

T.C.
YEDİTEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF SPORTS PHYSIOTHERAPY

**COMPARISON OF THE EFFECTS OF
SELF-MYOFASCIAL RELEASE AND
COMBINED CORE STABILIZATION
EXERCISES IN PHYSIOTHERAPY AND
REHABILITATION STUDENTS WITH
LOW BACK PAIN**

MASTER THESIS

UFUK DOĞANCALI PT, Msc

ISTANBUL - 2022

T.C.
YEDİTEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF SPORTS PHYSIOTHERAPY

**COMPARISON OF THE EFFECTS OF
SELF-MYOFASCIAL RELEASE AND
COMBINED CORE STABILIZATION
EXERCISES IN PHYSIOTHERAPY AND
REHABILITATION STUDENTS WITH
LOW BACK PAIN**

MASTER THESIS

UFUK DOĞANCALI, PT, MSc

ADVISER
PROF. DR. FERYAL SUBAŞI

ISTANBUL-2022

THESIS APPROVAL FORM

Institute : Yeditepe University Institute of Health Sciences
Programme : Sport Physiotherapy Master Program
Title of the Thesis : Comparison of the Effects of Self Myofascial Release and Combined Core Stabilization Exercises in Physiotherapy and Rehabilitation Students with Low Back Pain
Owner of the Thesis : Ufuk Doğancalı
Examination Date : 14.06.2022
This study have approved as a Master Thesis in regard to content and quality by the Jury.

	Title, Name-Surname (Institution)
Chair of the Jury:	Assoc. Dr. Özgül ÖZTÜRK (Acıbadem University)
Supervisor:	Prof. Dr. Feryal SUBAŞI (Yeditepe University)
Member/Examiner:	Assoc. Dr. Üyesi Elif DEVELİ (Yeditepe University)
Member/Examiner:	Assoc. Dr. Özgül ÖZTÜRK (Acıbadem University)

APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated and numbered

Prof. Dr. Bayram YILMAZ
Director of Institute of Health Sciences

DECLARATION

I hereby declare that this thesis is my own work that to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

14 June 2022

UFUK DOĞANCALI



DEDICATION

I would like to dedicate my dissertation work to my parents Gülay and Sinan Doğancı, whose support and presence give me strength and perseverance. During this time, it was always indispensable to have their emotional support to get through stressful times.

UFUK DOĞANCI



ACKNOWLEDGEMENT

Firstly, I would like to thank everyone who contributed to my dissertation.

I would like to express my sincere gratitude to my supervisor Professor Feryal Subaşı who supported and helped me. She has given me important advice at every stage of writing my dissertation on how to do this work successfully.

I really would like to thank my teacher, Elif Tuğçe Çil who helped me find my participants in this study and supported me while writing with her precious pieces of advice.

I would like to thank my teacher Güzin Kaya Aytutuldu, who helped me with her precious pieces of advice.

Moreover, I would like to express my sincere thanks to my psychologist Derya Yalçın, who helped me uplift my mood.

Finally, I would like to thank my mother Gülay Doğançalı and Yasemin İpekaltınyeleklioğlu for their tremendous support. Without their presence, I would not have completed my work successfully. In addition to that, I am thankful for my whole family.

TABLE OF CONTENTS

THESIS APPROVAL FORM	ii
DECLARATION	iii
DEDICATION	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS.....	vi
LIST OF TABLES.....	ix
LIST OF FIGURES.....	x
LIST OF SYMBOLS AND ABBREVIATIONS	xiii
ABSTRACT.....	xv
ÖZET.....	xvi
1 INTRODUCTION AND PURPOSE.....	1
2 THEORETICAL FRAMEWORK AND LITERATURE REVIEW	5
2.1 Muscular Tissue.....	5
2.2 Anatomy of the Spine	7
2.2.1 Vertebral Column.....	7
2.2.2 Lumbar Vertebrae	9
2.2.3 Biomechanics of the Spine.....	9
2.2.4 The Intervertebral Discs	11
2.2.5 Intervertebral Joint.....	13
2.2.6 Ligaments of Spine	15
2.2.7 Muscles of the Spine.....	16
2.2.7.1 Posterior Group Muscles.....	17
2.2.7.2 Anterior Group Muscles	19
2.3 Fascia	21
2.3.1 Histology of Fascia	22
2.3.2 Types of Fascia	23
2.3.3 Myofascial Meridians	26
2.3.4 Biomechanical Properties of Fascia	28
2.4 Low Back Pain	29
2.4.1 Possible Mechanisms of Low Back Pain	30

2.4.1.1 Radicular Pain	30
2.4.1.2 Facet Joint Syndrome.....	30
2.4.1.3 Sacroiliac Joint Pain.....	31
2.4.1.4 Lumbar Spinal Stenosis	31
2.4.1.5 Discogenic Pain	32
2.4.1.6 Non-Specific Low Back Pain	33
2.4.2 Risk Factors.....	33
2.4.3 Biomechanics of Non-Specific Low Back Pain	34
2.4.4 General Treatments for Low Back Pain.....	34
2.4.5 Physiotherapy Approaches	35
2.4.5.1 Exercise	35
2.4.5.2 Manipulations	35
2.4.5.3 Hotpack	35
2.4.5.4 TENS.....	35
2.4.5.5 Kinesiotaping.....	36
2.4.5.6 Ultrasound	36
2.4.5.7 Myofascial Release	37
2.4.5.8 Self Myofascial Release	37
2.5 Core Stability	39
2.5.1 Subsystems of Core Stability	39
2.5.1.1 Active Subsystems	39
2.5.1.2 Passive System	40
2.5.1.3 Neural Subsystem	40
2.5.2 Core Muscles and their functions	40
2.5.2.1 Thoracocolumnar Fascia	42
2.5.2.2 Paraspinal Muscles	43
2.5.2.3 Quadratus Lumborum	43
2.5.2.4 Anterior (Abdominal) Muscles.....	44
3. MATERIAL AND METHOD	45
3.1. Subjects	45
Inclusion Criteria.....	45
Exclusion Criteria.....	45

Flow of Research.....	46
Study Protocol.....	47
3.2 Evaluation	47
Sociodemographic Questionnaire	48
Visual Analogue Scale	48
Oswestry Disability Index	48
3.3 Intervention	49
3.3.1 Core Stability Exercises	51
3.3.2 Self-Myofascial Release	60
3.4 Statistical Analysis.....	63
4. RESULTS.....	64
5. DISCUSSION	97
6. CONCLUSION	105
7 REFERENCES.....	106
APPENDIX 1: INFORMED WRITTEN CONSENT	137
APPENDIX 2: ETHICAL COMMITTEE APPROVAL	140
APPENDIX 3: SOCIODEMOGRAPHIC QUESTIONNAIRE	142
APPENDIX 4: THE PERMISSION FOR THE OSWESTRY DISABILITY INDEX ..	143
APPENDIX 5: OSWESTRY SCALE	144

LIST OF TABLES

Table 3.1 The Exercise Program of two groups for each week	49
Table 4.1 Sociodemographic Features of University Students	64
Table 4.2 Intergroup Comparison of pre-findings of VAS-Activity&at rest of Groups .	65
Table 4.3 Intergroup Comparison of pre-findings of each Oswestry scores of Groups .	65
Table 4.4 Distribution of each and total Oswestry scores in Groups according to the severity level of disability at baseline	66
Table 4.5 Intragroup Comparison of Sudden effects of VAS Activity –VAS at rest of Groups	69
Table 4.6 Intragroup Comparison of Pre-findings of VAS Activity and VAS at Rest of Groups according to different week intervals	70
Table 4.7 Intragroup Comparison of Total and Each Oswestry Scores of Groups according to different weeks	71
Table 4.8 Intergroup Comparison of Differences in Sudden effects of VAS-Activity and VAS at Rest between Groups.....	74
Table 4.9 Intergroup Comparison of Differences in VAS Activity and VAS at rest between Groups according to different week intervals	75
Table 4.10 Intergroup Comparison of Each Oswestry Scores of Group according to different week intervals	76
Table 4.11 Distribution of each and total Oswestry scores in Groups according to the severity level of disability at mid and post interventions	81

LIST OF FIGURES

Figure 2.1 Neuromuscular Junction	6
Figure 2.2 The representation of the spine.....	8
Figure 2.3 Three axes of the motion.....	10
Figure 2.4 The position of the body and increasing moment on the spine	11
Figure 2.5 The Representation of the intervertebral Disc.....	12
Figure 2.6 The representation of the zygapophyseal Joint	14
Figure 2.7 The Representation of ligaments of the spine	15
Figure 2.8 Erector Spinae and Multifidus Muscles.....	17
Figure 2.9 Intertransversarii and Rotator Muscles.....	19
Figure 2.10 Abdominal Muscles	20
Figure 2.11 Six Myofascial Chains	27
Figure 2.12 Conventional TENS	36
Figure 3.1 Flowchart of the Study.....	46
Figure 3.2 Study Protocol	47
Figure 3.3 The demonstration of the Cat-Camel exercise	52
Figure 3.4 The demonstration of the Prayer Stretch.....	53
Figure 3.5 The demonstration of the Abdominal Draw-In Exercise	53
Figure 3.6 The demonstration of the Abdominal Draw-In with Knee to Chest Exercise	54
Figure 3.7 The demonstration of the Abdominal Draw-In with Knee to Chest Exercise	54
Figure 3.8 The demonstration of the Abdominal Draw-In with foot on the foam roller Exercise	55
Figure 3.9 The demonstration of the Supine Twist Exercise	55
Figure 3.10 The demonstration of the Plank Exercise	56
Figure 3.11 The demonstration of the Side Plank Exercise	56
Figure 3.12 The demonstration of the Press up Exercise	57
Figure 3.13 The demonstration of the Prone Cobra Exercise	57
Figure 3.14 The demonstration of the Superman Exercise.....	58
Figure 3.15 The demonstration of the Quadruped Opposite arm/leg Exercise.....	58

Figure 3.16 The demonstration of Bridge and Supine Single Leg Butt Lift Exercises..	59
Figure 3.17 The demonstration of the Supine Dead Bug	59
Figure 3.18 The demonstration of the Russian Twist with an object	60
Figure 3.19 The demonstration of Myofascial Release of Quadratus Lumborum.....	61
Figure 3.20 The demonstration of Myofascial Release of Paraspinal & Thoracolumbar Fascia.....	61
Figure 3.21 The demonstration of Myofascial Release of Piriformis and Gluteal Muscles.....	62
Figure 3.22 The demonstration of Myofascial Release of Psoas Major.....	62
Figure 4.1 Distribution of Gender	64
Figure 4.2 The Demonstration of change in VAS-A and VAS-R over 5 weeks in groups	75
Figure 4.4 The Demonstration of change in Total ODI over 5 weeks in groups	80
Figure 4.5 Distribution of pain intensity score in groups according to the severity level of disability	86
Figure 4.6 Distribution of self-care scores in groups according to the severity level of disability	87
Figure 4.7 Distribution of lifting scores in groups according to the severity level of disability	88
Figure 4.8 Distribution of walking scores in groups according to the severity level of disability	89
Figure 4.9 Distribution of sitting scores in groups according to the severity level of disability	90
Figure 4.10 Distribution of standing scores in groups according to the severity level of disability	91
Figure 4.11 Distribution of sleeping scores in groups according to the severity level of disability	92
Figure 4.12 Distribution of social life scores in groups according to the severity level of disability	93
Figure 4.13 Distribution of travelling scores in groups according to the severity level of disability	94

Figure 4.14 Distribution of change in pain scores in groups according to the severity level of disability	95
Figure 4.15 The Distribution of Total ODI score in groups according to the severity level of disability at different weeks	96



LIST OF SYMBOLS AND ABBREVIATIONS

%	the symbol of Percentage
AF	Anulus Fibrosis
AGE	Advanced Glycation End products
AL-TENS	Acupuncture like Transcutaneous Electrical Nerve Stimulation
ANOVA	Analysis of Variance
BFL	Back Functional Line
BMI	Body Mass Index
BSE	Back School Exercise
cm	Centimetre
C-MFR	Myofascial Release combined with core exercises
CNS	Central Nervous System
CSE	Core Stabilization Exercise
DAMP	Damage-associated Molecular Pattern
DFL	Deep Front Line
ES	Erector Spinae
FABQ	Fear Avoidance Beliefs Questionnaire
FC	Functional Capacity
FP	First Program
FRP	Flexion-Relaxation Phenomenon
IAP	Intra Abdominal Pressure
IVD	Intervertebral Discs
IL	Interleukin
Kg/m ²	Kilogram/meter ²
KP	Kinesiophobia
LBF	Lower Body Flexibility
LBP	Low Back Pain
LL	Lateral Line
MCID	Minimal Clinically Significant Difference
MFR	Myofascial Release
Mhz	Megahertz

MPQ	McGill Pain Questionnaire
MRI	Magnetic Resonance Imaging
NP	Nucleus Pulposus
NSAIDs	Nonsteroidal anti-inflammatory Drugs
NSLBP	Non-Specific Low Back Pain
ODI	Oswestry Disability Index
OÖİ	Oswestry Özürlülük İndeksi
QBPDS	Quebec Back Pain Disability Scale
QL	Quadratus Lumborum
QOL	Quality of Life
PI	Pain Intensity
PSIS	Posterior Superior Iliac Spine
PT	Physiotherapist
RMQ	Rolando Morris Questionnaire
ROM	Range of Motion
SBL	Superficial Back Line
SCM	Sternocleidomastoid Muscle
SD	Standard Deviation
SDD	Smallest Detectable Difference
SFMPQ	Short Form McGill Pain Questionnaire
SM	Spinal Mobility
SMFG	Self-Myofasyal Gevşetme
SMFR	Self-Myofascial Release
SPSS	Statistical Package for the Social Sciences
SS	Spinal Stenosis
TCF	Thoracocolumbar Fascia
TENS	Transcutaneous Electrical Nerve Stimulation
TFL	Tensor Fascia Lata
TMJ	Temporomandibular Joint
VAS	Visual Analogue Scale

ABSTRACT

DOĞANCALI, U. (2022). Comparison of the effects of self-myofascial release and combined core stabilization exercises in physiotherapy and rehabilitation students with low back pain, Yeditepe University, Institute of Health Sciences, Department of Sports Physiotherapy, Master Thesis. Istanbul.

The primary purpose of this study is to compare two treatment protocols, which are core stability exercises combined with the self-myofascial release and only self-myofascial release regarding the functional capacity and pain. 32 physiotherapy and rehabilitation students from Yeditepe University who had no medical problems except low back pain (18W,14M;26,78 $\pm$ 3,66) were included. The total duration of the study was 5 weeks. Group 1 (G1) received the self-myofascial release and core exercises, while group 2 (G2) received only the self-myofascial release. An evaluation was made during the pre-intervention, mid-intervention (3rd week), and post-intervention. Functional capacity was evaluated with Oswestry Scale (ODI), while the pain was measured with the Visual Analogue Scale (VAS). According to the intragroup results, both the VAS-activity and the VAS-at rest decreased in both groups between pre-and post-measurements ($p<0.05$). VAS-activity ($p>0.05$) and VAS-at rest ($p<0.05$) increased in the 1st week in G1, while only the VAS-activity increased in G2 in the 1st week. ($p>0.05$) ODI scores decreased in both groups (<0.001). While nearly all of the sub-ODI scores decreased in G1 significantly ($p<0.05$), the sub-scores of G2 decreased statistically significantly compared to pre-intervention scores ($p<0.05$), except for social life and walking. Regarding the intergroup scores, the sudden VAS at rest scores were found to be statistically significant ($p<0.05$). The decreases in VAS-activity and VAS-at rest were found to be statistically significant between groups in favour of G1 ($p<0.05$). The decreases in the total ODI scores was statistically different between groups in favour of G1 ($p=0.001$). The decrease in pain severity, walking, sitting, and standing sub-scores of ODI were statistically different between the two groups (in favour of G1) ($p<0.05$). As a result, it has been concluded that in contrast to only the SMFR protocol, the SMFR with core exercises could have more effective in physiotherapy students with low back pain regarding pain and functional capacity.

Key Words:Self-Myofascial Release,Core Exercise,Low Back Pain,Functional Status

ÖZET

DOĞANCALI, U. (2022). Bel ağrısı olan fizyoterapi ve rehabilitasyon öğrencilerinde self myofasyal gevşeme ile kombine uygulanan kor stabilizasyon egzersizlerinin etkilerinin karşılaştırılması, Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Spor Fizyoterapisi Anabilim Dalı, Yüksek Lisans Tezi. İstanbul.

Çalışmamıza 18-35 yaş arası (18K, 14E; 26, 78 ± 3, 66) herhangi bir medikal teşhisi bulunmayan 32 bel ağrısı olan fizyoterapi ve rehabilitasyon öğrencilerinde self myofasyal gevşeme ve kor stabilite egzersizlerini birlikte içeren protokol ile sadece self myofasyal gevşeme uygulanan protokolün ağrı ve fonksiyonel kapasite üzerindeki etkilerinin karşılaştırılması amaçlandı. Çalışmanın toplam süresi 5 haftadır. Grup 1'e (G1) hem self myofasyal gevşetme hem de kor egzersizleri verilirken, grup 2'e (G2) sadece self myofasyal gevşetme uygulanmıştır. Tedavi öncesi, tedavi ortası (3.hafta) ve tedavi sonunda değerlendirmeler yapılmıştır. Fonksiyonel kapasiteyi değerlendirmek için Oswestry anketi (OÖİ) ,ağrıyı tespit etmek için Visüel Analog (VAS) kullanılmıştır. Grup içi edilen sonuçlara göre, hem aktivite VAS hem de dinlenme VAS tedavi öncesi ve sonrası sonuçları açısından her iki grupta da azalmıştır ($p<0.05$). Aktivite ($p>0.05$) ve dinlenme ($p<0.05$) VAS sonuçları G1'de ilk çalışma sonrası artarken, SMFG grubunda sadece aktivite VAS artmış bulunmuştur ($p>0.05$). OÖİ toplam sonuçları her iki grupta da azalmıştır. ($<0,001$) OÖİ'nin alt parametrelerinin hepsi Kor ve SMFG grubunda azalırken ($p<0.05$), SMFG grubunda benzer şekilde skorlar azalmış, ancak yalnızca sosyal yaşam ve yürüme çalışmanın başı ile sonu arasında anlamlı bir sonuç elde edilememiştir ($p>0.05$). Gruplar arası karşılaştırmalarda, ani VAS dinlenme sonuçları anlamlı olarak farklı bulunmuştur ($p<0.05$). Tedavi öncesi ve sonrası VAS-aktivite ve VAS-dinlenmedeki azalma G1 lehine anlamlı olarak farklı bulunmuştur ($p<0.05$). Tedavi öncesine göre toplam OÖİ'deki azalma G1 lehine anlamlı olarak farklı bulunmuştur ($p=0,001$). Çalışmanın başına göre OÖİ'nin ağrı şiddeti, kaldırma, yürüme, oturma ve ayakta durma skorlarındaki azalma G1 lehine anlamlı olarak farklı bulunmuştur ($p<0.05$). Sonuç olarak Self-myofasyal gevşetmenin kor egzersizleriyle verilmesi tek başına verilmesine göre ağrı ve yaşam kalitesinde bel ağrısı olan fizik tedavi öğrencilerinde daha verimli sonuçlar verdiği görülmüştür.

Anahtar Kelimeler: Self Myofasyal Gevşetme, Kor Egzersizleri, Bel ağrısı, Fonksiyonel Durum

1. INTRODUCTION AND PURPOSE

Low back pain is one of the most frequent musculoskeletal problems all around the world. Low back pain has a variety of subdivisions, but the most common form is non-specific low back pain (NSLBP). Since non-specific low back pain might affect nearly all ages, this could create several socioeconomic problems in countries (1). According to recent studies, it has been demonstrated that 35 to 50 % of people have non-specific low back pain persisting for more than twelve months (2, 3). Recent studies showed that the annual prevalence of non-specific low back pain is found to be 15% to 45% and its point prevalence is approximately %30 (4, 5). This painful disorder could be caused by mainly traumatic injuries, postural problems, and lumbar-region-based strains. Regarding the risk factors for non-specific low back pain, there are two categories, which are individual and psychosocial. Individual factors are age, gender, fitness level, biomechanical changes, and fascial problems, whereas environmental factors are psychological health, economic status, and posture (6).

Among risk factors, poor posture and lack of exercise could be the most predisposing components for non-specific low back pain. The posture in a sitting position may lead to increased mechanical stress on the spine (7, 8) and may have an increased static load on the ligaments of the lumbar spine. Therefore, viscoelastic deformations on fascia (myofascial adhesions) could occur, thus leading to spasms of paraspinal muscles. This hyperexcitability of lumbar back muscles could trigger metabolic reactions, which could increase the likelihood of acceleration of disc degeneration and possibly disc herniation (9). Also, during the sustained sitting posture, the amount of lumbar lordosis could decrease and the posterior pelvic tilt may increase, thus possibly leading to the occurrence of pain (10). In addition, it has been suggested in studies that individuals, who do not perform exercise sufficiently could be more prone to develop muscle strain, spasm, intervertebral disc injuries, and eventually low back pain because the deeply-localized stabilizer muscles could weaken and not be able to maintain an optimal stabilization of trunk (11,12). A study has demonstrated that non-specific low back pain could highly affect certain occupations that necessitate the sitting posture for long periods, such as office workers and university students. Another study also suggested that university students could be more prone to develop such problems

(13) and because they tend to spend time sitting in front of the computer and their daily routine lacks regular physical exercise. As a result, like other populations, they develop some postural changes and become more susceptible to pain, myofascial injuries, and loss of functional capacity (14). In the management of LBP, it has been suggested that there are several evidence-based effective healing options, namely pharmacological treatments, physiotherapeutic approaches such as electrotherapy, hot pack, kinesiotaping, exercises, and manual therapy (15)

Myofascial release (MFR) is known as one of the applications of manual therapy and can be performed by a physiotherapist or patient himself with specific tools, such as a foam roller (Self Myofascial Release). In 1990, John F. Barnes stated that the MFR approach is based on the release of all tensions and painful points, and the main goal of MFR is based on relieving the pain by eliminating the fascia problems associated with mobility (16). Also, Myers has defined several myofascial meridians (a group of muscles). Those meridians are quite fundamental because it has been shown that when one of the muscles found in those chains is injured, it could directly affect other muscle groups located on the corresponding meridian and lead to low back pain via tensegrative properties of the fascia (17). For this reason, MFR is applied to those meridians to eliminate fascial problems effectively. Moreover, recently conducted studies have suggested that MFR could be quite effective in the management of non-specific low back pain (18, 19).

Among exercise procedures, Core stabilization has become one of the most recommended techniques to manage the symptoms of non-specific low back pain. Core stabilization is made up of passive, active, and neural systems. The muscles on the back are divided into global and core muscles (20). Global muscles provide general stabilization, while core muscles are responsible for segmental stabilization. Global muscles are erector spinae, and abdominal muscles, while core muscles are multifidus, deep rotators, and intertransversarii muscles. With those exercises, they can be strengthened (21). The basic framework of the core is formed by four elements, namely the pelvic floor muscles, the transversus abdominis, the paraspinal muscles, and the diaphragm (21). A study suggested that patients with non-specific low back pain could have delayed activation of Transversus abdominis during movements, hence leading to an insufficient stabilization of the trunk (22). Hides has stated that individuals with

LBP are more likely to have poor contraction of multifidus muscles (23). It has been suggested that when there is a diminished activation of core muscles, there is an increased burden on the surrounding structures and less control during gait or other movements, resulting in possibly LBP (22, 23). According to the study by Granacher, this method could allow the back muscles to gain the appropriate strength (24). A systematic review has proposed that core exercises could be effective in decreasing pain compared to normal home exercises, thus increasing functional capacity (25). According to recent studies, core exercises could have beneficial effects on patients with non-specific low back pain regarding pain and functional capacity, increasing the activation of the aforementioned muscle groups.

Apart from that, in recent studies, the myofascial release protocol has been recommended with the combination of other manual therapy methods, occupational therapy, and core exercises (26). Nevertheless, myofascial release combined with core exercise protocols has become quite prominent recently and studies had different protocols for comparison of the effectiveness of those interventions, such as „Core exercise versus myofascial release “ or „myofascial release combined core exercises versus core exercises alone “ (27). According to the recent systematic review, both myofascial release and myofascial release combined with other interventions seem to be effective in the management of non-specific low back pain, yet there is no consensus between studies regarding myofascial release protocols, myofascial meridians, and study duration (28, 29). To our best knowledge, there is no study conducted for the comparison of the effectiveness of self-myofascial release combined with core exercises and self-myofascial release alone on the patient with non-specific low back pain regarding pain intensity and functional capacity.

The purpose of this study was to compare two treatment protocols, which are core stability exercises combined with the self-myofascial release and only self-myofascial release. Thus, we aim to compare the effects of both protocols on functional capacity and pain.

Hypotheses of the Study:

H0: There is no difference between the clinical results (pain, functional capacity) of physiotherapy students with non-specific low back pain who underwent two different

rehabilitation programs (core stability exercises combined with self-myofascial release and only self-myofascial release)

H1: There is a difference between the clinical results (pain, functional capacity) of physiotherapy students with non-specific low back pain who underwent two different rehabilitation programs (core stability exercises combined with self-myofascial release and only self-myofascial release)



2 THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Muscular Tissue

Muscles are one of the most important basic tissues in our body. This organ helps us move and is responsible for protecting our internal organs. There are 3 types of muscles: skeletal muscles, smooth muscles, and cardiac muscles (30). Skeletal muscles are voluntary, while the other two are involuntary (31). Muscles have many important and indispensable functions in our body, such as movement, breathing, stabilization, gastrointestinal movement, and more (32, 33).

Each muscle fibre can be stimulated by neurons to produce contractions. Muscle cells are formed by myogenesis, and the primary form of muscle is myoblast cells. They differentiate into myocytes via myogenesis (34). Skeletal muscle fibres are composed of three distinct layers: the epimysium, the perimysium, and the endomysium. The endomysium can be said to be the muscle fibres. The muscle fascicles consist of muscle fibres (35).

The sarcomere is known to be the basic building block of muscle cells. Within each sarcomere, there are some special filaments, namely actin and myosin. Actin is thinner compared to myosin myofibrils. In addition, each fibril consists of light and dark areas, namely A, Z, H, and I. I band consists of actin, while the A band consists of myosin filaments. The H zone is located between I bands (36). During each contraction, the Z lines move closer to each other. Thanks to them, contraction takes place. In addition, there is another filament that keeps the actin and myosin filaments in place: Titin (37). At the neuromuscular junction, the stimulus arrives and depolarizes the muscle cell membrane through neurotransmitters released from the axon terminal (38). The action potential travels along the membrane and then enters the cell through the T-tubules, resulting in calcium release from the sarcoplasmic reticulum. The sudden increase in calcium level causes the tropomyosin molecule to expose the myosin binding site in actin (39). Finally, power stroke occurs in these areas, leading to contraction (Figure 2.1) (40, 41).

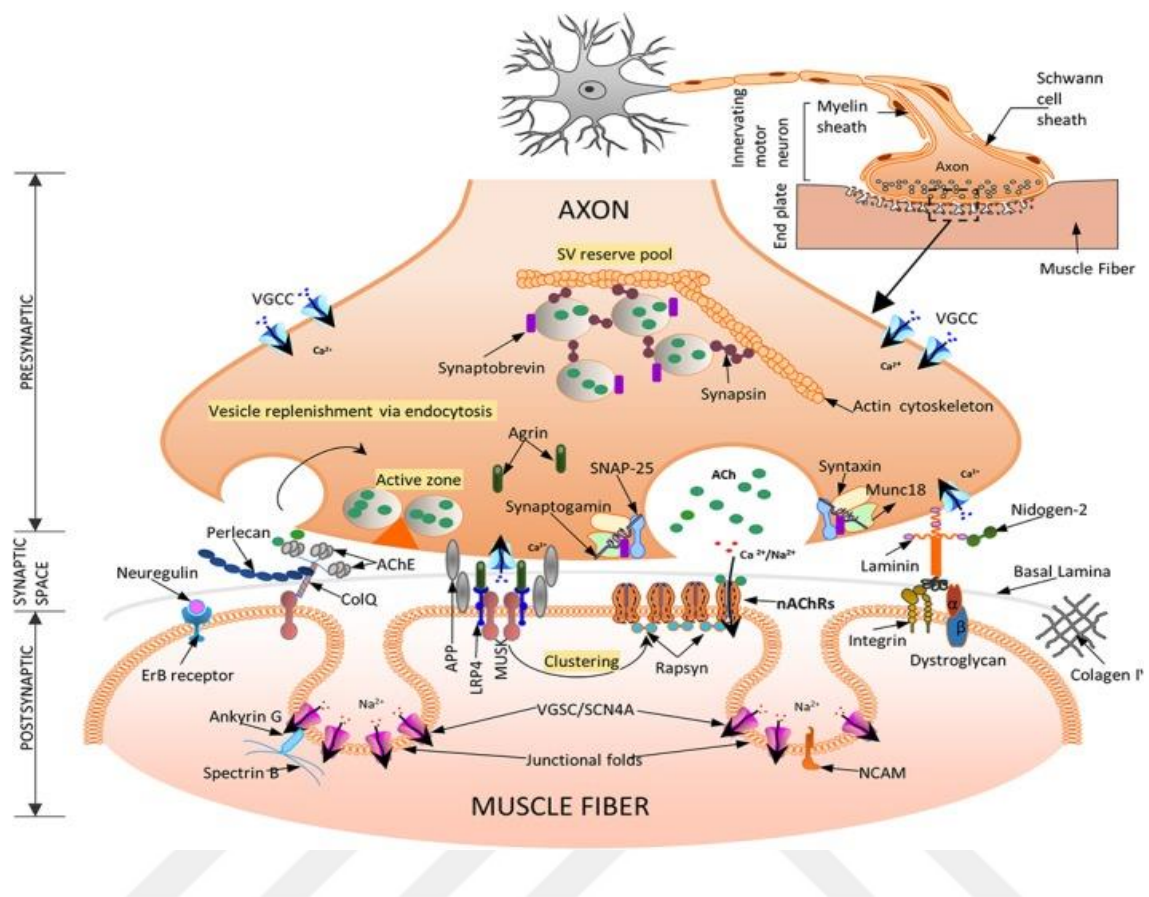


Figure 2.1 Neuromuscular Junction

Depending on the location of the skeletal muscles, their composition may vary in terms of the type of fibres. Type 1 fibres, for example, provide endurance, while type 2 fibres contribute to fast and explosive movements. Because they have different functions, their metabolism (aerobic and anaerobic capacities) is also different (42). In terms of fascicle arrangement, there are three main types: unipennate, multipennate, and longitudinal fascicles (43). In addition, skeletal muscles have a remarkable function in respiration because accessory muscles can facilitate overall inhalation and exhalation (44). Smooth muscles can control our internal organs such as the stomach, lungs, liver, and blood vessels. Just like skeletal muscles, they have actin and myosin filaments, but their arrangement in the cell is quite different. Their shape is fusiform (43). Originally, they originated in the mesoderm (45). As for their innervation, they receive information from the parasympathetic and sympathetic systems. Various molecules play a role in

contraction, such as calmodulin and myosin light chain kinase (46). Finally, cardiac muscle is a special tissue responsible for pumping blood and is composed of rectangular cells. The myocardium lies under the pericardium and is located on top of the endocardium (47). At the same time, actin and myosin filaments slide over each other, causing the heart to contract and pump blood repeatedly. The amount of force generated depends directly on the calcium level in the cardiac cells (48). There are 5 main phases of the action potential in cardiac cells. First, the cardiac cells depolarize rapidly, and then they repolarize rapidly and form a plateau. After this phase, rapid repolarization occurs and the voltage returns to the resting potential (49).

2.2 Anatomy of the Spine

It consists of the vertebral column and the spinal cord.

2.2.1 Vertebral Column

The vertebral column is our skeleton's primary axis. The vertebral column is composed of many different structures, including bones, ligaments, joints, and cartilaginous structures. The height of the column can change depending on gender. Male vertebrae tend to be longer than female vertebrae (50). The main function of the vertebral column is to protect the spinal cord and support our posture by providing attachment points for a variety of muscles (51). This structure includes a total of thirty-three vertebrae. It is known that seven of these are cervical vertebrae, twelve are thoracic vertebrae, five are lumbar vertebrae, five are sacral vertebrae, and four are coccygeal vertebrae. The vertebral column attaches to other bones such as the ribs, sternum, and skull (52). Spinal nerves originate from the vertebrae and have different functions depending on the vertebral level. The spinal canals in the cervical and lumbar regions are larger than those in the thoracic region (52). Because the spine is made of many strong materials, it can help us carry loads. A unique structure, the intervertebral disc, is located between two vertebrae. It is mainly responsible for reducing the frictional forces between vertebrae (53). As for the blood supply to the vertebral column, many important arteries branch off from other major vessels, namely the posterior intercostal artery, lateral sacral artery, lumbar artery, and vertebral artery. More specifically, the subclavian arteries arise from the subclavian artery. The posterior intercostal artery receives blood from the thoracic aorta. The lumbar arteries receive their blood from the abdominal aorta. Finally, the lateral sacral vessels derive from the iliac arteries. At the level of the spine, the blood vessels divide into two branches: the

anterior and the posterior. The anterior one supplies blood to the vertebral body, whereas the posterior one supplies blood to the neural arch, in which the spinal cord is located (52, 54). The neural part consists of the spinal cord and its processes, namely the filum terminale, the cauda equina, and the conus medullaris. The muscles are divided into two sections: intrinsic and extrinsic. The extrinsic muscles are divided into two categories, namely the medial (e.g. serratus posterior) and the superficial (e.g. rhomboid muscles). The intrinsic muscles of the back are divided into three parts, namely the superficial, the middle, and the deep. The superficial part consists of the neck flexors, such as the splenius muscles. The middle part consists mainly of the back extensor muscles, such as the erector spinae. The deep part consists of muscles responsible for stabilizing the trunk, such as the multifidus and deep rotators. They are believed to be rich in proprioceptors. In addition, there are deep suboccipital muscles in the neck (52, 55). The vertebrae can be connected by a specific type of joint known as a facet joint. The shape of the vertebrae may change depending on their location. For example, the first vertebra (atlas) has no vertebral body, whereas the second vertebra has a unique projection known as Dens that allows the head to rotate. The vertebrae in the thoracic region have special points of articulation for the ribs, while the lumbar vertebrae have very enlarged and rectangular vertebral bodies to support body weight (Figure 2.2) (56).

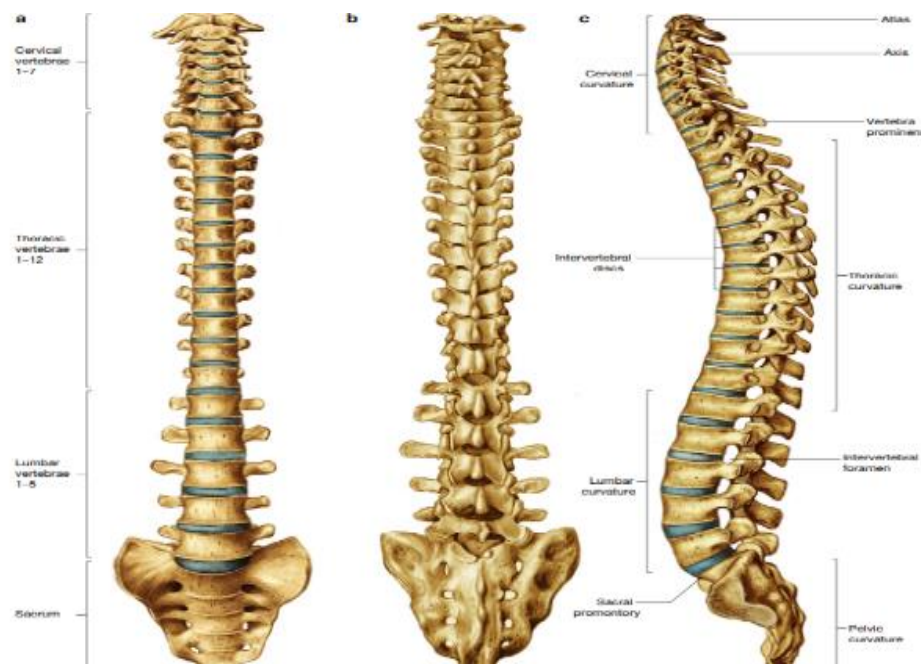


Figure 2.2 The representation of the spine

2.2.2 Lumbar Vertebrae

They are the lower part of the spinal cord. Compared to the other regions, they have a larger vertebral body to support the body weight. The lower the vertebral region, the larger its vertebral body. Unlike the upper vertebrae, they lack the foramen transversarium. There are a total of 5 lumbar vertebrae (52). In addition, they have a blunt spinous process that serves as an important attachment point site for muscles and ligaments. Most importantly, they have an articular arch consisting of two bilateral pedicles and bilateral laminae (57). This structure plays an important role in the formation of the vertebral canal, which houses the spinal cord. There are 4 articular processes, which are 2 superiorly and 2 inferiorly facing articular facets. The upward articular facet of a vertebra joins with the downward articular facet of the vertebra directly below it to form the facet joints, also known as the zygapophyseal joint. The zygapophyseal joint is directly responsible for providing additional stability to the vertebra. They have mammillary processes that form attachment sites for the multifidus muscle and the intertransversarii (58).

2.2.3 Biomechanics of the Spine

In the lumbar spine, there are static and dynamic structures. The static structures include the transverse processes, the pedicles, and the vertebral bodies of the zygapophyseal joint, while the dynamic structures are the intervertebral discs, ligaments, and muscles. It is well known that the spine is stabilized by ligaments and the surrounding connective tissue (59). The lumbar spine allows four different movements, namely flexion, extension, lateral flexion, and rotation. Depending on the movement performed, a specific point called the axis of rotation appears and its position can change. For example, during flexion of the lumbar spine, the point is located in front of the intervertebral discs. During lumbar extension, it is located behind the intervertebral discs. During lateral flexion to the right, the point shifts to the left, and during axial rotation, it is located in the middle of the intervertebral discs. In summary, the axis of motion depends on the type of motion we are performing (Figure 2.3) (60).

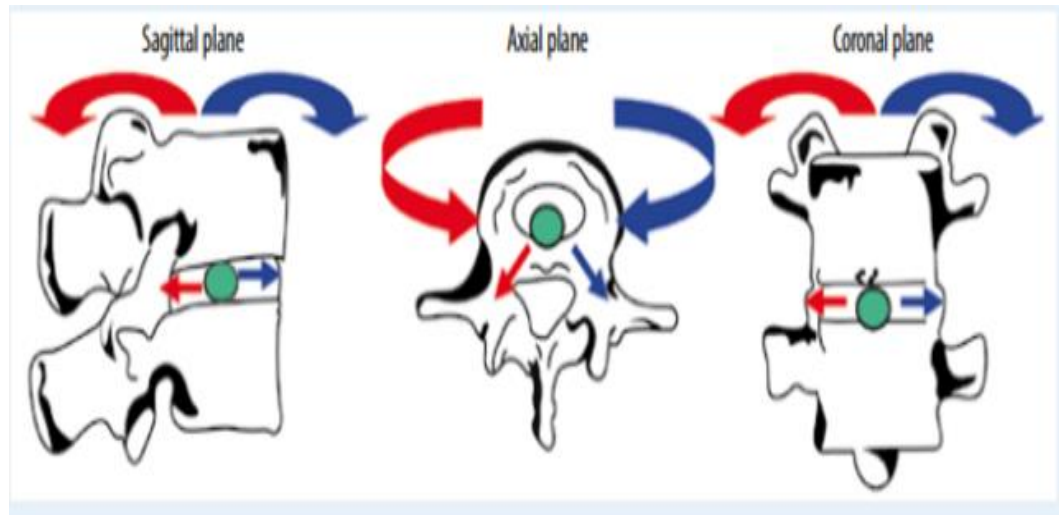


Figure 2.3 Three axes of the motion

The lumbar spine has a total of forty degrees of flexion, fifteen degrees of extension, thirty-five degrees of lateral flexion, and forty degrees of axial rotation. The lumbar spine contributes ninety-five degrees of flexion and extension, while the entire spine contributes more than two hundred and forty degrees. The same ratio applies to lateral flexion and rotation: 40 to 150 and 18 to 100, respectively (61). In addition, there are coupling movements in the spine. These movements can be explained by Fryettes' laws. According to his first law, contralateral rotation occurs when the lumbar spine is in a neutral position and one performs lateral flexion (62). According to his second law, rotation to the same side occurs when the lumbar spine is not neutral or flexed or extended and one performs lateral flexion. Thus, one movement is accompanied by another; these are coupling movements (63). In addition, there is a particular curvature in the lumbar region called lordosis. The normal lordosis is generally given as 30 degrees. However, it can change depending on the activity. More specifically, it decreases when we sit or increases when we stand. As lumbar lordosis increases, there are other changes in the body, such as decreased blood supply to the posterior portion of the annulus fibrosus and a decrease in the diameter of the spinal canal (64).

In addition, the centre of gravity is slightly more anterior than the spine. For this reason, it creates a bending moment on the spine. To compensate for this force, the muscles in the posterior region contract and press on the intervertebral discs. Depending

on our movement, the total pressure on the intervertebral discs varies between 0.1 and 2.3 MPa.⁵² We can measure 0.1 MPa when we lie on the bed, while 2.3 MPa is quite high and can be measured when we carry a heavy object of 20 kg away from the trunk. If we carry this object close to our trunk, we can reduce the pressure exerted on the intervertebral discs. In a sitting position, the pressure is 0.46 -0.83 MPa (Figure 2.4) (65, 66).

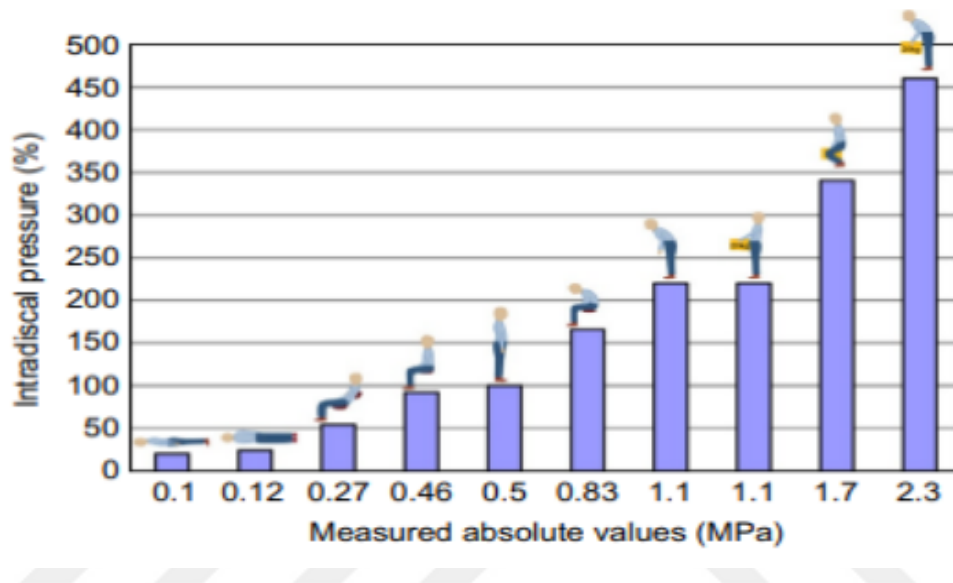


Figure 2.4 The position of the body and increasing moment on the spine

2.2.4 The Intervertebral Discs

Between the vertebrae are cushion-shaped structures called intervertebral disks. They can provide flexibility during spinal movements such as flexion and extension (67). Each intervertebral disk consists of two main components: the nucleus pulposus in the center and the annulus fibrosus surrounding the nucleus pulposus. Because there are numerous fibroblast cells in the annulus fibrosus, it is quite possible that new collagen fibres are constantly being formed (68). The collagen fibres are arranged randomly, while the elastin fibres are arranged in a circular pattern. The shape of these structures is circular. The main fibres formed in them are collagen 1 and 2. The annulus fibrosis consists of many layers, about 15-25, each layer being called lamellae (Figure 2.5) (69).

Aggrecan, fibrillin, and elastin are known to be the molecules responsible for connecting two lamellae.⁶⁹ Cells in the outer layer appear to be more slender and

arranged parallel to the fibroblast cells, while the inner cells are more oval. In addition, the cells have many cytoplasmic projections, which are thought to contribute to the sensation of mechanical stress (70). The nucleus pulposus is composed of a variety of molecules, namely chondrocyte-derived proteins, proteoglycans, and type 2 collagen (71). Therefore, it acts like jelly. Thanks to its composition, the nucleus pulposus gives the disk the ability to withstand an axial load and another type of compressive force. This is because it has a matrix packed with glycosaminoglycans and hyaluronic acid (72).

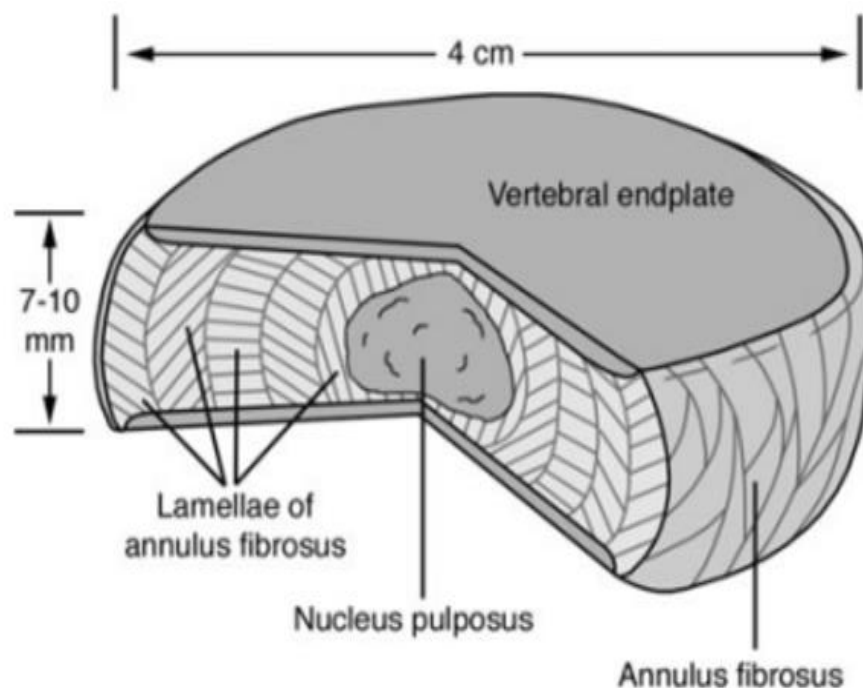


Figure 2.5 The Representation of the intervertebral Disc

There are molecules for the construction and destruction of this matrix. The degrading molecules are mostly leukocytes that secrete various interleukins such as IL - 1 and TNF-alpha (73). As for the molecules that support the formation of the matrix, they stimulate fibroblasts with the help of growth factors. These molecules inhibit the activity of metalloproteinases, thus increasing matrix synthesis (74). Many studies have concluded that the molecule TNF-alpha is responsible for decreasing matrix synthesis (75). As for the blood supply to the discs, the outer surface of the discs is supplied with

blood by arteries. The inner parts can be supplied by diffusion. The main vessel is the spinal artery (76).

In addition, there is another structure located in the inner and upper parts of the intervertebral discs known as endplates. Anatomically, it is located between each intervertebral disc and the vertebral bone. Its structure is very thin and consists of collagen fibres (77). Biomechanically, the intervertebral discs act as shock absorbers during movement. The annulus fibrosus is very tough and is responsible for maintaining its stiffness in the face of compressive or tensile forces, while the nucleus pulposus can change shape as needed (78). During flexion, the anterior portion of the intervertebral discs is compressed and the other portion is stretched, while during extension, the posterior portion of the discs is compressed. In addition, the intervertebral discs are at greater risk during rotational movements because the ligaments can offer less resistance to rotation (79-81).

2.2.5 Intervertebral Joint

There is a special connection between the vertebrae called the zygapophyseal joint. This joint is known as the synovial joint and is located nearly in each vertebra from the cranial to the sacral region. For this reason, it consists of a capsule and hyaline cartilage (82). The other name for this joint is facet joint. The facet joints are located between the lamina and the pedicle. Their function is to connect the superior and inferior articular prominences to increase the stability of the spine. This joint is stabilized by many different ligaments, namely the intertransverse ligament, the supraspinous ligament, the interspinous ligament, and the flavum ligament. Depending on the location of the vertebra, the position of the superior articular facet varies (83). For example, a vertebra in the cervical spine has an angle of about 40-50 degrees, while this process in the lumbar spine has an angle of 80-90 degrees. In other words, the lower the vertebra is, the greater its degree. It is supplied with blood by the segmental arteries. The capsule of the facet joints consists of two regions composed of different fibres. More specifically, the outer region is mainly composed of collagen, while the inner side is essentially composed of elastic fibres (84). This capsule connects to the surrounding muscles or ligaments, such as the multifidus. As for its innervation, it is supplied by the sinuvertebral nerve and the medial branch nerve, which are responsible for the innervation of many deep low back muscles (85). This particular fibrocartilaginous joint

generally allows flexion, extension, lateral bending, translation, and rotation (Figure 2.6) (86).

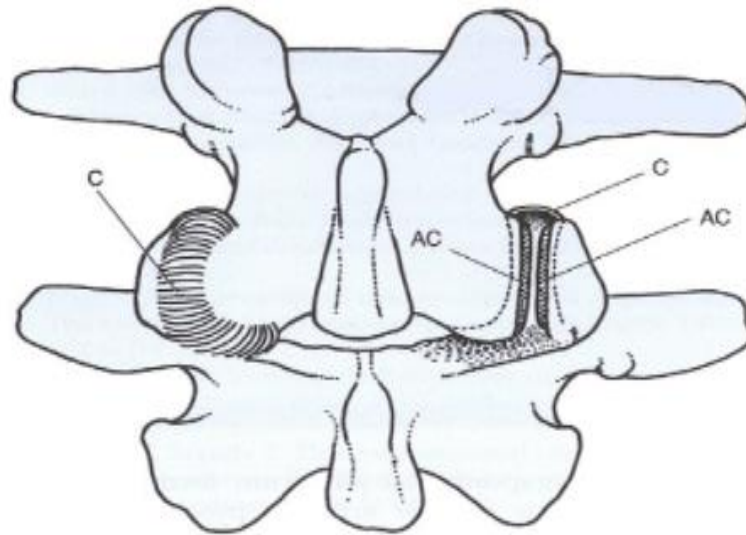


Figure 2.6 The representation of the zygapophyseal Joint

As for the biomechanical properties of the facet joints, they provide additional stabilization and restrict movement. It is well known that the shape and position of the facet joints change at the spinal level. Since the position of the zygapophyseal joint tends to be oblique, it restricts many movements (86). At the level of the cervical spine, the position is more sagittal. For this reason, almost all movements can be performed and they have less resistance to forwarding displacement. However, in the lumbar region, only flexion and extension are possible. In the thoracic spine, the degree is about (83), allowing rotation and lateral flexion. In addition, the ability to move can be affected by the shape of the facets. More specifically, the C-shaped facets may limit more forward dislocations compared with the J-shaped facets (86, 87). Not surprisingly, the older we get, the less the facets can stabilize our spine and make us more prone to low back pain. This is because the position of the facets becomes more sagittal as we age, and there are other mechanisms thought to contribute to pathologies in this joint, such as osteoarthritis and degeneration of the cartilage (88). When the facet joint is over stressed, it responds to the stress by increasing the amount of fluid and becoming

tenser, resulting in pain. The most sensitive area of all is known to be L4-L5. This area is known to be intensely innervated. Specifically, when osteoarthritis-associated changes occur in this region, they result in pain and inflammation by stimulating chemicals such as substance P and phospholipase (89).

2.2.6 Ligaments of Spine

The ligaments of the spine are divided into two sections, namely intersegmental and segmental ligaments. The intersegmental ligaments are the anterior and posterior longitudinal ligaments, while the segmental ligaments are the ligamentum flavum, the interspinous ligament, and the supraspinous ligament (90, 91).

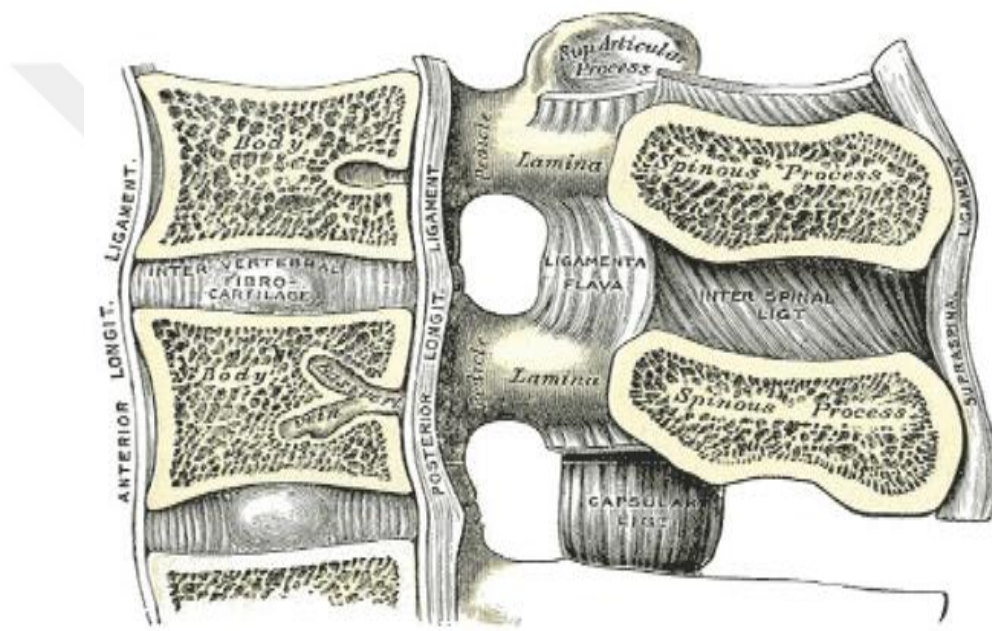


Figure 2.7 The Representation of ligaments of the spine

The anterior longitudinal ligament is located at the anterior part of the entire spine. It originates at the occiput and descends anteriorly to the sacrum (92). In addition, it may attach to the lumbar vertebrae, especially to the annulus fibrosus. As for its function, it is responsible for preventing the anterior discs from separating when we extend the spine. It is innervated by branches of the grey rami (92).

The posterior longitudinal ligament runs from the sacrum to the occiput, just behind the spine (93). This ligament is also known to attach to the annulus fibrosus. At the level of the pedicle, it narrows. As for its innervation, the sinuvertebral nerves

conduct impulses to the posterior longitudinal ligament. Functionally, it is responsible for preventing the posterior disks from separating when we flex the spine (94).

The interspinous ligament is responsible for connecting the spinous processes. It is known that its fibres connect to the ligamentum flavum in the anterior region. In the posterior region, it connects with the supraspinous ligament. In addition, this part connects with the thoracolumbar fascia. It is innervated by the dorsal rami (95). Although the interspinous ligament can resist lumbar flexion, its resistance to forwarding motion is not very great. It is also thought to have no remarkable mechanical support from the extensor muscles (96). According to some recent studies, this ligament can counterbalance anterior and posterior forces coming from limbs to vertebra from the limbs through the thoracolumbar fascia. The supraspinous, interspinous, and thoracolumbar fascia can be thought to work together and play a role in stabilizing the lumbar vertebrae by properly transmitting forces (97).

The ligamentum flavum connects two adjacent vertebral laminae. On the medial side, it fuses with the interspinous ligament, while on the lateral side, it fuses with the vertebral joint. It is well known that this ligament is essentially composed of elastin fibres. This yellowish ligament contains a small number of collagen bundles (98). Thanks to its elastin-rich structure, it can protect the spine from collapse. The ligamentum flavum can be affected by a herniated disk, which can lead to lower back pain. According to some studies, hypertrophy of the ligamentum flavum occurs with age, leading to many serious health problems such as spinal stenosis and low back pain (99).

The other ligament in the lumbar region is the iliolumbar ligament. It is supplied by the nerves from L4 and L5. This ligament is thought to contribute to sacral stability thanks to its firm anchorage between the iliac crest and L5 (100). Moreover, because it is full of Ruffini, Pacinian corpuscles, and free nerve endings, it can easily cause low back pain. Primarily, it is capable of inhibiting motion in the lumbosacral and sacroiliac joints (101).

2.2.7 Muscles of the Spine

The lumbar region consists of many different muscle groups. They are divided into two groups: the posterior and anterior muscles. The posterior muscles are erector

spinae, multifidus, rotatores, and interspinalis. The anterior muscles are internal oblique, external oblique, transversus abdominis, rectus abdominis, and quadratus lumborum.

2.2.7.1 Posterior Group Muscles

The muscle groups of the erector spinae are a combination of intrinsic intermediary muscles that are primarily responsible for erecting the spine and giving it additional stability (Figure 2.8) (102).

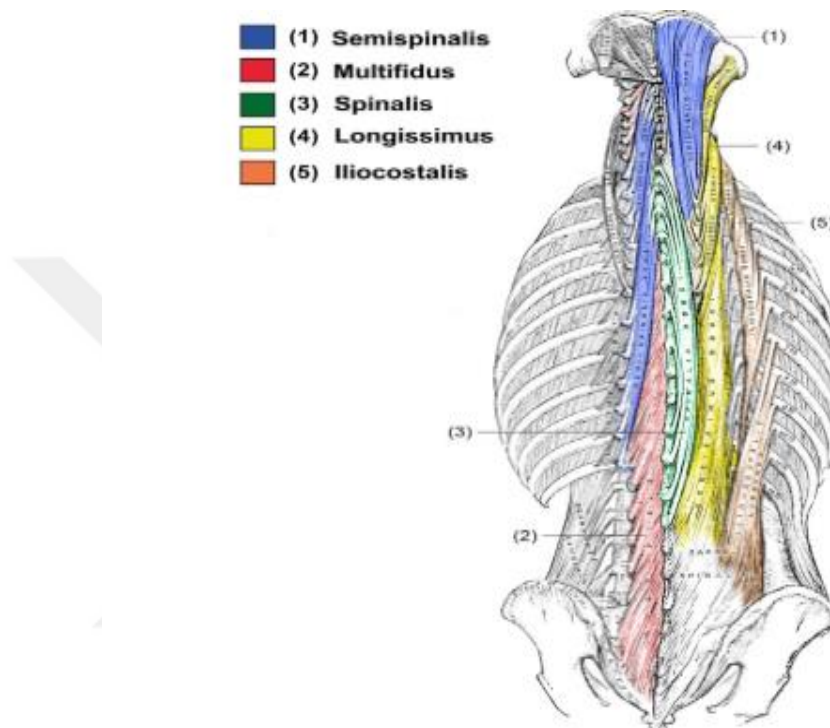


Figure 2.8 Erector Spinae and Multifidus Muscles

Sufficient extensor force can be generated thanks to a series of muscles arranged bilaterally to the spine and extending vertically throughout the spine. The erector spinae is also responsible for the rotation of the back and allows lateral flexion of the trunk (103). Overall, it represents a significant increase in our stability. The erector group overlies the transversospinalis. Compared to the superficial back muscles, such as the trapezius (located in the first layer) or the serratus posterior inferior (located in the third layer), they are located deeper (104). Because it occupies a very large area of the human body, it differs in size and structure in each vertical region. For example, as it extends to the spine, it becomes smaller. Some other structures cover the erector muscles. For example, the nuchal ligament lies around the cervical part of the erector spinae, whereas

the thoracolumbar fascia lies on the thoracic and lumbar parts of the erector spinae (102, 103). It divides into 3 important muscles, namely the spinalis, iliocostalis, and longissimus. All of these muscle groups are also subdivided into 3 parts, namely capitis, thoracis, and cervicis. The most lateral part is the iliocostalis, the muscle located in the middle is the longissimus, and the most medial muscle is the spinalis (103). They originate from the sacroiliac and supraspinous ligaments, the sacrum, and the lumbar region. The iliocostalis lumborum muscle has two main functions. When it contracts bilaterally, it is involved in the extension and axial rotation of the lower lumbar vertebral segments. When it contracts unilaterally, it is responsible for triple motion (extension - axial rotation - lateral flexion) (105, 106). The multifidus muscle has many origins that derive from PSIS, the posterior aspect of the sacrum, and the mammillary processes. It covers the spaces between the transverse and spinous processes (107). Primarily in the lumbar region, this muscle consists of three layers. Functionally, it extends the spine and contributes to stabilization, and because it produces the bowstring effect, it plays a role in lumbar lordosis (108). The rotatores muscles are located in the dorsal region. They have a rectangular shape and are located under the multifidus muscles. They run along the entire spine. It is known that they are more developed in the thoracic part, compared to the cervical and lumbar spine. They are innervated by the medial branch of the dorsal rami. Functionally, they are responsible for stabilizing the individual spinal segments. When they are contracted unilaterally, they can rotate the vertebra. When contracted bilaterally, they help the spine to extend (102). The interspinales muscles are short and small muscles located between each spinous process. Just like the rotators, they receive motor supply from the medial branch of the dorsal rami, just like rotatores. Their main function is to stabilize the spine. In addition, they make a small contribution to spinal extension. The interspinales muscles are more likely to be found in the cervical spine. Because they contain too many muscle spindles, they have proprioceptive input for our spinal movements (Figure 2.9) (102).

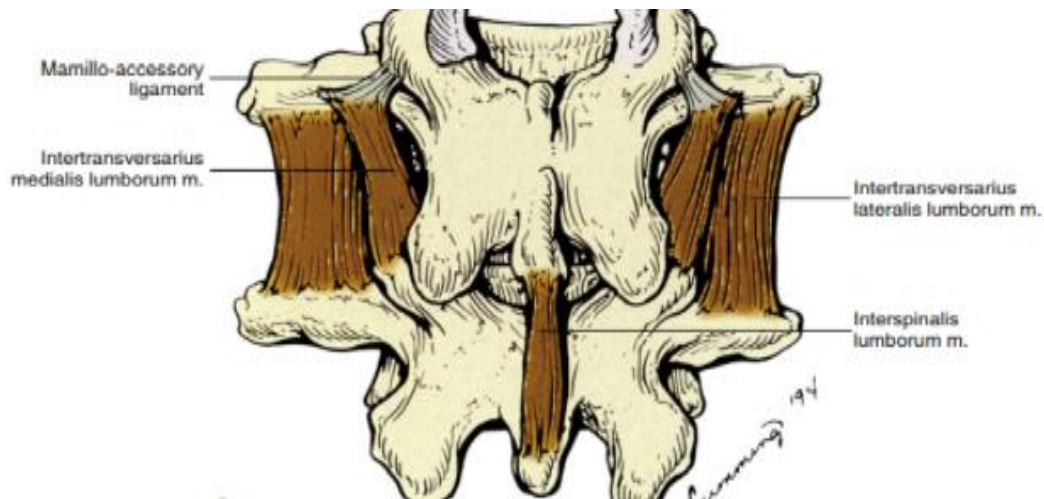


Figure 2.9 Intertranversarii and Rotator Muscles

2.2.7.2 Anterior Group Muscles

They do not attach to the spine, but their action has a direct effect on it. They are known to be located in front of the abdominal cavity and are mainly responsible for flexion of the spine. The most superficial abdominal muscle is the external oblique muscle. Below it is the internal oblique muscle and the transversus abdominis. The deepest muscle is the rectus abdominis (109).

The external oblique muscle is a very powerful muscle found on the lateral side of the trunk. It originates at the lower parts of the 5th and 12th ribs and runs to the cartilaginous part of the ribs. Some parts of this muscle unite with the latissimus dorsi and iliac crest, while the upper and middle parts merge with the serratus anterior muscle. As for its nerve supply, it is innervated by the ventral branches of the T7 and T12 spinal nerves. Functionally, it is responsible for pulling the lower ribs downward. It also helps us with each exhalation and plays a role in maintaining the IAP. When it is unilaterally contracted, lateral flexion and rotation of the trunk occur (Figure 2.10) (110, 111).

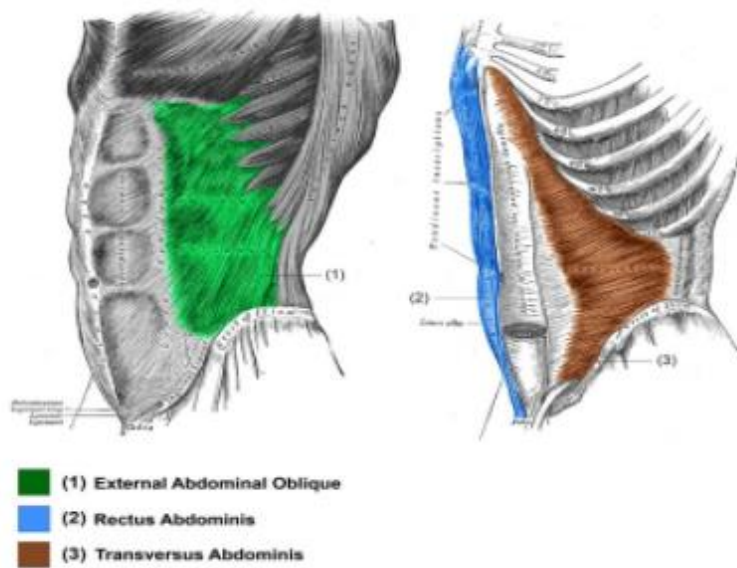


Figure 2.10 Abdominal Muscles

The internal oblique muscle is located directly below the external oblique muscle. Its muscle fibres run directly perpendicular to those of the other. It originates from the iliac crest, the external part of the inguinal ligament, and the TFL muscle. It runs to the 9th and 12th ribs and the linea Alba (102). At the level of the pubic crest, its fibres unite with the transversus abdominis. As for its motor supply, it is innervated by the T7-L1 spinal nerves. Since this muscle is capable of stabilizing the pelvis and thoracic cavity and compressing the abdominal cavity with each exhalation, it is considered one of the muscles that support respiration. When unilaterally contracted, it is responsible for the contralateral rotation and lateral flexion of the trunk (104).

The transversus abdominis is a deeper muscle compared with the external and internal obliques. It originates from the anterior part of the iliac crest, the TFL, the internal cartilaginous parts of the 6 ribs, and the inguinal ligament. These fibres run down to the linea alba and the pubic crest. It is known that many fibres run posterior to the rectus muscle. As for its motor supply, it is innervated by spinal nerves T7-11 and L1 (112). Functionally, it is responsible for maintaining core stability. According to

some studies, because it is associated with the TFL, it has a remarkable moment and influence on the lumbar segment (113).

The rectus abdominis is a paired and long muscle that runs anterior to the abdominal cavity. It is sheathed by the rectal sheath. This sheath is composed of the aponeuroses of the laterally located abdominal muscles (114). Anatomically, this muscle is divided by the linea alba. On each side of the rectus muscle is a special line, the linea semilunaris. It originates from the cartilaginous portions of the 5th through 7th ribs and the xiphoid process. It runs down and attaches to the pubic crest and the symphysis pubis. This muscle is divided into 6 parts by bands of connective tissue. As for its motor supply, it is innervated by spinal nerves T6 to T12 (115). Functionally, it is responsible for trunk flexion and anterior pelvic tilt when the lumbar spine is stabilized. It also makes a notable contribution to the respiration and protection of many gastrointestinal organs (116).

The quadratus lumborum is a very large muscle located between the 12th rib, the lumbar vertebrae, and the ilium. It attaches to the transverse processes of the lumbar vertebrae. Although its function remains a mystery, it is thought to pull the lower ribs down and fix the diaphragm during each breath. In addition, it plays a role in lateral flexion and extension (117).

2.3 Fascia

Fascia is one of the most important structures in the human body when it comes to the causes of a variety of health problems in the human body. If we have a healthy fascia, we can provide a perfect environment for our muscles during movements, reducing the occurrence of syndromes and diseases. The fascial problems seem to contribute to low back pain (118). They are mainly composed of fibrous connective tissue. The function of the fascia is to hold all structures such as organs, vessels, and ligaments in place when they move (119). At the same time, this specialized tissue can allow them to move on top of each other. This is because the fascia can reduce friction as much as possible (120). Fascia is found throughout the body, especially around muscles, specific organs, and bones. As for the other functions of fascia, they allow our fascia-encased structures to maintain their current properties, such as the ability to stretch. Not only are fasciae able to maintain the properties of muscles, but they also contribute to their tone. Depending on the location of the fasciae, their tasks and

structural properties change. In addition, their hardness can vary depending on their location. For example, fascial tissue should be harder in the back or thighs than in the arms or face to contribute to the upright posture of the body (121). Because fascia has a very close relationship with muscles, any problem affecting fascial tissue can easily lead to problems and restrictions in movement. For example, a restriction in a certain area can affect other areas through the connections between the fascial layers (122). The fasciae have a very remarkable function in proprioception, nociception, and force transmission. As for the classification of fascia, it can be divided into three areas: superficial, deep, and muscular (123). Superficial fascia is found almost everywhere and contains many collagen and elastin fibres, which is why it can help the tissue move freely and has elastic properties. It is thicker on the posterior side and in the lower limbs. It also contains superficial veins and lymphatic structures. The scrotum, platysma muscle, and external anal sphincter are the best examples of the superficial fascia (120, 124). The deep fascia consists of dense fibrous tissue. As for the task of deep fascia, it can sheath muscle fibres and cardiovascular structures such as arteries and veins. In addition, it plays an important role in sheathing nerves (120, 125). The deep fascia surrounding muscle fibres can be divided into three main components: Epimysium, Perimysium, and Endomysium. The outermost epimysium is responsible for separating muscle segments from each other, and the perimysium plays a role in separating muscle fibre groups. The endomysium covers the individual muscle fibres. At this point, other structures can be identified, such as the peritenon and the periosteum. As for the function of the peritenon, it is responsible for covering the fasciae so that they can move freely within it, and it can not only cover the fasciae but also connect the tendons to the bones, and it is also found around the internal organs and is called visceral fascia (124).

2.3.1 Histology of Fascia

Since fascia is one of the connective tissues, it is made up of many different materials, which are cells, ground substance, and diverse fibres. The fascial tissue is dependent on the amount of these aforementioned structures (126). Collagen is a very crucial substance found in the fascia. It is known that this is a helix glycoprotein. Fascia can withstand the tension thanks to collagen molecules (127). There are approximately 25 collagens in the body. But the most abundant and found collagen in the body is the first one. However, fascia contains more than one collagen fibre. Mainly, it is made up

of 1, 3, 4, 5, 6, 11, 12, 14, and 21 collagen fibres (128). Unsurprisingly, since fascial tissue can resist tension and mechanical forces, it is found in musculoskeletal system structures. Also, there are elastin fibres, which give the fascia its ability to stretch (129).

Fascial tissue contains also reticular fibres that are made up of mainly type 3 collagens. They are responsible for forming the external membranes of blood vessels, nerves, and sometimes muscles of internal organs. It is known that collagen fibres should be a mixture of both fibril-associated collagens with interrupted triple helices and fibrillar type. When it comes to the main purpose of fibril-associated fibres, they are responsible for arranging the thickness of fibre and attaching the basement membrane. Thanks to them, fascial tissue can maintain its main property (129).

When it comes to the most abundant cell found in the fascia, there are fibroblasts, fat cells, myofibroblasts, and different immune cells. In terms of fibroblasts, they are known to be able to produce collagen molecules. They react to many responses. For example, if there is no sufficient mobilization in the tissue, the specific amount of type 1 collagen fibres transforms into type 3 (130). Depending on the mechanical forces, many alterations are happening at the level of musculoskeletal parts, such as ligaments, and tendons. One of them is the increase in the number of fibroblasts. Also, cartilage cells keep more and more minerals (131).

Myofibroblasts give the fascia the ability to contract. It is because it consists of myofilaments. However, if their number increases dramatically, this causes many fascial problems, such as Dupuytren Disease. In addition, since there is a multitude of immune cells, this tissue can easily develop inflammatory conditions, thus leading to pain (132).

Apart from that, there are many fibre arrangements in the fascia, which are woven, irregular fusocellular, unilateral and multidirectional parallel arranged orientations (133).

2.3.2 Types of Fascia

Fascia is divided into four: linking, fascicular, compression, and separation fasciae. The linking fascia is known to be responsible for the movement and stabilization of the surrounding structures themselves. As for its composition, it is predominantly composed of type 1 collagen fibres. In addition, this type of fascia is highly organized due to its regular, orderly composition (134). The linking fascia is

found in many parts of the human body, such as the muscles, under the trunk, and the neck, and it is responsible for the formation of some structures in the nervous system and many connections between two parts (135).

It is well known that the linking fascia is mainly composed of two elements, a dynamic part, and a passive part. Not surprisingly, the dynamic part is responsible for the large fascial areas. This part plays a role in the movement of our joints and to some extent in their stabilization. Since this part is highly connected to the movement, it contains a large number of contractile structures with proprioceptive agents (136). This does not mean that this part directly contributes to the movement we want to perform. The best example of the connecting fascia might be the thoracolumbar fascia. This is because it controls our overall stability and provides a connection between the limbs and the trunk (137). The proprioceptive agents thought to be embedded in this part are Pacinian corpuscles. Therefore, they are also very sensitive to pressure changes. On the other hand, the passive part surrounds the muscles and forms various types of sheaths around the body. Moreover, this part is found at the junctions, such as the arches and the aponeuroses. Unlike the dynamic part, this part can deliver the force exerted. The dynamic part unlike the passive part can participate in movement (138).

The fascicular fascia organizes and puts everything in its proper place. This type of fascia is mainly responsible for forming tunnels of different sizes through which vessels, nerves, and muscle fibres pass. This means that the fascicular fascia connects all of these aforementioned structures. Unlike the linking fascia, it consists of remarkably dense and organized structures (139). The fascicular fascia is believed to contain the other types of collagen in addition to the first and third collagen fibres, namely the fifth, sixth, twelfth, and fourteenth. It is well known that muscles are composed of three main parts, namely epimysium, perimysium, and endomysium (140).

The primary function of the fascicular fascia is to form these layers sequentially. It forms small, tiny tunnels and passageways. Fascia is thought to contain the Golgi tendon organs, which are very receptive and sensitive to changes in muscle tension and can prevent injury (141). In addition, the fascicular fascia is known to be capable of transmitting myofascial forces to the whole body, more specifically to the muscles that are synergic with the movement being performed. In addition, it can form a barrier between blood vessels and nerves. This is because the nerves that run within these

layers require a blood supply. In this way, the neural elements are supplied with sufficient blood. In summary, the fascicular fascia is very important thanks to its network and support for vessels, nerves, and contractile fibres (141).

As for the compression fascia, it is known that they wrap the structures and exert a certain pressure on them, just like a sock. Because they wrap our legs or arms, it is generally believed that they contribute significantly to venous return. It is no wonder that they give us stability and thus promote our movements (142). As for their composition, we can say that they are composed of multifrontal tissue cells and regularly arranged tissues. The simplest examples of the compression fascia are brachial fascia, crural fascia, fascia of the forearm, and fascia lata. Even if we assume that the proprioceptors are located in this fascial tissue, we can neglect their presence. For this reason, the compression fascia is not as conspicuous as the linking and the fascicular fascia in terms of proprioceptive inputs (135).

The separating fascia is mainly composed of two different types of connective tissue, namely loose and irregularly thick (dense) connective tissue, with the third collagen fibres predominating compared to the other collagens. In addition, a smaller proportion of fifth and seventh collagens are believed to be found therein (135). The third collagen (also known as reticular fibres) is responsible for giving the tissue the strength it needs to withstand forces, while the elastin fibres ensure that the fascia expands. As the name suggests, this fascia can divide our body structures into many compartments. In this way, the systems and organs can all function together without interfering with each other (135, 139).

Fascia can not only divide our body into many functional compartments but also reduce the frictional forces so that the tissues can slide over each other. Unfortunately, when an accident or postural problems occur, the fascial area can be severely affected, resulting in a type of adhesion within. Since fascial tissue is a close-knit family, these adhesions can affect other regions as well. As for the classification of separating fascia, it can be said that there are four main subdivisions, namely subserous, parietal, extraserosal, and subcutaneous fascia (135, 143).

In addition, the tissue that envelops the tendons and large muscle groups is considered part of the separating fascia. First, the subserous fascia is known as the visceral fascia. It forms the surfaces of the internal organs under the parietal layer. It is

commonly known that the subserous fascia holds the exact location of the organs in the abdominal cavity. In addition, the subserous fascia can be called different names depending on the part of the body, for example, meninges or pleura. The parietal fascia is known to completely envelop the visceral fascia (143, 144). The extraserosal fascia fills the gap between these two structures. As for the innervation of the separating fascia, it has been shown to contain many mechanoreceptors that respond to pressure sensitivity, such as Pacinian corpuscle and Ruffini bodies. All in all, the separating fascia organizes our body and places structures in the correct position to optimize overall function (145).

2.3.3 Myofascial Meridians

According to recent studies, fascia consists of a total of 6 different fascial bands, namely the superficial back line, superficial front line, back functional line, front functional line, spiral line, and lateral line. Since the fascial bands are interconnected, a problem in one part can directly or indirectly affect another part, like a long chain. For example, if there is a tight and stiff fascia under the foot, it can even affect the TMJ and lead to TMJ dysfunction (146).

The superficial front line is located in the anterior part of the body. This band is known to extend bilaterally from the foot to a specific region of the skull called the epicranial aponeurosis. This fascial line is mainly responsible for flexion of the abdominal muscles (rectus abdominis), the extension of the legs (quadriceps), and dorsiflexion of the ankles (tibialis anterior). This system also consists of muscles in the neck, such as the sternocleidomastoid muscle and sternalis (Figure 2.11) (147). Because it closes the anterior part of the abdominal cavity, it also has a protective function for the internal organs from possible external forces (Figure 2.11) (147).

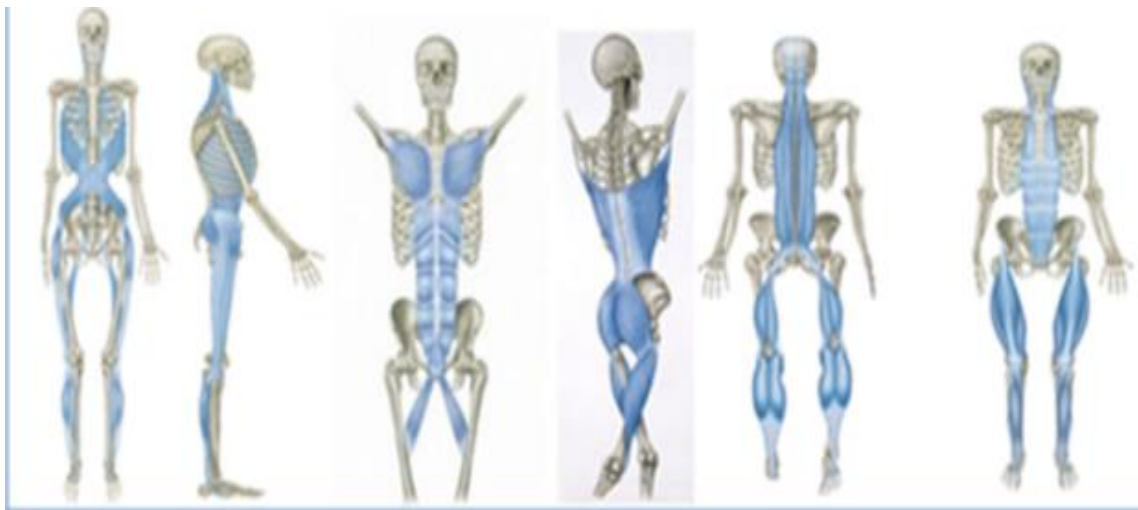


Figure 2.11 Six Myofascial Chains

Second, the superficial back line consists of the ligaments that run forward from the toes to the base of the eyebrows. This line has two bilateral bands. The main function of the superficial back band is to extend the spine and hip joint and flex the foot and knee joints. This fascial tissue maintains an upright posture against gravitational forces. This band includes the biceps surae and erector spinae. This line includes Flexor Digitorum Brevis, Gastrocnemius, Hamstring, Erector Spinae, Scalp Fascia, and Sacrotuberous Ligament (148).

Third, the lateral band runs from the malleolus lateralis to the mastoid prominence. It dips laterally into the thorax and visits the hip joint before reaching the mastoid process. It can balance and compensate for the forces on the left and right sides. In this way, we can perform more precise movements during extensions and flexions. The lateral band includes ankle evertors (peroneus longus and brevis), hip abductors such as the gluteus medius, TFL, splenius capitis, SCM, gluteus maximus, and lateral abdominal muscles responsible for lateral flexion (147, 149).

The spiral line begins at the feet and travels to the hip joint. At the level of the knee, it divides into two parts, one to the iliac spine, another to the posterior aspect of the pubic bone, and eventually fuses with the existing fascial tissue. The anterior part passes through the trunk at the level of the transverse column and rises through the

posterior part of the spine. Its function in the body is to perform medial rotation of the limbs and spine (147).

When it comes to the functional lines, they connect a femur to the contralateral humerus. It has a helical structure and is used functionally in sports that require strong rotational manoeuvres: Back functional line includes the vastus lateralis, subpatellar tendon, thoracolumbar fascia, gluteus maximus, and latissimus dorsi, whereas the front functional line includes the adductor longus, rectus abdominis, and pectoralis major (147, 150).

Spiral Line is also very fundamental. It includes splenius capitis, rhomboideus, serratus anterior, external oblique, internal oblique, rectus sheath, TFL, peroneus longus, biceps femoris, erector spinae, and sacrotuberous ligament (147).

The deep front line includes a variety of muscles. They are classified into three; anterior, posterior, and middle. In the anterior view, there are the anterior diaphragm, hyoid muscles, adductor longus, brevis, iliopsoas muscle, pectineus, and longus colli. In the posterior view, there are the posterior diaphragm, heart muscle, scalenes, adductor magnus, and pelvic floor muscles. In addition, there are muscles in the middle, namely; the tibialis posterior, and long toe flexors (147).

Moreover, there are other myofascial chains, namely; deep front arm line (biceps brachii, thenar muscle, brachialis), superficial front arm line (pectoralis major, latissimus dorsi), deep back arm line (triceps brachii, hypothenar muscles), and superficial back arm line (deltoid, trapezius, extensor group) (147).

2.3.4 Biomechanical Properties of Fascia

It is known that fascial tissue is mainly composed of collagen fibres. These collagen fibres are arranged in a very special way at each level of the fascia. What is special and unique about fascia is that it has anisotropic properties. Anisotropic means that a particular tissue can change its available mechanical properties when any forces are applied. According to the studies, there are many biomechanical properties of fascia, namely biotensegrity, contractility, piezoelectric effect, thixotropy, mechanotransduction, viscoelasticity, etc. (151). Biotensegrity is the fundamental property of fascial tissue. Fascia tissue is composed of myofascial chains that are interconnected like a spider web, allowing them to distribute forces to each other. If one side of the body is damaged, the other parts along the chain may also be affected (152).

Mechanotransduction is one of the most important properties of fascia. Metabolic processes at the cellular level can be triggered by tensile or compressive forces. In this way, a simple force can lead to a variety of chemical chains. Reactions include the release of cytokines and adhesion kinases.

Fibroblasts are also very sensitive to this type of mechanism. They can increase extracellular matrix synthesis via mechanotransduction (153). Viscoelasticity indicates that fascia exhibits properties of both solid and fluid materials. More specifically, it is elastic and viscous. Normally, elastic material can return to its initial position when the force is removed, but viscoelastic material can maintain the changes even when the forces are removed. The force should be applied slowly so that fibroblast cells can change the extracellular matrix by increasing the synthesis of tropocollagens. In summary, changes in viscoelastic materials, such as gene expression, persist even when no force is applied (154). Thixotropy means that when we apply a force or pressure to a viscous material, its viscosity decreases. The molecules become freer and freer. Since fascia is made of water molecules, it has this property. When we apply force to the fasciae, they become progressively softer and more viscous (155). The piezoelectric effect is very important for fascia. Bones and many proteins have this property. The piezoelectric effect is very similar to mechanotransduction. This time, it means that an electric field is created when a sufficient force is applied to the tissue. This electrical energy causes the fibroblasts to produce more and more collagen molecules, thus changing the composition of the fascia (156). Contractility is another biomechanical feature of the fascia. Because it contains myofibroblasts, it is capable of contracting (157).

2.4 Low Back Pain

Low back pain is one of the most troublesome events in adulthood. Not only is it annoying, but it is also a very common problem that limits our daily activities (158). Although the prevalence may vary by country, it is approximately 84% (159). LBP is divided into three, acute, subacute, and chronic. Chronic low back pain is a painful condition that affects the lower lumbar region. This syndrome can last more than four months and results in a gradual decrease in activity. Because this condition is difficult to treat, it places a significant economic burden on governments. It requires high costs for treatments in rehabilitation. Since those affected can no longer work, this leads to an

increase in economic consequences (160). As for the origin of the pain, it is very difficult to figure out which structure is affected and has caused the symptoms that the patient complains of. In deciding the cause, clinicians sometimes make mistakes that lead to misleading treatments. The reason for low back pain usually cannot be determined by clinicians (161). For this reason, they refer to this as a nonspecific condition. Generally, it is thought that muscle tension and spasms lead to painful points or areas in the area. In addition, the physician or physical therapist should examine the movements of the sacrum, assess the mobility of the sacroiliac joint, and palpate the muscles (162).

2.4.1 Possible Mechanisms of Low Back Pain

NSLBP pain could be caused by six main conditions: radicular pain, facet joint syndrome, sacroiliac joint pain, lumbar spinal stenosis, discogenic pain, and non-specific low back pain (163).

2.4.1.1 Radicular Pain

This condition is directly related to the dorsal root and possibly its ganglion. Because it is a lesion or inflamed area, the patient feels some type of painful area on the back that corresponds to the level of the spinal cord. One of the most common causes of radicular pain is disk herniation. In this case, as pressure is exerted on the nerve, the patient may experience numbness or their motor functions may be affected. Not surprisingly, radicular pain has an impact on reflexes (164).

2.4.1.2 Facet Joint Syndrome

This joint is located at the posterior border of the spine, where the inferior and superior spinous processes of two subsequent vertebrae are connected (165). This joint is innervated by the medial branch of the dorsal rami. This nerve is known to supply the very deep rotators of the back. This area contains a variety of nociceptive nerves and sympathetic efferent fibres (166). Recent studies have concluded that perceived pain originates from the basic components of the zygapophyseal joint, which may be the synovial membrane, fibrotic capsule, damage to the bone, and the surfaces of the facet joint (167). In general, people with facet joint syndrome have somatic referral pain on the thigh, particularly on the inner side or right quadriceps (167). Pain in the back is perceived as much worse compared to the pain in the leg. The intensity of the pain may increase when the patient performs movements that require rotational patterns or bending to the side. Just as with rheumatic disease, the patient cannot move freely in the

morning (168, 169). In addition, the patient may have difficulty maintaining an upright position on his or her feet after sitting for long periods.

According to scientist Jackson, there are 7 components of facet joint syndrome, namely age, recurrent back pain, normal walking, no pain in the thigh, a correct walking pattern, having no symptoms during the Valsalva manoeuvre, and a dramatic increase in pain during lumbar extension of the back (170). In addition, it is very difficult to determine the pathologic findings by radiologic examination (171). As important as the radiologic examination is, history and clinical examination are equally important in diagnosing facet joint syndrome (171, 172).

2.4.1.3 Sacroiliac Joint Pain

This particular joint is known to provide adequate support to the upper part of the body. It is responsible for the movement of the sacrum. For this reason, any problem related to the sacroiliac joint can directly affect the upper vertebrae. Although the innervation of this joint is unknown, many believe it is innervated by the dorsal rami (173). A study from 2012 concluded that the sacroiliac joint is innervated by the fifth dorsal spinal nerve and the lateral dorsal portion of vertebrae S1 through S3. In their study, these nerves inhibited their activity and the pain felt by patients decreased dramatically. The sacroiliac joint can trigger pain in this way (174). In addition, the other elements of the joint can also contribute to the development of pain. For this reason, the physical therapist can palpate the joint and determine how mobile this joint is.

Other conditions that affect the sacroiliac joint may include osteoarthritis and soft tissue injuries (175). The stress test is one of the most common physical exams used to diagnose this condition and can produce symptoms by applying pressure to the pelvis. Although this condition may be the primary cause of low back pain, unfortunately, many physicians overlook the presence of such a condition. If a patient suffers from increased pain when changing from standing to sitting and adopts a deviated posture, we should directly suspect a pathological condition in this area (158).

2.4.1.4 Lumbar Spinal Stenosis

Spinal stenosis is an abnormal narrowing of the spinal canal that results in excessive pressure on the nerves and blood vessels and symptoms. Because of this, the patient may experience numbness in the affected area or muscle weakness and, of course, pain (176). Depending on which structure is affected, symptoms may be

unilateral or bilateral. Sometimes dermatologic areas are also affected. In lateral recess stenosis, the patient usually has unilateral radiculopathy. This condition may develop over time or be present at birth (177). Predisposing factors may be ageing, because the older we are, the more worn the vertebral structures are (178). SS may be caused by rheumatic diseases such as ankylosing spondylitis or diabetes. The normal width of the spinal canal is about 20 mm, but if such a disease is present, the width may decrease to about 10 mm (179). Compared with sacroiliac joint pain, sitting posture, and lying on the bed can relieve back pain while standing for a long time can dramatically increase the pain (180). In addition, trunk flexion can relieve pain. Unfortunately, none of these measures is sufficient to relieve the perceived pain if it is severe.

In addition, the patient may have difficulty retaining urine (181). Lumbar stenosis can be diagnosed based on the patient's history, radiologic examination, and general examination. The most important findings for lumbar stenosis are the presence of pain in the thigh, advanced age, and worsening pain with walking or an upright position. At this point, a special test called the Stoop test can be used. During the Stoop test, sensory and motor symptoms become more severe as the patient walks. For example, the perceived pain worsens, but when he stoops, these symptoms are relieved. The patient has the same comfort when he leans forward while sitting. All of these findings indicate that the Stoop test is positive and that he has lumbar stenosis (182). According to recent studies, the prognosis of lumbar stenosis can improve or worsen over the years. For this reason, physicians cannot make improvements in spinal stenosis for granted (183).

2.4.1.5 Discogenic Pain

It is known that 39% of patients complaining of chronic low back pain have this type of pain. There is no specific finding for discogenic pain. Nevertheless, this pathology occurs even when there is no deformity of the spine (184). It is well known that intervertebral discs are shell-like structures consisting of two specific parts, the annulus fibrosus on the outside and the nucleus pulposus on the inside. When degeneration occurs in the vertebrae in either the nucleus pulposus or annulus fibrosus, symptoms may result (185). In addition, to diagnose discogenic pain, it is highly recommended to first rule out other possible conditions. Regardless of how many studies have been conducted over the past decade to determine the underlying cause of

discogenic pain, they have not been able to determine the exact cause (158). Instead, they have made some assumptions. One of these assumptions is that it has to do with the growth of the nerves that are responsible for transmitting pain. When these nerves invade the discs, the symptoms occur (186). The other assumption is that the discogenic pain is caused by endogenous signalling molecules called damage-associated molecular patterns. These molecules are thought to lead to an autoinflammatory response (186, 187). For this reason, once released, they may enhance the activity of proinflammatory cytokines such as IL 6 and IL 8 and matrix metalloproteinases. In this way, DAMP can trigger a series of inflammatory chemical reactions within the discs, leading to pain (188). Apart from these mechanisms, anaerobic bacterial infections are thought to have a crucial influence on discogenic pain (186). As for the diagnosis of this pathology, IMR can be used to determine whether there is degeneration of the endplates or vertebrae. Patients with diabetes are at higher risk of developing such pain because AGE molecules make us more susceptible to inflammation and degradation of these structures. AGE molecules are thought to increase oxidative stress and inflammatory responses (189,190).

2.4.1.6 Non-Specific Low Back Pain

NSLBP occurs also without a physiological or anatomical problem in our body. For this reason, the main cause cannot be easily identified. According to recent studies, this pain is due to biopsychosocial elements. In addition, centralization can occur and the pain can last for years. NSLBP can have a great impact on individuals of all ages. Since this condition is very difficult to handle, it poses a great economic and social burden on our lives. This condition has no specific pathophysiological explanation. According to recent studies, the prevalence was found to be higher in developed countries. Many possible reasons could result in NSLBP, such as tumours, cauda equina syndrome, osteoporosis, infections, aneurysm, or fractures in the lumbar spine (162).

2.4.2 Risk Factors

Patients may be more susceptible to developing non-specific chronic low back pain if they have the following characteristics; (191, 192)

- Severe anxiety or depression
- Lifting heavy objects
- Older age

- Excessive body weight
- Smoking
- Lack of exercise
- Occupational activity
- Sedentary lifestyle

2.4.3 Biomechanics of Non-Specific Low Back Pain

During sedentary work, the lumbar structures are subject to several mechanical forces. University students have to spend most of their time sitting in front of a computer. The sustained flexed posture may have many impacts. While sitting, there is an increased utilization of passive structures, specifically ligaments (11). Normally, there should be a healthy lumbar lordosis, but improper sitting for long periods could make it impossible to sustain this curvature. If this posture is maintained for several hours per day, lumbar lordosis decreases, intervertebral joint laxity increases and it may lead to a significant decrease in passive flexion stiffness. This results in pathological changes in the lumbar region (12). The passive structures become less and less strong and are no longer able to support the surrounding structures. For this reason, the responsibility of back paraspinal muscles increases dramatically, leading to hyperexcitability, spasms, and pain. In addition, since there could be weakened muscles and ligaments and decreased lordosis, the amount of burden on the intervertebral discs increases and triggers the excessive proliferation of inflammatory agents and metabolic chains, thus accelerating the degradation of discs (11, 12, 193).

2.4.4 General Treatments for Low Back Pain

Generally, patients with low back pain use NSAIDs to control their pain (194). Acetaminophen may be useful for low back pain. This agent appears to be safer compared with NSAIDs because of its negative effect on the gastrointestinal tract (195). Tramadol may be used by these patients if they cannot tolerate NSAIDs. In addition, muscle relaxants are thought to relieve pain and improve function (196).

Patients tend to resort to non-pharmacological treatments, namely acupuncture, exercise therapy, behavioural therapy, acupuncture, pressure point massage, and yoga (197).

Acupuncture is believed to relieve chronic pain and improve patient functioning. Unfortunately, this treatment has not yet been shown to be superior to the others (198).

Acupuncture and pressure point massage is thought to make a small contribution to reducing the severity of pain. It is well known that massage can be very satisfying when combined with adequate stretching and appropriate exercise programs (199).

Another treatment approach in the management of low back pain is cognitive-behavioural therapy. This method is based on treating psychological problems and freeing the person from them. This approach can be as satisfying as exercise programs, and recent studies support this treatment (195). In addition, there are many other treatment options, such as yoga, lumbar support, and physical therapy approaches (200). If symptoms persist and are severe, surgery should be considered (201).

2.4.5 Physiotherapy Approaches

2.4.5.1 Exercise

The exercise program is the most popular and useful approach. The main goal of regular exercise is to strengthen the muscles as much as possible. In this way, we can reduce pain and increase the patient's functionality (202). The most common exercise protocol is core stabilization exercises. Core exercises are covered in the next chapter.

2.4.5.2 Manipulations

Similarly, spinal manipulation is one of the most effective treatment options for low back pain (203). This approach includes many different mobilization techniques, namely low-amplitude, high-velocity thrust, and changing amplitude with low-velocity. The main purpose is to increase ROM and relieve pain by mobilizing the sacroiliac joint or lumbar region (204).

2.4.5.3 Hotpack

In clinics, most patients receive heat applications using hot packs. When we heat the tissues, blood flow, and overall metabolism increase significantly. In addition, heat reduces muscle spindle activity while having a stimulating effect on type 1a-b fibres. According to recent studies, it can probably alleviate pain by relieving spasms or tension (205,206).

2.4.5.4 TENS

TENS is the most common use of electrotherapy for pain conditions such as fibromyalgia, osteoarthritis, postoperative pain, neuropathic pain, and especially low back pain. It is known that there are three versions of TENS, namely conventional, acupuncture-like and intensive TENS (207). In the conventional TENS, we focus on the a-beta fibres. These fibres are stimulated and make the gate close, which relieves the

pain. The general frequency is 50-100 Hz. It has high intensity and low frequency (208). Different TENS relieves pain through different mechanisms, namely segmental, extra segmental, peripheral, and neurochemical. For example, conventional TENS is based on the segmental mechanism, while AL - like TENS - relies on the extra segmental pathway (Figure 2.12) (209).

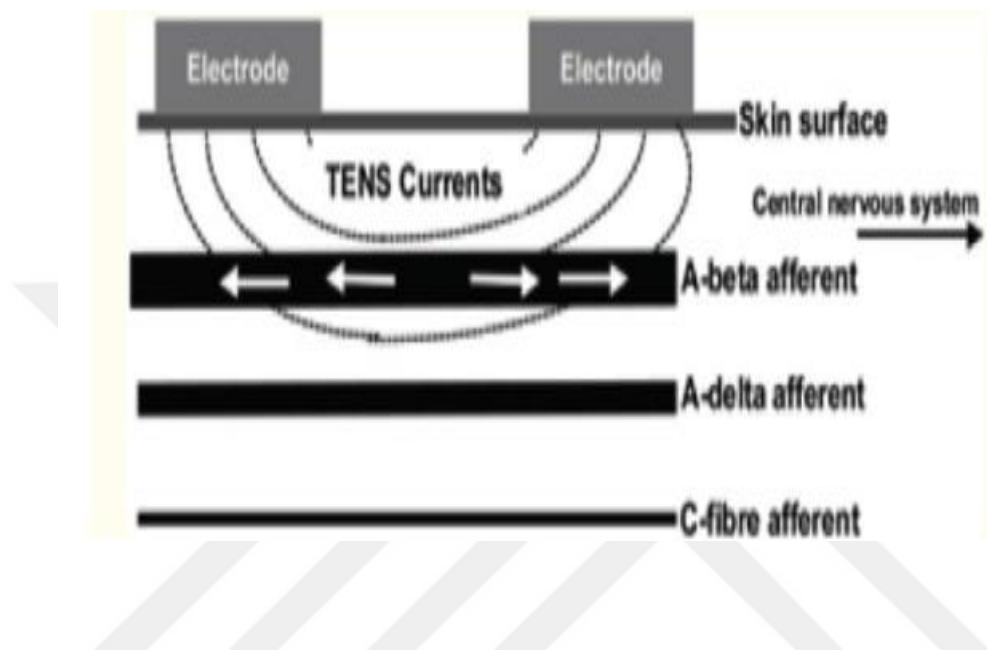


Figure 2.12 Conventional TENS

2.4.5.5 Kinesiotaping

Kinesiotaping can be used after the electrotherapeutic means and therapeutic exercises to maintain the healing effect longer. Kenzo Kase developed this technique. Even though the pain mechanisms cannot be explained, many clinicians have been using this method for years (210). The bandage is made of special waterproof material. This bandage has been known to stretch up to 140% of its normal size (211). As the kinesiotape exerts lifting forces, pressure on pain receptors is reduced, resulting in pain relief. In addition, kinesiotaping can promote blood and lymphatic circulation. Kinesiotaping can be applied to the lumbosacral area of a patient suffering from low back pain (212).

2.4.5.6 Ultrasound

Ultrasound is another electrotherapeutic application commonly used in the treatment of low back pain. Therapeutic ultrasound transmits waves into the tissue to increase the temperature of the tissue and stimulate some physiological responses (213).

These responses are divided into thermal and non-thermal effects. In general, it has a special crystal that generates waves. Their amplitude varies between 0, 1, and 3 watts/cm². The frequency is three MHz (214, 215). This application is generally used in 2 ways, continuous or pulsed (215).

2.4.5.7 Myofascial Release

Myofascial release is one of the most effective applications in physiotherapy treatment. This approach is mainly based on mild forces of short duration to allow the physical therapist to treat the affected connective tissue. The goal of myofascial release is to relieve pain, restore normal tissue length, and optimize functional capacity as much as possible (216). According to many recent studies, the myofascial release seems to be more efficient when we use it together with other modalities (217).

Because fascial tissues are interconnected throughout the body, an injury to one side can directly affect the other, resulting in functional impairment (218). If we eliminate excessive stress on neurovascular structures by using these techniques, perceived pain can decrease significantly (219). The pliability of fascia is of great importance. The most common causes of this are altered biomechanics, insufficient muscle strength, and poor motor coordination (220).

This method consists of gentle and sustained touches of a long duration. There are two types of myofascial release, the direct method, and the indirect method. The direct method is generally based on application over the affected/injured fascia. The physical therapist should use his/her elbow to penetrate the tissue. The force applied should be a few kilograms. Unlike the direct technique, the indirect technique involves a gentler pressure. It should be only a few kilograms (220). The physical therapist should glide his hands along the restrictive lines. He should then stretch the fascia so that the tissue can release itself. Both techniques are based on the biomechanical properties of fascia (piezoelectricity, mechanotransduction, thixotropy, viscoelasticity). In this way, the fascial tissue becomes more pliable and elastic, and the functional capacity increases (221).

2.4.5.8 Self Myofascial Release

People struggle with muscle, fascial tissue, or myofascial injuries that manifest as muscle spasms, pain, or restriction, resulting in impaired ROM and quality of

activities of daily living. This technique is a very well-known method that is believed to reduce restrictions in many parts of the body. Not surprisingly, this technique seems to be very effective in various conditions, such as persistent low back pain and problems with the temporomandibular joint (222). As for low back pain, the therapist examines and inspects the affected area, which is indicated as the source of pain, and he can easily discover some structures that feel immobile and hard. Normally, they should be pliable and move freely. The affected area is not only inelastic but also has restricted blood flow and lymphatic circulation, which is why the healing process is delayed and symptoms such as pain persist for a long period. As the tissue becomes more elastic and relaxed, allowing blood to circulate freely, symptoms subside and ROM returns to normal (223).

In the self-myofascial release technique, the patient must apply pressure for a certain time to allow the tissues to relax and the tension to disappear (223). Since it is very difficult to find out the main area responsible for the pain, the application is performed on a large area of the body (224). Interestingly, this technique can be combined with other treatment modalities to maximize healing ability (223, 224). During SMFR, one should obtain a foam roller and apply pressure to the affected areas from which the pain originates to loosen the contracted myofascial structures (225). The self-myofascial technique is a subversion of myofascial treatments. This technique is believed to be a fairly beneficial and cost-effective way to eliminate pain and correct muscular imbalances and optimize endothelial functions. One of the tools used in the Self Myofascial Release technique is the foam roller. During the application of SMFR, autogenic inhibition allows the surrounding muscles to recover and decrease the activity of the muscle spindles. The patient should apply sufficient pressure to the painful areas they are suffering from for the autogenic inhibition mechanism to work (225).

To increase density, it is advisable to increase the amount of mass by using firmer objects. For example, the physical therapist might use a softer foam roller or ball at the beginning of the treatment. Once the patient becomes accustomed to this intensity, he or she can change the hardness of the object. To increase the pressure, the size of the objects could be reduced so that the forces act more effectively on the appropriate areas. In this way, PT can focus more precisely on the painful tissue. In addition, while lying on the floor, the patient can reduce the contact area by lifting their limbs and rolling the

foam roller with one leg on the floor and the other in the air. In this way, the body weight is better distributed to the affected areas. Another tool used in the SMR technique is tennis or lacrosse balls. They are thought to relax the tissues and stretch the areas that feel stiff (21).

2.5 Core Stability

The core is defined as a group of muscles responsible for stabilizing our body. This group of muscles is responsible not only for stabilization but also for maintaining optimal joint motion and providing adequate proximal stability. If the core mechanism did not exist in our body, we would not be able to maintain the balance between force pairs and a healthy kinetic chain from heel to head. The core area is composed of the lumbar, pelvic, and hip regions (226). Core stability can be provided thanks to the activation of the lumbar muscles, the abdominal muscles, some hip muscles, the diaphragm, and the muscles of the pelvic region. When these muscles provide sufficient proximal stability, distal stability is also created, improving ROM overall and increasing athletic performance. It is well known that trunk stability not only improves athletic performance but also reduces the likelihood of musculoskeletal injuries. For this reason, most athletes perform as many trunk exercises as possible to reduce the risk of injury. As for the functions of the core stability, there are three main components, namely the healthy distribution of body weight, the absorption of internal and external forces, and the transmission of ground reaction forces (227).

2.5.1 Subsystems of Core Stability

In addition, there are subsystems responsible for core stability, namely active, passive, and neural systems (228).

2.5.1.1 Active Subsystems

The active subsystem consists of the global muscles, core muscles, tendons, and fascial tissue. This system not only generates sufficient force but also provides the CNS with the necessary proprioceptive information along with the passive system. This muscle group is located superficially compared to the core muscles. Because they cover large areas, they can generate torque and encompass more than one joint (228). They are responsible for connecting the rib cage to the pelvis. Even though the global muscles are not able to provide core stabilization, they provide general stabilization. In addition, they can exert compressive forces on underlying structures, such as the rectus

abdominis, internal oblique, external oblique, lateral quadratus lumborum, erector spinae, and hip flexor (iliopsoas) (228). The core muscles are located very deep compared to the global muscles. Because they must withstand mechanical forces over a long time, these muscles are composed mainly of type 1 muscle fibres. They can attach each spinal segment, providing segmental stability. For example, the transversus abdominis, multifidus, deep rotators, and deep region of the quadratus lumborum (228).

2.5.1.2 Passive System

The passive system consists mainly of four structures: ligaments, vertebrae, facet joints, and intervertebral disks. They are mainly responsible for receiving and transmitting proprioceptive information to the CNS via embedded Golgi tendon organs and muscle spindles from ligaments, tendons, and muscles. In this way, we can efficiently sense our movements. Not surprisingly, these structures are known to mechanically support the trunk to stabilize it (229).

2.5.1.3 Neural Subsystem

This control is responsible for capturing all the input and transmitting it to the brain. The neural system can control the core muscles. In this way, it makes a remarkable contribution to the stability of the spine. The components of the neural subsystem are embedded in tendons, muscles, or ligaments. Depending on the proprioceptive needs, this system can determine our movement. When needed, it stimulates the active and passive systems to perform a balanced, controlled movement (229).

2.5.2 Core Muscles and their functions

It is well known that there are many muscles responsible for stabilizing the trunk. First, the rectus abdominis can normally flex the trunk. As for its core function, it can limit the excessive anterior rotation of the pelvis. When the pelvis extends posteriorly, this muscle can limit the movement (230).

The external and internal oblique muscles are normally responsible for lateral flexion of the trunk. But in terms of their core abilities, they, along with the rectus abdominis, help stabilize the pelvis. In addition, they can control backward and lateral flexions of the spine. Both, along with the transversus abdominis, can increase the intraabdominal pressure. They are known to relieve pressure on the spine because they

exert pressure on the thoracolumbar fascia. Similarly, the external and internal obliques can prevent excessive posterior or lateral movement of the spine (230).

The transversus abdominis normally plays an important role in the rotation. As for its core functions, it increases pressure on the thoracolumbar fascia, increasing intraabdominal pressure. It is well known that this muscle is activated by using the drawing-in manoeuvre (112).

The quadratus lumborum consists of two parts, one deep and one lateral. It is capable of lifting the pelvis and flexing the spine to either side. When it comes to its core abilities, it can give us frontal and sagittal support. Just like the transversus abdominis, it can provide stability in each segment. In addition, because its fibres attach to the ribs, it pulls against the force of the diaphragm, facilitating inspiration (231).

The multifidus is a deeply found muscle that allows spinal extension and contralateral rotational movements. Just like the transversus abdominis, it is activated by drawing-in and bracing techniques. Since the multifidus is responsible for extension and rotation, it supports us against excessive flexion and contralateral rotational movements. There is another group of muscles that are very close to the multifidus, the intersegmental rotators, and the intertransversarii muscles. Since they have abundant muscle spindles, their contribution to proprioceptive inputs cannot be overlooked. In addition, they can help the muscles generate sufficient torque. As for their core capabilities, it provides segmental support and stability to the spine (232).

The other muscle responsible for spinal extension is the erector spinae. Because the erector spinae extends the spine, it is also called the antigravity muscle. Unfortunately, it cannot provide segmental stability to the spine, but only global support (233).

Finally, the iliopsoas should be mentioned at this point. Normally, its main function is to flex the hip, but it is also capable of indirectly extending the lumbar region. The iliacus is thought to provide the necessary stabilization to the pelvis and hip joint, while the psoas muscle is known to stabilize the lumbar region of the spine forward when we are carrying a very heavy object (234).

Since there are also muscles in the neck that are related to core stability, they will be briefly discussed here. First, the sternocleidomastoid and scalenus muscles stand out. They are particularly supportive of inspiration because they are responsible for

raising the ribs, clavicle, and sternum to a certain degree so that the lungs can expand as they should. The SCM can mainly flex the neck. As for its core function, it can support the head against gravity. The upper trapezius and cervical erector spinae also support the head against the same forces. They are mainly global muscles. When it comes to the segmental muscles of the cervical spine, the longus Colli, rectus capitis anterior and lateralis come to mind. They provide deep stabilization of the cervical spine (235).

2.5.2.1 Thoracocolumnar Fascia

This fascia is a very large and delta-shaped tissue consisting of the thoracic and lumbar regions. It is quite well known that this fascia can wrap our main deep back muscles. The main function of this fascia is to stabilize our trunk and transfer the load. It can also limit excessive forward flexion. In the thoracic region, the thoracolumbar fascia appears to be weaker than in the lumbar region. It may attach to the spinous processes and corresponding ribs (236). As for its attachments in the lumbar region, the thoracolumbar fascia is known to attach to some bony structures, namely the sacrum and vertebrae. More specifically, this multilayered connective tissue is mainly composed of three parts, namely the anterior, middle, and posterior layers. Each of these layers has different origins (234). The anterior layer attaches to the anterior part of the transverse processes, the middle layer has attachments to the tip of the transverse processes, and finally, the posterior part has fibres originating from the spinous processes and spinous ligament. In addition, the posterior layer is considered the thickest and strongest of all (236). These three parts unite on each side of the trunk to form the attachment points for the abdominal muscles, namely the internal oblique and transversus abdominis. Because these layers have gaps, they are filled by many important muscles. More specifically, between the anterior and middle parts is the quadratus lumborum muscle, while the space between the middle and posterior parts houses the erector spinae and the deep back muscles. In addition, some muscles may attach to some of these layers (236). The latissimus dorsi attaches to the posterior layer, whereas the psoas major muscle attaches to the anterior part of this fascia. Interestingly, this dense connective tissue provides a type of communication between the upper and lower limbs. The gluteus maximus fibres extend to the fascia and the latissimus dorsi fibres on the contralateral side absorb the energy coming from them. The thoracolumbar fascia is responsible for transmitting this elasticity and force between them. Together

with the contraction of all the included muscles and other muscles that attach to it, it can increase intra-abdominal pressure, providing our spine with the necessary core stability (234, 236).

2.5.2.2 Paraspinal Muscles

They are composed of the extensors of the spine. There are two main subgroups of them, namely the erector spinae and the deep groups. The erector spinae is composed of two parts, the iliocostalis, and the longissimus. Since they are composed of long fibres, their strength is quite high and they have great power for the extension. Depending on the spinal region, their attachments may vary (237). For example, in the lumbar region, the iliocostalis muscle has attachments at the seventh to twelfth ribs, while the iliocostalis cervicis muscle attaches to the posterior tubercles of the cervical vertebrae. The deep muscles include the multifidus muscle, the deep rotators, and the intertransversarii muscles. Because they consist of a large number of muscle spindles, they are considered to be of great importance for proprioception. Even though they cannot stretch our back as much as the erector spinae groups, they can stabilize our vertebrae through their segmental functions. Multifidus muscle gets activated using drawing in or bracing manoeuvre just like transversus abdominis. It provides stabilization against flexion and rotative forces on the spine. Erector spinae provides control against anterior bending movements. It provides stabilization against flexion forces. It is no wonder that with decreased muscle mass in the deep muscles, we become more prone to low back pain (234, 237).

2.5.2.3 Quadratus Lumborum

It is the main component of the thoracolumbar fascia, which is known to attach its fibres to the spine in the lumbar region. More specifically, it originally attaches to the twelfth rib and all lumbar vertebrae. As far as its attachment is concerned, it attaches to the posterior region of the iliac crest (238). The quadratus lumborum consists of three distinct parts, namely the longitudinal fascicles, superior obliques, and inferior obliques. It is well known that the first two play a very important role in respiration because they hold the twelfth rib in position during each inspiration, thus assisting in breathing. However, the obliquus inferior oblique muscle is capable of unilateral flexion of the lumbar spine (238). Even though this muscle group is considered weak, its contribution to the core stability cannot be overlooked. However, some recent studies concluded that the quadratus lumborum muscle is very weak compared to the erector spinae muscle

and the multifidus muscle in providing trunk stability. According to these studies, the ratio between erector spinae and quadratus lumborum in terms of stabilizing force is nine. ($ES / QL = 9$) The same ratio for the multifidus with QL was reported to be fourteen. ($Multifidus / QL = 14$) Instead, this muscle plays an important role in the transmission of force pairs to each other. This muscle is responsible for sustaining anterior and sagittal view stability. Deeper fibres provide segmental stability for our spine. When it comes to the innervation of this muscle, it is supplied by the 12th intercostal, ilioinguinal, and iliohypogastric nerves. Quadratus lumborum receives blood from the iliolumbar arteries (234).

2.5.2.4 Anterior (Abdominal) Muscles

They are composed of four different parts, the rectus abdominis, the transversus abdominis, the internal oblique muscle, and the external oblique muscle. The rectus abdominis is a multi-part muscle that covers the internal organs and is located inside a special tissue called the rectus sheath. It originally attaches to the symphysis pubis and its fibres run to the processus xiphoideus in the middle and cartilaginous regions of the fifth, sixth and seventh ribs. It is well known that this muscle is responsible for trunk flexion. It is supplied by both the superior and inferior epigastric vessels. In the middle, there is a large partition called the linea alba. When it comes to stabilizing the core stabilization, it can increase intra-abdominal pressure by co-contracting with the other abdominal muscles (234, 239). The rectus abdominis is responsible for stabilizing the pelvis for anterior rotation. Internal and external oblique muscles are known to be responsible for withstanding the forces that may lead to side bending and backward bending. It is known that they can be activated by bracing manoeuvre and they are synergistic to transversus abdominis to boost the IAP. They are together able to increase the tension on TCF. Transversus abdominis is activated by the drawing-in manoeuvre and is responsible for generating sufficient tension on the thoracolumbar fascia, increasing IAP (112).

3. MATERIAL AND METHOD

3.1. Subjects

Thirty-two physical therapy and rehabilitation students from Yeditepe University between the ages of 18 and 35 participated (Average age-Gender; 26, 78 ± 3, 66; F/M: 18/10) in our study. The participants took part in the study between October 2021 and February 2022. This study was conducted online via Zoom because of the pandemic COVID -19. This study took place at Yeditepe University. This study is an experimental and randomized controlled trial.

Participants who were eligible for the inclusion criteria were divided into two groups by randomization. Our randomization was based on paper selection. To be more precise, we wrote numbers from 1 to 32 on small paper. Since this was an online study, we selected one paper for each participant. Participants numbered 1 to 16 were selected for the self-myofascial release group combined with core exercises, while participants numbered 17 to 32 were assigned to the self-myofascial release group only. The Ethics Committee of Yeditepe University accepted the study protocol on October 19, 2021, under the number 202109095. (Appendix 2). Participants voluntarily agreed to participate in the study. Each patient was informed of the purpose and plan, and each participant provided written informed consent (Appendix 1).

Inclusion Criteria

- Being between in ages of 18-35.
- Being a physiotherapy and rehabilitation student at Yeditepe University.
- Having non-specific low back pain prolonging more than 6 months
- Having an activity VAS score of more than 6 for pain
- Having neither orthopaedic nor neurological problems

Exclusion Criteria

- The presence of the musculoskeletal condition in 2 months
- Neurological or vestibular diseases.
- Osteopenia or Osteoporosis
- Radiculopathy
- Spondylolysis, Scoliosis
- Rheumatismal or myopathic diseases
- Taking medications that may affect the balance or the locomotor system

- Having a history of surgery carried out in the spinal cord and low back area
- The presence of ongoing inflammation in the body
- Surgery in 6 months
- Pregnancy

Flow of Research

In our study, we aimed to collect 32 physical therapy and rehabilitation students suffering from nonspecific low back pain. Using a sociodemographic questionnaire, we were able to determine which participants were eligible for our study and which were not. The students who met the inclusion criteria were randomly divided into two groups. Randomization was performed at the beginning of the study. Students numbered 1 to 16 participated in the Self-Myofascial Release with Core Stabilization group, while students numbered 17 to 32 participated in the Self-Myofascial Release group. (Figure 3.1 Flowchart) All students who were willing to participate in our study signed an informed consent form before the study began. Data collection took place on the first day, midway, and at the end of the study. Some participants wanted to leave the study because they had contracted coronavirus and were no longer able to perform the desired movements (Figure 3.1).

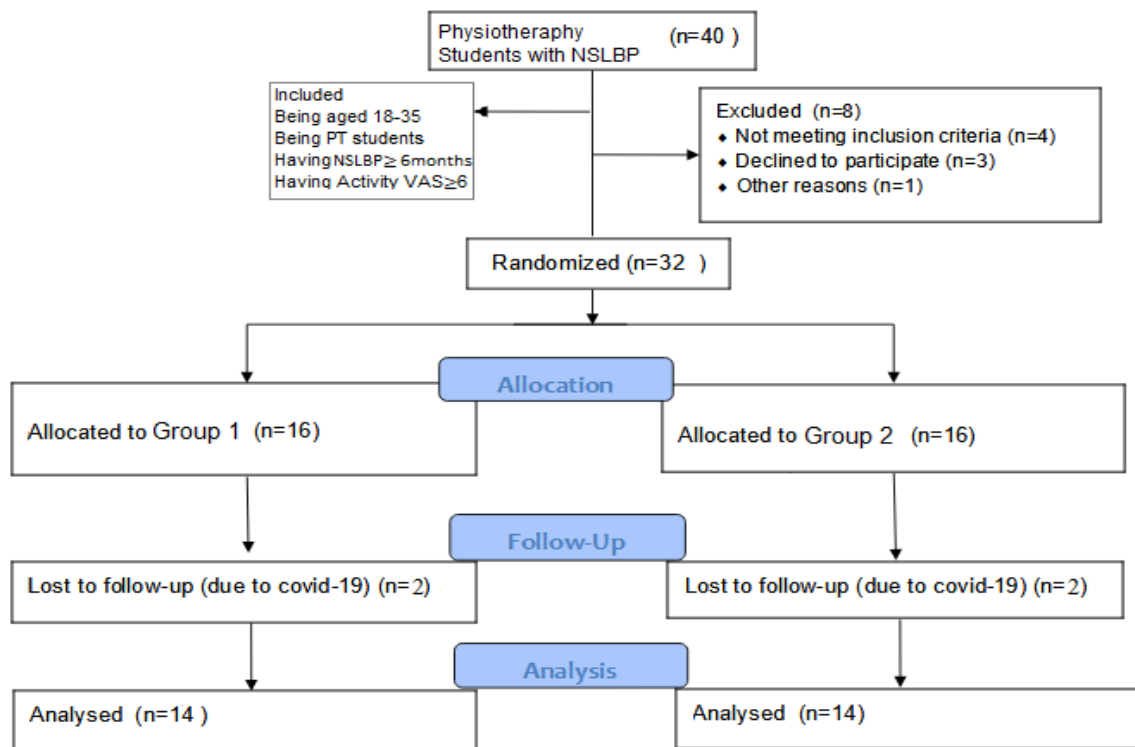


Figure 3.1 Flowchart of the Study

Study Protocol

The first group received an online core exercise program and self-myofascial release techniques for 5 weeks. Before they begin to perform core exercises, firstly they performed a warm-up for 5 minutes. Warm-up consists of light jogging, high knee, modified jumping jack and stretching. After core exercises, each participant performed a cool-down. Cool-down included light jogging, high knee, modified jumping jack, and stretching. Finally, the myofascial release was performed. An assessment was done at the beginning of the study. The first examination took place during the first week before the first program. Only VAS scores were measured in 7 days so that we could find the sudden effects of protocols. ODI scores were measured only once in 1st week. Another examinations took place in the 3rd week and at the end of 5 weeks. The duration of this protocol is approximately 1 hour and the frequency of this protocol is 2 times per week.

The second group received only the online self-application of Myofascial Release. An assessment was done at the beginning of the study. In this study, each participant had to get a foam roller and a small tennis ball to perform self-myofascial release at home. The foam roller is a piece of very popular equipment for self-myofascial release. This tool can apply a sufficient amount of pressure on soft tissues, such as muscles, and fascias by using our body weight. In this way, these tense areas can relax, decreasing pain. In our study, a standard foam roller (6 ×36 inches) was used. The first examination took place in the first week. Another examinations took place in the 3rd week and at the end of 5 weeks. The duration of this protocol is about 20-25 minutes and the frequency of this protocol is 2 times per week. Moreover, each subgroup of the ODI scale was measured intragroup and intergroup (Figure 3.2).

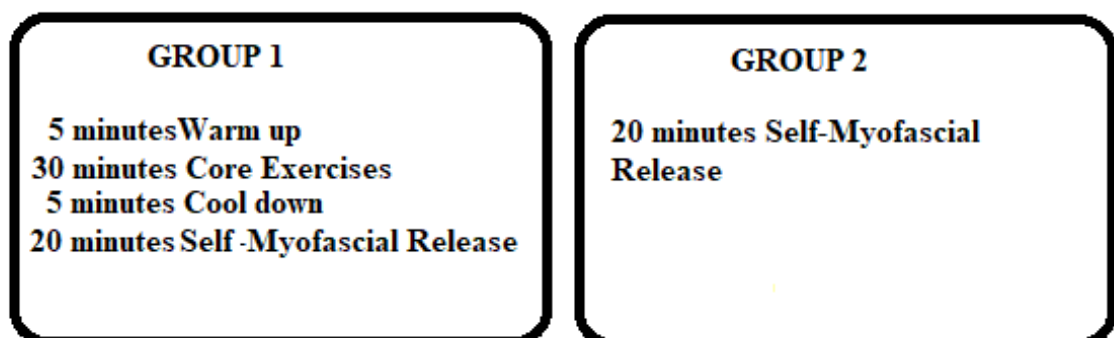


Figure 3.2 Study Protocol

3.2 Evaluation

Before all interventions, all participants filled sociodemographic questionnaire

so that we could determine the suitable population for our study. In our study, we measured pain intensity with the Visual Analogue Scale (VAS) and functional capacity with Oswestry Disability Index (ODI). Evaluations have been performed at pre-intervention, mid-intervention (3rd week), and post-intervention (5th week).

Sociodemographic Questionnaire

The sociodemographic questionnaire was used in this study to collect personal information about each participant. In the first part, age, gender, occupation, income level, marital status, and education level were recorded. In the second part, the questions are mainly related to health. In particular, these include smoking and alcohol habits, use of medication, activity level, and chronic diseases (APPENDIX 3).

Visual Analogue Scale

The Visual Analogue Scale is one of the most important instruments for determining the degree of pain. This instrument can be used in epidemiological and clinical studies. With the help of VAS, we can evaluate the intensity of symptoms. On this scale, there are numbers from 0 to 10. 0 means no pain, while 10 stands for unbearable pain. 5 represents moderate pain. Numbers from 5 to 10 represent severe pain. Numbers from 0 to 5 represent mild pain. Facial figures are located on the scale so that participants can easily find their pain level. In our study, VAS has been measured two times in the first week to show sudden effects. VAS is also divided into 2 parts, VAS-activity and VAS-at rest. The Cronbach score for VAS is 0.989 (240).

Oswestry Disability Index

The Oswestry Questionnaire is one of the most popular tools for determining the level of function in patients with low back pain. This questionnaire consists of ten different parts, namely pain intensity, self-care, carrying heavy objects, walking, sitting, standing, sleeping, social life, travelling, and degree of change in pain. Each question contains six different answers representing an increasing worsening of symptoms from 1 to 6. In other words, 1 represents no disability, while 6 represents maximum disability. When the patient has answered all the questions, the total score is added. Then the total score is divided by the worst maximum score and multiplied by one hundred. 0-20% represents minimal disability. 20-40% stands for mild disability. 40-60% stands for severe disability. 60-80% stands for very severe disability and finally, 80-100% means the patient may be disabled and bedridden. If patients are torn between two answers, they should choose the one that is most appropriate for them. The total duration of the

ODI is approximately five minutes. The Cronbach score for Oswestry is 0.722. In our study, in addition to the total ODI score, we have shown the change in each sub-ODI score. Also, we demonstrated the distribution of total ODI and sub-scores in groups according to the severity level of disability at different weeks (241).

3.3 Intervention

The first group received both core stabilization exercises mentioned below and self-myofascial release techniques, while the second group received only self-myofascial release techniques. During warm-up and cool-down, the participants performed light jogging, high knee, and modified jumping jack. During high knees, participants lift their knees until the level of the hip, while jogging. During the modified jumping jacks, the participants raise their arms at the top of the head, while they move only one leg. Normally, one should jump to perform the jumping jack, but in this study, we used the modified jumping jack.

As for stretchings, participants pull their legs towards the chest for gluteal stretch, perform lunge and extend forwardly on one leg to stretch. Finally, they put one leg onto a chair and stretch their hamstring muscles. Each stretch should not be longer than 30 seconds and can be performed 3 times (242).

Table 3.1 The Exercise Program of two groups for each week

Self-Myofascial + Exercise Group (2 days a week)	Self-Myofascial Group (2 days a week)
Protocol: Week 1, 2, 3, 4, 5: 5 minutes of warm-up (jogging in place, high knee, modified jumping jack) + stretching (gluteal, kneeling lunge, chair hamstring (30-sec x 3 rep)) 15 minutes of Core stabilization exercises 5 minutes of cool-down (jogging, modified jumping jack) 18 minutes of Myofascial Release techniques	Protocol : Week 1, 2, 3, 4, 5 Only self-myofascial release techniques are applied. In this study, each participant got a foam roller and a small tennis ball to perform self-myofascial release at home. The foam roller is very popular equipment for self-myofascial release. This tool can apply a sufficient amount of pressure on soft tissues. In this way, these tense areas can relax, decreasing pain. We used a standard foam roller (6 ×36 inches).

Core Stabilization Exercises	Self Myofascial Release Applications
Week 1 : • Supine abdominal draw-in (10x2) • Abdominal draw-in with a knee to chest (10x2) • Abdominal draw-in with heel slide (10x2) • Supine Twist (6x2) • Prone bridging on elbows (10 seconds-1min x 2) • Side Bridging on elbows (10 seconds – 1min x 2) • Press-ups (6x2) • Quadruped Opposite arm leg (8 times for each side) • Bridge (10 x2) (3-5 seconds) Cat stretches (5 times) Week 2: • Abdominal draw-in with heel slide (20 x 3-5 seconds) • Supine Twist (10 x2) • Supine Dead bugs (8x2) • Side Bridging on elbows (15 sec.1 min x 3 for each side) • Press-ups (8 x 2 for 3-5 seconds) • Prone Cobras (10 x1) • Supine single-leg butt lift (8 x 3-5 seconds for each side) • Quadruped Opposite arm leg (10	Week 1 : • The self-myofascial release of quadratus lumborum (4,5 minutes) / (20-sec x3 times) with 1 min rest interval • The self-myofascial release of thoracosacrolumbar fascia and paravertebral muscles (4,5 minutes) (T12 -L1) • The self-Myofascial release of the psoas muscle (4,5 minutes) • The self-Myofascial release of piriformis muscle +gluteals (4,5 minutes) Week 2 : • The self-myofascial release of quadratus lumborum (4,5 minutes) / (20-sec x3 times) with 1 min rest interval • The self-myofascial release of thoracosacrolumbar fascia and paravertebral muscles (4,5 minutes) (T12 -L1) • The self-Myofascial release of the psoas muscle (4,5 minutes) • The self-Myofascial release of piriformis muscle +gluteals (4,5 minutes) Week 3 : • The self-myofascial release of

times for each side) • Prone bridging on elbows with single-leg hip extension (15 times for each side) • Semi Curl up (10 x2) Week 3-5: • Supine Dead bugs (12x2) • Prone bridging on elbows with single-leg hip extension (15 times for each side) • Side Bridging on elbows (15-sec x 1 min 3 for each side) • Abdominal Draw-in with feet on the ball- add movement (10x1) • Prone Cobras (12 x2) • Supine single-leg butt lift (10 x 5-7 seconds for each side) • Quadruped Opposite arm leg (12 times for each side) • Lunge (8 x2) • Seated Russian Twist (8 x2) • Side Bridging with hip ABD, hip flexion, hip extension (8x1)	quadratus lumborum (4,5 minutes) / (20-sec x3 times) with 1 min rest interval • The self-myofascial release of thoracosacrolumbar fascia and paravertebral muscles (4,5 minutes) (T12 -L1) • The self-Myofascial release of the psoas muscle (4,5 minutes) • The self-Myofascial release of piriformis muscle +gluteals (4,5 minutes) Week 4 : • The self-myofascial release of quadratus lumborum (4,5 minutes) / (20-sec x3 times) with 1 min rest interval • The self-myofascial release of thoracosacrolumbar fascia and paravertebral muscles (4,5 minutes) (T12 -L1) • The self-Myofascial release of the psoas muscle (4,5 minutes) • The self-Myofascial release of piriformis muscle +gluteals (4,5 minutes) Week 5: The same protocol was carried out.
---	--

3.3.1 Core Stability Exercises

The core is made up of many different muscle groups, which are paraspinal muscles, diaphragm, pelvic floor muscles, and abdominal muscles. They are capable of maintaining stability in our body, allowing our distal limbs to move comfortably and

freely. When they become weak, we become more prone to developing pain in our spine. It is very important to engage our core muscles efficiently to reduce the risk of injury and optimize stability. For this reason, core stability exercises can be used to improve and strengthen them step by step (226,227). Core stability exercises were introduced to our first group in the study. The main purpose was to strengthen these muscles. In this way, we can eliminate the pain and reduce the risk of recurrence of low back pain. This program consists of three main groups, namely warm-up, strengthening of muscles, and cool-down. Before we start each program, participants in the first group perform three movements to warm up. Those in the myofascial group did not perform warm-up exercises (242). The exercises can be classified into three difficulties, easy, medium, and difficult. If a participant perform the current exercise easily and we increased the difficulty, by moving on to the next movement. These exercises were done twice a week for 5 weeks. According to a study, the total duration of weeks was 6 and the frequency of exercises was 3 times. But in this study, we had to perform this protocol 2 times per week for 5 weeks. Each session lasted 60 minutes, just like Ozsoy's study (17). According to two studies, the duration of the study was 4 weeks. The frequency was 3 times per week (243, 244). According to another study, the duration of the study was 6 weeks, but the frequency was 2 times per week (245). All of these studies have conducted the study with a duration of the core exercise of 30 minutes (243-245). Exercises were mainly selected by using a study (17).

a-) Cat-Camel Exercise

This exercise was performed for stretching. The participants should be in a quadruped position. Then, participants should inhale and arch their back towards the ceiling. The neck stays tucked. After that, he should exhale, raise his chin and lower his spine (Figure 3.3).

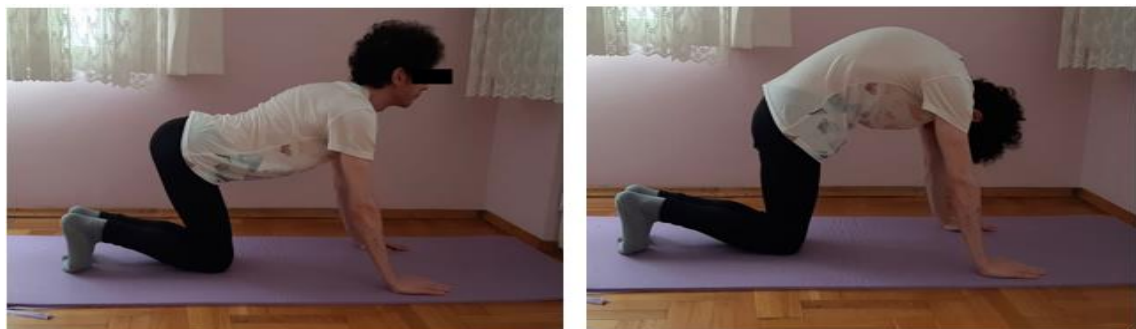


Figure 3.3 The demonstration of the Cat-Camel exercise

b-) Prayer stretch

The patient should kneel on his hands and sit on the heels. Then, his shoulder touches the floor and stretches as far as possible, allowing muscles to relax. This position can be held as much as the participant wants (Figure 3.4).



Figure 3.4 The demonstration of the Prayer Stretch

c-) Supine Abdominal Draw-in

The patient is in the prone position, the legs flexed, and both heels on the ground. The patient should push his low back to the ground and pull the pelvis in. During each push, the patient should hold the position for 5 seconds. The repetitions vary from 10 to 20 (Figure 3.5).



Figure 3.5 The demonstration of the Abdominal Draw-In Exercise

d-) Abdominal Draw-In with Knee to Chest

The patient should perform the supine abdominal draw-in first. Then, he should lift one leg and pull it towards the chest, while holding ADI. He should repeat this movement 10-20 times (Figure 3.6).

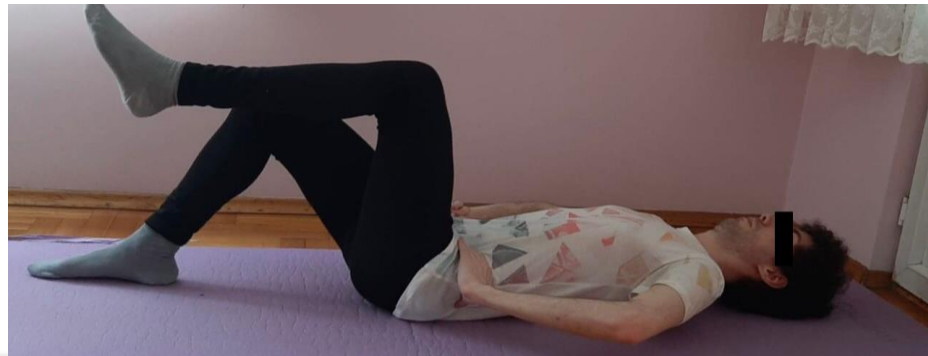


Figure 3.6 The demonstration of the Abdominal Draw-In with Knee to Chest Exercise

e-) Abdominal Draw-In with Heel Slide

Firstly, the abdominal draw-in should be provided. After that, one heel can be pulled to the hip joint. The patient should maintain the abdominal draw-in while pulling his heels. Repetitions can be 10- 20 times (Figure 3.7).



Figure 3.7 The demonstration of the Abdominal Draw-In with Knee to Chest Exercise

f-) Abdominal Draw-In with feet on the foam roller

The participant should be able to maintain the abdominal draw-in while his foot is on the ball and he slowly moves the ball back and forth (Figure 3.8).



Figure 3.8 The demonstration of the Abdominal Draw-In with foot on the foam roller Exercise

g-) Supine Twist

The participant should bend his knees and lie on his back. He should then firstly perform abdominal draw-in and then rotate the knees side to side in a slow manner. When the patient completes the right and left rotation, he should release the draw-in and start all over again. Repetitions can be 10-20 times (Figure 3.9).



Figure 3.9 The demonstration of the Supine Twist Exercise

h-) Plank

The participant should be in the prone position, but only his forearms and knees are in contact with the floor. The patient should contract his abdominals to perform abdominal draw-in. Then he should hold the position for at least 10 seconds or maximally 1 minute. When the participant got used to this difficulty, only his toes and forearms should be in contact with the ground. The important is that shoulder, trunk and hips should be in line. Repetitions could be 3-5 times. We can increase the duration if we want to increase the difficulty (Figure 3.10).



Figure 3.10 The demonstration of the Plank Exercise

i-) Side Plank

The participant should lie on his forearms and one knee. Shoulders, hips, and trunk should be in one line. When the participant got used to this difficulty, only his toes and forearms should be in contact with the ground. The duration can vary from 15 seconds to 1 minute. As the participant gets used to the previous difficulty, we should encourage him to hold the position for 15 seconds more. This movement should be performed for both sides. Repetitions could be 3-5 times (Figure 3.11).



Figure 3.11 The demonstration of the Side Plank Exercise

j-) Press Up

The participant should be in the prone position. The legs are extended and the abdominal region is in contact with the ground. The participant should extend his upper trunk, using shoulder retractors, without overextending his neck. In this way, his chest rises. The participant should hold the position for 3-5 seconds and slowly return to the

initial position. Repetitions could be 15-20 times. The important thing is that the pelvis bone should be in contact with the ground while performing this movement (Figure 3.12).



Figure 3.12 The demonstration of the Press up Exercise

k-) Prone Cobra

The participant should be in the prone position. The legs are extended. At this movement, he should hold his arms extended at the sides of the trunk. While rising the head, he can contract his gluteal muscles and retract his shoulders. It is important to hold the position for 3-5 seconds. Repetitions can be 15-20 times. He should keep his chin tucked (Figure 3.13).

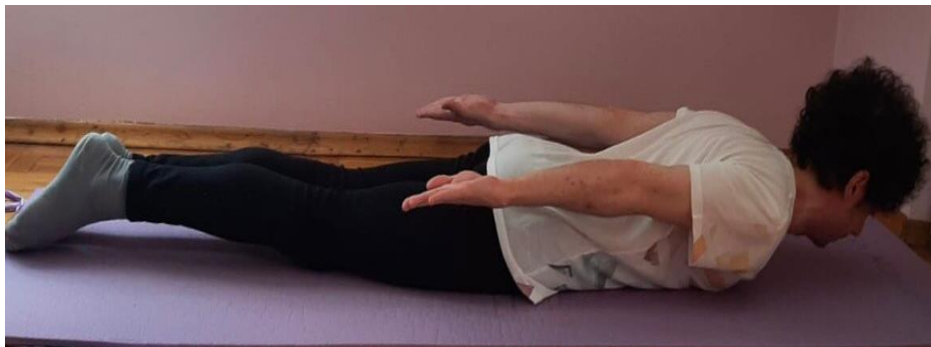


Figure 3.13 The demonstration of the Prone Cobra Exercise

i-) Superman

When the patient got used to the prone cobra, this movement can be recommended. The participant should be in the prone position and legs are extended. He should retract his shoulders and lift his arms right before his head. Legs should be also lifted like superman. While performing this movement, the abdominal draw-in should

be done. It is recommended to hold the position for 3-5 seconds and the repetitions should be 10-15 times (Figure 3.14).



Figure 3.14 The demonstration of the Superman Exercise

m-) Quadruped Opposite arm/leg

The patient should be in the quadruped position. The knees are flexed to 90 degrees. Firstly, he should activate his core muscles and then lift one arm. At the same time, he should lift the contralateral leg, while maintaining the abdominal draw-in. The repetitions should be 10 times for each side (Figure 3.15).



Figure 3.15 The demonstration of the Quadruped Opposite arm/leg Exercise

n-) Bridge Exercise

The participant should be in the supine position, his arms on the ground. The knees should be flexed to 90 degrees. He should engage the abdominal draw-in and lift his butts. The trunk should be in line with the legs. While performing this movement, he should maintain the draw-in. It is important to hold the position for 3-5 seconds and the repetitions can be 10-15 times. If we would like to increase the difficulty, the arms

should be across the chest and perform the same movement. (Supine Butt Lift with Arms across Chest) If the participant wants to make it harder, one leg should be lifted during the movement (Supine Single Leg Butt Lift) (Figure 3.16).



Figure 3.16 The demonstration of Bridge and Supine Single Leg Butt Lift Exercises

o-) Lunge

The participant should take a step forward and flex both knees. The flexion angle of the knee should be 90. He should lower his upper body in this way and take no more steps forwardly. We can perform the lunge for 10 repetitions for each side and then switch to the other side.

p-) Supine Dead Bugs

The participant should be in the supine position. The abdominal draw-in should be performed. The arms are perpendicular to the ground. The knees and hips should be flexed to 90. The participant should extend one leg and maintain the position. Then, he can extend the other leg and maintain the draw-in. Repetition can be 10-20 times. 1-2 sets are enough (Figure 3.17).

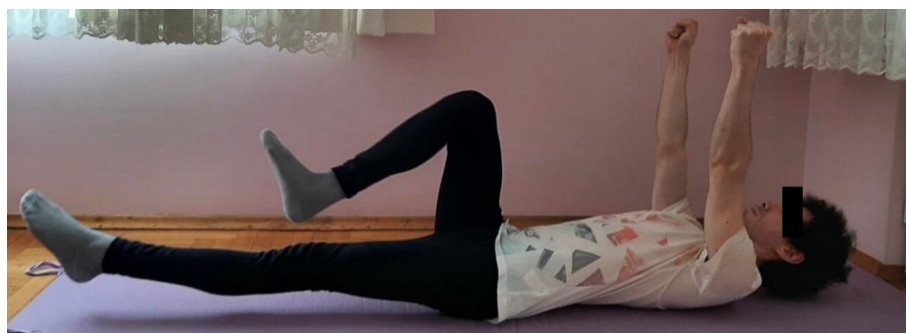


Figure 3.17 The demonstration of the Supine Dead Bug

r-) Seated Russian Twist with Medicine Ball

One should sit with the foot without contact with the ground. He should hold a medicine ball and rotate this trunk side to side while maintaining the V position. Repetition can be 10-15 times (Figure 3.18).



Figure 3.18 The demonstration of the Russian Twist with an object

3.3.2 Self-Myofascial Release

Self-myofascial release is a very effective intervention in the management of low back pain (17). It requires a foam roller and a tennis ball (225). The duration, frequency, and the areas to be rolled can vary. The frequency of SMFR can be 2 times a week, according to one study (246). But the frequency was determined as 3 in other studies also (246). According to a study, there should be three sets of 20 seconds for each area with an interval of one minute (247). According to another study, the duration was 30 seconds with 3 sets (17). In the Ajimshas study, the number of sets was 2 (148). Generally, nearly all previous studies applied SMFR to gluteal and paravertebral muscles (246, 247). Also, in some studies, they applied SMFR to psoas major and quadratus lumborum to reduce pain (17, 246, and 247). In this study, each participant had to get a foam roller and a small tennis ball to perform self-myofascial release at home. The foam roller is a piece of very popular equipment for self-myofascial release. This tool can apply a sufficient amount of pressure on soft tissues, such as muscles, and fascias by using our body weight. In this way, these tense areas can relax, decreasing pain. The foam rollers can be found generally in two sizes, which are standard (6 × 36 inches) and small (6 × 18 inches) (225).

a-) Self-Myofascial Release for quadratus lumborum

The participant should lie on the foam roller. The side abdominal part should be

in contact with the foam roller. The ipsilateral leg should be extended, while the other leg should be flexed to 90 degrees. The participant should roll the foam roller under the quadratus lumborum as slowly as possible and rotate the trunk horizontally while going down and vertically to the ground while going up (Figure 3.19) (246).



Figure 3.19 The demonstration of Myofascial Release of Quadratus Lumborum

b-) Self-Myofascial Release for paraspinal muscles and thoracolumbar fascia

The participant should be in the supine position and his back is in contact with the foam roller. He slowly moves the foam roller and rolls it from T12 to L5. The duration should be 30 seconds. There are 3 sets (Figure 3.20) (17).



Figure 3.20 The demonstration of Myofascial Release of Paraspinal & Thoracolumbar Fascia

c-) Self-Myofascial Release for the piriformis and gluteal muscles

The participant should place a tennis ball under his gluteus maximus muscle. The ipsilateral leg is extended, while the other leg is flexed to 90 degrees. The trunk is

in the upright position. He slowly rolls the tennis ball back and forth. The same protocol is performed for the other side. The duration of each movement is 30 seconds. 2 sets are possible (Figure 3.21) (148).



Figure 3.21 The demonstration of Myofascial Release of Piriformis and Gluteal Muscles

d-) Self-Myofascial Release for psoas major

The participant should be in the prone position. His legs, chest, and arms are in contact with the mat. He should place a tennis ball right next to the umbilicus. Then he moves slowly and minimally back and forth on the ball. The same protocol is used for the other side. Since the ball could hurt and disturb the participant, the duration should not be more than 30 seconds. If possible, participants perform this movement in 2 sets (Figure 3.22) (246).



Figure 3.22 The demonstration of Myofascial Release of Psoas Major

3.4 Statistical Analysis

We utilized Statistical Package Analyze for Social Sciences (SPSS) version 21.0 for data analyses in our study. Descriptive statistics, mean $\pm$ standard deviation ($X \pm SD$) or percentages (%), were gathered. The level of significance was accepted as $p \leq 0,05$. To understand which parameters are parametric or which parameters are non-parametric, we used 1 sample Kolmogorov-Smirnov test. Independent samples t-test (when samples are not parametric conditions) and Mann–Whitney U-test (when samples are not parametric conditions) were used to compare the continuous variables between the two groups. The paired sample t-test or Wilcoxon test was used to find the mean difference between before and after treatments. The chi-square test was used to find the relationship between two categorical variables, such as intervention groups and ODI disability levels. The significance level of this study was $P < 0.05$.

Regarding the Power analysis of this study, we used the smallest detectable difference (Smallest Detectable Difference, SDD) for ODI, which is 16.8, and the minimal clinically significant difference (MCID), which is 18.5. The confidence interval was 85%, which should be taken for each group. The number of cases was determined as 16. Thus, to reject the null hypothesis, it is planned to take 32 cases, 16 people in each group, in the study. If the power of the study is %80, the total participants should be 28, 14 people in each group (248).

4. RESULTS

In our study, we analyzed a total of 28 physiotherapy and rehabilitation students at Yeditepe University, who have been suffering from NSLBP. In the first group, the participants (n=14; 4M, 10F) received core stabilization exercises combined with SMFR (G1). In the second group, the participants (n=14; 6M, 8F) only performed SMFR (G2).

- **G1:** Core stabilization exercises combined with Self-myofascial release group
- **G2:** Self-myofascial release group

The sociodemographic features of the participants, such as age, weight, height, and BMI are shown below in Table 4.1. It has been demonstrated that there was no statistically meaningful difference between the two groups regarding age, height, weight, and BMI. Before the statistical analyses, we determined if the values are normally distributed or not. The independent t-test was used for parametric values, while the man-Whitney-u test was utilized for non-parametric values. We used the independent t-test (Table 4.1).

Table 4.1 Sociodemographic Features of University Students

	G1 (n= 14) Mean $\pm$ SD	G2 (n= 14) Mean $\pm$ SD	F	p value
Age (year)	25.92 $\pm$ 3.26	27.64 $\pm$ 4.06	1.510	.741
Weight (kg)	71.78 $\pm$ 16.59	64.00 $\pm$ 11.63	2.066	.260
Height (cm)	170.50 $\pm$ 7.61	170.64 $\pm$ 7.24	0.003	.960
BMI (kg/m²)	24.62 $\pm$ 4.97	21.88 $\pm$ 2.82	3.217	.085

Data expressed as mean $\pm$ standard deviation. G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, BMI. Body Mass Index, kg: kilogram, cm: centimeter, kg/m²: kilogram/meter²

The graphic below shows the distribution of gender in groups (Figure 4.1).

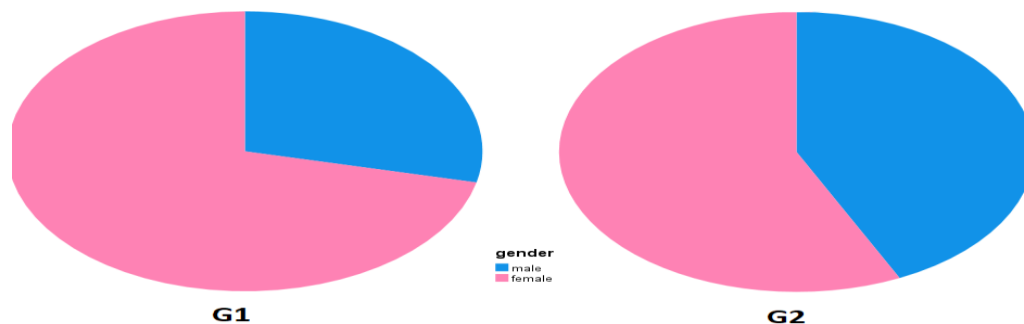


Figure 4.1 Distribution of Gender

According to Kolmogorov-Smirnov, all pre-intervention values were determined as normally distributed or non-normally distributed. Normally distributed values were analyzed using parametric tests, such as the t-test, while non-normally distributed values were analyzed using non-parametric tests, such as the Mann-Whitney U test.

Given the fact that all pre-VAS scores were found to be normally distributed, the independent t-test was used to compare values. According to test results, there were no statistically significant values between groups (Table 4.2).

Table 4.2 Intergroup Comparison of pre-findings of VAS-Activity&at rest of Groups

	G1 (n= 14) Mean $\pm$ SD	G2 (n= 14) Mean $\pm$ SD	F	p value
Pre-VAS-Activity	6.42 $\pm$ 0.64	6.14 $\pm$ 0.36	-1.340	.180
Pre-VAS-at rest	4.42 $\pm$ 2.20	3.85 $\pm$ 1.87	-0.800	.424

Data expressed as mean $\pm$ standard deviation. G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Independent T-Test

As a result of the Kolmogorov Smirnov test, the Oswestry scores were found not to be normally distributed. For this reason, we used a non-parametric test, more specifically the Mann-Whitney u test. It has not been found a statistically significant value between groups (Table 4.3).

The Kolmogorov Smirnov test was used to analyze values if they are normally distributed or not. According to the result, they were not normally distributed. Consequently, we used Mann-Whitney u test to compare the groups. Only pre-walking scores between groups were found statistically significant. The other values were not statistically significant (Table 4.3).

Table 4.3 Intergroup Comparison of pre-findings of each Oswestry scores of Groups

	G1 (n= 14) Mean $\pm$ SD	G2 (n= 14) Mean $\pm$ SD	Z	P value
Pain Intensity	2.42 $\pm$ 0.75	1.85 $\pm$ 0.86	-1.571	.116
Self-Care	1.21 $\pm$ 0.97	1.07 $\pm$ 0.91	-0.434	.664
Lifting	1.85 $\pm$ 0.94	1.64 $\pm$ 1.15	-0.335	.738
Walking	1.71 $\pm$ 0.72	0.92 $\pm$ 0.82	-2.417	.016
Sitting	1.64 $\pm$ 0.74	1.42 $\pm$ 0.75	-0.950	.342

Standing	2.14 ± 0.77	1.50 ± 0.85	-1.872	.061
Sleeping	0.78 ± 0.89	1.00 ± 0.87	-0.771	.441
Social Life	1.28 ± 0.61	0.85 ± 0.66	-1.703	.089
Travelling	1.71 ± 0.61	1.28 ± 0.72	-1.781	.075
Degree of pain change	2.21 ± 1.12	1.71 ± 0.91	-1.216	.224
Oswestry Total	16.64 ± 3.62	13.28 ± 6.21	-1.774	.076

Data expressed as mean ± standard deviation. G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Mann-Whitney U Test

At baseline, we have analyzed the relationship between intervention groups and the severity level of each score. We used the Chi-square test. According to the results, no score has been found statistically significant (Table 4.4).

Table 4.4 Distribution of each and total Oswestry scores in Groups according to the severity level of disability at baseline

	Degree of Disability	G1 (n= 14) % (n)	G2 (n= 14) % (n)	X2	p value
Pain Intensity	No	0(0)	0(0)	6.729	.081
	Minimal	0(0)	28.6(4)		
	Moderate	71.4(10)	50.0(7)		
	Severe	14.3(2)	21.4(3)		
	Very Severe	14.3(2)	0(0)		
	Bed-bound	0(0)	0(0)		
Self care	No	28.6(4)	28.6(4)	.900	.825
	Minimal	28.6(4)	42.9(6)		
	Moderate	35.7(5)	21.4(3)		
	Severe	7.1(1)	7.1(1)		
	Very Severe	0(0)	0(0)		
	Bed-bound	0(0)	0(0)		
	No	0(0)	21.4(3)		

Lifting	Minimal	42.9(6)	21.4(3)	5.778	.216
	Moderate	35.7(5)	28.6(4)		
	Severe	14.3(2)	28.6(4)		
	Very Severe	7.1(1)	0(0)		
	Bed-bound	0(0)	0(0)		
Walking	No	7.1(1)	35.7(5)	6.090	.107
	Minimal	21.4(3)	35.7(5)		
	Moderate	64.3(9)	28.6(4)		
	Severe	7.1(1)	0(0)		
	Very Severe	0(0)	0(0)		
	Bed-bound	0(0)	0(0)		
Sitting	No	0(0)	0(0)	1.815	.404
	Minimal	50.0(7)	71.4(10)		
	Moderate	35.7(5)	14.3(2)		
	Severe	14.3(2)	14.3(2)		
	Very Severe	0(0)	0(0)		
	Bed-bound	0(0)	0(0)		
Standing	No	0(0)	14.3(2)	4.250	.373
	Minimal	14.3(2)	28.6(4)		
	Moderate	64.3(9)	50.0(7)		
	Severe	14.3(2)	7.1(1)		
	Very Severe	7.1(1)	0(0)		
	Bed-bound	0(0)	0(0)		
Sleeping	No	42.9(6)	28.6(4)	.810	.847
	Minimal	42.9(6)	50.0(7)		
	Moderate	7.1(1)	14.3(2)		
	Severe	7.1(1)	7.1(1)		

	Very Severe	0(0)	0(0)		
	Bed-bound	0(0)	0(0)		
Social Life	No	7.1(1)	28.6(4)	3.086	.214
	Minimal	57.1(8)	57.1(8)		
	Moderate	35.7(5)	14.3(2)		
	Severe	0(0)	0(0)		
	Very Severe	0(0)	0(0)		
	Bed-bound	0(0)	0(0)		
Traveling	No	0(0)	7.1(1)	4.416	.220
	Minimal	35.7(5)	64.3(9)		
	Moderate	57.1(8)	21.4(3)		
	Severe	7.1(1)	7.1(1)		
	Very Severe	0(0)	0(0)		
	Bed-bound	0(0)	0(0)		
Degree of pain change	No	0(0)	0(0)	2.967	.397
	Minimal	35.7(5)	50.0(7)		
	Moderate	21.4(3)	35.7(5)		
	Severe	28.6(4)	7.1(1)		
	Very Severe	14.3(2)	7.1(1)		
	Bed-bound	0(0)	0(0)		
Total Oswestry Score	Minimal	7.1(1)	35.7(5)	3.556	.169
	Moderate	78.6(11)	50.0(7)		
	Severe	14.3(2)	14.3(2)		
	Very Severe	0(0)	0(0)		
	Bed-bound	0(0)	0(0)		

Data expressed as a percentage (total number). G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Chi-Square Test

According to Kolmogorov-Smirnov, all values were determined as normally distributed or non-normally distributed. Normally distributed values were analyzed using parametric tests, such as paired t-test, while non-normally distributed values were analyzed using non-parametric tests, such as the Wilcoxon test.

According to the Kolmogorov Smirnov test, the values were found non-normally distributed, which is why the Wilcoxon test was used. The results suggested that VAS-activity in both groups has increased compared to the pre-measurements. The intragroup comparisons in VAS-activity were found not to be statistically significant. The VAS at rest scores have only increased in group 1, while there is no change detected in the SMFR group. The intergroup change in the VAS at rest of group 1 was statistically significant (Table 4.5).

Table 4.5 Intragroup Comparison of Sudden effects of VAS Activity –VAS at rest of Groups

		G1 (n= 14) Mean ± SD	z	P value	G2 (n= 14) Mean ± SD	z	p value
VAS-A	T0	6.42 ± 0.64	-0.577	.564	6.14 ± 0.36	-1.000	.317
	T1	6.50 ± 0.75			6.21 ± 0.42		
VAS-R	T0	4.42 ± 2.20	-2.000	.046	3.85 ± 1.87	0.000	1
	T1	4.71 ± 2.43			3.85 ± 1.87		

Data expressed as mean ± standard deviation. T0: pre-intervention measurement, T1:post-intervention measurement in the first week, VAS-A: Visual analogue scale-Activity, R-VAS: Visual Analogue Scale-at rest, G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Wilcoxon Test

According to the Kolmogorov- Smirnov test, all VAS-activity and VAS-at rest at different weeks were found to be non-normally distributed. For this reason, the Wilcoxon test, which is a non-parametric test, was used to compare pre-and post-measurement scores within each group. The VAS-activity resultss in both groups at each interval have decreased and were statistically significant. Only the decrease in VAS-at rest between pre-and post-measurements in group 2 was not statistically significant. Generally, the decreases were higher in group 1 (Table 4.6).

Table 4.6 Intragroup Comparison of Pre-findings of VAS Activity and VAS at Rest of Groups according to different week intervals

		G1 (n= 14) Mean ± SD	z	P value	G2 (n= 14) Mean ± SD	z	p value
VAS-A	T0	6.42 ± 0.64	-3.373	<0.001	6.14 ± 0.36	-2.264	.024
	T1	4.42 ± 0.93			5.50 ± 0.94		
	T1	4.42 ± 0.93	-3.126	.002	5.50 ± 0.94	-2.236	.025
	T2	2.92 ± 0.99			5.14 ± 1.09		
	T0	6.42 ± 0.64	-3.384	<0.001	6.14 ± 0.36	-2.274	.008
	T2	2.92 ± 0.99			5.14 ± 1.09		
VAS-R	T0	4.42 ± 2.20	-3.126	.002	3.85 ± 1.87	-1.027	.305
	T1	3.07 ± 1.94			3.57 ± 1.60		
	T1	3.07 ± 1.94	-3.064	.002	3.57 ± 1.60	-2.828	.005
	T2	1.85 ± 1.65			3.00 ± 1.75		
	T0	4.42 ± 2.20	-3.316	<0.001	3.85 ± 1.87	-2.144	.032
	T2	1.85 ± 1.65			3.00 ± 1.75		

Data expressed as mean ± standard deviation. T0: pre-intervention measurement, T1: mid-measurement at 3rd week, T2: post-intervention measurement, VAS-A: Visual analogue scale-Activity, VAS-R: Visual Analogue Scale at rest, G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Wilcoxon Test

Given the fact that all Oswestry values were not normally distributed, the non-parametric test Wilcoxon was used to compare the scores before and after within each group at different week intervals. According to the results, nearly all scores have decreased at each group and interval. Only the social life score in group 2 had no change between pre-and mid-measurements. Regarding the pain intensity, every score has decreased and all values were statistically significant. However, the pain intensity score between pre-and mid-measurements in the SMFR group was not statistically significant. The same result can be said for self-care and standing. Regarding the lifting, all scores have diminished and all before-after results at different week intervals in group 1 were statistically significant, while only the lifting score between pre-and post-measurements in group 2 was found to be statistically significant. The same result has been found for the sitting. In terms of the walking, all values have decreased and all scores in group 1 were statistically meaningful, whereas the decreases in group 2 had no

statistically significant results. Regarding the sleeping, those values have decreased and both groups had statistically significant values at the pre-mid and pre-post measurements but no statistically meaningful decreases at mid-post measurements. In terms of social life, there was no change in group 2 between pre-mid measurements and the other scores decreased in both groups. Only the per-post score in group 1 was statistically significant. Regarding the travelling and degree of change in pain, each score has diminished and all p values in both groups were less than 0, 05 and statistically significant (Table 4.7). Regarding the total ODI score, even though the total ODI scores in both groups have decreased at different intervals, the amount of decrease seemed to be higher in group 1. All values were found statistically significant (Table 4.7).

Table 4.7 Intragroup Comparison of Total and Each Oswestry Scores of Groups according to different weeks

		G1 (n= 14) Mean ± SD	Z	P value	G2 (n= 14) Mean ± SD	Z	P value
Pain Intensity	T0	2.42 ± 0.75	-3.207	.001	1.85 ± 0.86	-0.447	.655
	T1	1.57 ± 0.85			1.78 ± 0.97		
	T1	1.57 ± 0.85	-3.071	.002	1.78 ± 0.97	-2.449	.014
	T2	0.57 ± 0.75			1.35 ± 0.92		
	T0	2.42 ± 0.75	-3.442	<0.001	1.85 ± 0.86	-2.646	.008
	T2	0.57 ± 0.75			1.35 ± 0.92		
Self-Care	T0	1.21 ± 0.97	-2.121	.034	1.07 ± 0.91	-1.414	.157
	T1	0.78 ± 0.69			0.92 ± 0.82		
	T1	0.78 ± 0.69	-2.449	.014	0.92 ± 0.82	-2.828	.005
	T2	0.35 ± 0.49			0.35 ± 0.63		
	T0	1.21 ± 0.97	-2.762	.006	1.07 ± 0.91	-2.887	.004
	T2	0.35 ± 0.49			0.35 ± 0.63		
Lifting	T0	1.85 ± 0.94	-2.646	.008	1.64 ± 1.15	-1.732	.083

	T1	1.35 ± 0.74			1.42 ± 1.15		
	T1	1.35 ± 0.74	-2.333	.020	1.42 ± 1.15	-1.633	.102
	T2	0.85 ± 0.77			1.14 ± 0.94		
	T0	1.85 ± 0.94	-3.071	.002	1.64 ± 1.15	-2.333	.020
	T2	0.85 ± 0.77			1.14 ± 0.94		
Walking	T0	1.71 ± 0.72	-2.588	.010	0.92 ± 0.82	-0.577	.564
	T1	0.85 ± 0.77			0.85 ± 0.86		
	T1	0.85 ± 0.77	-2.000	.046	0.85 ± 0.86	-1.000	.317
	T2	0.57 ± 0.75			0.71 ± 0.82		
	T0	1.71 ± 0.72	-2.859	.004	0.92 ± 0.82	-1.342	.180
	T2	0.57 ± 0.75			0.71 ± 0.82		
Sitting	T0	1.64 ± 0.74	-2.333	.020	1.42 ± 0.75	-1.732	.083
	T1	1.14 ± 0.36			1.21 ± 0.69		
	T1	1.14 ± 0.36	-2.646	.008	1.21 ± 0.69	-1.414	.157
	T2	0.64 ± 0.63			1.07 ± 0.82		
	T0	1.64 ± 0.74	-3.125	.002	1.42 ± 0.75	-2.236	.025
	T2	0.64 ± 0.63			1.07 ± 0.82		
Standing	T0	2.14 ± 0.77	-2.530	.011	1.50 ± 0.85	-1.414	.157
	T1	1.50 ± 0.65			1.35 ± 0.84		
	T1	1.50 ± 0.65	-2.646	.008	1.35 ± 0.84	-2.000	.046
	T2	1.00 ± 0.55			1.07 ± 0.82		
	T0	2.14 ± 0.77	-3.066	.002	1.50 ± 0.85	-2.449	.014
	T2	1.00 ± 0.55			1.07 ± 0.82		
Sleeping	T0	0.78 ± 0.89	-2.499	.014	1.00 ± 0.87	-2.236	.025
	T1	0.35 ± 0.74			0.64 ± 0.92		
	T1	0.35 ± 0.74	-1.342	.180	0.64 ± 0.92	-1.414	.157

	T2	0.14 ± 0.36			0.50 ± 0.85		
	T0	0.78 ± 0.89	-2.530	.011	1.00 ± 0.87	-2.333	.020
	T2	0.14 ± 0.36			0.50 ± 0.85		
Social Life	T0	1.28 ± 0.61	-1.857	.063	0.85 ± 0.66	0	1
	T1	0.85 ± 0.66			0.85 ± 0.77		
	T1	0.85 ± 0.66	-1,732	.083	0.85 ± 0.77	-1.414	.157
	T2	0.64 ± 0.74			0.71 ± 0.72		
	T0	1.28 ± 0.61	-2.251	.024	0.85 ± 0.66	-1.414	.157
	T2	0.64 ± 0.74			0.71 ± 0.72		
Traveling	T0	1.71 ± 0.61	-2.714	.007	1.28 ± 0.72	-2.236	.025
	T1	1.07 ± 0.26			0.92 ± 0.73		
	T1	1.07 ± 0.26	-2.000	.046	0.92 ± 0.73	-2.000	.046
	T2	0.78 ± 0.57			0.64 ± 0.63		
	T0	1.71 ± 0.61	-2.919	.004	1.28 ± 0.72	-3.000	.003
	T2	0.78 ± 0.57			0.64 ± 0.63		
Degree of change in pain	T0	2.21 ± 1.12	-2,588	.010	1.71 ± 0.91	-2.449	.014
	T1	1.35 ± 0.92			1.28 ± 0.91		
	T1	1.35 ± 0.92	-2.530	.011	1.28 ± 0.91	-2.449	.014
	T2	0.78 ± 0.57			0.85 ± 0.86		
	T0	2.21 ± 1.12	-3.133	.002	1.71 ± 0.91	-2.972	.003
	T2	0.78 ± 0.57			0.85 ± 0.86		
Total Oswestry scores	T0	16.64 ± 3.62	-3.304	<0.001	13.28 ± 6.21	-2.728	.006
	T1	10.57 ± 2.65			11.14 ± 5.70		
	T1	10.57 ± 2.65	-3.309	<0.001	11.14 ± 5.70	-2.862	.004
	T2	6.28 ± 3.04			8.42 ± 5.37		

	T0	16.64 ± 3.62	-3.309	<0.001	13.28 ± 6.21	-3.301	<0.001
	T2	6.28 ± 3.04			8.42 ± 5.37		

Data expressed as mean ± standard deviation. T0: pre-intervention measurement, T1: mid-measurement at 3rd week, T2: post-intervention measurement, G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Wilcoxon Test

In terms of the differences in sudden VAS-activity and VAS at rest scores in pre- and post-intervention in the first week, firstly the normality test was used. According to the Kolmogorov- Smirnov test, all differences between pre-and post-program in sudden activity and resting VAS scores were found to be non-normally distributed. For this reason, the Mann-Whitney U, which is a non-parametric test, was used to compare the groups. Both activity and resting VAS have increased more in group 1. In group 2, there was no change regarding the resting VAS. According to the results, the difference in activity VAS between pre-and post-program among groups was found not to be significant, whereas the difference in resting VAS between pre-and post-program among groups was statistically significant. This indicated that core combined SMFR could have an adverse effect on resting VAS compared to only SMFR (Table 4.8).

Table 4.8 Intergroup Comparison of Differences in Sudden effects of VAS-Activity and VAS at Rest between Groups

	G1 (n= 14)	G2 (n= 14)	z	P value
	Mean ± SD	Mean ± SD		
Δ VAS-A T₀₋₁	0.14 ± 0.36	0.07 ± 0.26	-0.600	.549
Δ VAS-R T₀₋₁	0.28 ± 0.46	0.00 ± 0.00	-2.121	.034

Data expressed as mean ± standard deviation. Δ: Difference, T0-1: difference in measurements between pre-intervention and post-intervention in the 1st week, VAS-A: Visual analogue scale-Activity, VAS-R: Visual Analogue Scale at rest, G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Mann-Whitney U Test

In terms of the difference in VAS-activity and VAS at rest results at different weeks, firstly the normality test was used. According to the Kolmogorov-Smirnov test, all differences in VAS-activity and VAS at rest results were found to be non-normally distributed, which is why the Mann-Whitney U was utilized to be able to compare the groups. Generally, the differences in group 1 were higher than in the SMFR group. It suggests that Core stabilization with SMFR was more effective compared to the only SMFR in terms of pain intensity. According to the results, differences in VAS-activity between 1st-3rd, 3rd-5th, and 1st-5th weeks (pre-mid, mid-post, and pre-post

measurements) among groups were found to be statistically significant in favour of G1. Similarly, the differences in VAS at rest were statistically significant at 1st-3rd and 1st-5th weeks (pre-mid and pre-post measurements) among groups in favour of G1. Only the difference in VAS at rest was not found to be statistically significant between 3rd-5th weeks (mid-post measurements) among groups (Table 4.9).

Table 4.9 Intergroup Comparison of Differences in VAS Activity and VAS at rest between Groups according to different week intervals

	Week	G1 (n= 14) Mean $\pm$ SD	G2 (n= 14) Mean $\pm$ SD	z	P value
Δ VAS-A	T₀₋₁	-2.00 $\pm$ 0.67	-0.64 $\pm$ 0.92	-3.462	<0.001
	T₁₋₂	-1.50 $\pm$ 1.01	-0.35 $\pm$ 0.49	-3.248	.001
	T₀₋₂	-3.07 $\pm$ 1.85	-1.00 $\pm$ 1.03	-3.636	<0.001
Δ VAS-R	T₀₋₁	-1.35 $\pm$ 0.84	-0.28 $\pm$ 0.99	-2.726	.006
	T₁₋₂	-1.21 $\pm$ 1.12	-0.57 $\pm$ 0.51	-1.716	.086
	T₀₋₂	-2.57 $\pm$ 1.22	-0.85 $\pm$ 1.23	-3.202	.001

Data expressed as mean $\pm$ standard deviation. Δ : Difference, T0-1: the difference between pre-mid measurements (weeks 1-3), T1-2: the difference between mid-post measurements (weeks 3-5), T0-2: the difference between pre-post measurement (weeks 1-5), VAS-A: Visual analogue scale-Activity, VAS-R: Visual Analogue Scale at rest, G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Mann-Whitney U Test

Both activity and resting VAS scores have decreased in both groups over 5 weeks. The graphics below showed the change in both VAS-activity and VAS at rest scores over time (Figure 4.2).

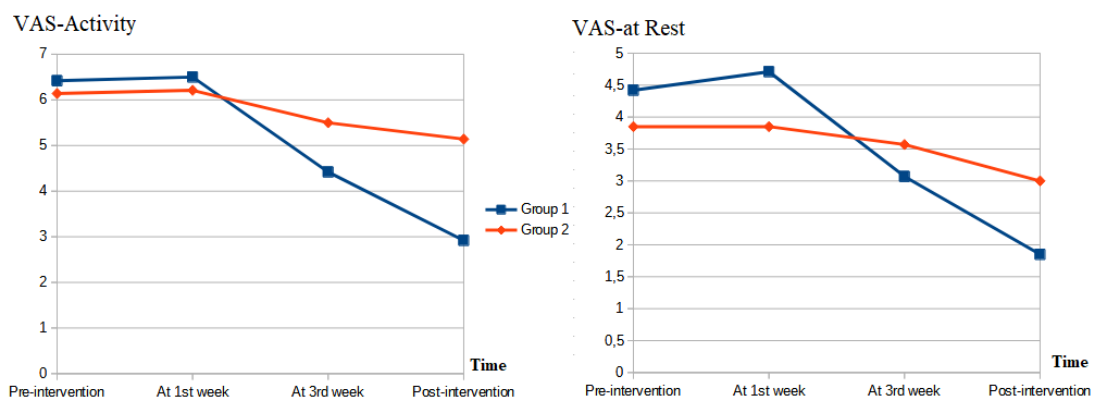


Figure 4.2 The Demonstration of change in VAS-A and VAS-R over 5 weeks in groups

Regarding the difference in each and total Oswestry scores, the normality test firstly was used. According to the Kolmogorov- Smirnov test, all differences in total Oswestry scores were found to be non-normally distributed. That is why non-parametric tests were used. At this point, the Mann-Whitney u test was used to compare the differences between groups. All the differences in group 1 were found to be higher compared to group 2. It means that Core stabilization with SMFR was more effective compared to the only SMFR.

Even though all differences were generally higher in group 1, only self-care scores between 3rd-5th weeks (mid-post measurements) had a higher change in group 2. But this score was not statistically significant. The difference in travelling scores between 3rd-5th weeks (mid-post measurements) was found equal between groups. Regarding the difference in pain intensity, all differences among groups were found to be statistically significant. In terms of the difference in lifting scores, only the differences between 1st-3rd weeks (pre-mid measurements) among groups were found to be statistically significant in favour of G1. In terms of the difference in walking and standing, the differences between 1st-3rd and 1st-5th weeks (pre-mid and pre-post measurements) among groups were found to be statistically significant in favour of G1. The difference in sitting only has a statistically significant difference between 3rd-5th and 1st-5th weeks (mid-post and pre-post measurements) in favour of G1. The other differences were not found to be statistically significant (Table 4.10).

Table 4.10 Intergroup Comparison of Each Oswestry Scores of Group according to different week intervals

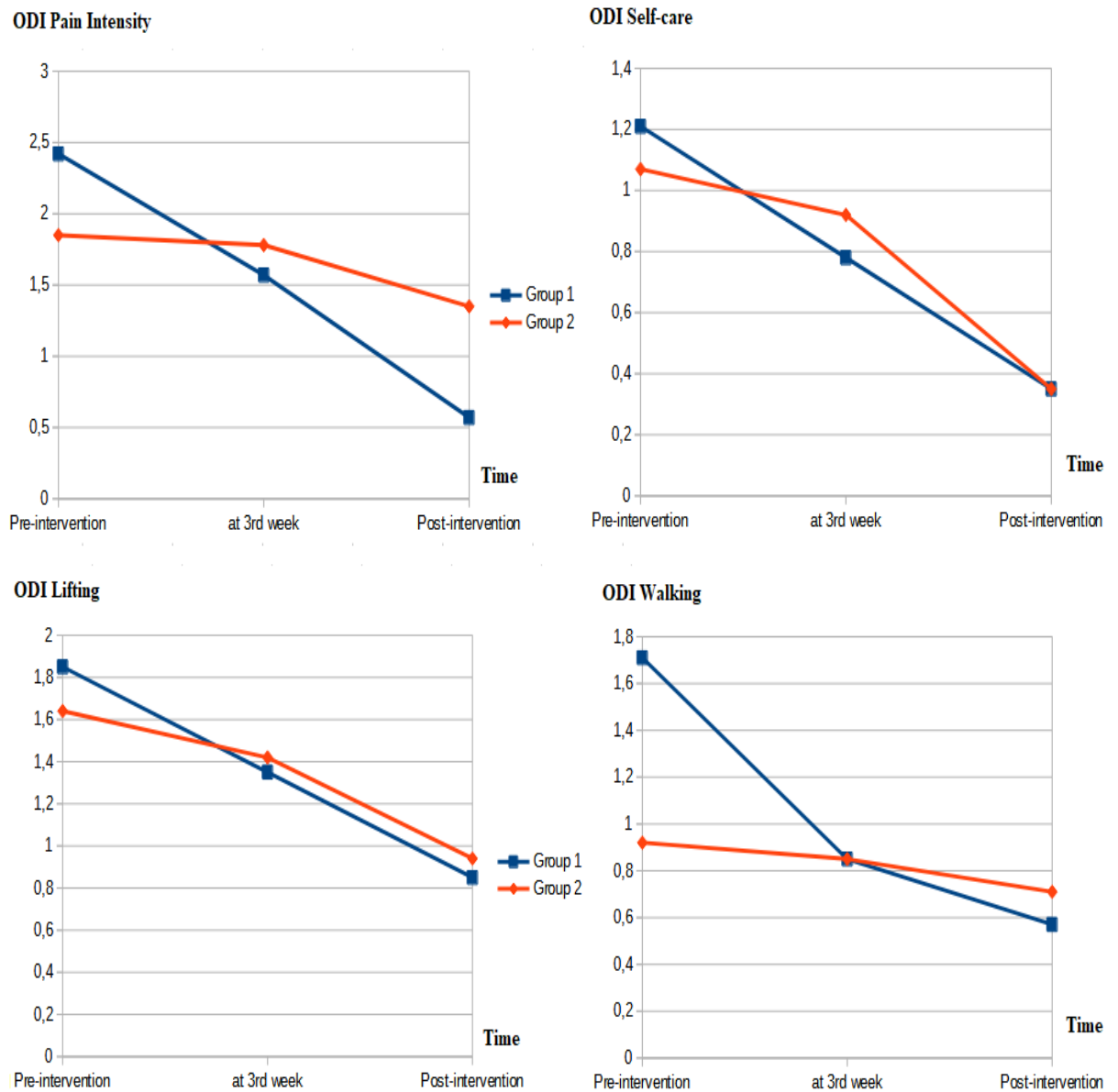
		G1 (n= 14) Mean ± SD	G2 (n= 14) Mean ± SD	Z	P value
Δ Pain intensity	T₀₋₁	-0.85 ± 0.53	-0.07 ± 0.61	-3.066	.004
	T₁₋₂	-1.00 ± 0.67	-0.42 ± 0.51	-2.241	.044
	T₀₋₂	-1.85 ± 0.53	-0.50 ± 0.51	-4.251	<0.001
Δ Self-care	T₀₋₁	-0.42 ± 0.64	-0.14 ± 0.36	-1.340	.180
	T₁₋₂	-0.42 ± 0.51	-0.57 ± 0.51	-0.742	.458
	T₀₋₂	-0.78 ± 0.80	-0.71 ± 0.61	-0.126	.900

Δ Lifting	T₀₋₁	-0.50 ± 0.51	-0.22 ± 0.47	-2.111	.035
	T₁₋₂	-0.50 ± 0.65	-0.28 ± 0.61	-1.093	.275
	T₀₋₂	-1.00 ± 0.67	-0.50 ± 0.65	-1.933	.053
Δ Walking	T₀₋₁	-0.85 ± 0.94	-0.71 ± 0.47	-2.528	.011
	T₁₋₂	-0.28 ± 0.46	-0.00 ± 0.55	-1.394	.163
	T₀₋₂	-1.14 ± 0.94	-0.21 ± 0.57	-2.668	.008
Δ Sitting	T₀₋₁	-0.50 ± 0.65	-0.21 ± 0.42	-1.268	.205
	T₁₋₂	-0.50 ± 0.51	-0.14 ± 0.36	-1.987	.047
	T₀₋₂	-1.00 ± 0.78	-0.35 ± 0.49	-2.419	.016
Δ Standing	T₀₋₁	-0.64 ± 0.84	-0.14 ± 0.36	-2.028	.043
	T₁₋₂	-0.50 ± 0.51	-0.28 ± 0.46	-1.140	.254
	T₀₋₂	-1.14 ± 1.02	-0.42 ± 0.51	-2.239	.025
Δ Sleeping	T₀₋₁	-0.42 ± 0.51	-0.35 ± 0.49	-0.380	.704
	T₁₋₂	-0.21 ± 0.57	-0.14 ± 0.36	-0.076	.940
	T₀₋₂	-0.64 ± 0.84	-0.42 ± 0.51	-0.524	.600
Δ Social life	T₀₋₁	-0.42 ± 0.75	0.00 ± 0.39	-1.730	.084
	T₁₋₂	-0.21 ± 0.42	-0.14 ± 0.36	-0.485	.628
	T₀₋₂	-0.64 ± 0.84	-0.14 ± 0.36	-1.795	.073
Δ Traveling	T₀₋₁	-0.64 ± 0.63	-0.35 ± 0.49	-1.232	.218
	T₁₋₂	-0.28 ± 0.46	-0.28 ± 0.46	0.000	1
	T₀₋₂	-0.92 ± 0.73	-0.64 ± 0.49	-1.067	.286
Δ Degree of pain change	T₀₋₁	-0.85 ± 0.94	-0.42 ± 0.51	-1.171	.242
	T₁₋₂	-0.57 ± 0.64	-0.50 ± 0.51	-0.183	.855

	T₀₋₂	-1.42 ± 1.08	-0.85 ± 0.66	-1.461	.144
Δ Total	T₀₋₁	-6.07 ± 3.38	-2.14 ± 2.31	-1.182	<0.001
Oswestry	T₁₋₂	-4.28 ± 1.97	-2.71 ± 2.23	-0.190	.030
Score	T₀₋₂	-10.21 ± 4.40	-4.85 ± 3.20	-1.199	.001

Data expressed as mean ± standard deviation. T0: pre-intervention measurement, T1: mid-measurement at 3rd week, T2: post-intervention measurement, G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, *: Mann-Whitney U Test

We have also demonstrated the change in each sub-score of the ODI scale. The line graphics below showed those changes over 5 weeks in two groups (Figure 4.3).



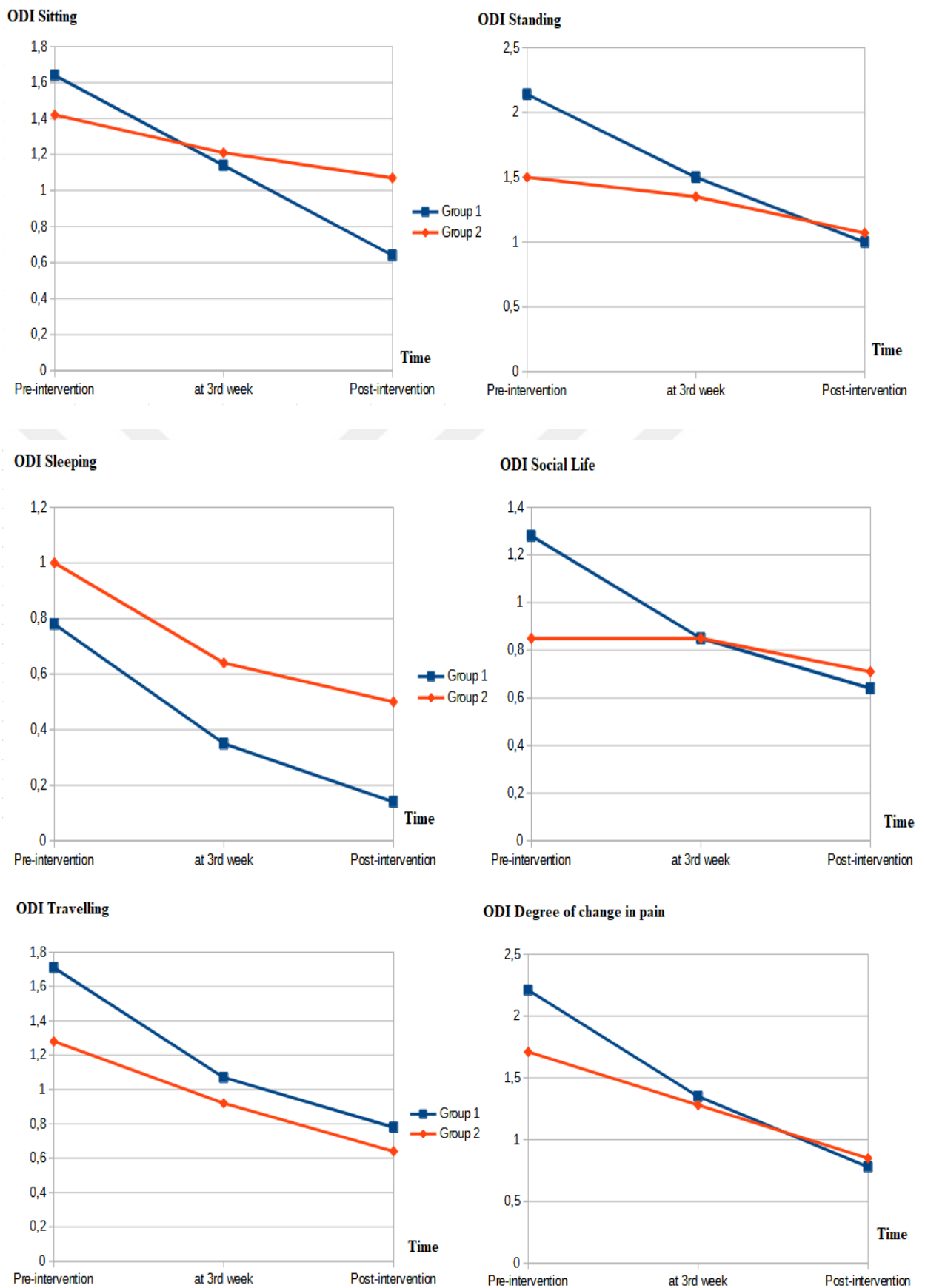


Figure 4.3 The Demonstration of change in each sub-score of ODI over 5 weeks

In our study, we demonstrated a decrease in total ODI scores in both groups. The line graphic below showed those changes in both groups over 5 weeks (Figure 4.4).

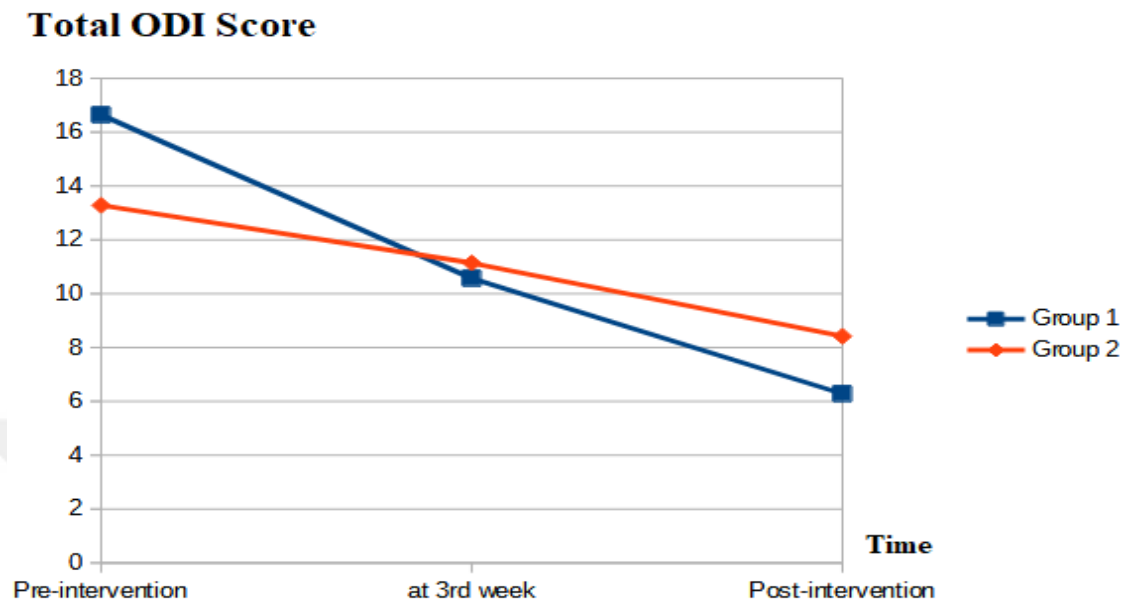


Figure 4.4 The Demonstration of change in Total ODI over 5 weeks in groups

We have shown the distribution of Oswestry scores according to different severity levels at mid and post-intervention. We analyzed the relationship between the severity level of each score and intervention groups. For this reason, we have used the Chi-Square test.

According to the results, the percentages of no disability and minimal disability were higher in G1, but only pain intensity, lifting, and travelling at mid-intervention were statistically significant. The percentages of no disability and minimal disability in sleeping and social life were the same. Also, the percentages of no disability and minimal disability in standing and degree of pain change were higher in G2. However, those scores were not statistically significant (Table 4.11).

Table 4.11 Distribution of each and total Oswestry scores in Groups according to the severity level of disability at mid and post interventions

	T	Degree of Disability	G1 (n= 14) % (n)	G2 (n= 14) % (n)	X²	p value
Pain Intensity	T1	No	0(0)	14.3(2)	9.933	.042
		Minimal	57.1(8)	14.3(2)		
		Moderate	35.7(5)	50.0(7)		
		Severe	0(0)	21.4(3)		
		Very Severe	7.1(1)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	No	57.1(8)	21.4(3)	5.273	.153
		Minimal	28.6(4)	28.6(4)		
		Moderate	14.3(2)	42.9(6)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
Self Care	T1	No	35.7(5)	28.6(4)	1.511	.680
		Minimal	50.0(7)	57.1(8)		
		Moderate	14.3(2)	7.1(1)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	No	64.3(9)	71.4(10)	1.553	.460
		Minimal	35.7(5)	21.4(3)		
		Moderate	0(0)	7.1(1)		
		Severe	0(0)	0(0)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
		No	0(0)	28.6(4)		
		Minimal	78.6(11)	21.4(3)		

Lifting	T1	Moderate	7.1(1)	28.6(4)	10.571	.014
		Severe	14.3(2)	21.4(3)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	No	28.6(4)	28.6(4)	5.143	.162
		Minimal	64.3(9)	35.7(5)		
		Moderate	0(0)	28.6(4)		
		Severe	7.1(1)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
Walking	T1	No	35.7(5)	42.9(6)	0.634	.728
		Minimal	42.9(6)	28.6(4)		
		Moderate	21.4(3)	28.6(4)		
		Severe	0(0)	0(0)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	No	57.1(8)	50.0(7)	0.267	.875
		Minimal	28.6(4)	28.6(4)		
		Moderate	14.3(2)	21.4(3)		
		Severe	0(0)	0(0)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
Sitting	T1	No	0(0)	7.1(1)	2.182	.536
		Minimal	85.7(12)	71.4(10)		
		Moderate	14.3(2)	14.3(2)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
		No	42.9(6)	21.4(3)		

	T2	Minimal	50.0(7)	57.1(8)	2.400	.494
		Moderate	7.1(1)	14.3(2)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
Standing	T1	No	7.1(1)	14.3(2)	2.117	.549
		Minimal	35.7(5)	42.9(6)		
		Moderate	57.1(8)	35.7(5)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	No	14.3(2)	21.4(3)	1.422	.700
		Minimal	71.4(10)	57.1(8)		
		Moderate	14.3(2)	14.3(2)		
		Severe	0(0)	0(0)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
Sleeping	T1	No	78.6(11)	57.1(8)	3.607	.307
		Minimal	7.1(1)	28.6(4)		
		Moderate	14.3(2)	7.1(1)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	No	85.7(12)	64.3(9)	2.095	.351
		Minimal	14.3(2)	28.6(4)		
		Moderate	0(0)	0(0)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
		No	28.6(4)	35.7(5)		

Social Life	T1	Minimal	57.1(8)	42.9(6)	.597	.742
		Moderate	14.3(2)	21.4(3)		
		Severe	0(0)	0(0)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	No	50.0(7)	42.9(6)	.168	.920
		Minimal	35.7(5)	42.9(6)		
		Moderate	14.3(2)	14.3(2)		
		Severe	0(0)	0(0)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
Travelling	T1	No	0(0)	28.6(4)	6.800	.033
		Minimal	92.2(13)	50.0(7)		
		Moderate	7.1(1)	21.4(3)		
		Severe	0(0)	0(0)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	No	28.6(4)	42.9(6)	.650	.723
		Minimal	64.3(9)	50.0(7)		
		Moderate	7.1(1)	7.1(1)		
		Severe	0(0)	0(0)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T1	No	14.3(2)	7.1(1)	4.063	.398
		Minimal	50.0(7)	71.4(10)		
		Moderate	21.4(3)	14.3(2)		
		Severe	14.3(2)	0(0)		
		Very Severe	0(0)	7.1(1)		
		Bed-bound	0(0)	0(0)		

Degree of pain change	T2	No	28.6(4)	35.7(5)	1.361	.715
		Minimal	64.3(9)	50.0(7)		
		Moderate	7.1(1)	7.1(1)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
Total Oswestry Score	T1	Minimal	50.0(7)	35.7(5)	1.400	.497
		Moderate	50.0(7)	57.1(8)		
		Severe	0(0)	7.1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		
	T2	Minimal	92.2(13)	78.6(11)	1.500	.472
		Moderate	7.1(1)	14.3(2)		
		Severe	0(0)	7,1(1)		
		Very Severe	0(0)	0(0)		
		Bed-bound	0(0)	0(0)		

Data expressed as a percentage (total number). G1: Core stabilization exercises combined with SMFR, G2: self-myofascial release group, T1: mid-measurement at 3 weeks, T2: post-intervention measurement *: Chi-Square Test

The distributions of pain intensity scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, a higher amount of participants in G1 (85, 7%) reached no disability or minimal disability level compared to G2 (50%) (Figure 4.5).

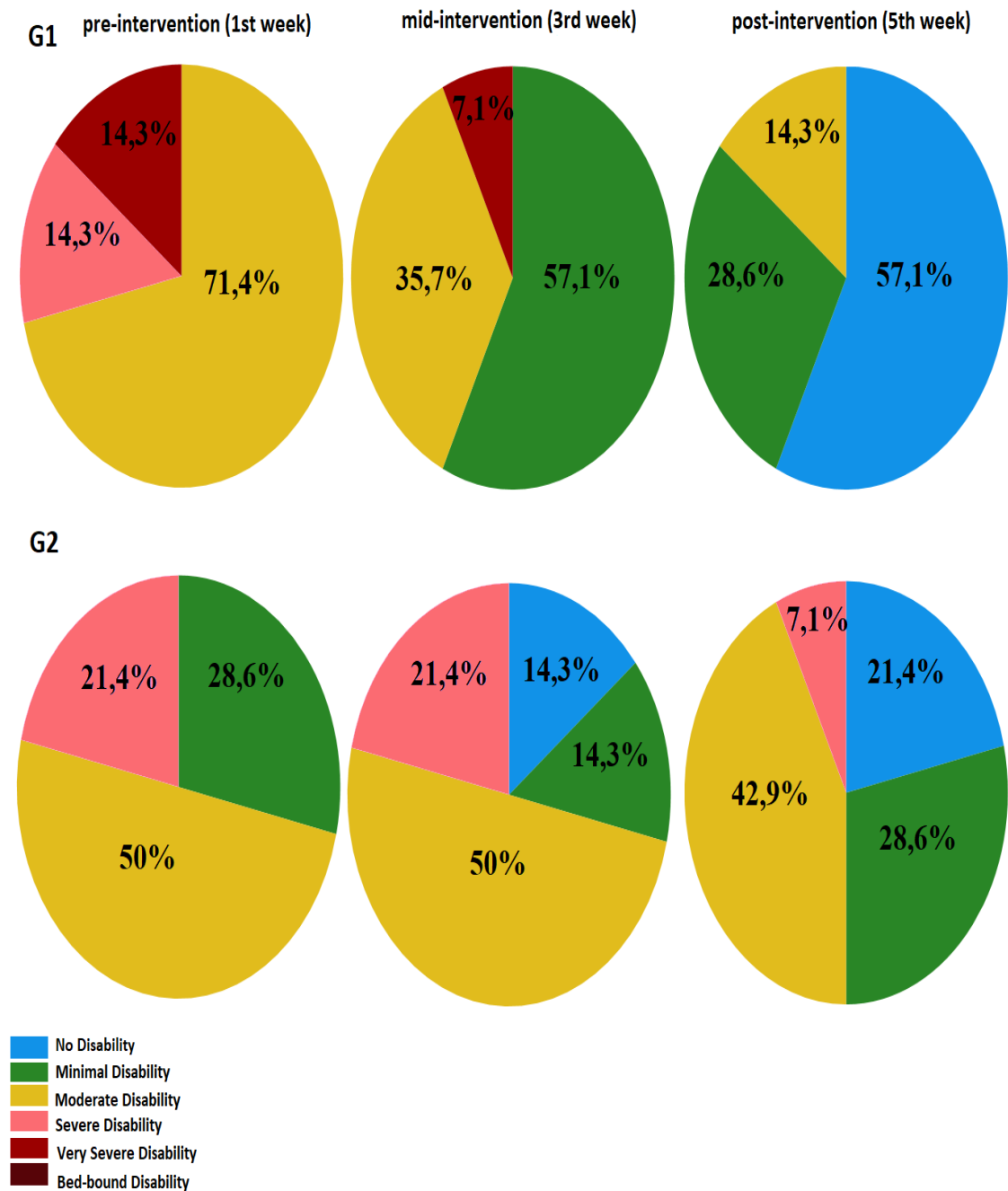


Figure 4.5 Distribution of pain intensity score in groups according to the severity level of disability

The distributions of self-care scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, a higher amount of participants in G1 (100%) reached no disability or minimal disability level compared to G2 (92, 9%) (Figure 4.6).

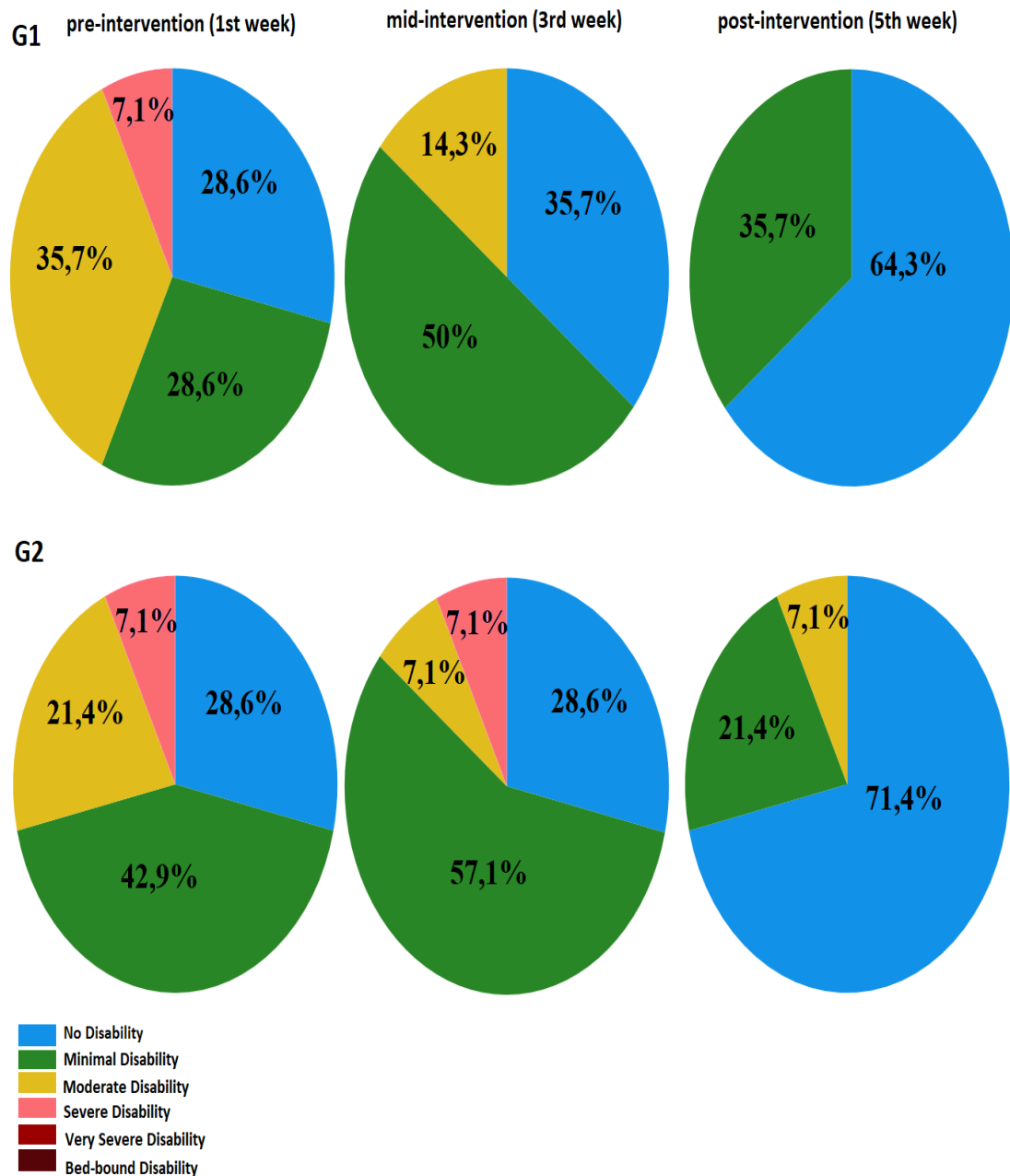


Figure 4.6 Distribution of self-care scores in groups according to the severity level of disability

The distributions of lifting scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, a higher amount of participants in G1 (92, 9%) reached no disability or minimal disability level compared to G2 (64, 3%) (Figure 4.7).

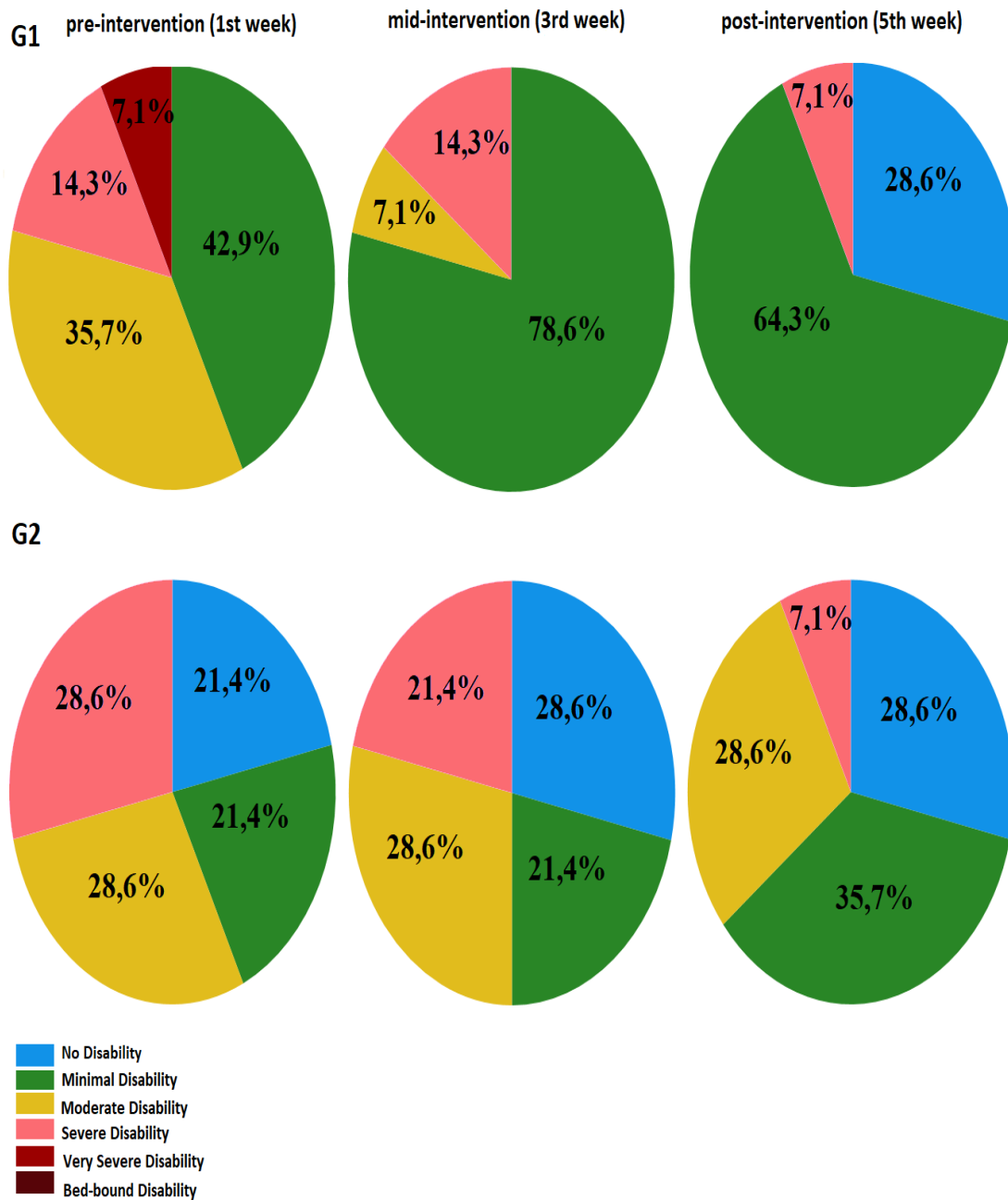


Figure 4.7 Distribution of lifting scores in groups according to the severity level of disability

The distributions of walking scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, a higher amount of participants in G1 (85, 7%) reached no disability or minimal disability level compared to G2 (78, 6%) (Figure 4.8).

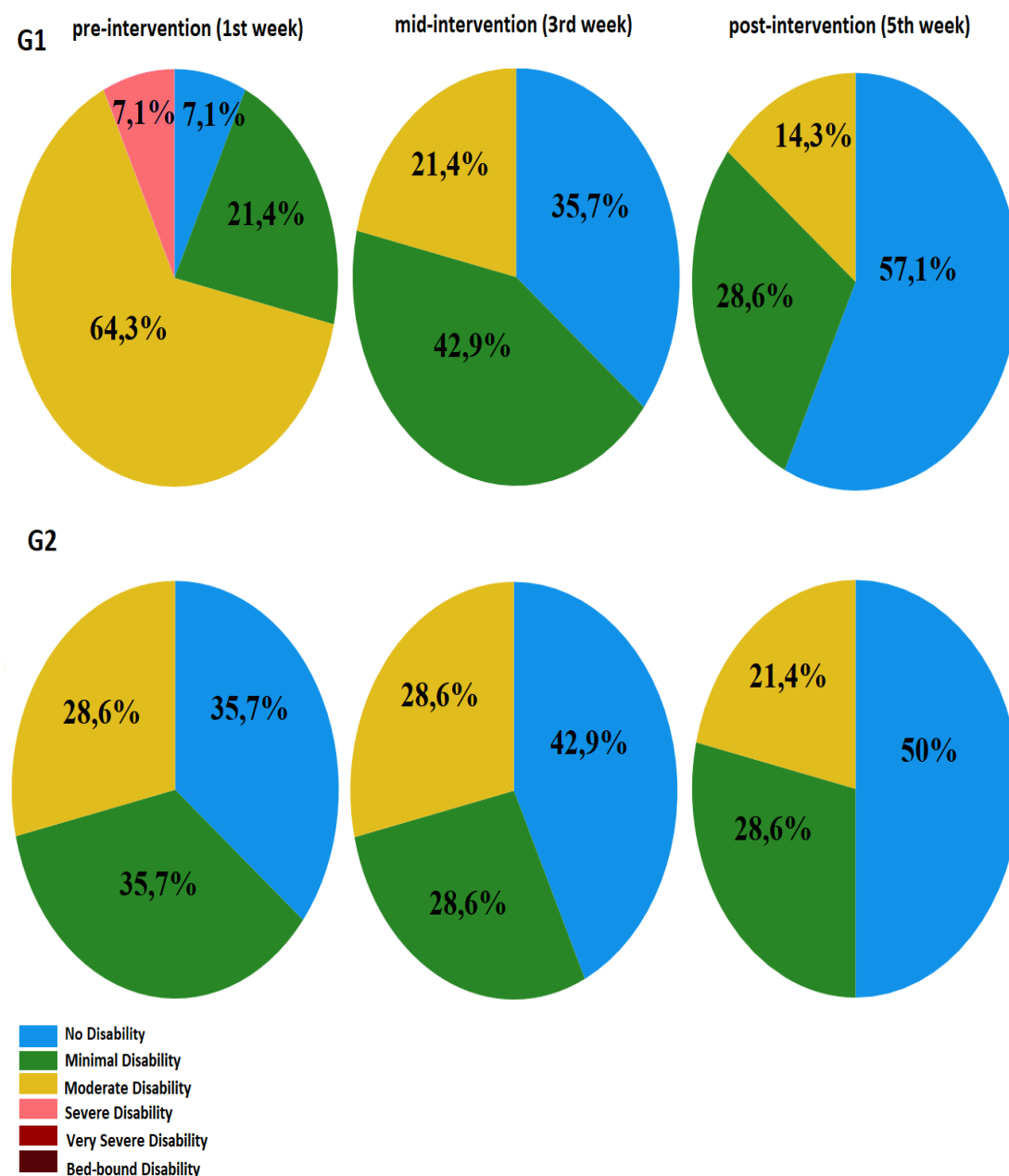


Figure 4.8 Distribution of walking scores in groups according to the severity level of disability

The distributions of sitting scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, a higher amount of participants in G1 (92, 9%) reached no disability or minimal disability level compared to G2 (78, 5%) (Figure 4.9).

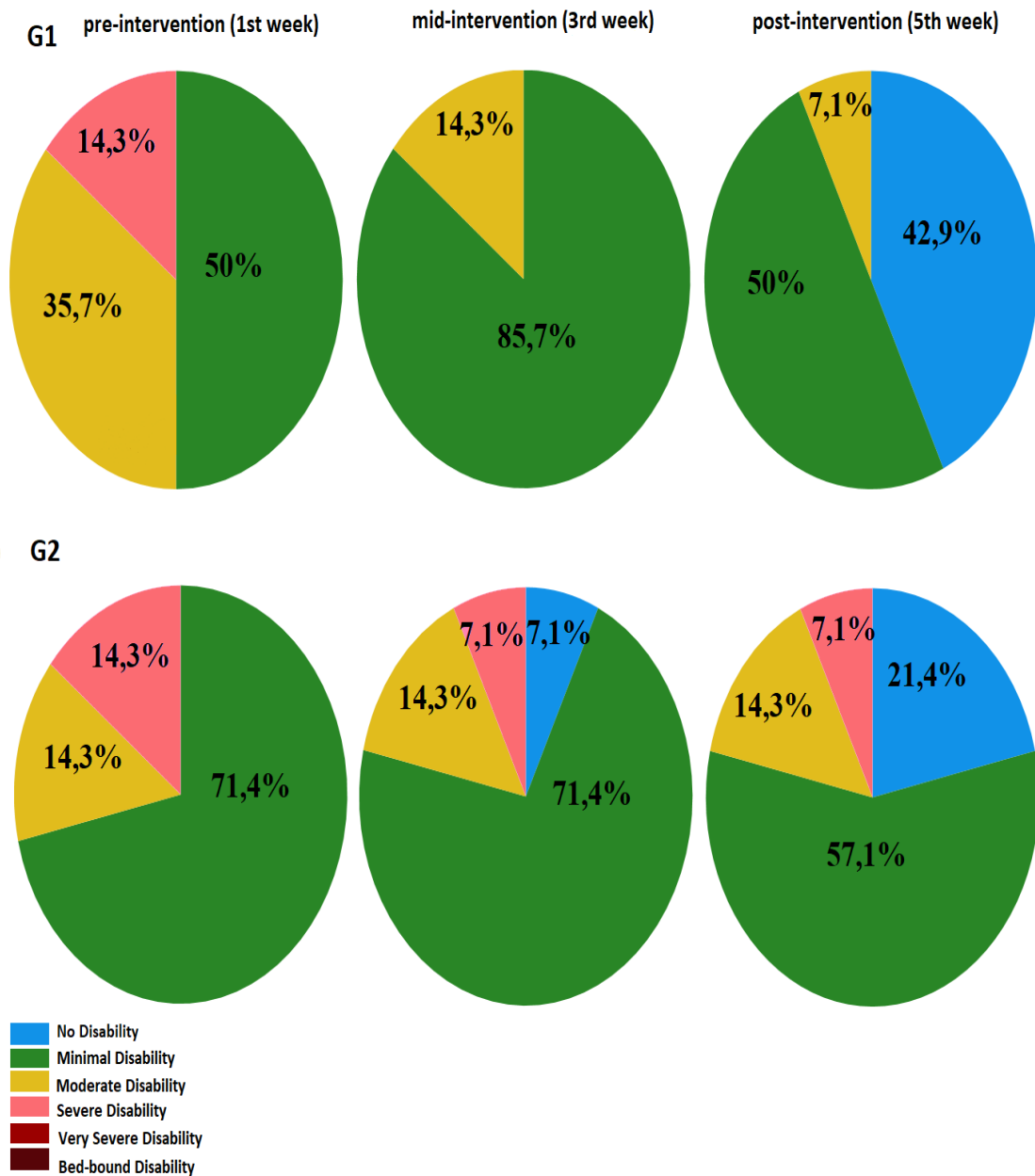


Figure 4.9 Distribution of sitting scores in groups according to the severity level of disability

The distributions of standing scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, a higher amount of participants in G1 (85, 7%) reached no disability or minimal disability level compared to G2 (78, 5%) (Figure 4.10).

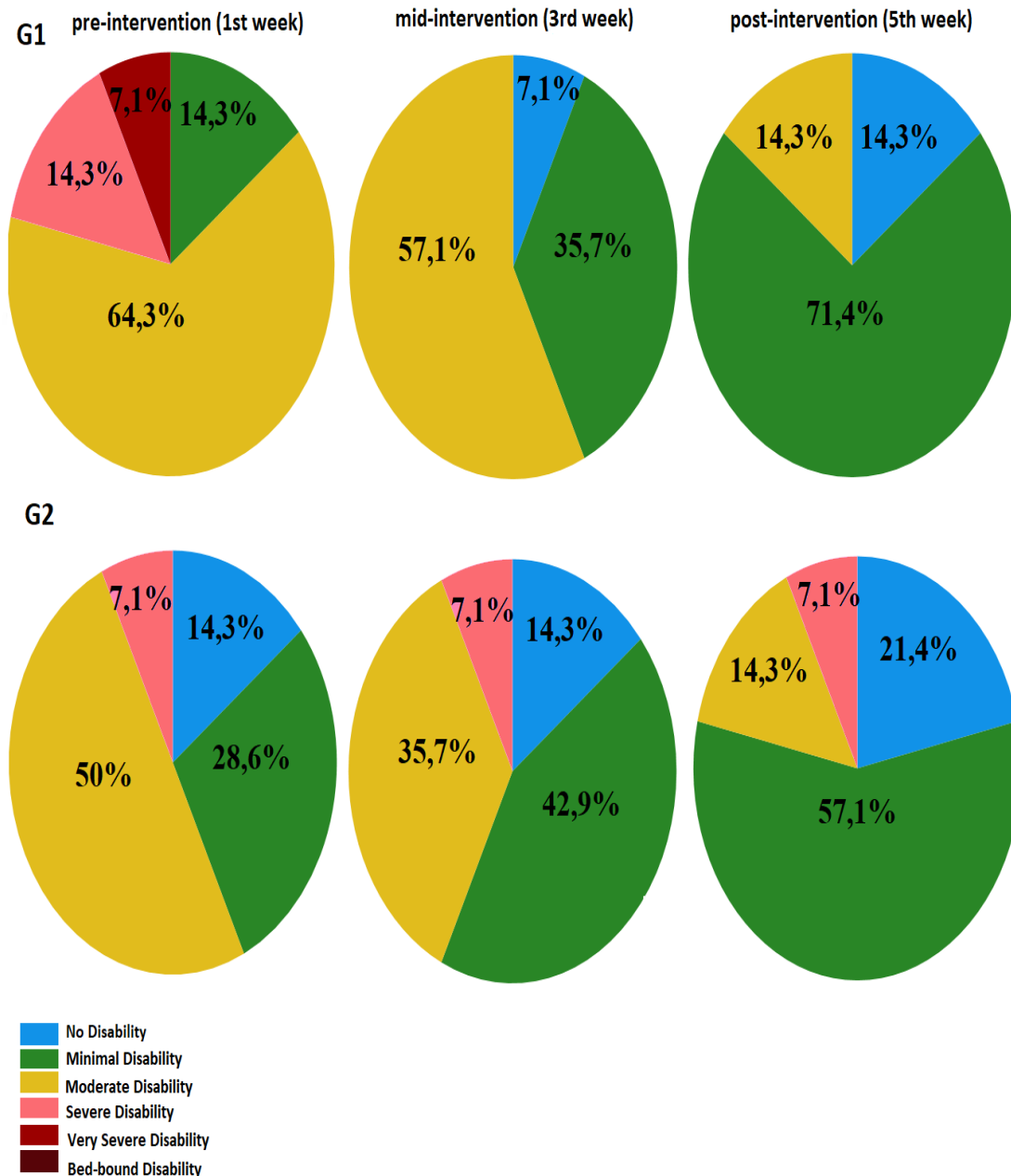


Figure 4.10 Distribution of standing scores in groups according to the severity level of disability

The distributions of sleeping scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, a higher amount of participants in G1 (100%) reached no disability or minimal disability level compared to G2 (92, 7%) (Figure 4.11).

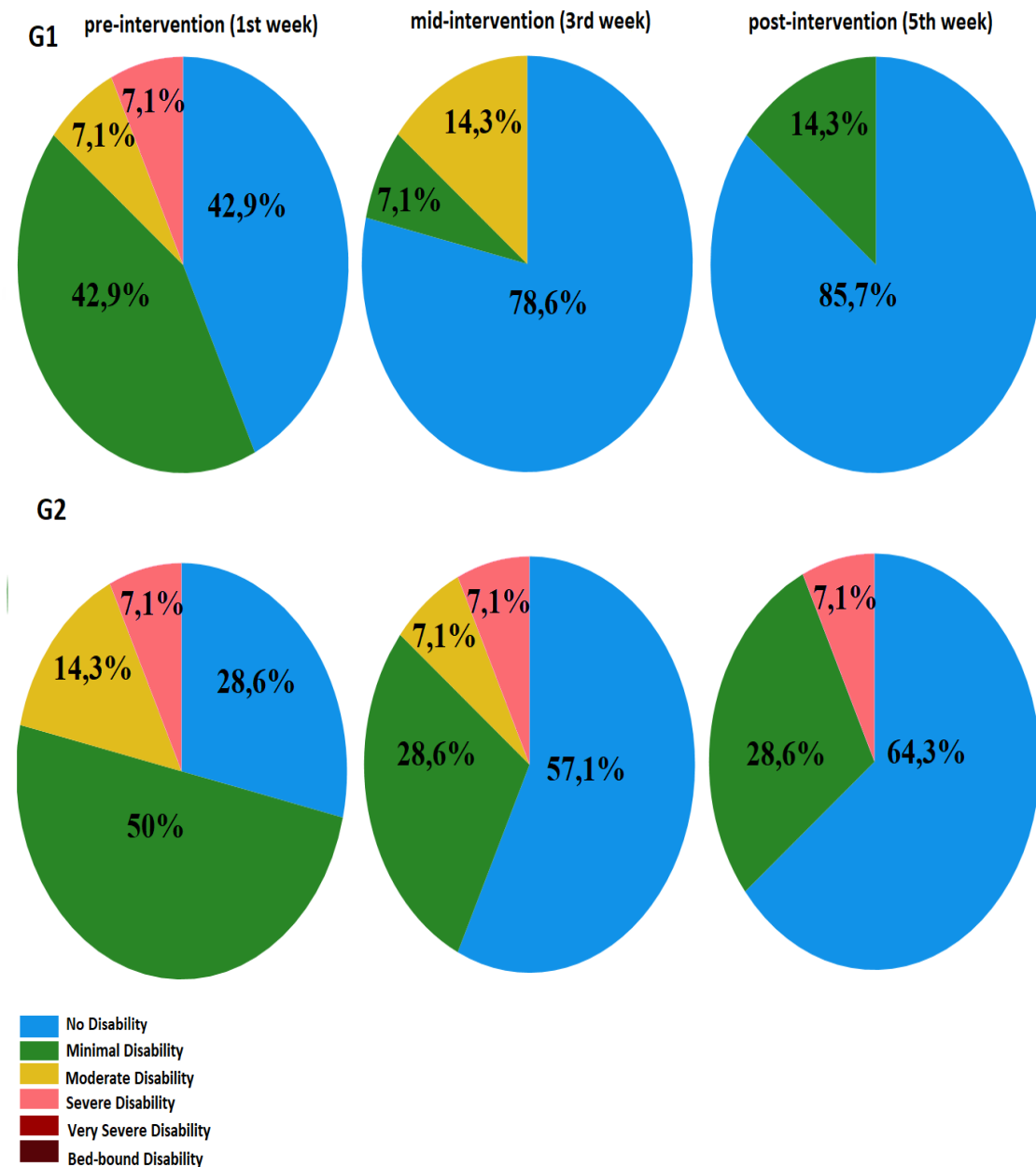


Figure 4.11 Distribution of sleeping scores in groups according to the severity level of disability

The distributions of social life scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, the distributions of participants in either group who have reached no or minimal disability level were the same. But, the distribution of participants with no disability was higher in G1 (Figure 4.12).

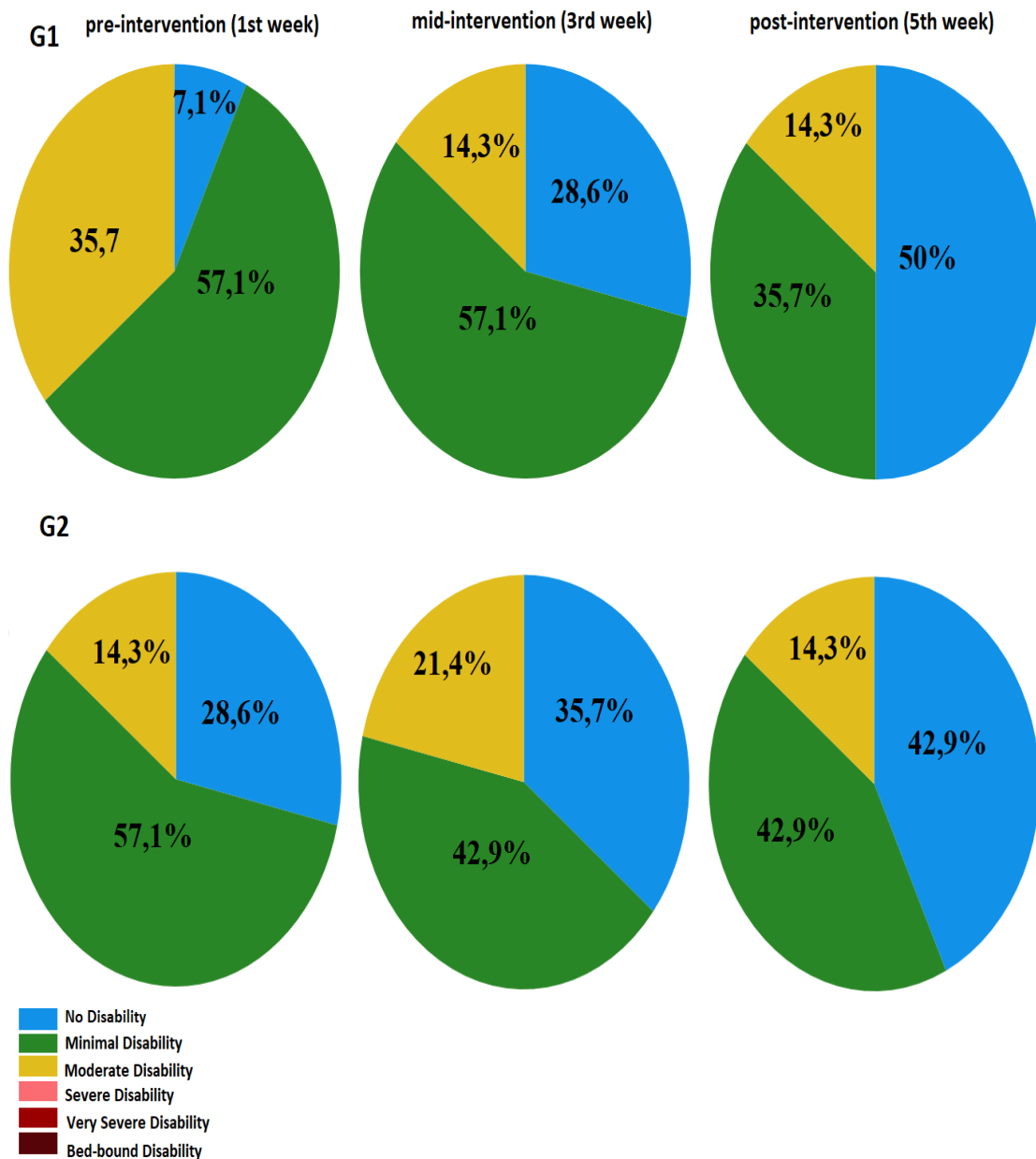


Figure 4.12 Distribution of social life scores in groups according to the severity level of disability

The distributions of travelling scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, the distributions of participants in either group who have reached no or minimal disability level were the same. But, the distribution of participants with no disability was higher in G2 (Figure 4.13).

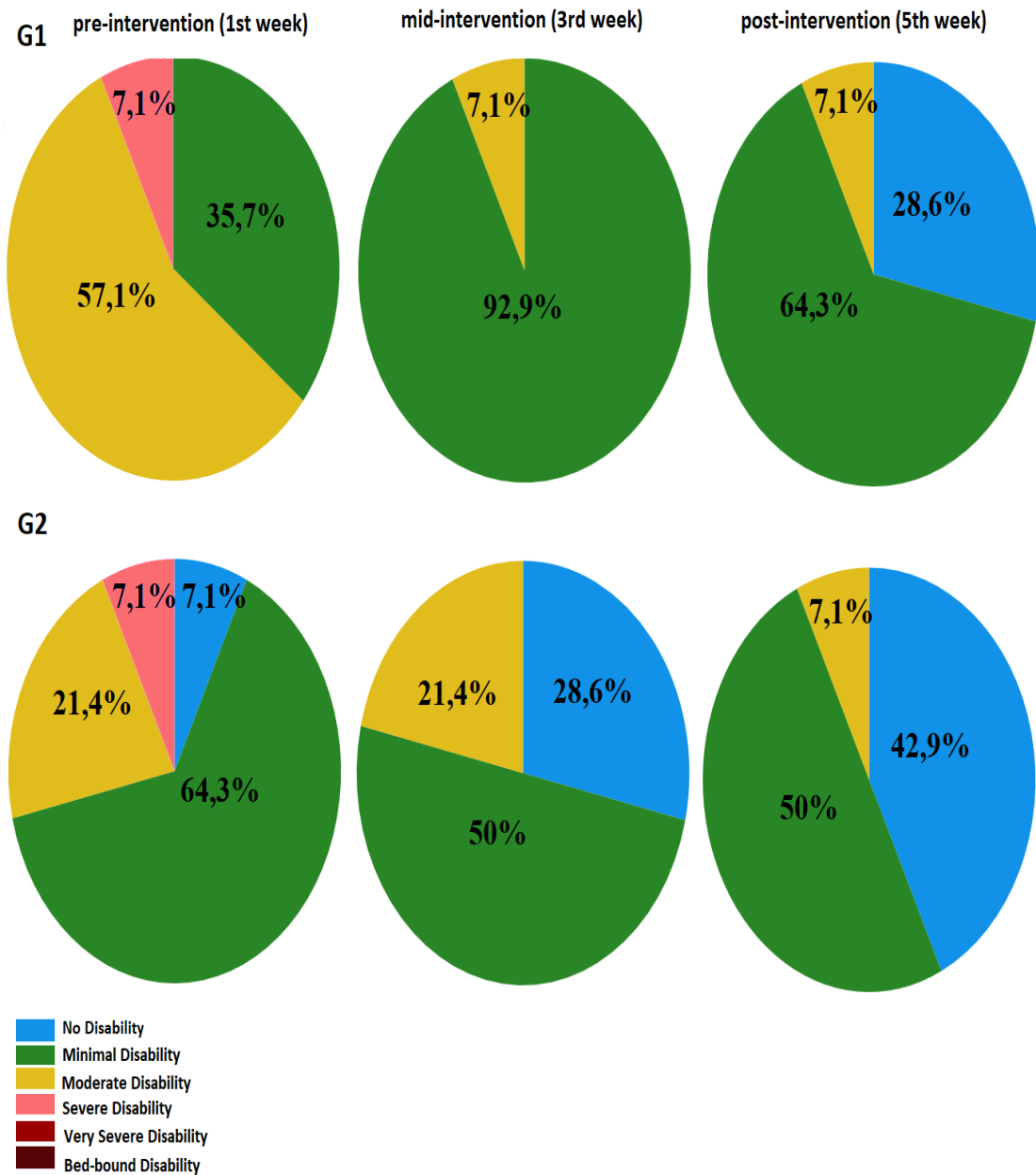


Figure 4.13 Distribution of travelling scores in groups according to the severity level of disability

The distributions of the degree of change in pain scores in groups according to the severity level of disability have changed over 5 weeks. At post-intervention, a higher amount of participants in G1 (92, 9%) reached no disability or minimal disability level compared to G2 (85, 7%) (Figure 4.14).

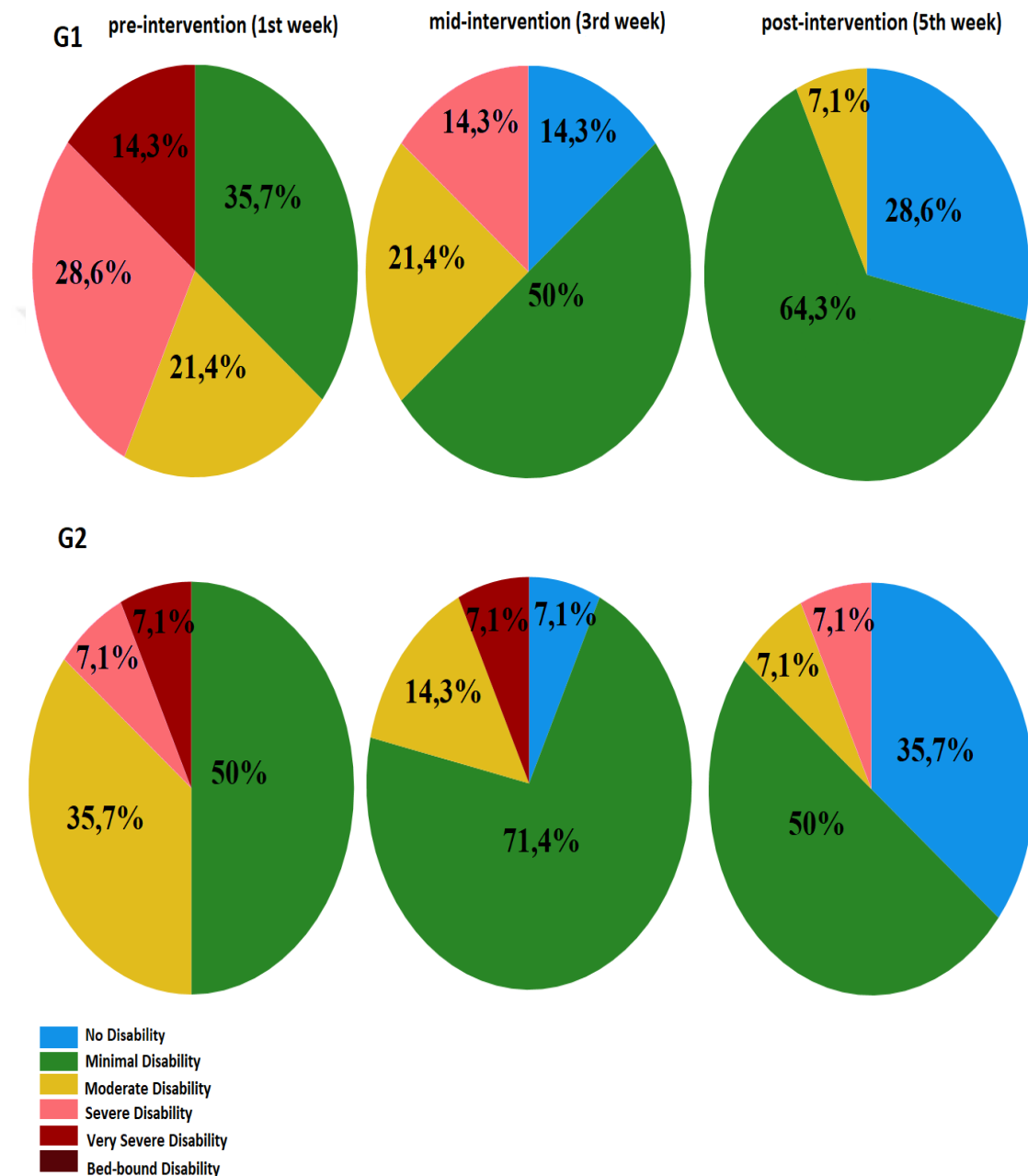


Figure 4.14 Distribution of change in pain scores in groups according to the severity level of disability

The Distributions of total ODI scores in groups according to the severity level of disability have been changed as a percentage over 5 weeks. At post-intervention, G1 has a higher percentage (92, 9%) of minimal disability compared to G2 (7, 1%) (Figure 4.15).

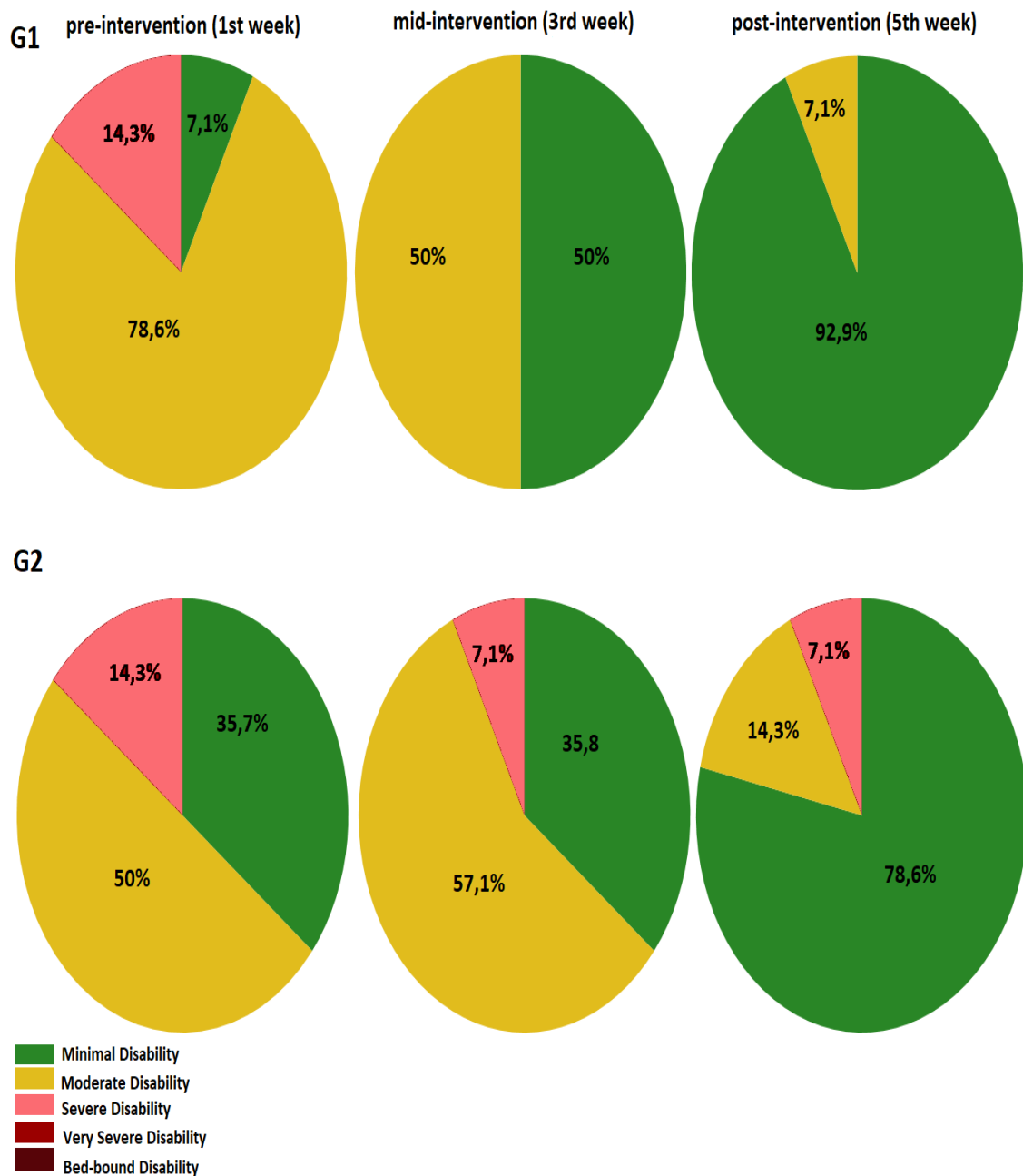


Figure 4.15 The Distribution of Total ODI score in groups according to the severity level of disability at different weeks

5. DISCUSSION

The main outcome of this study is that compared with the only self-myofascial release (SMFR); core combined with SMFR (C-SMFR) can lead to better short and long-term improvements in pain intensity and functional status in physiotherapy students with LBP, according to the statistical analysis ($p < 0.05$, table 4.9 and 10). Consistent with our hypothesis, we demonstrated that the core combined with SMFR was more effective to relieve pain and boost the functional status compared to the protocol without core exercises. Nevertheless, the core exercises with SMFR could have adverse effects on pain in the first week.

We compared the effectiveness of 2 SMFR protocols, which are C-SMFR and only SMFR over 5 weeks (2 times/week) for pain and functional status. G1 (C-SMFR) received core exercises and SMFR of superficial back line, deep front line, back functional line, and lateral line for 20 minutes. G2 (SMFR) received SMFR of the same chains. Pre-intervention, mid-intervention at the third week, and post-intervention at the fifth-week scores were collected (VAS at rest, VAS-Activity, ODI with sub scores). Only VAS was taken in the first week twice for sudden effects in two groups. According to the results, there was an increase in VAS at rest in G1 in the first week ($p = 0.046$), and the increase in VAS at rest of G1 was significant between groups ($p < 0.05$). The decrease in VAS-Activity and VAS at rest in the two groups was significant ($p < 0.05$). The decrease in both VAS scores was higher in G1 and differences between groups were significant at pre-mid, mid-post, and pre-post measurements in favour of G1 ($p < 0.05$). There is a decrease in total ODI in each group ($p = 0.01$), and differences between groups were significant at pre-mid, mid-post, and pre-post measurements ($p < 0.05$) in favour of G1. The decrease in sub-ODI scores, such as pain intensity, lifting, walking, standing, and sitting was significant between the two groups regarding pre-and-post measurements in favour of G1 ($p < 0.05$). The decrease in pain intensity, lifting, walking, and standing was significant between the two groups regarding pre-and-mid measurements in favour of G1 ($p < 0.05$). The decrease in pain intensity and sitting was significant between the two groups regarding mid-and post measurements in favour of G1 ($p < 0.05$). In addition, we showed the correlation and distribution of total ODI and sub-scores in groups according to the severity level of disability at different weeks (1st, 3rd, and 5th). Only three sub-ODI scores (pain intensity, lifting, and travelling) were

statistically significant correlations with the SMFR protocols at mid-intervention ($p < 0.05$).

Özsoy et al compared MFR combined with core exercises and only core exercises for six weeks on 45 elderly with NSLBP. 45 participants were allocated to MFR combined with core exercises and only core exercises. Each group received treatment protocols 3 times for 6 weeks. The first group received core exercises, with a duration of 30 minutes, followed by MFR of superficial back line (30 seconds x 3 sets). The second group took only the core exercises. Evaluations were made during pre-and post-interventions. They evaluated pain intensity using VAS and they measured the functional status with ODI. Also, lower body flexibility (LBF), Kinesiophobia (KP), core stability endurance (CSE), spinal mobility (SM), quality of life, and gait were measured. According to the results, the first group had significant improvements in core stability endurance ($p = 0.031$) and spinal mobility ($p = 0.022$) during the post-intervention. However, there were no statistically significant improvements between groups for pain and the functional status ($p > 0.05$). Intragroup quality of life, lower back flexibility, pain intensity, and functional status results were significant in the post-intervention ($p < 0.001$). They suggested that MFR combined with core exercises could be more beneficial for the elderly with NSLBP on pain and functional status (26). In contrast to Özsoy, we mainly focused on university students with NSLBP and did not concentrate only on the superficial back line and also on the back functional line, lateral line, and deep front line. Also, the total duration was shorter, the frequency was lower and each session had the same duration as that of Özsoy. Even though our total number of sessions was less than Özsoy, we reached statistically significant differences even at the end of 3 weeks in each group and between groups in favour of C-SMFR, regarding pain and functional status. Therefore, it may be concluded that the combined MFR protocols could be more effective in relieving pain (during activity and resting) and increasing functional status. Moreover, it might conclude that the utilization of more than one chain could have a more positive impact on the course of treatment of LBP regarding pain and functional status.

A randomized controlled study conducted by Ajimsha et al compared MFR and sham MFR on 80 nurses over 8 weeks with chronic LBP, regarding pain and functional status. Participants were allocated to MFR and sham MFR groups and those protocols were

given 3 times per week. The total duration of each protocol was one hour, (40 minutes MFR or sham MFR of the superficial back line and the back functional line followed by twenty minutes of specific back exercises (SBE). Group one received MFR with specific back exercises, while Group two received sham MFR with specific back exercises. Measurements were made during pre-intervention, in the 8th week, and the 12th week. They evaluated pain using McGill Pain Questionnaire (MPQ) and they measured functional status with Quebec Back Pain Disability Scale. The results showed that the MFR group had significant intra-and intergroup improvements in the eighth, and twelfth weeks for MPQ and functional status ($p < 0.005$) (148). They suggested that MFR could have better effects on pain and functional status. In the comparison of this study, our total number of sessions was fewer. Our duration of exercise was higher, while our duration of MFR was shorter. In addition to the superficial back line and back functional line, we used also the deep front line and lateral line. Apart from that, we measured functional status with ODI and each sub-score of ODI was evaluated separately and showed the distributions of severity levels, which shows one of the unique properties of our study. Similarly, we could find statistically significant results between the two groups in favour of core exercises combined with SMFR. As a result, our study might reveal that the significant improvements in pain and functional capacity in G1 could be associated with the combined protocols. Also, the representation of change in each sub-ODI score and distribution of severity levels weekly could give a better understanding of the evaluation of the functional status.

In another study, the effectiveness of MFR and sham MFR were investigated over twelve weeks on 45 participants with LBP. In contrast to Özsoy and Ajimsha, their protocols did not include core exercises. The first group received MFR and the second group received sham MFR twice a week. MFR was applied on the superficial Back line, deep front line, and lateral line. Each protocol was used over two weeks and the duration was 40 minutes. The measurements were made in pre-intervention, in the 2nd week, and the 12th week. The pain intensity was evaluated with the Short-Form McGill Pain Questionnaire (SFMPQ) and VAS, functional status was evaluated with Rolando Morris Questionnaire (RMQ). Also, the Fear-avoidance beliefs questionnaire (FABQ) was used. In the 2nd and 12th weeks, VAS and SFMPQ intragroup differences were statistically significant in both groups ($p < 0.01$). In the 12th week, they found

statistically significant improvements between groups regarding only SFMPQ ($p=0.04$). Also, in the 12th week, they found statistically significant differences between groups regarding RMQ ($p=0.03$). (246). In 2019, Arguisuelas et al conducted the same protocol on fewer individuals with flexion-relaxation phenomenon (FRP). Pre-and post-measurements were performed, using SFMPQ and RMQ. According to the results, intragroup improvements in pain and functional status were significant in the MFR group in the post-intervention ($p<0.05$). The difference between groups was significant in the post-intervention regarding pain and the functional status ($p<0.05$). Flexion-relaxation phenomenon has decreased in the MFR group and has been found statistically significant between groups in the post-intervention, in favour of the MFR group ($p<0.05$). Those studies of Arguisuelas showed that MFR could have beneficial effects on the Flexion-relaxation phenomenon, functional status, and pain in a patient with LBP (249). In contrast to Arguisuelas, we emphasized 4 myofascial lines and we used SMFR. Similarly, we could find statistically significant improvements even in the 3rd week in each group and between groups regarding pain and functional status. In contrast to Arguisuelas, we used ODI for the evaluation of the functional status and our study included a more comprehensive evaluation of the functional status with both total ODI and its sub-ODI scores. We might deduce that the ODI questionnaire with its sub-scores could give a more far-reaching understanding of the functional status of patients with LBP.

In another study, MFR has been evaluated over six weeks (three times per week) on elderly patients with LBP. MFR protocol was given to patients for thirty minutes, followed by heat therapy. Pre- and Post-intervention evaluations were performed. They evaluated the degree of disability with the Pain Disability Index, depression with the Beck Depression Inventory, and quality of sleep (QOS) with the insomnia severity index. According to the results, they found significant differences between pre-post improvements, regarding disability, depression, and quality of sleep ($p<0.05$). They concluded that MFR could be beneficial for disability, depression, and quality of sleep (250). In contrast to this study, we compared two different SMFR protocols regarding pain and functional status. One of our groups received core exercises combined with SMFR. Similarly, at the end of the study, we found statistically significant improvements in both groups in the functional status. In contrast, our study duration

was shorter than this study (5 weeks), but we showed a statistically significant decrease in pain between the two groups both in the 3rd week and 5th week. Furthermore, we did not measure depression and did not comprehensively evaluate the quality of sleep. Since psychological health and sleep habits could be affected by LBP, it may be deduced that those parameters might be measured in future studies in addition to pain and functional status.

Seong Yu et al investigated the effectiveness of core exercises (abdominal draw-in exercises) and MFR on 40 elderly women regarding pain, flexibility, and balance. After the allocation to groups, which are core or MFR, each protocol was performed for 8 weeks (3 times per week). The first group performed the core exercise program. The second group received the MFR of the deep front line. Participants were evaluated at the pre-and post-intervention. They evaluated pain intensity, balance, and flexibility. According to the results, they found statistically significant intragroup improvements at the post-intervention, regarding pain and flexibility in the MFR group ($p < 0.05$). Statistically significant intragroup improvements were found regarding pain and balance in the ADIE group ($p < 0.05$). No statistically significant differences were found between groups in the eighth week ($p > 0.05$). They concluded that MFR could have a positive impact on pain and flexibility in elderly women, whereas core exercises could benefit more pain and balance (251). In contrast, we showed both short and long-term effects of different SMFR protocols on pain and functional status. Our study had a shorter duration and fewer sessions. Nevertheless, we found significant decreases in pain and improvements in the functional status between groups in the 3rd and 5th weeks in favour of C-SMFR. This could be related to the difference in the study protocols. However, in our study, we measured neither the lumbar flexibility nor the balance. We could suggest the fact that those parameters should be examined in future studies to assess the functional status from a better perspective.

In a recent study, the effectiveness of SMFR and Core (Lumbar Stabilization) Exercises (LSE) were evaluated over 6 weeks (3 times/week) on thirty patients with NSLBP. Group one received SMFR of the superficial back line using a lacrosse ball (3 rep x 30 seconds) with a duration of 15 minutes and group two received core exercises. Measurements were done in the pre-and post-intervention using VAS, ODI, trigger point palpation, and ROM. VAS was divided into VAS activity and resting VAS at rest.

According to the results, intragroup parameters (VAS activity, VAS at rest, ODI, and ROM) in each group improved statistically significantly in the post-intervention ($p < 0.05$). They found significant improvements between groups in the post-intervention, in favour of the SMFR group regarding ROM right rotation, ROM left lateral flexion, and trigger point location ($p < 0.05$). They concluded that both protocols seem to be effective regarding pain, functional status, and ROM. However, SMFR could be more beneficial for trigger points and Lumbar ROMs (252). Similarly, they measured VAS by dividing it into activity and resting sections and we used SMFR in our study. In contrast, we also showed the acute effects of two protocols on both VAS scores. Regarding sessions, we had fewer sessions compared to this study. Fewer sessions notwithstanding, we demonstrated statistically significant improvements between groups regarding pain and functional status. This could be related to the fact that we compared C-SMFR and SMFR. Compared to this study, we demonstrated the distribution of the total ODI and sub-ODI scores according to the severity levels in different weeks (pre-, mid-(3rd), and post-intervention). Even though we could find a statistically significant correlation between ODI-intensity levels and the type of protocol only in three sub-ODI scores, it might be concluded that the demonstration of those distributions could provide a better chance of monitoring the change in the functional status of patients.

In another study conducted by Branchini, the effectiveness of myofascial release was compared with exercises combined physiotherapy program over twenty-four participants with low back pain. Group one received myofascial release with a duration of forty-five minutes, whereas group 2 received core exercises, relaxation exercises, diaphragm exercises, stretching, and proprioceptive exercises. All interventions were performed two times for 4 weeks. Measurements were done during the pre-intervention, post-intervention, 1 month after interventions, and 3 months after interventions. The pain was measured with VAS and brief pain inventory, whereas the functional status was measured with Rolando Morris Questionnaire. According to the results, all intergroup scores of the first group changed statistically significantly ($p < 0.05$). In contrast to Lee Zhi et al, both pain and the functional status have improved statistically significantly in the first group during the post-intervention, after 1 month, and after 3 months ($p < 0.05$). Branchini et al concluded that the MFR protocol was more effective

than the other protocol in terms of pain and functional status in patients with LBP (253). In contrast to this study, our study had a higher duration and more sessions. Similarly, we found statistically significant differences between groups regarding pain and functional status. Like Branchini, our study showed statistically significant short and long-term effects of two SMFR protocols on pain and functional status. In contrast, our MFR protocol had a shorter duration of 20 minutes. Also, our protocols included core exercises combined with MFR and only MFR. In contrast to Branchini, our study had no follow-up period. The follow-up period allows getting an idea about how the interventions had post-effects on patients over a longer amount of time. Therefore, we could suggest in future studies follow-up measurements for the pain and functional status.

To the best of our knowledge, there are no studies that compared the effectiveness of core exercises combined with SMFR and SMFR regarding pain and functional capacity.

The majority of previous studies in the literature emphasized the application of MFR for LBP. There is only one recent study that investigated the effectiveness of the SMFR protocol. Therefore, our study had contributions to this purpose. Also, previous studies generally focused on the comparison of the core combined MFR and core exercises, MFR versus sham MFR, or core versus MFR protocols. Unfortunately, there were no studies that compared core combined SMFR and SMFR on pain and functional status, which means that in the literature, there was a missing point on which SMFR protocol is more effective than another in terms of pain and functional status. Thanks to our study, we would like to demonstrate that core exercises combined with SMFR could be a better option in the management of LBP. Furthermore, the functional status has always been examined using the total ODI or RMQ score without their sub-scores nor distribution of ODI scores according to severity levels. Taking into consideration our results, we are of the opinion that the representation of each sub-ODI score and the distributions according to severity levels in two groups might provide a better understanding of following the patient with LBP. In addition, previous studies focused on generally one or two myofascial meridians. No studies were conducted to include the combination of four myofascial meridians (SBL, BFL, DFL, and LL). As a result, it could be deduced that the utilization of those aforementioned four myofascial meridians together could be more effective in the management of LBP.

The limitations of the study:

- We examined the five-week results regarding pain and functional capacity, but the follow-up effects remain unknown
- The sample size could have been higher.
- We could not include the measurements for Lumbar ROMs, lumbar flexibility, and depression, due to the pandemic.

The suggestions:

- In future studies, Myofascial release could be compared with both core-combined myofascial release and core exercises alone.
- Lumbar ROM, flexibility, and depression can be measured to evaluate the functional status in a better way.

6. CONCLUSION

- Core exercises combined with Self-Myofascial Release and only Self-Myofascial Release have been found effective in decreasing pain and improving the functional capacity of students with NSLBP in the 3rd and 5th weeks.
- Core exercises combined with Self-Myofascial Release were found more effective than Self-Myofascial Release in the 3rd (short-term) and 5th weeks (lon-term) regarding pain and functional capacity.
- Core exercises combined with Self-Myofascial Release were found more effective than Self-Myofascial Release between 1st-3rd weeks (pre-mid measurements) regarding pain intensity, lifting, walking, and standing.
- Core exercises combined with Self-Myofascial Release were found more effective than Self-Myofascial Release between 3rd-5th weeks (mid-post measurements) regarding pain intensity and sitting.
- Core exercises combined with Self-Myofascial Release were found more effective than Self-Myofascial Release between 1st-5th weeks (pre-post measurements) regarding pain intensity, walking, sitting, and standing.
- Core exercises combined with Self-Myofascial Release could have negative effects on resting pain intensity in the 1st week of the protocol.

7 REFERENCES

- 1 Golob AL, Wipf JE. Low back pain. *Med Clin North Am.* 2014;98(3):405–428.
- 2 Ayanniyi, O., Ukpai, B. O. O., & Adeniyi, AF. Differences in prevalence of self-reported musculoskeletal symptoms among computer and non-computer users in a Nigerian population: a cross-sectional study. *BMC Musculoskeletal Disorders.* 2010;11(1):1-9.
- 3 Janwantanakul, P, Pensri, P, Jiamjarasrangsi, V, & Sinsongsook, T. Prevalence of self-reported musculoskeletal symptoms among office workers. *Occupational medicine.* 2008;58(6):436-438.
- 4 Juul-Kristensen, B., Søgaard, K., Støyer, J., & Jensen, C. Computer users' risk factors for developing shoulder, elbow and back symptoms. *Scandinavian journal of work, environment & health.* 2004:390-398.
- 5 Sitthipornvorakul, E., Janwantanakul, P., & Lohsoonthorn, V. The effect of daily walking steps on preventing neck and low back pain in sedentary workers: a 1-year prospective cohort study. *European spine journal.* 2015;24(3):417-424.
- 6 Hoy D, March L, Brooks P, et al. The global burden of low back pain: estimates from the global burden of disease 2010 study. *Ann Rheum Dis.* 2014;73(6):968–974.
- 7 Akkarakittichoke, N.; Janwantanakul, P. Seat Pressure Distribution Characteristics during 1 Hour Sitting in Office Workers With and Without Chronic Low Back Pain. *Saf. Health Work.* 2017;8:212–219.
- 8 Anggiat, L., Hon, W. H. C., & Baait, S. N. The incidence of low back pain among university students. *Jurnal Pro-Life.* 2018;5(3):677-687.

- 9 Beach, T. A. C., Parkinson, R. J., Stothart, J. P., & Callaghan, J. P. Effects of prolonged sitting on the passive flexion stiffness of the in vivo lumbar spine. *The Spine Journal*. 2005;5(2):145–154.
- 10 Kett, A. R., Sichting, F., & Milani, T. L. The Effect of Sitting Posture and Postural Activity on Low Back Muscle Stiffness. *Biomechanics*. 2021;1(2):214-224.
- 11 Citko A, Górski S, Marcinowicz L, Górski A. Sedentary Lifestyle and Nonspecific Low Back Pain in Medical Personnel in North-East Poland. *Biomed Res Int*. 2018:2018
- 12 Teichtahl, A. J., Urquhart, D. M., Wang, Y., Wluka, A. E., O’Sullivan, R., Jones, G., & Cicuttini, F. M. Physical inactivity is associated with narrower lumbar intervertebral discs, high fat content of paraspinal muscles and low back pain and disability. *Arthritis research & therapy*. 2015;17(1):114.
- 13 Morais, M. L., Silva, V. K. O., & Silva, J. M. N. D. Prevalence of low back pain and associated factors among physiotherapy students. *BrJP*. 2018;1:241-247.
- 14 Manchikanti, L, Singh, V, Falco, FJ, Benyamin, RM, Hirsch, JA, Epidemiology of low back pain in adults. *Neuromodulation*. 2014;17(2):3–10.
- 15 Almeida M, Saragiotto, Richards B, Maher C. Primary care management of non-specific low back pain: key messages from recent clinical guidelines. *Med J Aust*. 2018;208(6):272-275
- 16 Barnes, M. F. The basic science of myofascial release: morphologic change in connective tissue. *Journal of bodywork and movement therapies*. 1997;1(4):231-238.
- 17 Myers TW, *Anatomy Trains E-Book: Myofascial Meridians for Manual and Movement Therapists*. Elsevier Health Sciences; 2013.

- 18 Wu, Z., Wang, Y., Ye, X., Chen, Z., Zhou, R., Ye, Z., Huang, J., Zhu, Y., Chen, G., & Xu, X. Myofascial Release for Chronic Low Back Pain: A Systematic Review and Meta-Analysis. *Frontiers in medicine*. 2021;8:697986.
- 19 Cheatham, S. W., Kolber, M. J., Cain, M., & Lee, M. The effects of self-myofascial release using a foam roll or roller massager on joint range of motion, muscle recovery, and performance: a systematic review. *International journal of sports physical therapy*. 2015;10(6):827.
- 20 Panjabi, M. M. The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. *Journal of spinal disorders*. 1992;5:390-390.
- 21 Akuthota V, Ferreiro A, Moore T, Fredericson M. Core stability exercise principles. *Current sports medicine reports*. 2008;7(1):39-44.
- 22 Hodges, P. W., & Richardson, C. A. Inefficient muscular stabilization of the lumbar spine associated with low back pain: a motor control evaluation of transversus abdominis. *Spine*. 1996;21(22):2640-2650.
- 23 Hides, J., Stanton, W., Mendis, M. D., & Sexton, M. The relationship of transversus abdominis and lumbar multifidus clinical muscle tests in patients with chronic low back pain. *Manual therapy*. 2011;16(6):573-577.
- 24 Granacher, U., Schellbach, J., Klein, K., Prieske, O., Baeyens, J. P., & Muehlbauer, T. Effects of core strength training using stable versus unstable surfaces on physical fitness in adolescents: a randomized controlled trial. *BMC sports science, medicine and rehabilitation*. 2014;6(1):1-11.
- 25 Frizziero, A., Pellizzon, G., Vittadini, F., Bigliardi, D., & Costantino, C. Efficacy of core stability in non-specific chronic low back pain. *Journal of functional morphology and kinesiology*. 2021;6(2):37.

- 26 Ozsoy, G., Ilcin, N., Ozsoy, I., Gurpinar, B., Buyukturan, O., Buyukturan, B., & Sas, S. The effects of myofascial release technique combined with core stabilization exercise in elderly with non-specific low back pain: A randomized controlled, single-blind study. *Clinical interventions in aging*. 2019;14:1729.
- 27 Meltzer, K. R., Cao, T. V., Schad, J. F., King, H., Stoll, S. T., & Standley, P. R. In vitro modeling of repetitive motion injury and myofascial release. *Journal of bodywork and movement therapies*. 2010;14(2):162-171.
- 28 Akhtar, M. W., Karimi, H., & Gilani, S. A. Effectiveness of core stabilization exercises and routine exercise therapy in management of pain in chronic non-specific low back pain: A randomized controlled clinical trial. *Pakistan journal of medical sciences*. 2017;33(4):1002
- 29 Majeed A, S., Ts, A., Sugunan, A., & Ms, A. The effectiveness of a simplified core stabilization program (TRICCS-Trivandrum Community-based Core Stabilisation) for community-based intervention in chronic non-specific low back pain. *Journal of orthopaedic surgery and research*. 2019;14(1):86.
- 30 Goodman CA, Hornberger TA, Robling AG. Bone and skeletal muscle: Key players in mechanotransduction and potential overlapping mechanisms. *Bone*. 2015;80:24-36.
- 31 Wilke J, Engeroff T, Nürnberger F, Vogt L, Banzer W. Anatomical study of the morphological continuity between iliotibial tract and the fibularis longus fascia. *Surg Radiol Anat*. 2016;38(3): 349-52.
- 32 Frontera WR, Ochala J. Skeletal muscle: a brief review of structure and function. *Calcif Tissue Int*. 2015;96(3):183-95.
- 33 Hafen, B. B., Shook, M., & Burns, B. *Anatomy, Smooth Muscle*; 2018.

- 34 Giordani, L. , & Puri, P. L. Epigenetic control of skeletal muscle regeneration. *FEBS Journal*. 2013;280(17):4014–4025.
- 35 Gillies, A. R. , & Lieber, R. L. Structure and function of the skeletal muscle extracellular matrix. *Muscle & Nerve*. 2011;44(3):318–331.
- 36 Huxley, H. E. The double array of filaments in cross-striated muscle. *Journal of Cell Biology*. 1957;3(5):631–648.
- 37 Hu, L.-Y. R. , Ackermann, M. A. , & Kontogianni-Konstantopoulos, A. The sarcomeric M-region: A molecular command center for diverse cellular processes. *BioMed Research International*. 2015;2015:1–25.
- 38 Denker, A. , & Rizzoli, S. O. Synaptic vesicle pools: An update. *Frontiers in Synaptic Neuroscience*. 2010;2:135.
- 39 Franzini-Armstrong, C. Functional implications of RyR-dHPR relationships in skeletal and cardiac muscles. *Biological Research*. 2004;37(4):507–512.
- 40 Fitts, R. H. The cross-bridge cycle and skeletal muscle fatigue. *Journal of Applied Physiology*. 2008;104(2):551–558.
- 41 Mukund, K., & Subramaniam, S. Skeletal muscle: A review of molecular structure and function, in health and disease. *Wiley interdisciplinary reviews. Systems biology and medicine*. 2020;12(1):1462.
- 42 Kelly, A. M. The diversity of muscle fiber types and its origin during development. *Myology*. 1994;1:119-133.
- 43 Lieber, R. L. , & Friden, J. Functional and clinical significance of skeletal muscle architecture. *Muscle & Nerve*. 2000;23(11):1647–1666.

- 44 Gransee, H. M., Mantilla, C. B., & Sieck, G. C. Respiratory muscle plasticity. *Comprehensive Physiology*. 2012;2(2):1441–1462.
- 45 Sinha S, Iyer D, Granata A. Embryonic origins of human vascular smooth muscle cells: implications for in vitro modeling and clinical application. *Cell Mol Life Sci*. 2014;71(12):2271-88.
- 46 Jackson WF, Boerman EM. Voltage-gated Ca²⁺ channel activity modulates smooth muscle cell calcium waves in hamster cremaster arterioles. *Am J Physiol Heart Circ Physiol*. 2018;315(4):871-8.
- 47 Mollova M, Bersell K, Walsh S, Savla J, Das LT, Park SY, Silberstein LE, Dos Remedios CG, Graham D, Colan S, Kühn B. Cardiomyocyte proliferation contributes to heart growth in young humans. *Proc Natl Acad Sci U S A*. 2013;110(4):1446-51.
- 48 Di Maio A, Karko K, Snopko RM, Mejía-Alvarez R, Franzini-Armstrong C. T-tubule formation in cardiomyocytes: two possible mechanisms? *J Muscle Res Cell Motil*. 2007;28(4-5):231-41.
- 49 Sallé L, Brette F. T-tubules: a key structure of cardiac function and dysfunction. *Arch Mal Coeur Vaiss*. 2007;100(3):225-30.
- 50 Kayalioglu, G. The Vertebral Column and Spinal Meninges. *The Spinal Cord*. 2009:17–36.
- 51 Mansfield, P. J., & Neumann, D. A. *Essentials of kinesiology for the physical therapist assistant e-book*. Elsevier Health Sciences. 2018.
- 52 DeSai, C., Reddy, V., & Agarwal, A. Anatomy, back, vertebral column. *StatPearls*. 2021.

- 53 Simonetti, L., Agati, R., De Santis, F., & Leonardi, M. Anatomia e fisiopatologia dell'unità funzionale disco-somatica. *Rivista di Neuroradiologia*. 2001;14(1):7-16.
- 54 Boll DT, Bulow H, Blackham KA, Aschoff AJ, Schmitz BL. MDCT angiography of the spinal vasculature and the artery of Adamkiewicz. *AJR Am J Roentgenol*. 2006;187(4):1054-60.
- 55 Lawry, G. V., Kreder, H. J., Hawker, G., & Jerome, D. *Fam's Musculoskeletal Examination and Joint Injection Techniques E-Book: Expert Consult*. Elsevier Health Sciences. 2010.
- 56 Mahadevan, V. *Anatomy of the vertebral column. Surgery (Oxford)*. 2018;36(7):327-332.
- 57 Lafian AM, Torralba KD. Lumbar Spinal Stenosis in Older Adults. *Rheum Dis Clin North Am*. 2018;44(3):501-512.
- 58 Berger-Pasternak B, Brylka D, Sipko T. Lumbar Spine Kinematics in Asymptomatic People When Changing Body Position From Sitting to Standing. *J Manipulative Physiol Ther*. 2021;44(2):113-119.
- 59 Pintar, F.A., Yoganandan, N., Myers, T., Elhagediab, A., Sances, A., Jr. Biomechanical properties of human lumbar spine ligaments. *J. Biomech*. 1992;25:1351-6.
- 60 CANBULAT, Nazan, et al. A rehabilitation protocol for patients with lumbar degenerative disc disease treated with posterior transpedicular dynamic stabilization. *Turkish Neurosurgery*. 2017;27.3:426-435.

- 61 Yoganandan N, Ray G, Pintar FA, Myklebust JB, Sances A Jr: Stiffness and strain energy criteria to evaluate the threshold of injury to an intervertebral joint. *J Biomech.* 1989;22(2):135-42.
- 62 Nelson, K. E., & Glonek, T. (Eds.). *Somatic dysfunction in osteopathic family medicine.* Lippincott Williams & Wilkins. 2007.
- 63 Greenman, P. E. *Principles of manual medicine.* Lippincott Williams & Wilkins. 2003:53-65
- 64 Adams, M. A., McNally, D. S., Chinn, H., & Dolan, P. The clinical biomechanics award paper 1993 posture and the compressive strength of the lumbar spine. *Clinical Biomechanics.* 1994;9(1):5-14.
- 65 Wilke, H.-J., & Volkheimer, D. *Basic Biomechanics of the Lumbar Spine.* Biomechanics of the Spine. 2018:51–67.
- 66 Nachemson, A. L. F., & Morris, J. M. In vivo measurements of intradiscal pressure: discometry, a method for the determination of pressure in the lower lumbar discs. *JBJS.* 1964;46(5):1077-1092.
- 67 Shah, J. S., Hampson, W. G., & Jayson, M. I. The distribution of surface strain in the cadaveric lumbar spine. *The Journal of Bone and Joint Surgery. British volume.* 1978;60(2):246-251.
- 68 Marchand F, Ahmed AM. Investigation of the laminate structure of lumbar disc annulus fibrosus. *Spine.* 1990;15:402–10.
- 69 Melrose J, Smith SM, Appleyard RC, et al. Aggrecan, versican and type VI collagen are components of annular translamellar crossbridges in the intervertebral disc. *Eur Spine J.* 2008;17(2):314–24.

70 Bruehlmann SB, Rattner JB, Matyas JR, Duncan NA. Regional variations in the cellular matrix of the annulus fibrosus of the intervertebral disc. *J Anat.* 2002;201:159–171.

71 Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. *J Bone Joint Surg Am.* 1990;72:403–408.

72 Raj, P. P. *Intervertebral Disc: Anatomy-Physiology-Pathophysiology-Treatment.* Pain Practice. 2008;8(1):18–44.

73 Buckwalter JA, Mow VC, Boden SD, et al. Intervertebral disk structure, composition, and mechanical function. *Orthopaedic basic science - biology and biomechanics of the musculoskeletal system.* Rosemont (IL): American Academy of Orthopaedic Surgeons. 2000.

74 Shinmei M, Masuda K, Kikuchi T, et al. Interleukin-1, tumour necrosis factor, and interleukin-6 as mediators of cartilage destruction. *Semin Arthritis Rheum.* 1989;18:27–32.

75 Weiler C, Nerlich AG, Bachmeier BE, et al. Expression and distribution of tumor necrosis factor alpha in human lumbar intervertebral discs: a study in surgical specimen and autopsy controls. *Spine.* 2005;30(1):44–53.

76 Crock HV, Goldwasser M, Yoshizawa H. Vascular anatomy related to the intervertebral disc. In: Ghosh P, ed. *Biology of the Intervertebral Disc.* Boca Raton, FL: CRC Press. 1991:109–133.

77 Roberts S, Menage J, Urban JPG. Biochemical and structural properties of the cartilage end-plate and its relation to the intervertebral disc. *Spine*. 1989;14:166–174.

78 Meakin JR, Hukins DW. Effect of removing the nucleus pulposus on the deformation of the annulus fibrosus during compression of the intervertebral disc. *J Biomech*. 2000;33(5):575–80.

79 White AA, Panjabi MM. Clinical biomechanics of the spine. Philadelphia: Lippincott. 1978.

80 Kolber, M.J. and W.J. Hanney, The dynamic disc model: a systematic review of the literature. *Phys Ther Rev*. 2009;14(3):181-189.

81 Schnebel, B.E., et al., A digitizing technique for the study of movement of intradiscal dye in response to flexion and extension of the lumbar spine. *Spine (Phila Pa 1976)*. 1988;3(3):309-12.

82 Bogduk N. The innervation of the lumbar spine. *Spine*. 1983;8:286–293.

83 Glover JR. Arthrography of the joints of the lumbar vertebral arches. *Orthop Clin North Am*. 1977;8:37–42.

84 Vora, A. J., Doerr, K. D., & Wolfer, L. R. Functional Anatomy and Pathophysiology of Axial Low Back Pain: Disc, Posterior Elements, Sacroiliac Joint, and Associated Pain Generators. *Physical Medicine and Rehabilitation Clinics of North America*. 2010;21(4):679–709.

85 Bogduk N, Tynan W, Wilson AS. The nerve supply to the human lumbar intervertebral discs. *J Anat*. 1981;132:39–56.

- 86 Bogduk N. The zygapophysial joints. Clinical anatomy of the lumbar spine and sacrum. 4th edition. New York: Elsevier. 2005:29–37
- 87 Yahia LH, Garzon S. Structure on the capsular ligaments of the facet joints. Ann Anat. 1993;175:185–8.
- 88 Fujiwara A, Tamai K, An HS, et al. Orientation and osteoarthritis of the lumbar facet joint. Clin Orthop Relat Res. 2001;385:88–94.
- 89 Lee HM, Weinstein JN, Meller ST, et al. The role of steroids and their effects on phospholipase A2. An animal model of radiculopathy. Spine. 2000;25(15):2004–5
- 90 Cleveland, M. K., & Tubbs, R. S. The Ligaments of the Lumbar Spine. In *Surgical Anatomy of the Lateral Transpsoas Approach to the Lumbar Spine* Elsevier. 2020:97-112.
- 91 Sassack, B., & Carrier, J. D. Anatomy, Back, Lumbar Spine. 2020.
- 92 Willard FH. The muscular, ligamentous, and neural structure of the lumbosacrum. In: Vleeming A, Mooney V, Stoeckart R, editors. Movement, stability and lumbopelvic pain: integration of research and therapy. Churchill Livingstone/Elsevier. 2007:7–21.
- 93 Loughenbury PR, Wadhwani S, Soames RW. The posterior longitudinal ligament and peridural (epidural) membrane. Clin Anat. 2006;19(6):487-92.
- 94 Putz R. [Anatomic-functional viewpoints in treatment of injuries of the spine]. Langenbecks Arch Chir Suppl Kongressbd. 1992:256-62.
- 95 Aspden RM, Bornsetin NH, Hukins DW, et al. Collagen organization in the interspinous ligament and its relationship to tissue function. J Anat. 1987;155:141–51.

- 96 Hindle RJ, Pearce MJ, Cross A. Mechanical function of the human lumbar interspinous and supraspinous ligaments. *J Biomed Eng.* 1990;12(4):340–4
- 97 Willard FH. The muscular, ligamentous and neural structure of the lumbosacrum and its relationship to low back pain. In: Vleeming A, Mooney V, Stoeckart R, editors. *Movement, stability and lumbopelvic pain. Integration of research and therapy.* Edinburgh (UK): Elsevier. 2007:7–11.
- 98 Nikolai Bogduk. *Clinical and Radiological Anatomy of the Lumbar Spine* 5th Edition. Churchill Livingstone: Elsevier. 2012.
- 99 Shrader PK, Grob D, Rahn BA, et al. Histology of the ligamentum flavum in patients with degenerative lumbar spinal stenosis. *Eur Spine J.* 1999;8:323–38
- 100 Leong, J. C., Luk, K. D., Chow, D. H., & Woo, C. W. The biomechanical functions of the iliolumbar ligament in maintaining stability of the lumbosacral junction. *Spine.* 1987;12(7):669-674.
- 101 Pool-Goudzwaard, A. L., Kleinrensink, G. J., Snijders, C. J., Entius, C., & Stoeckart, R. The sacroiliac part of the iliolumbar ligament. *The Journal of Anatomy.* 2001;199(4):457-463.
- 102 Toumanidou, T. Spinal Muscles. *Biomechanics of the Spine.* 2018:141–166.
- 103 Drake, R.L., Vogl, A.W., Mitchell, A.W.M. *Gray's Anatomy for students*, second ed. Churchill Livingstone, England. 2004.
- 104 Bakkum, B. W., & Cramer, G. D. Muscles That Influence the Spine. *Clinical Anatomy of the Spine, Spinal Cord, and Ans.* 2014:98–134.
- 105 Bogduk, N. *Clinical anatomy of the lumbar spine and sacrum.* Elsevier Health Sciences. 2005.

106 Middleditch, A., Oliver, J., Middleditch, A., & Oliver, J. Structure of the vertebral column. *Functional Anatomy of the Spine*: Butterworth Heinemann. 2005:1-62.

107 Valencia, F., and R. R. Munro. "Morphology of the lumbar multifidus in man." *JOURNAL OF ANATOMY*. Vol. 139. No. AUG. 40 WEST 20TH STREET, NEW YORK, NY 10011-4211: CAMBRIDGE UNIV PRESS, 1984.

108 Lonnemann, M. E., Paris, S. V., & Gorniak, G. C. A morphological comparison of the human lumbar multifidus by chemical dissection. *Journal of Manual & Manipulative Therapy*. 2008;16(4):84E-92E.

109 Jelinek, L. A., Scharbach, S., Kashyap, S., & Ferguson, T. *Anatomy, Abdomen and Pelvis, Anterolateral Abdominal Wall Fascia*. 2017.

110 Creze M, Soubeyrand M, Yue JL, Gagey O, Maître X, Bellin M. Magnetic resonance elastography of the lumbar back muscles: a preliminary study. *Clin Anat*. 2018;31:514-520.

111 Fan, C., Fede, C., Gaudreault, N., Porzionato, A., Macchi, V., De Caro, R., & Stecco, C. Anatomical and functional relationships between the external abdominal oblique muscle and the posterior layer of the thoracolumbar fascia. *Clinical Anatomy*. 2018.

112 Hodges, P. W. Is there a role for transversus abdominis in lumbo-pelvic stability?. *Manual therapy*. 1999;4(2):74-86.

113 Barker, P. J., Urquhart, D. M., Story, I. H., Fahrer, M., & Briggs, C. A. The middle layer of lumbar fascia and attachments to lumbar transverse processes: implications for segmental control and fracture. *European spine journal*. 2007;16(12):2232-2237.

- 114 Puneekar IRA, Khouri JS, Catanzaro M, Shaikh AL, Langstein HN. Redefining the Rectus Sheath: Implications for Abdominal Wall Repair. *Plast Reconstr Surg.* 2018;141(2):473-479.
- 115 Stecco C, Azzena GP, Macchi V, Porzionato A, Behr A, Rambaldo A, Tiengo C, De Caro R. Rectus abdominis muscle innervation: an anatomical study with surgical implications in diep flap harvesting. *Surg Radiol Anat.* 2018;40(8):865-872.
- 116 Brown SH et al. Architectural analysis of human abdominal wall muscles. *Spine.* 2011;36(5):355-362
- 117 Phillips, S., Mercer, S., & Bogduk, N. Anatomy and biomechanics of quadratus lumborum. *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine.* 2008;222(2):151-159.
- 118 Wendell-Smith, C. P. Fascia: an illustrative problem in international terminology. *Surgical and Radiologic Anatomy.* 1998;19(5):273-277.
- 119 Federative Committee on Anatomical Terminology. *Terminologia anatomica: international anatomical terminology.* Georg Thieme Verlag. 1998.
- 120 Stecco A, Stern R, Fantoni I, De Caro R, Stecco C. Fascial Disorders: Implications for Treatment. *PM R.* 2016;8(2):161-8.
- 121 Schleip R, Jäger H, Klingler W. What is 'fascia'? A review of different nomenclatures. *J Bodyw Mov Ther.* 2012;16(4):496-502.
- 122 Fascial nomenclature:an update. Bordini B, Walkowski S, Morabito B, Varacallo MA. *Cureus.* 2019;11(9)

- 123 Abu-Hijleh, M. F., Roshier, A. L., Al-Shboul, Q., Dharap, A. S., & Harris, P. F. The membranous layer of superficial fascia: evidence for its widespread distribution in the body. *Surgical and Radiologic Anatomy*. 2006;28(6):606-619.
- 124 Findley T, Chaudhry H, Stecco A, Roman M. Fascia research--a narrative review. *J Bodyw Mov Ther*. 2012;16(1):67-75.
- 125 Stecco C, Macchi V, Porzionato A, Duparc F, De Caro R. The fascia: the forgotten structure. *Ital J Anat Embryol*. 2011;116(3):127-38.
- 126 Ross MH, Pawlina P. *Histology: a text and atlas: with correlated cell and molecular biology*. 6th ed. Baltimore: Wolters Kluwer/Lippincott Williams & Wilkins. 2011:158–217.
- 127 Scott, J.E. Proteoglycan: collagen interactions and subfibrillar structure in collagen fibrils. Implications in the development and ageing of connective tissues. *J. Anat*. 1990;169:23–35.
- 128 Gelse K, Poschl E, Aigner T. Collagens—structure, function, and biosynthesis. *Adv Drug Deliver Rev*. 2003;55:1531–1546.
- 129 Uitto, J. Biochemistry of the elastic fibers in normal connective tissues and its alterations in diseases. *Journal of Investigative Dermatology*. 1979;72(1):1-10.
- 130 Rosch, R., Klinge, U., Si, Z., Junge, K., Klosterhalfen, B., & Schumpelick, V. A role for the collagen I/III and MMP-1/-13 genes in primary inguinal hernia?. *BMC medical genetics*. 2002;3(1):1-6.
- 131 Milz S, Benjamin M, Putz R. Molecular parameters indicating adaptation to mechanical stress in fibrous connective tissue. *Adv Anat Embryol Cell Biol*. 2005;178:1–71.

- 132 Schleip, R., Gabbiani, G., Wilke, J., Naylor, I., Hinz, B., Zorn, A., Jäger, H., Breul, R., Schreiner, S., & Klingler, W. Fascia Is Able to Actively Contract and May Thereby Influence Musculoskeletal Dynamics: A Histochemical and Mechanographic Investigation. *Frontiers in physiology*. 2019;10:336.
- 133 Kumka, M., & Bonar, J. Fascia: a morphological description and classification system based on a literature review. *The Journal of the Canadian Chiropractic Association*. 2012;56(3):179–191.
- 134 Ross MH, Pawlina P. *Histology: a text and atlas: with correlated cell and molecular biology*. 6th ed. Baltimore: Wolters Kluwer/Lippincott Williams & Wilkins. 2011:158–217.
- 135 Kumka, M., & Bonar, J. Fascia: a morphological description and classification system based on a literature review. *The Journal of the Canadian Chiropractic Association*. 2012;56(3):179–191.
- 136 Kiernan JA. *Barr's the human nervous system: an anatomical viewpoint*. 9th ed. Baltimore: Wolters Kluwer/Lippincott Williams & Wilkins. 2009:35–48.
- 137 Vleeming A, Pool-Goudzwaard AL, Stoeckart R, et al. The posterior layer of the thoracolumbar fascia, its function in load transfer from spine to legs. *Spine*. 1995;20(7):753–758.
- 138 Schleip R, Klingler W, Lehmann-Horn F. Active fascial contractility: Fascia may be able to actively contract in a smooth muscle-like manner and thereby influence musculoskeletal dynamics. *Med Hypotheses*. 2005;65:273–277.
- 139 Terminologia Histologica . International terms for human cytology and histology/ Federative International Committee on Anatomical Terminology (FICAT) Baltimore: Wolters Kluwer/Lippincott Williams & Wilkins. 2008:1–207.

- 140 Purslow P. The structure and functional significance of variations in the connective tissue within muscle. *Comp Biochem Phys A*. 2002;33(4):947–966.
- 141 Gartner L, Hiatt J. *Color Textbook of Histology*. 3rd ed. Edinburgh: Saunders & Elsevier. 2007:1–592.
- 142 Fourie W. Fascia lata: Merely a thigh stocking, or a coordinator of complex thigh muscular activity? *J Bodyw Mov Ther*. 2008;12(3):265.
- 143 Hedley G. Notes on visceral adhesions as fascial pathology. *J Bodyw Mov Ther*. 2010;14(3):255–61.
- 144 Terminologia Anatomica: international anatomical terminology. Federative Committee of Anatomical Terminology (FCAT) Stuttgart, New York: Thieme. 1998:1–292.
- 145 Langevin H, Sherman K. Pathophysiological model for chronic low back pain integrating connective tissue and nervous system mechanisms. *Med Hypotheses*. 2007;68(1):74–80.
- 146 Norton-old, K. J., Schache, A. G., Barker, P. J., Clark, R. A., Harrison, S. M., & Briggs, C. A. Anatomical and mechanical relationship between the proximal attachment of adductor longus and the distal rectus sheath. *Clinical Anatomy*. 2013;26(4):522-530.
- 147 Myers, T. W. *Anatomy Trains—Myofascial meridians for manual and movement therapists*, Churchill Livingstone; 2009.
- 148 Ajimsha, M. S., Daniel, B., & Chithra, S. Effectiveness of myofascial release in the management of chronic low back pain in nursing professionals. *Journal of bodywork and movement therapies*. 2014;18(2):273-281.

- 149 Rosario, J. L. Understanding muscular chains-A review for clinical application of chain stretching exercises aimed to correct posture. *EC Orthop.* 2017;5(6):209-34.
- 150 Wilke, J., Krause, F., Vogt, L., & Banzer, W. What is evidence-based about myofascial chains: a systematic review. *Archives of physical medicine and rehabilitation.* 2016;97(3):454-461.
- 151 Tozzi, P. A unifying neuro-fasciogenic model of somatic dysfunction – Underlying mechanisms and treatment – Part I. *Journal of Bodywork and Movement Therapies.* 2015;19(2):310–326.
- 152 Levin, S.M., Martin, D.C. Biotensegrity: the mechanics of fascia. In: Schleip, R., Chaitow, L., Findley, T.W., Huijing, P. (Eds.), *Fascia e the Tensional Network of the Human Body. The Science and Clinical Applications in Manual and Movement Therapy.* Elsevier, Edinburgh. 2012:137-142.
- 153 Ingber DE. Mechanosensation through integrins: Cells act locally but think globally. *Proc Natl Acad Sci USA.* 2003;100(4):1472–1474.
- 154 Kirilova, M. Time-dependent properties of human umbilical fascia. *Connect. Tissue Res.* 2012;53(1):21-8.
- 155 Findley T. W. Second international fascia research congress. *International journal of therapeutic massage & bodywork.* 2009;2(2):1–6.
- 156 Stroe, MC., Crolet, JM., Racila, M. Mechanotransduction in cortical bone and the role of piezoelectricity: a numerical approach. *Comput. Methods Biomech. Biomed. Engin.* 2013;16(2):119-29
- 157 Staubesand, J., Baumbach, KU., Li, Y. La structure fine de l’aponévrose jambière. *Phlébologie.* 1997;50(1):105-13.

- 158 Allegri, M., Montella, S., Salici, F., Valente, A., Marchesini, M., Compagnone, C., ... & Fanelli, G. Mechanisms of low back pain: a guide for diagnosis and therapy. *F1000Research*. 2016;5.
- 159 Balagué F, Mannion AF, Pellisé F, et al. : Non-specific low back pain. *Lancet*. 2012;379(9814):482–91.
- 160 Cougot, B., Petit, A., Paget, C., Roedlich, C., Fleury-Bahi, G., Fouquet, M., ... & Tripodi, D. Chronic low back pain among French healthcare workers and prognostic factors of return to work (RTW): a non-randomized controlled trial. *Journal of Occupational Medicine and Toxicology*. 2015;10(1):1-15.
- 161 Amirdelfan K, McRoberts P, Deer TR: The differential diagnosis of low back pain: a primer on the evolving paradigm. *Neuromodulation*. 2014;17(2):11–7.
- 162 Braun J, Baraliakos X, Regel A, et al. : Assessment of spinal pain. *Best Pract Res Clin Rheumatol*. 2014;28(6):875–87.
- 163 Bogduk N: On the definitions and physiology of back pain, referred pain, and radicular pain. *Pain*. 2009;147(1–3):17–9.
- 164 Valkenburg, H. A. The epidemiology of low back pain. In *Symposium on idiopathic low back pain*. Mosby. 1982.
- 165 Yahia LH, Garzon S. Structure on the capsular ligaments of the facet joints. *Ann Anat*. 1993;175(2):185–188.
- 166 Lau P, Mercer S, Govind J, Bogduk N. The surgical anatomy of lumbar medial branch neurotomy (facet denervation) *Pain Med*. 2004;5(3):289–298.

- 167 van Kleef M, Vanelderen P, Cohen SP, et al. :12. Pain originating from the lumbar facet joints. *Pain Pract.* 2010;10(5):459–69.
- 168 Filippiadis DK, Kelekis A: A review of percutaneous techniques for low back pain and neuralgia: current trends in epidural infiltrations, intervertebral disk and facet joint therapies. *Br J Radiol.* 2016;89(1057).
- 169 Kalichman L, Li L, Kim DH, et al. Facet joint osteoarthritis and low back pain in the community-based population. *Spine (Phila Pa 1976).* 2008;33(23):2560–2565.
- 170 Beresford ZM, Kendall RW, Willick SE: Lumbar facet syndromes. *Curr Sports Med Rep.* 2010;9(1):50–6.
- 171 Hofmann, U. K., Keller, R. L., Walter, C., & Mittag, F. Predictability of the effects of facet joint infiltration in the degenerate lumbar spine when assessing MRI scans. *Journal of Orthopaedic Surgery and Research.* 2017;12(1):1-8.
- 172 Perolat, R., Kastler, A., Nicot, B., Pellat, J. M., Tahon, F., Attie, A., Heck, O., Boubagra, K., Grand, S., & Krainik, A. Facet joint syndrome: from diagnosis to interventional management. *Insights into imaging.* 2018;9(5):773–789.
- 173 Cohen SP. Sacroiliac joint pain: a comprehensive review of anatomy, diagnosis, and treatment. *Anesth Analg.* 2005;101(5):1440–1453.
- 174 Grob KR, Neuhuber WL, Kissling RO: [Innervation of the sacroiliac joint of the human]. *Z Rheumatol.* 1995;54(2):117–22.
- 175 Laslett M, Aprill CN, McDonald B, Young SB. Diagnosis of sacroiliac joint pain: validity of individual provocation tests and composites of tests. *Man Ther.* 2005;10(3):207–218.

- 176 Genevay, S., & Atlas, S. J. Lumbar spinal stenosis. Best practice & research. Clinical rheumatology. 2010;24(2):253–265.
- 177 Bridwell KH. Lumbar spinal stenosis. Diagnosis, management, and treatment. Clin Geriatr Med. 1994;10(4):677–701.
- 178 Ciol MA, Deyo RA, Howell E, Kreif S. An assessment of surgery for spinal stenosis: time trends, geographic variations, complications, and reoperations. J Am Geriatr Soc. 1996;44(3):285–90.
- 179 Hasegawa T, An HS, Haughton VM, et al., Lumbar foraminal stenosis: critical heights of the intervertebral discs and foramina. A cryomicrotome study in cadavera. J Bone Joint Surg Am. 1995;77(1):32–8.
- 180 Lee CK, Rauschnig W, Glenn W: Lateral lumbar spinal canal stenosis: classification, pathologic anatomy and surgical decompression. Spine (Phila Pa 1976). 1988;13(3):313–20.
- 181 Rauschnig W: Normal and pathologic anatomy of the lumbar root canals. Spine (Phila Pa 1976). 1987;12(10):1008–19.
- 182 De Schepper, E. I., Overvest, G. M., Suri, P., Peul, W. C., Oei, E. H., Koes, B. W., ... & Luijsterburg, P. A. Diagnosis of lumbar spinal stenosis: an updated systematic review of the accuracy of diagnostic tests. Spine. 2013;38(8):469-481.
- 183 Johnsson KE, Rosén I, Udén A: The natural course of lumbar spinal stenosis. Clin Orthop Relat Res. 1992;(279):82–6
- 184 Amirdelfan K, Webster L, Poree L, Sukul V, McRoberts P. Treatment options for failed back surgery syndrome patients with refractory chronic pain: an evidence based approach. Spine. 2017;42(14):S41–S52.

- 185 Roberts S, Evans H, Trivedi J, et al. : Histology and pathology of the human intervertebral disc. *J Bone Joint Surg Am*. 2006;88(2):10–4.
- 186 He L, Hu X, Tang Y, et al. : Efficacy of coblation annuloplasty in discogenic low back pain: a prospective observational study. *Medicine (Baltimore)*. 2015;94(19):846.
- 187 Roh, J. S., & Sohn, D. H. Damage-Associated Molecular Patterns in Inflammatory Diseases. *Immune network*. 2018;18(4).
- 188 Manchikanti L, Singh V, Pampati V: Evaluation of the relative contributions of various structures in chronic low back pain. *Pain Physician*. 2001;4(4):308–16.
- 189 Fields AJ, Berg-Johansen B, Metz LN, et al. : Alterations in intervertebral disc composition, matrix homeostasis and biomechanical behavior in the UCD-T2DM rat model of type 2 diabetes. *J Orthop Res*. 2015;33(5):738–46.
- 190 Albert HB, Sorensen JS, Christensen BS, et al. : Antibiotic treatment in patients with chronic low back pain and vertebral bone edema (Modic type 1 changes): a double-blind randomized clinical controlled trial of efficacy. *Eur Spine J*. 2013;22(4):697–707.
- 191 Schistad, E.I.; Espeland, A.; Rygh, L.J.; Roe, C.; Gjerstad, J. The association between Modic changes and pain during 1-year follow-up in patients with lumbar radicular pain. *Skelet. Radiol*. 2014;43:1271–1279
- 192 Valat JP, Goupille P, Védere V. Low back pain: risk factors for chronicity. *Rev Rhum Engl Ed*. 1997;64(3):189-94
- 193 Makhsous, M., Lin, F., Bankard, J., Hendrix, R. W., Hepler, M., & Press, J. Biomechanical effects of sitting with adjustable ischial and lumbar support on occupational low back pain: evaluation of sitting load and back muscle activity. *BMC musculoskeletal disorders*. 2009;10(1):1-11.

194 Last, A. R., & Hulbert, K. Chronic low back pain: evaluation and management. *American family physician*. 2009;79(12):1067-1074.

195 Chou R, Qaseem A, Snow V, et al., for the Clinical Efficacy Assessment Subcommittee of the American College of Physicians, American Pain Society Low Back Pain Guidelines Panel. Diagnosis and treatment of low back pain: a joint clinical practice guideline from the American College of Physicians and the American Pain Society [published correction appears in *Ann Intern Med*. 2008.148(3): p.247–248] *Ann Intern Med*. 2007;147(7):478–491.

196 Malanga G, Wolff E. Evidence-informed management of chronic low back pain with nonsteroidal anti-inflammatory drugs, muscle relaxants, and simple analgesics. *Spine J*. 2008;8(1):173–184.

197 Koes, B. W., Van Tulder, M., & Thomas, S. Diagnosis and treatment of low back pain. *Bmj*. 2006;332(7555):1430-1434.

198 Witt CM, Jena S, Selim D, et al. Pragmatic randomized trial evaluating the clinical and economic effectiveness of acupuncture for chronic low back pain. *Am J Epidemiol*. 2006;164(5):487–496.

199 Furlan, A. D., Giraldo, M., Baskwill, A., Irvin, E., & Imamura, M. Massage for low-back pain. *Cochrane database of systematic reviews*. 2015;(9).

200 Chou R, Huffman LH, for the American Pain Society and the American College of Physicians. Nonpharmacologic therapies for acute and chronic low back pain: a review of the evidence for an American Pain Society/American College of Physicians clinical

practice guideline [published correction appears in Ann Intern Med. 2008;148(3):p.247–248]. Ann Intern Med. 2007;147(7):492–504.

201 Don AS, Carragee E. A brief overview of evidence-informed management of chronic low back pain with surgery. *Spine J.* 2008;8(1):258–265.

202 van Tulder M, Malmivaara A, Hayden J, Koes B. Statistical significance versus clinical importance: trials on exercise therapy for chronic low back pain as example. *Spine.* 2007;32(16):1785–1790.

203 Black, L. I., Clarke, T. C., Barnes, P. M., Stussman, B. J., & Nahin, R. L. Use of complementary health approaches among children aged 4–17 years in the United States: National Health Interview Survey, 2007–2012. National health statistics reports. 2015;(78):1.

204 Haldeman S, Dagenais S, Budgell B, Grunnet-Nilsson N, Hooper P, Meeker W, Triano J. *Principles and Practice of Chiropractic* New York: McGraw-Hill. 2005.

205 Nadler SF, Weingand K, Kruse RJ. The physiologic basis and clinical applications of cryotherapy and thermotherapy for the pain practitioner. *Pain Physician.* 2004;7:395–9

206 Kim, E.-J., Choi, Y.-D., Lim, C.-Y., Kim, K.-H., & Lee, S.-D. Effect of heating and cooling combination therapy on patients with chronic low back pain: study protocol for a randomized controlled trial. *Trials.* 2015;16(1).

207 Johnson, M. Transcutaneous electrical nerve stimulation: mechanisms, clinical application and evidence. *Reviews in pain.* 2007;1(1):7-11.

208 Charlton J. *Core Curriculum for Professional Education in Pain*. 3rd ed. Seattle: IASP press. 2005:93–96

209 Johnson MI. Transcutaneous Electrical Nerve Stimulation. *In*: Kitchen S, editor. *Electrotherapy: Evidence-Based Practice*. Edinburgh: Churchill Livingstone. 2002:259–286.

210 Castro-Sánchez AM, Lara-Palomo IC, Matarán-Peñarrocha GA, Fernández-Sánchez M, Sánchez-Labraca N, ArroyoMorales M. Kinesio Taping reduces disability and pain slightly in chronic non-specific low back pain: a randomised trial. *J Physiother*. 2012;58:89-95.

211 Kase K, Wallis J, Kase T. Clinical therapeutic applications of the Kinesio taping method. 2nd ed. Tokyo: Ken Ikai Co Ltd; 2003.

212 Uzunkulaoglu, A., Aytekin, M. G., Ay, S., & Ergin, S. The effectiveness of Kinesio taping on pain and clinical features in chronic non-specific low back pain: A randomized controlled clinical trial. *Turkish journal of physical medicine and rehabilitation*. 2018;64(2):126.

213 Ebadi, S., Henschke, N., Forogh, B., Ansari, N. N., van Tulder, M. W., Babaei-Ghazani, A., & Fallah, E. Therapeutic ultrasound for chronic low back pain. *Cochrane Database of Systematic Reviews*. 2020;(7).

214 Allen RJ. Physical Agents Used in the Management of Chronic Pain by Physical Therapists. *Physical Medicine and Rehabilitation Clinics of North America*. 2006;17:315–45

215 Robertson VJ, Ward A, Low J, Reed A. *Electrotherapy Explained: Principles and Practice*. 4th Edition. Butterworth Heinemann, 2006.

216 Barnes, J. F. *Myofascial Release: The search for excellence: a comprehensive evaluatory and treatment approach*. JF Barnes; 1990.

217 McKenney, K., Elder, A. S., Elder, C., & Hutchins, A. Myofascial release as a treatment for orthopaedic conditions: a systematic review. *Journal of athletic training*. 2013;48(4):522-527.

218 Schleip, R. Fascial plasticity—a new neurobiological explanation: Part 1. *Journal of Bodywork and movement therapies*. 2003;7(1):11-19.

219 Ajimsha, M. S., Al-Mudahka, N. R., & Al-Madzhar, J. A. Effectiveness of myofascial release: Systematic review of randomized controlled trials. *Journal of Bodywork and Movement Therapies*. 2015;19(1):102–112.

220 Sandhouse, M. *Glossary of Osteopathic Terminology*. American Association of Colleges of Osteopathic Medicine; 2011.

221 Pischinger, A. *The extracellular matrix and ground regulation: Basis for a holistic biological medicine*. North Atlantic Books; 2007.

222 Macdonald GZ, Button DC, Drinkwater EJ, et al. Foam rolling as a recovery tool after an intense bout of physical activity. *Med Sci Sports Exerc*. 2014;46(1):131-142.

- 223 Curran, PF, Fiore, RD, and Crisco, JJ. A comparison of the pressure exerted on soft tissue by 2 myofascial rollers. *J Sport Rehabil.* 2008;17:432–442.
- 224 Halperin I Aboodarda SJ Button DC, et al. Roller massager improves range of motion of plantar flexor muscles without subsequent decreases in force parameters. *Int J Sports Phys Ther.* 2014;9(1):92-102.
- 225 Beardsley, C., & Škarabot, J. Effects of self-myofascial release: A systematic review. *Journal of Bodywork and Movement Therapies.* 2015;19(4):747–758.
- 226 Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function. Part 2. *N Am J Sports Phys Ther.* 2006;1(3):132—9.
- 227 Hibbs AE, Thompson KG, French D, Wrigley A, Spears I. Optimizing performance by improving core stability and core strength. *Sports Med.* 2008;38(12):995—1008.
- 228 Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *J Spinal Disord.* 1992;5:383-389
- 229 Huxel Bliven, K. C., & Anderson, B. E. Core Stability Training for Injury Prevention. *Sports Health: A Multidisciplinary Approach.* 2013;5(6):514–522.
- 230 Colston M. Core stability, part 1: overview of the concept. *Int J Athl Ther Train.* 2012;17(1):8-13.

231 Andrews, J. R., Harrelson, G. L., & Wilk, K. E. Physical Rehabilitation of the Injured Athlete: Expert Consult-Online and Print. Elsevier Health Sciences; 2012.

232 Freeman, M. D., Woodham, M. A., & Woodham, A. W. The Role of the Lumbar Multifidus in Chronic Low Back Pain: A Review. PM&R. 2010;2(2):142–146.

233 Willardson, J. M., Fontana, F. E., & Bressel, E. Effect of surface stability on core muscle activity for dynamic resistance exercises. International journal of sports physiology and performance. 2009;4(1):97-109.

234 Akuthota, V., & Nadler, S. F. Core strengthening. Archives of physical medicine and rehabilitation. 2004;85:86-92.

235 Sawant, S. A., Desai, M. S., & Kumar, A. Immediate and long term effect of kinesiотaping on cervical core in forward head posture: one week follow up study. Int J Physiother Res. 2017;5(6): 2521-26.

236 Richardson C, Jull G, Hodges P, Hides J. Therapeutic exercise for spinal segmental stabilization in low back pain: scientific basis and clinical approach. Edinburgh (NY): Churchill Livingstone;1999.

237 Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. Spine.1996;21:2763-9.

238 McGill SM. Low back stability: from formal description to issues for performance and rehabilitation. Exerc Sport Sci Rev. 2001;29:26-31

239 Sahrmann, S. A. *Diagnosis and Treatment of Movement Impairment Syndromes*; Mosby: St. Louis, MO, USA; 2002.

240 Aun C, Lam YM, Collect B. Evaluation of the use of visual analogue scale in Chinese patients. *Pain*. 1986;25:215-21

241 Fairbank JCT, Couper J, Davies JB, O'Brian JP. The Oswestry low back pain disability questionnaire. *Physiotherapy*. 1980;66:271-3

242 Princeton University athletic medicine ,Lumbar/Core Strength and Stability Exercises ,2019 , <https://uhs.princeton.edu/sites/uhs/files/documents/Lumbar.pdf>, (February 2021)

243 Hlaing, S. S., Puntumetakul, R., Khine, E. E., & Boucaut, R. Effects of core stabilization exercise and strengthening exercise on proprioception, balance, muscle thickness and pain related outcomes in patients with subacute nonspecific low back pain: a randomized controlled trial. *BMC musculoskeletal disorders*. 2021;22(1):1-13.

244 Cho, H. Y., Kim, E. H., & Kim, J. Effects of the CORE Exercise Program on Pain and Active Range of Motion in Patients with Chronic Low Back Pain. *Journal of physical therapy science*. 2014;26(8):1237-1240.

245 França, F. R., Burke, T. N., Hanada, E. S., & Marques, A. P. Segmental stabilization and muscular strengthening in chronic low back pain: a comparative study. *Clinics*. 2010;65(10):1013-1017.

246 Arguisuelas, M. D., Lisón, J. F., Sánchez-Zuriaga, D., Martínez-Hurtado, I., & Doménech-Fernández, J. Effects of myofascial release in nonspecific chronic low back pain: a randomized clinical trial. *Spine*. 2017;42(9):627-634.

247 Boff, T. A., Pasinato, F., Ben, Â. J., Bosmans, J. E., van Tulder, M., & Carregaro, R. L. Effectiveness of spinal manipulation and myofascial release compared with spinal manipulation alone on health-related outcomes in individuals with non-specific low back pain: randomized controlled trial. *Physiotherapy*. 2020;107:71-80.

248 Lauridsen, H. H., Hartvigsen, J., Manniche, C., Korsholm, L., & Grunnet-Nilsson, N. Responsiveness and minimal clinically important difference for pain and disability instruments in low back pain patients. *BMC Musculoskeletal Disorders*. 2016;7(1):1-16.

249 Arguisuelas, M. D., Lison, J. F., Domenech-Fernandez, J., Martinez-Hurtado, I., Coloma, P. S., & Sanchez-Zuriaga, D. Effects of myofascial release in erector spinae myoelectric activity and lumbar spine kinematics in non-specific chronic low back pain: randomized controlled trial. *Clinical Biomechanics*, 2019;63:27-33.

250 Arun, B. Effects of myofascial release therapy on pain related disability, quality of sleep and depression in older adults with chronic low back pain. *Int J Physiother Res*, 2014;2(1):318-23.

251 Yu, S. H., Sim, Y. H., Kim, M. H., Bang, J. H., Son, K. H., Kim, J. W., & Kim, H. J. The effect of abdominal drawing-in exercise and myofascial release on pain, flexibility, and balance of elderly females. *Journal of Physical Therapy Science*, 2016;28(10): 2812-2815.

252 Ling, L. Z., Singh, K., Govind, S., & Wah, Y. C. Effect of Lumbar Stabilization Exercise and Myofascial Release Therapy in Non-specific Low Back Pain: A

Randomized Controlled Trial. Journal of Positive School Psychology, 2022;6(3):4035-4046.

253 Branchini, M., Lopopolo, F., Andreoli, E., Loreti, I., Marchand, A. M., & Stecco, A. Fascial Manipulation® for chronic aspecific low back pain: a single blinded randomized controlled trial. F1000Research, 2015,4: 1208.



APPENDIX 1: INFORMED WRITTEN CONSENT

Yeditepe Üniversitesi, Sağlık Bilimleri Fakültesi, Fizyoterapi ve Rehabilitasyon Bölümü olarak bel ağrısı olan fizik tedavi ve rehabilitasyon öğrencilerinde self myofasyal gevşeme ile kombine uygulanan kor stabilizasyon egzersizlerin etkilerini karşılaştırarak araştırmayı planlamaktayız.

Çalışmaya katılım gönüllülük esasına dayalıdır. Çalışmaya katılmayı isteyip istemediğinize karar vermeden önce araştırmanın neden ve nasıl yapılacağını, bilgilerinizin nasıl kullanılacağını ve çalışmanın neleri içerdiğini anlamanız önemlidir. Lütfen aşağıdaki bilgileri dikkatlice okumak için zaman ayırınız. Eğer anlamadığınızı ve sizin için açık olmayan şeyler varsa ya da daha fazla bilgi almak isterseniz lütfen bize sorunuz. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuyup anladıktan sonra araştırmaya katılmak isterseniz formu imzalayınız.

Araştırmaya katılmayı kabul ederseniz, değerlendirmeleriniz Fzt. Ufuk DOĞANCALI tarafından yapılacak ve bulgular kaydedilecektir. Araştırma kapsamında, size girişimsel olmayan fiziksel değerlendirme anketleri, kor egzersizleri ve self myofasyal gevşeme tekniği uygulanacaktır. Bel ağrısı olan fizik tedavi ve rehabilitasyon öğrencilerinde self miyofasiyal gevşeme tekniği ile birlikte uygulanan kor stabilite egzersizlerini içeren protokolün etkilerinin, sadece self myofasyal gevşeme uygulanan protokol ile karşılaştırılması amaçlanmaktadır. Birinci gruba; Online egzersiz programı ve self miyofasiyal gevşeme verilecek ve 5 hafta boyunca haftada 2 kez 1 saat süresince uygulanacaktır. Egzersiz öncesi ve sonunda ısınma ve soğuma uygulanacaktır. İkinci grup, yalnızca çevrimiçi haftada 2 kez 30 dakika şeklinde kendi kendine miyofasiyal gevşeme yapacaktır. Her iki grupta da çalışmanın başında, 3. hafta ve 5 hafta sonunda bir değerlendirme yapılacaktır. Değerlendirmede görsel ağrı skalası, Oswestry ölçeği kullanılacak ve değerlendirme 10 dakika olacaktır. Elde edilen sonuçlar bilgisayara kaydedilecek ve analiz edilecektir. Bu çalışmada 32 kişi alınması hedeflenmektedir. Katılımcılar rastgele gruplara ayrılacaktır. Araştırmada iki değerlendirme ölçütü kullanılacaktır. Bunlardan birincisi visuel analog skalası. Bu skala ağrınızın tayininde kullanılacaktır. İkincisi Oswestry skalasıdır. Bu skala sizin fonksiyonel kapasitenizi ölçerken kullanılacaktır.

Çalışmaya katılmakla herhangi bir parasal yük altına girmeyeceksiniz ve aynı şekilde bir ödeme yapılmayacak. Araştırmamız katılımcı açısından her hangi bir risk teşkil

etmemektedir. Araştırmada yapılacak değerlendirmelerin sonuçları yalnızca araştırma kapsamındaki çalışmada kullanılacaktır. Bu amaçların dışında bu kayıtlar kullanılamayacak ve başkalarına verilmeyecektir. Araştırma bir kongrede ya da dergide yayın olarak kabul edilse bile kimliğinizi ortaya çıkarabilecek kayıtlar gizli tutulacaktır. Araştırmaya katılım tamamen isteğe bağlıdır, istediğiniz zaman herhangi bir ceza veya yaptırıma maruz kalmaksızın araştırmadan çekilebilirsiniz.

Kor Egzersizleri: Karın, bel ve kalça hareketlerini kontrol ve dengede tutan kasların çalıştırılmasına yönelik egzersizlerdir. Böylelikle bel ağrısının azalması amaçlanır.

Self Myofasyal Gevşeme: Esnekliği artırmak, egzersiz sonrasında kas ağrısını azaltmak, çabuk iyileşmeyi sağlamak veya bel ağrısı gibi durumlarda sıklıkla kullanılan bir yöntemdir. Birey tarafından aktif olarak gerçekleştirilir. Bir masaj köpüğü sıklıkla kullanılır. Her bölge için yaklaşık 4-5 dakika sürer. Her gevşeme arası 1 dakika ara verilir.

Değerlendirme Yöntemleri

VAS: Visual Analog Skala (VAS) sayısal olarak ölçülemeyen bazı değerleri sayısal hale çevirmek için kullanılır. 1'den 10' a kadar değerler mevcut olup, hastadan bunun üzerinde kendi durumunun hangisine denk geldiği sorulur. Mesela ağrı için bir uca hiç ağrı yok, diğer uca çok şiddetli ağrı yazılır ve hasta kendi o anki durumunu skala üzerinde işaretler.

Oswestry Anketi: Oswestry bel ağrısı olan hastalarda özürlülüğün ölçülmesi için kullanılan bir ankettir. Oswestry indeksinde anket 10 temel bölümden oluşmaktadır. Her işlevin farklı yönlerini ele alan sorular vardır. Her öge 0 ile 5 arasında puanlanmıştır, daha yüksek değerler daha büyük sakatlık ifade eder.

Danışman

Prof. Dr Feryal Subaşı
Yeditepe Üniversitesi

Araştırmacı

Fzt. Ufuk Doğancı
Yeditepe Üniversitesi

Araştırmacı

Dr.Öğr. Güzin Kaya Aytutuldu
Yeditepe Üniversitesi

ONAY FORMU

Bilgilendirilmiş gönüllü olur formundaki tüm açıklamaları okudum. Bana yukarıda konusu ve amacı belirtilen araştırma ile ilgili yazılı ve sözlü açıklama fizyoterapist Ufuk Doğancı tarafından yapıldı. Araştırmaya katılmaya gönüllü olduğumu, istediğim zaman gerekçeli veya gerekçesiz olarak araştırmadan ayrılabilceğimi biliyorum.

[Gönüllü] adı soyadı, telefon numarası, tarih, adresi, imzası		
[Araştırmacı] adı-soyad, telefon numarası, tarih, adresi, imza		
[Tanık] adı soyad, telefon numarası, tarih, adresi, imza		

APPENDIX 2: ETHICAL COMMITTEE APPROVAL



T.C. YEDİTEPE ÜNİVERSİTESİ
GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR
ETİK KURULU

Versiyon No
1.0
Sayfa 1 / 2

KARAR FORMU

21.10.2021

ETİK KURUL BİLGİLERİ	Etik Kurulun Adı	Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu
	Açık Adres	
	İnternet Sayfası	
	Telefon	
	E-posta	

DEĞERLENDİRİLEN BELGELER	Islak imzalı başvuru dosyası, CD'si ve elektronik başvuru	☒
	Araştırma başlığı ve araştırmacıların isimleri	☒
	Başvuru dilekçesi	☒
	Araştırmanın;	☒
	• Niteliği	☒
	• Önemi ve özgün değeri	☒
	• Amaç ve hedefleri	☒
	• Yöntemi	☒
	• Yönetimi	☒
	• Yaygın etkisi	☒
	• Araştırma bütçesi (Mevcutsa)	☒
	• Süresi ve uygunluğu (Zaman cetveli)	☒
	• Kaynakları	☒
	Araştırma izin belgesi / belgeleri	☒
	Bilgilendirilmiş Gönüllü Olur Formu (yapılan araştırmaya özel olarak hazırlanmış)	☒
	Taahhütname-1	☒
	Dünya Tıp Birliği Helsinki Bildirgesinin son versiyonunun ve Sağlık Bakanlığı'nın ilgili tüm kılavuzlarının okunmasına dair taahhüt	☒
	Taahhütname-2	☒
	Daha önce yapılmış etik kurul başvuruları mevcut olup olmadığına dair taahhüt	☒
	Taahhütname-3	☒
	Araştırma sırasında araştırma bütçesinde yer almayan ve gönüllünün kendisine veya Sosyal Güvenlik Kurumuna ek yük getirecek hiçbir işlem uygulanmayacağına dair taahhüt	☒
	Taahhütname-4	☒
	COVID-19 hastalarında tedavi yaklaşımları ve bilimsel araştırmalar genelgesi okunmasına dair taahhüt	☒
	Araştırmacıların her birisine ait özgeçmiş formu	☒
	Ek belgeler (Varsa kullanılan ölçek izinleri vb.)	☒

KARAR BİLGİLERİ	Başvuru Numarası	202109095
	Toplantı Tarihi	18.10.2021
	Toplantı Yeri	Çevirim içi (Google Meet)
	Karar No	3

Araştırmanın Başlığı: Bel ağrısı olan fizyoterapi ve rehabilitasyon öğrencilerinde self myofasyal gevşeme ile kombine uygulanan kor stabilizasyon egzersizlerinin etkilerinin karşılaştırılması

Araştırmacılar: Ufuk Doğancı, Prof. Dr. Feryal Subaşı, Öğr. Gör. Güzin Kaya Aytutuldu



T.C. YEDİTEPE ÜNİVERSİTESİ
GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR
ETİK KURULU

Versiyon No
1.0
Sayfa 2 / 2

BAŞVURU NUMARASI: 202109095

KARAR

21.10.2021

☒ KABUL	☐ RET ☐ KAPSAM DIŞI (GİRİŞİMSEL) ☐ BİLİMSEL VE/VEYA ETİK KURALLARA AYKIRI ☐ BİR SORUMLU ARAŞTIRMACININ (TEZ İŞE TEZ DANIŞMANI), BİR TOPLANTIYA İKİ (2) ADETTEN FAZLA ÇALIŞMA BAŞVURUSUNDA BULUNMASI ☐ KURUM İÇİ BAŞVURULARINDA YEDİTEPE UZANTILI E-POSTA HESABI İLE GİRİŞ YAPILMAMIŞ OLMASI ☐ ŞARTLI KABULDE BELİRTİLEN REVİZYONLARIN ZAMANINDA VE/VEYA İSTENİLDİĞİ ŞEKİLDE YAPILMAMIŞ OLMASI
--	---

Prof. Dr. Didem ÖZDEMİR ÖZENEN Başkan <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok	Doç. Dr. Gökhan ERTAŞ Başkan Yardımcısı <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok	Doç. Dr. Elif SUNGURTEKİN EKÇİ Raportör <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							
Prof. Dr. Feryal SUBAŞI Üye <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok	Doç. Dr. Mehmet Engin CELEP Üye <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok	Dr. Öğr. Üyesi E. Çiğdem KELEŞ Üye <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							
Dr. Öğr. Üyesi Binnur OKAN BAKIR Üye <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok	Dr. Öğr. Üyesi E. Nur ÖZDAMAR Üye <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok	Dr. Öğr. Üyesi SEVİM ŞEN Üye <table><tr><td colspan="2">Katılım</td><td colspan="2">İlişki</td></tr><tr><td>☐Var</td><td>☐Yok</td><td>☐Var</td><td>☐Yok</td></tr></table>	Katılım		İlişki		☐ Var	☐ Yok	☐ Var	☐ Yok
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							
Katılım		İlişki																								
☐ Var	☐ Yok	☐ Var	☐ Yok																							

Araştırmanın Başlığı

Bel ağrısı olan fizyoterapi ve rehabilitasyon öğrencilerinde self myofasyal gevşeme ile kombine uygulanan kor stabilizasyon egzersizlerinin etkilerinin karşılaştırılması

Araştırmacılar

Ufuk Doğançalı, Prof. Dr. Feryal Subaşı, Öğr. Gör. Güzin Kaya Aytutuldu

APPENDIX 3: SOCIODEMOGRAPHIC QUESTIONNAIRE

Sociodemographic Questionnaire :

1-) Age : Height : Weight: BMI:

2-) City :

3-) Your number :

4-) Gender :

5-) Your Job + University :

6-) Do you have any disease diagnosed by the doctor? Yes / No

7-) If your answer is yes, which of the following is your diagnosed disease (You can tick more than one option.

- Cardiovascular Diseases
- Cancer
- Diabetes
- Hypertension
- Orthopedic Disease (spondylolysis, scoliosis)
- Rheumatismal or myopathic diseases
- Neurological Problems (Neuropathy, radiculopathy, balance problems..)
- Trauma (a musculoskeletal disorder in the last 2 months)
- Digestive System Diseases (Liver, stomach, etc.)
- Respiratory System Diseases (Lung, etc.)
- Mental Problems (Depression, Overeating, Vomiting, Night Eating, etc.)
- Musculoskeletal Problems
- Endocrine (Hormonal) Diseases, Vitamin and Mineral Deficiency (Iron, B12, etc.)
- Osteopenia or Osteoporosis
- Having Inflammation
- Other (Please specify)

8-) Do you take any drugs regularly? Yes / No

Name of drug:.....

9-) Have you had a medical operation before? Yes / No

If yes, please specify name

10-) Have you ever had an accident? Yes /No

11-) How long have you been experiencing low back pain?

- less than 3 months
- 3 -6 months
- 6 to 12 months
- 1 year +

APPENDIX 4: THE PERMISSION FOR THE OSWESTRY DISABILITY INDEX

Von: Edibe Ünal <

Gesendet: Freitag, 4. Juni 2021 04:07

An: ufuk doğancı

Betreff: Re: ODI Skala izni

Sayın Ufuk Doğancı,
Türkçe versiyonunu yaptığım ODI ölçeğini, ilgili yüksek lisans tez çalışmanızda kullanmanızda sakınca yoktur.

Çalışmanızda başarılar dilerim.

Prof. Dr. Edibe Ünal
Hacettepe Üniversitesi
Fizik Tedavi ve Rehabilitasyon Fakültesi

ufuk doğancı <

Sayın Prof. Dr. Edibe Ünal

Ben Yeditepe Üniversitesi Spor fizyoterapisi yüksek lisans öğrencisi, Fizyoterapist Ufuk Doğancı. Bu dönem yapacağım Yüksek Lisans tez çalışmam kapsamında "Oswestry Disabilite İndeksi" kullanmak istiyorum. ODI skalasını kullanabilmek için sizin izniniz almanız gerekmektedir. İzniniz olursa Skalayı aşağıda başlığı ve araştırmacıların belirttiğim YL tez çalışmamda kullanmak istiyorum. Zaman ayırdığınız için çok teşekkür ediyorum.

Saygılarımla.

APPENDIX 5: OSWESTRY SCALE

1-Ağrınızın şiddeti nasıl?

- 1)Gelip geçici ve çok hafif bir ağrı
- 2)Sürekli, fakat hafif bir ağrı
- 3)Gelip geçici ve orta şiddette bir ağrı
- 4)Sürekli ve orta şiddette bir ağrı
- 5)Gelip geçici ve şiddetli bir ağrı
- 6)Şiddetli ve çok değişmeyen bir ağrı

2-Kişisel bakım

- 1)Ağrıdan kaçınmak için günlük yaşamımda (yıkama, giyinme şekli vb) değişiklik yapmadım
- 2)Biraz ağrı yapsa da yıkama ve giyinme şeklinde değişiklik yapmadım.
- 3)Yıkama ve giyinmem ağrımı artırıyor, fakat bunları değiştirmeden idare ediyorum
- 4)Yıkama ve giyinmem ağrımı artırıyor, bu yüzden bunları yapma şeklimde değişiklik yaptım.
- 5)Ağrı nedeniyle yıkama ve giyinmede bir miktar yardım alıyorum.
- 6)Ağrı nedeniyle yıkama ve giyinmeyi yardımsız yapamıyorum.

3-Yük Kaldırma

- 1)Ağır yükleri ağrı olmadan kaldırabiliyorum.
- 2)Ağır yükleri kaldırırken bir miktar ağrı oluyor.
- 3)Ağrı yüzünden ağır yükleri kaldıramıyorum.
- 4)Ağrı, ağır yükleri kaldırmamı önlüyor, fakat uygun pozisyon varsa bunu başarabilirim.
- 5>Sadece çok hafif yükleri kaldırabiliyorum
- 6)Hiç yük kaldıramıyorum

4-Yürüme

- 1)Yürürken ağrı yok
- 2)Yürümeyle biraz ağrı var, fakat mesafeyle artmıyor
- 3)Ağrıda belirgin artma olmaksızın 2 km den fazla yürüyemiyorum
- 4)Ağrıda belirgin artma olmaksızın 500 m den fazla yürüyemiyorum
- 5)Ağrıda belirgin artma olmaksızın yürüyemiyorum
- 6)Hiç yürüyemiyorum

5-Oturma

- 1)Herhangi bir sandalyede istediğim kadar uzun oturabilirim
- 2)Sadece uygun bir sandalyede istediğim kadar uzun oturabilirim
- 3)Ağrı bir saatten uzun oturmamı önlüyor
- 4)Ağrı yarım saatten uzun oturmamı önlüyor
- 5)Ağrı 10 dakikadan fazla oturmamı önlüyor

- 6)Ağrımı arttırdığı için oturmaktan kaçınıyorum

6-Ayakta durma

- 1)Ağrı olmaksızın istediğim kadar uzun ayakta durabilirim
- 2)Ayakta durmakla biraz ağrı oluyor, fakat bu zamanla artmıyor.
- 3)Bir saatten uzun ayakta kaldığımda ağrı şiddetleniyor.
- 4)Yarım saatten uzun ayakta kaldığımda ağrı şiddetleniyor.
- 5)On dakikadan uzun ayakta kaldığımda ağrı şiddetleniyor.
- 6)Ağrımı arttırdığı için ayakta durmaktan kaçınıyorum

7-Uyuma

- 1)Yatakta ağrı yok
- 2)Yatakta ağrı var, fakat iyi uyuyorum
- 3)Ağrı nedeniyle normal uykumun 3/4 ünü uyuyorum
- 4)Ağrı nedeniyle normal uykumun yarısını uyuyorum
- 5)Ağrı nedeniyle normal uykumun 1/4 ünü uyuyorum
- 6)Ağrı nedeniyle hiç uyuyamıyorum

8-Sosyal yaşam

- 1)Sosyal yaşamım normal ve ağrı yaratmıyor.
- 2)Sosyal yaşamım normal, fakat ağrımı artırıyor.
- 3)Ağrı, dansetmek, futbol oynamak gibi daha fazla enerji gerektiren ilgilerimi kısıtlamak dışında sosyal yaşamımda belirgin etki yaratmıyor.
- 4)Ağrı, sosyal yaşamımı kısıtlıyor, bu nedenle çok sık dışarıya çıkamıyorum.
- 5)Ağrı, aile içi yaşamımı da kısıtlıyor.
- 6)Ağrı nedeniyle hemen hemen tüm sosyal yaşamım kısıtlandı.

9-Seyahat

- 1)Seyahatte ağrı olmuyor.
- 2)Seyahatte biraz ağrı oluyor, fakat artmıyor.
- 3)Seyahatte ağrı artıyor, fakat bu ağrı seyahat şeklini değiştirmedir.
- 4)Seyahatte olan şiddetli ağrılarım nedeniyle başka seyahat şekilleri arıyorum.
- 5)Ancak yatarak seyahat edebiliyorum.
- 6)Ağrı nedeniyle seyahat edemiyorum.

10-Ağrının değişme derecesi

- 1)Ağrı hızla iyileşiyor.
- 2)Ağrı artıp azalıyor, fakat genelde iyiye gidiyor.

- 3)Ađrım iyileřiyor, fakat dűzelme yavař.
- 4)Ađrım ne kűtűleřiyor, ne de iyileřiyor.
- 5)Ađrım yavař yavař kűtűleřiyor.
- 6)Ađrım hızla kűtűleřiyor



