sizes (oxygen tank, pressure mattress, traction equipment and oxygen concentrators ventilators). At the same time, tidying beds of various heights increase the risk of a low back trauma for nurses (El-Soud *et al*., 2014; Ibrahim *et al*., 2019). Therefore, precautions and prevention of LBP in nurses is essential for nurses to work under

healthy and safe conditions in order to maintain their professions and provide better support and services for patients.

Physical and mental demands may cause nurses to quit their jobs at early years of servicing. This is because nurses may be exposed to several hazards that may result in LBP while providing patient care during working. LBP among nurses may lead to disruption to the quality of patient care, increases absence to work and job-related disability costs. There are several strategies to overcome LBP by including coping techniques and intervention programs such as physiotherapy, active treatments (i.e., core-strengthening exercises and physical fitness programs), and passive treatments (i.e., manual therapy, soft tissue techniques, traction, electrotherapy, and heat and cold therapies) (Ibrahim *et al*., 2020). Exercise is commonly prescribed can reduce pain and disability function, decreasing the risk of chronic LBP, and increase work attendance (Saragiotto, Maher, Yamato, Costa, Menezes Costa, *et al*., 2016). However, to the best of our knowledge, study on the mechanics during nurses-related tasks (i.e., walking, and carrying and transferring load) among nurses with CNLBP and long-term effects of exercise on full body mechanics, functional disability outcome and pain score among female nurses with CNLBP are still in insufficient amount.

2.3 Exercise intervention in managing LBP

Exercise is a planned, structured and repetitive physical activity with the goal to improve or maintain one or more components of physical fitness (Hayden *et al*., 2005). Exercise therapy should be used as the primary treatment of various LBP. This is because exercise program yields effective pain reduction, functional ability and speed up the return to work compared with general medical care and passive treatment measures (Hayden *et al*., 2005). According to Searle *et al*., (2015), exercise programs

which focus on strengthening and stabilizing the musculature are able to relieve LBP better than cardiopulmonary (ie., fitness) program. Besides that, passive treatments such as ultrasound, hot and cold therapy and massage also failed to relieve pain in adults with CNLBP without following proper exercise (Owen *et al*., 2020). In other words, exercise has been shown to be effective in reducing pain in adults with LBP compared to non-exercise-based treatments. There are numerous studies that have been conducted to investigate the effects of exercise intervention in treating LBP which involved various exercise programs such as sling exercise (Yue *et al*., 2014), dynamic strengthening exercise and stabilisation muscles exercise (Moon *et al*., 2013; Sipaviciene & Kliziene, 2020), pilates, yoga and motor control exercise (Owen *et al*., 2020).

LBP, arthritis, fibromyalgia and dysmenorrhoea or any chronic pains can be treated by following guideline provided and promoted by American College of Sports Medicine (ACSM). Exercise can be performed individually or with the assistance of certified trainer or any exercise professionals. Also, exercise vary in intensity, duration, frequency and type (i.e., aerobic, anaerobic, flexibility, resistance exercise, or balance). Based on previous studies conducted by Saragiotto *et al*. (2016) & (Fransen *et al*., 2015), exercise intervention can be implemented ranging from once a week, twice a week or twice a day with short series of exercises. For intensity, some studies describe based on low intensity (very light) to maximum effort (vigorous) (Regnaux *et al*., 2015) or low intensity only (Fransen *et al*., 2014) or moderate to high (Fransen *et al*., 2015). Specifically, Cramp *et al*. (2013) described baseline intensity for aerobic interventions is about 70% to 85% of heart rate maximum or heart rate reserve (HRR), meanwhile for resistance exercise ranged from 70% to 80% of an individual's 1-RM and 50% to 70% for maximum voluntary contraction (Koopman *et*

al., 2015). In addition, Cramp *et al*., (2013) suggested mostly exercise intervention can be around 45 to 60, 90 or 120 minutes. However, it is recommended to perform more regularly compared to longer sessions such as 15 minutes per session.

Ibrahim *et al*., (2020) conducted a study regarding the interactive LBP intervention module based on the Back School Program among 284 nurses in government hospitals in Penang who had been experiencing LBP for three consecutive months. This study involved 142 nurses in intervention group (four males and 138 females) and 142 nurses in control group (seven males and 135 females) who were randomly selected from four selected hospitals. The intervention group undergone four sessions of health education sessions and three sessions of exercise program which consisted of muscle stretching, strengthening, mobilizing, and core stability exercises using a gym ball for six weeks. Meanwhile the control group was given standard care and advice for a sedentary lifestyle by an attending doctor without any specific module or exercise program. The results were examined using the Oswestry Low Back Pain Disability Questionnaire (ODQ) before (baseline), during exercise intervention (third week) and after exercise intervention (six week). Based on the results, they found that symptoms of LBP in intervention group was reducing and the results can be seen as early as three weeks, and this effect was sustained until the sixth week of the intervention. This result was supported by Chung *et al*., (2013) study in which exercise involving a gym ball was able to produce greater improvements in functional disorder indexes and increase the activity of all trunk muscles. Therefore, the Back School Program was effective and can be practiced among nurses with and without LBP.

Samer *et al*., (2014) conducted a study based on effect of educational program with clinical training on reducing of work-related low back pain among 70 Malaysian nurses (6 males and 64 females) working at Hospital Universiti Sains Malaysia