CAN LONG TERM MUSCULOSKELETAL, SPINAL PAIN IMPROVE WITH MOVEMENT EDUCATION USING SEMG BIOFEEDBACK

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I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), or material which to a substantial extent has been submitted for the award of any other degree or diploma of an institution of higher learning.

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Table of Contents

ATTESTATION ...................................................................................................................... 1
EXECUTIVE SUMMARY ...................................................................................................... 3
CHAPTER 1: INTRODUCTION .............................................................................................. 4
CHAPTER 2: LITERATURE ..................................................................................................... 9
SUMMARY ............................................................................................................................ 15
CHAPTER 3: PROJECT METHODOLOGY ............................................................................. 16
  RESEARCH PARTICIPANTS ............................................................................................. 18
  SEMG SENSOR PLACEMENT SITES USED DURING RESEARCH ....................................... 22
  METHODS OF DATA COLLECTION ............................................................................... 24
  RESEARCH PROCESS ..................................................................................................... 28
  SEMG RECORDINGS ..................................................................................................... 29
  PRE AND POST SEMG ASSESSMENT ............................................................................. 30
CHAPTER 4 DATA ANALYSIS ............................................................................................ 44
  MIND MAPPING ............................................................................................................ 44
  MIND MAP DOCUMENTATION EXPORTED INTO THE TABLE ..................................... 45
CHAPTER 5: RESEARCH FINDINGS ..................................................................................... 50
  HOW DID THE RESEARCH IMPACT THE PARTICIPANTS? ............................................. 51
  MY RESEARCH QUESTION WAS: .................................................................................. 54
  HOW DID THE RESEARCH PROCESS IMPACT ME, THE CLINICIAN? ............................. 64
CHAPTER 6: CRITICAL REFLECTIVE COMMENTARY ......................................................... 65
  SO, WHAT DID I FIND OUT? ......................................................................................... 65
CHAPTER 7: REFLECTIVE SUMMARY ................................................................................. 69
  CONCLUSION: ............................................................................................................... 70
REFERENCES: .................................................................................................................... 71
Executive Summary

This practitioner thesis describes the impact of using surface electromyography (SEMG) as a biofeedback tool at home and work to improve long-term spinal musculoskeletal pain.

My research focuses on discovering experimental data about the subject of SEMG and its use within the context of biofeedback rehabilitation of musculoskeletal pain.

My professional aim in completing the MProfPrac is to develop a more profound knowledge as a practitioner.

My research project utilised a Phenomenological paradigm and an Action Research methodology/framework of investigation, action and reflection. My data collection included mixed methods of SEMG recordings, pain questionnaire, well-being scale and participant self-assessment.

Key learnings confirm that the use of SEMG as a biofeedback modality in the treatment of long-term musculoskeletal spinal pain is beneficial and problematic. Data analysis is better understood and interpreted by clinicians and practitioners rather than patients. Participants' willingness to engage with the SEMG is determined by their technological capabilities and motivation to learn new movement habits to improve their pain symptoms.

My research findings propose that:

- Skilled professionals or competent users best do the use of SEMG biofeedback.
- Sensor placement, data interpretation, and movement modifications require a high level of self-confidence or muscle anatomy and biomechanics expertise.
- SEMG devices can be made user friendly.
- SEMG biofeedback is extremely helpful to people suffering from musculoskeletal, spinal pain.
- SEMG biofeedback enables individuals to discover activities at home, work and in the gym, which cause them muscular stress, which they did not know.
- An improvement in muscular awareness from SEMG biofeedback correlates with an improvement in back pain.
- SEMG biofeedback encourages learning new movements, altering, and training new neural pathways, enabling greater muscular control.
- The nervous system's malleability means that the nervous system itself is a logical target of treatment using SEMG biofeedback.
- Musculoskeletal pain is multifactorial; pain can have multiple causes. Including poor sleep, emotional stress, depression, anxiety, and low muscular and physical awareness.
CHAPTER 1: Introduction

In this practitioner thesis, I define a clinical project's development within my practice framework as a musculoskeletal practitioner treating long-term spinal pain. In this first chapter, I discuss my framework of practice, the changes in my clinical approach associated with developing the desired change and the impending impact on my thesis.

The focus of my research is to discover experimental data about SEMG biofeedback rehabilitation. As described by Neblett (2016), SEMG biofeedback has two primary goals. Firstly, to increase muscular awareness and, secondly, improve control of muscles. SEMG biofeedback benefits are immense. It allows both the patient and clinician to have instantaneous access to muscle functioning, which is impossible with manual palpation or visual observation.

I aim to show that SEMG has been overlooked as a handy clinical biofeedback tool in assessing and treating musculoskeletal injuries. My objective is to introduce an effective strategy to assist those affected by back pain, minimise the health costs on society and reduce the length of time people suffer. My professional aim in completing the Master of Professional Practice (MProfPrac) is to develop more profound knowledge as a practitioner with expertise in SEMG as a biofeedback modality, a comprehensive understanding of SEMG literature, and a leader in the field of SEMG technological innovations.

Enthusiasm for this work includes understanding and appreciating the developmental experiences and skills I have attained during my 32-year career as a musculoskeletal practitioner.

My practice framework as a musculoskeletal practitioner began in 2011 when I completed the Bachelor of Applied Management degree with a major in Innovation and Entrepreneurship. This study and reflection time enabled me to truly understand what I had learned in my career as a remedial massage therapist and businessman. This was my first dive into academia since high school; I found this process challenging, inspiring and informative.

My early years of practice educated me in many ways, I had the drive to excel, be professional, set new standards of industry excellence, be inquisitive and look for innovative ways to make my business better. I have always had a deep desire to help people in pain.

The platform from which my practice framework emerged began out of my desires for innovation; this cemented my values and professional perspectives. My life goal has been to create a product that will impact the musculoskeletal world. To achieve this, I had to immerse myself in academia, reflect deeply and gain a new skill set.

My career began as a part-time remedial massage therapist in 1987; while working full-time as a horticulturist. I found the direction I was after; massage was the perfect combination of hard physical work and helping people. My introduction to science began in 1989 when I was introduced to Dr John Knight, one of the world’s top Ironman triathletes. He had a PhD in Physical Chemistry and was a client of mine. John explained to me the process of making a hypothesis and gathering evidence to test it. Together we conducted an N=1 experiment to improve his overall flexibility and improve swimming performance. This introduction to
scientific principles set the platform for my future learnings. It increased my observational abilities and grounded my ideas in practice and experience.

Early on in my massage career, I looked for inspiration and guidance from clients who were active business leaders and some clients who were New Zealand's leading sportsmen and women. Their drive, focus, determination, and courage inspired me to set goals, be my best every day and not be afraid of failure. I was developing into a businessperson, professionalising my passion for helping people in pain; however, I had a great deal to learn.

In 1992 I found the world of strength and fitness, the personal impact on me was enlightening, and immediately I implemented what I learned through exercise into my client treatments. This widened my eyes to the scope of possibilities as a remedial clinician and further ignited my desire to continually improve.

I began to dream of future opportunities in the fitness area. I recognised the need for an exercise facility where people received the right advice and guidance on exercising safely for musculoskeletal rehabilitation every time they work out. Creating this facility was my goal and became a reality in 2004.

A theme of my professional life is forming win/win relationships. From 1993 to 2002, I worked with various practitioners to share expertise and improve my skillset, including General Practitioners, Exercise Physiologists, Massage Therapists and Physiotherapists. I wanted to find answers to questions regarding back pain. However, a clinical Neurophysiologist I met in 2002 named Dr Peter Taylor, with who I would form the most scientifically rewarding friendship.

Through observation of fellow practitioners and exposure to clients in pain, I recognised what was missing in the field of musculoskeletal treatments. What was missing was evidence-based exercise rehabilitation. This was my lightbulb moment; I needed to find out what exercise therapy would work; I needed Peter's assistance to achieve this goal.

Peter used electromyography (EMG) for his patient assessments; I hoped this would be a valuable tool for analysing my exercise methodology. Electromyography is a diagnostic procedure to assess the health of muscles and the nerve cells that control them (motor neurons). Motor neurons transmit electrical signals that cause muscles to contract.

I explained my hypotheses to Peter; the first question I wanted to explore was:

- Using EMG as a measurement tool, could a specific set of exercises manipulate muscle activation patterns during a person's walking gait to reduce stress on their spinal muscles?
- The second question was, could a change in exercise technique create greater muscle activation using less weight for exercises specifically for the hamstrings and gluteal muscles?

We conducted a research project using 30 clients to test my exercise rehabilitation questions. We set the criteria for participants to have a minimum five-year history of low back pain. This
pain history was essential as it removed the percentage of people who suffer short periods of acute back pain. This allowed us to deal with chronic cases where individuals no longer responded to hands-on therapy, including treatments such as Physiotherapy, Osteopathy, or Chiropractic manipulations. Back pain has two categories, acute or chronic. Acute back pain lasts a few days to a few weeks. It usually resolves on its own within a few days, often with self-care, and there is no loss of function. In rare cases, it may take 12 weeks to resolve, and symptoms disappear. Chronic back pain continues for 12 weeks or longer, which does not respond to treatment. Chronic back pain can become severe, with neurological symptoms affecting the buttocks, legs, and feet. About 20 per cent of people with acute back pain develop chronic symptoms, (Stein et al., 2006).

The Oswestry Pain Questionnaire was used pre and post, SEMG muscle outputs were recorded during walking gait, and musculoskeletal range of motion measurements was also done pre vs post. The study's basis was to compare my strictly supervised exercise methodology results on an experimental group versus a control group doing unsupervised general gym exercise. The results were encouraging; they identified that strictly supervised activities, combined with explicit instruction and tuition each training session, improve musculoskeletal pain significantly and significantly improve back pain. Undoubtedly, this early research provided some answers to my questions; however, more depth was needed. This project provided the initial framework for my MProfPrac.

So, the lead up to my MProfPrac has been a trial-and-error journey to find optimal data gathering methods. From 2004 to 2009, I experimented using video analysis to assess client musculoskeletal dysfunction. I recorded 16893 video analysis files of clients before deciding this study system was not robust and would fail scientific validity.

Instinctively I knew I needed a comprehensive SEMG system to test my hypotheses. In 2009 I purchased a 16 channel (SEMG). Over the next two years, I assessed over 1000 clients with back pain. I found answers to both of my earlier questions. I discovered low self-awareness and physical conditioning are two of the main reasons people suffer long-term back pain and why current mainstream hands-on therapies can have limited success as treatment.

This raised the question of why some musculoskeletal therapists from a variety of disciplines believe in ineffective treatments? Research by Zadro et al., (2019) acknowledges several physical therapists do not follow evidence-based treatment principles when addressing patients suffering musculoskeletal complaints.

This justified the argument for the benefit of many musculoskeletal conditions of SEMG as a biofeedback modality. SEMG, used as an application by clinicians to assess clients, encourages improved muscular control, muscle engagement, self-awareness and complements current treatments methods.

The use of SEMG for biofeedback is beneficial in treating chronic low back pain. Neblett (2016) claims SEMG is one of the earliest biofeedback modalities invented. It was used in 1920 by Edmond Jacobson to develop therapeutic muscle relaxation techniques.
My learning agreement outcomes begin with an all-encompassing question:

**Can long term musculoskeletal, spinal pain improve with movement education using SEMG biofeedback?**

I aimed to discover the following:

- Understand which SEMG biofeedback modalities work most effectively for our clients when rehabilitating spinal pain.
- Find which SEMG processes make clients feel comfortable within their bodies.
- Discover which biofeedback modalities cause clients the least stress, physically and mentally.
- Understand physiological trigger complexities seen through SEMG biofeedback underlying musculoskeletal pain, such as hot flushes, stress, anxiety, past experiences, and how they present themselves during SEMG biofeedback sessions.
- Understand the impact of back pain rehabilitation in a motivating, supportive, caring environment.

I will describe what has inspired me to undertake this work. My practice framework has evolved over 32 years from my early days as a massage therapist, transitioning from a businessman leading a team to an innovative SEMG entrepreneur.

I have dreamed of making a positive difference in the world. My desire to be an innovator within the musculoskeletal industry has driven me to expand my practice framework, develop new skills and obtain more profound knowledge.

Writing my review of learning disclosed my journey to this point and illustrated my interest in using SEMG biofeedback in musculoskeletal rehabilitation.

This demonstrated to me how far I have transitioned within my framework of practice. My professional perspectives immersed in my early years. I learned through observations, finding kinaesthetic learning, unveiling hard-work ethics, a massage therapy career, discovering scientific methods, engaging in academia, and evolving to emerge as an innovative therapist.

My drive for answers using SEMG as an assessment and biofeedback tool treating spinal pain was the launch platform for my practice framework and inspiration for the MProfPrac.

My experience exposed to clients' needs in pain drove my desire to create more effective scientific assessment methods and enhanced exercise prescription. What has been transparently evident to me is the opportunity for SEMG to improve practitioner-client relationships. Most importantly, SEMG biofeedback can unmask, for those suffering musculoskeletal pain, an understanding of the everyday lifestyle factors contributing to their pain.
This process of evaluating my past as a professional therapist has enabled me to reflect on how I performed. I am highly aware that my experience is personal, and not everyone will understand my reasons; however, these motives are essential to me.

As a professional leader, I will strive to influence clinical practice standards within the Allied Health industry e.g. Physiotherapy, Osteopathy, and Chiropractic. I will introduce a new SEMG device to enhance practitioners' abilities during client assessments and exercise prescription.

Motivation is not complete without reflecting upon what will encourage practitioners to embrace the latest SEMG science into their practice; most may have never seen SEMG biofeedback modalities before. I hope this study will clarify the benefits of its use.

Reflecting, lessons learned from this study include awakening and realising the necessity for high-quality research on SEMG and its benefits as a biofeedback modality. Also, and most importantly, it seems the clinical application of SEMG into private musculoskeletal practice has been overlooked to the detriment of society.

In answering my research question, "can long term musculoskeletal, spinal pain improve with movement education using SEMG biofeedback? Lessons learnt from this study have impacted change in my practice. My clinical approach to low back pain management now includes pain scale and mental well-being analysis monthly, combined with self-discovery opportunities for clients with their ability to have in-depth SEMG biofeedback analysis performed by experienced clinicians within the clinical environment.

Most importantly, this study has unmasked the functional application parameters for SEMG best use. Determining whether SEMG is most effective in the clinic for patients by experienced clinicians or used at home and work by patients benefiting those suffering from musculoskeletal pain.

My professional impact practice change will be my ability to work alongside musculoskeletal practitioners and clinic owners from various fields to understand how SEMG can benefit patients and be implemented into their practice.

In this chapter, I have explored my motivations for this project. I have delved into the background of this work, both personally and professionally. I have identified an opportunity in the musculoskeletal market for a SEMG device to enhance current best practices.
CHAPTER 2: Literature

My previous chapter reviews my development as a musculoskeletal therapist and my scientific approach to innovative investigations. This chapter will begin with definitions and provide an overview of the current literature on SEMG, identifying its applications for biofeedback, the inconsistencies in the literature regarding sensor use, placement, configuration, and reasons for clinical application limitations.

Florimond (2009) describes Surface Electromyography (SEMG) as a non-invasive technique of measuring electrical muscle activity. SEMG can be used to measure muscle contractions and assist with muscle relaxation. SEMG is unique in revealing what muscles do during movement and posture; it also reveals the interplay and coordination of muscles. SEMG measures muscle activity of which is impossible by other means such as palpation or observation.

SEMG biofeedback is an influential rehabilitation tool. SEMG biofeedback involves measuring a participant’s muscle tension and conveying it into understandable visual feedback. SEMG biofeedback aims to consciously raise a person's muscular awareness and control through interaction between the participant and the SEMG signal. SEMG biofeedback has a motivating influence on the recipient to play an active role in the rehabilitation process. It provides an additional benefit to the therapist, encouraging clear and precise exercise instruction, (Florimond, 2009).

Bossley and Miles (2009) have said that the annual cost of musculoskeletal conditions to New Zealand is an enormous $5,571 million; back pain alone contributes to 51% of this cost. They say New Zealand faces considerable financial stress if the burden of musculoskeletal conditions is not tackled. We could reduce this cost by implementing a SEMG biofeedback modality for various clinicians in the initial clinical assessment and exercise prescription process of those suffering moderate back pain levels.

As described by (Neblett, 2016), SEMG biofeedback aims to encourage control over biological processes by teaching increased muscular awareness via visual muscle activity. First generation biofeedback SEMG was limited to the technology available at the time, early modalities provided an analogue needle display, or a sound to the user. Throughout the decade's biofeedback has evolved, from digital numerical displays in the 1970s to interactive colourful multimedia displays today. SEMG biofeedback benefits are immense. It allows both the patient and clinician to have instantaneous access to muscle functioning, which is impossible with manual palpation or visual observation. Research by Ambroz et al., (2000), using SEMG, have shown that individuals who suffer chronic back pain can have up to three times higher spinal muscle activity when standing and two times higher muscle activity performing dynamic movements. Their findings indicated SEMG assessment of the lumbar paraspinals as a practical objective tool in evaluating people with chronic lower back pain. In a study conducted by Donaldson, et al., (1994) to assess "the application of single motor unit biofeedback training (SMUBT) for chronic lower back pain" (p.23). They found SMUBT and education therapy to be extremely helpful compared to a relaxation therapy treatment. The long-term outcomes were positive, with participants of the SMUBT having pain relief and reduced symptoms at the four years reassessment mark post clinical trial. With similarities to
my research project regarding the use of SEMG biofeedback assessing upper trapezius and erector spinal muscles, a study conducted by Ma et al., (2011) found that six weeks of SEMG biofeedback training produced more significant positive results for neck and shoulder pain for computer users. Their study was a randomised control trial involving four groups: an exercise group, a passive treatment group, a biofeedback group, and a control group. They concluded six weeks of biofeedback training was more favourable, reducing pain and encouraging muscle excitement in patients with shoulder pain and work-related neck discomfort, compared to participants doing vigorous exercise or receiving passive treatment.

Research conducted by Middaugh and Morrissette (2002) discovered that SEMG biofeedback reduces upper trapezius muscle hyperactivity and improves posture. This research's significance in relation to my project is that they tested the muscle activity of participants seated at workstations. Still, they also assessed muscle activity of the upper Trapezius muscles walking. They used a portable SEMG device to provide visual feedback of muscle activity, encouraging participants to maintain correct head position walking. They understood the importance of improved muscle control in both seated and dynamic movements, combined with Physiotherapy, which achieves more significant outcomes for tension headaches. Combining SEMG biofeedback and physical therapy, they point out that poor posture can be improved, and excessive muscle load tolerance can be reduced.

Research conducted by Ehrenborg and Archenholtz (2010) challenges the benefits of using SEMG biofeedback as a training method for people who have suffered whiplash injuries. They performed a randomised controlled trial for over four weeks. They discovered there were no extra benefits of using SEMG biofeedback when compared to participants receiving rehabilitation alone. They stated, "Both treatment and control groups improved significantly" (p.715).

It is essential to acknowledge the SEMG signal is a measure of muscle excitement and effort, not a measure of muscle force output. Sperlich et al., (2018) articulate SEMG as a measure of muscle activation via neural excitation and not a measure of true muscle force alone. They claim "SEMG measures changes in the polarity of muscle fibres membrane from neural excitation" (p.4). Measuring muscle force is very complex; the signal produced from SEMG biofeedback is not an accurate muscle force indication. The harder one contracts their muscles, the larger the SEMG signal. Instead, view SEMG biofeedback as a measure of effort; the harder you try to engage the muscle, the larger the SEMG signal.

During my research project, I am assessing improvements in muscular control and its effect on musculoskeletal pain. Research by Kadefor et al., (1999) shows individuals can lose control of low-level motor units in the upper Trapezius muscles. These motor units are referred to as 'Cinderella units' (working all the time); they forget how to rest. They can fatigue over time, degenerate, and become a significant source of chronic pain. I have witnessed these Cinderella units when assessing clients for 15 years and observed their impact on causing chronic musculoskeletal pain. Kadefor et al., (1999) evaluated 24 various arm positions in three participants using fine wire EMG inserted into the upper Trapezius muscle.
discovered low threshold motor units were active and measurable in the upper Trapezius muscle in various arm positions; this outcome was present in all three research participants.

Research by Hermens and Hutten (2002) theorised that the muscle activation patterns in people who suffer chronic pain are different from those with no pain. To discover this, they used a myofeedback modality. They concluded muscles act differently in people suffering chronic pain; through myofeedback, they observed prolonged activation of muscles after a task and a decreased ability for the muscles to relax and calm down. They give specific reference to the 'Cinderella Theory', the continual firing of uncontrolled low-level motor units and their possible contribution to chronic pain. With myofeedback, their participants learned to calm down uncontrolled low-level motor unit firing and respectively improved muscle activation patterns, resulting in a reduction of pain severity.

Currently, there is a significant gap in the literature concerning how SEMG biofeedback is best used to positively affect chronic low back pain or neck pain. Specifically, the calming of Cinderella low-level uncontrolled motor units and amplification of underactive muscles with low muscle outputs.

SEMG technology has evolved over the past ten years with the development of Bluetooth technology. When a large amount of electromyography research was done in the eighties and nineties, SEMG analysis was not wireless, and scientific testing was limited concerning what movements could be tested. Recipients would be connected to a SEMG device connected to a computer by a cable. Testing certain activities were restricted due to cable length.

Figure 1: 2006 SEMG technology. Sourced from author.
Today with current technology, SEMG sensors are small, and participants can wear them with minimal movement restrictions.

*Figure 2: 2020 MrEMG sensors. Sourced from author.*

Today data feedback in real-time can be viewed via an electromyogram on an iPad to enhance muscle excitation during an activity.

*Figure 3: 2020 SEMG iPad electromyogram. Sourced from author.*
This advancement in SEMG technology changes the parameters of research and enhances opportunities for cognitive biofeedback therapy.

There is a direct effect on behavioural cognition from SEMG biofeedback education. There are comparisons between cognitive behavioural education and SEMG biofeedback within the literature, discovering they both positively treat back pain. (Newton-John, Spence & Schotte, 1995).

This principal reason for this research is to show SEMG, as a biofeedback tool, can help musculoskeletal pain. I will display the ease of use for myself, the clinician, and the participants; I will show the benefits, including education through (cognitive behavioural therapy) on participants movement habits and how movement change improves pain. This is important as it provides an opportunity for possible low back pain resolution for some people. This treatment form is currently unavailable in mainstream medicine to those with long term back pain in New Zealand.

Research indicates there is conflicting evidence on the benefits of SEMG in the analysis of spinal muscle activity in people with chronic back pain. A study by Bush et al., (1985) concluded SEMG biofeedback is not a specific treatment for individuals with chronic lower back pain compared to other interventions. However, in this study, all participant groups improved; they summarised that hypnotisability was a predictive factor in the placebo group’s positive outcome.

Digging deeper into these papers, I found inconsistencies with experiments, such as sensor construction, electrode size and placement, amplitude recordings, and the reference electrode's location. Based on these findings, many experiments would be difficult to replicate. These inconsistencies identified by a leading group of researchers in the field of SEMG.

In 1996 the group SENIAM (surface EMG for a non-invasive assessment of muscles) was established. This group consist of 16 partners from nine European countries involved in the project. The partners included a balanced group of technical and clinical expertise in SEMG.

Firstly, this group set out two clear objectives to create a helpful exchange of clinical experience and SEMG data by solving critical items that present such discussions. Secondly, to establish a European co-operation of basic and applied research on SEMG. ("Welcome at Seniam.org", n.d. Why this project section, para.3).

Hermens and Freriks (1997), as part of the SENIAM group, produced a report with guideline recommendations using SEMG named SENIAM 8. Their goal was to set a high standard in the use and application of SEMG on the neuromuscular system’s assessment and functioning. They reached a consensus to optimise sensor configuration and electrode placement, precisely on 20 muscles on the body. They specifically note "one has to realise that such recommendations will never be finished. The scientific and clinical progress being made in this field will cause that these recommendations have to be updated from time to time" (p.i).

The MrEMG system used in this research has been manufactured following the SENIAM recommended specifications of electrode size, electrode placement and sensor configuration.
H. J. Hermens et al., (2000), in the "Journal of Electromyography and Kinesiology", produced a journal article called *Development of recommendations for SEMG sensors and sensor placement procedures*. "In this article 144 peer-reviewed papers were scanned on the applied SEMG properties and sensor placement procedures" (p.361). They discovered a large discrepancy in research methodologies and explanation of sensor properties and placement methods. As referred to by H. J. Hermens et al., (2000), when one is performing SEMG research, sensor properties, manufacturer type, number of contact points, shape, size, material, inter-electrode distance, sensor placement procedure, skin preparation, technique, electrode paste, muscles, location on muscles, area of the reference electrode, electrode crosstalk, equipment and signal processing are all factors that must be acknowledged. Due to the inconsistencies stated, I have identified limitations from the literature showing the actual benefits of SEMG biofeedback as a tool when assessing and treating musculoskeletal conditions, including back pain. I expect this is why today's practitioners have overlooked SEMG as a useful clinical tool for patient care.

Practitioners have identified the application of SEMG in everyday clinical environments as complex and complicated. In my personal experience speaking to various therapists, the benefits of its application in musculoskeletal rehabilitation are not well known. From now on, two questions must be asked: What are the barriers to the use of SEMG present for clinicians and practitioners? Why is SEMG not more widely used in rehabilitation as a biofeedback modality?

To gain insight into these questions, we address a qualitative, phenomenological study by Feldner et al., (2019). They set out with the objective to discover why SEMG is not widely used in clinical applications of neurologic rehabilitation, possible benefits, and drawbacks. Their goal was to examine the perceived value from a clinical stakeholder's perspective. Their findings concluded SEMG implementation had several potential benefits. The clinicians interviewed identified several barriers to SEMG implementation. Including limited resources and time, the complexity of systems and SEMG's need to be streamlined for ease of use and practical clinical applications. These findings indicate the need for new simplistic SEMG systems and templated clinical application methods to encourage use within clinical environments.
Summary
This chapter has explored the literature offering a theoretical and practical basis of the use and applications of SEMG as a biofeedback modality. Considering new knowledge uncovered as part of the project and the literature findings, I foresee an untapped opportunity to help those with spinal pain—by introducing an easy-to-use application of SEMG biofeedback, encouraging movement coaching in clinical environments by trained professionals. The literature confirms my practitioner knowledge base using SEMG biofeedback as a beneficial tool in treating long-term musculoskeletal, spinal pain. Literature supports my position in that SEMG systems have been complicated in nature, not user friendly for practitioners and not set up with easily understandable electromyograms that provide immediate beneficial information to practitioners and patients. At the beginning of my project, I had not appreciated how complex it was to produce an efficient, reliable SEMG system. The technology and resources required to manufacture a product of this nature are immense and require the synergy of high levels of expertise from many fields. I now understand why organisations such as SENIAM have come together to share knowledge and set common standards of recommendations for SEMG system manufacture.

What has not emerged in my literature is a definitive understanding of why SEMG as a biofeedback modality in the treatment of long-term musculoskeletal, spinal pain has been overlooked in New Zealand. SEMG has been implemented successfully in other parts of the world. The application of SEMG biofeedback is not part of the Physiotherapy curriculum at Otago University. Currently, students receive one lecture during their four-year study from my colleague Dr Peter Taylor Clinical Neurophysiologist, on electromyography and its application in nerve conduction studies.

I hope the MrEMG system created as part of this MProfPrac will fulfil this space.
CHAPTER 3: Project Methodology

In the previous chapter, I have explored my theoretical framework and provided the context of my profession as a musculoskeletal therapist. The field of SEMG biofeedback has been well researched; however, there are gaps in the literature regarding the use of SEMG as a biofeedback modality in treating musculoskeletal, spinal pain in the clinic, at home and at work. The motivation chapter provides background regarding my clinical practice and presents an opportunity to apply SEMG within musculoskeletal clinical environments. This chapter explains my research methodology and the particular methods I have used to carry out this work.

My research method used a Phenomenological paradigm and an Action Research methodology/framework of investigation, action and reflection. Costley et al., (2010), a framework for work-based research, guided me. My data collection included mixed methods of SEMG recordings, pain questionnaire, well-being scale and participant self-assessment.

My research included a constructivist design to advance critical thinking, creation, analysis, and evaluation. As explained by (Killam, 2013), "constructivism research is about finding the meaning in the experiences of individuals" (p.457). A constructivist's axiology ensues my responsibility to guarantee all participants' voices are represented. Constructivism is based on relativism, experiences and social interactions that influence each participants' reality, and their reality is considered correct; their experience using SEMG biofeedback will be their own. The epistemology of constructivism ensures I the researcher and the participant co-create findings. This will involve interaction between myself and the participants throughout the research. Constructivism uses qualitative data collection methods and will be represented in this project through a self-assessment form and well-being scale (Killam, 2013).

The paradigm of Ethnography will be used on this journey; Costley et al., (2010) describe ethnography as a broad methodological qualitative category. It involves working in the research field with your participants, making observations, gathering unstructured data via interviews or discussions while exploring social situations. I will use ethnography to capture the participant's emotion and the context in their everyday life behaviour.

A literature search aided with validating and supporting my research discoveries.

The Otago Polytechnic Ethics Committee reviewed my Ethics application. The project was approved under category B. Approval was given from the Kaitohutohu Office of Otago Polytechnic. My preparation included a consent form process; project information was in the form of a flyer on a noticeboard. A gatekeeper was used to manage applicants.
My research question is:

Can long term musculoskeletal, spinal pain improve with movement education using SEMG biofeedback?

My research aimed to investigate the following information to assist with answering the question:

• Understand which SEMG biofeedback modalities work most effectively for our clients when rehabilitating spinal pain.

• Find which SEMG processes make clients feel comfortable within their bodies.

• Discover which biofeedback modalities cause clients the least stress, physically and mentally.

• Understand physiological trigger complexities seen through SEMG biofeedback underlying musculoskeletal pain, such as hot flushes, stress, anxiety, past experiences, and how they present themselves during SEMG biofeedback sessions.

• Understand the impact of back pain rehabilitation in a motivating, supportive, caring environment.

Each of these points will be addressed in Chapter 6: Research findings.

Participants were recruited, through my company Body Synergy. Applicants had to meet a criterion to be eligible to apply as a participant. It was essential participants were part of our rehabilitative space for a minimum of three years. Therefore, providing an opportunity to see if SEMG biofeedback could improve their pain and mental well-being levels beyond what improvements they had already achieved.

The criteria were as follows:

• Had been a member of Body Synergy Gym for three years.

• Were over 18 years of age.

• Still suffered spinal pain, symptoms muscular or neurological.

• Were comfortable wearing surface EMG sensors for one day per week for six weeks at work and home.

• Were available from 1st February 2020 to the 14th of March 2020.

• Willing to note take weekly, reflecting on their experience wearing surface EMG sensors and the impact the biofeedback had on their pain and lifestyle.
• Available for two musculoskeletal assessments, one pre the research project and one post.
• Available for two briefing morning teas, one pre the research project and one post

Research Participants
Nine participants in total, eight female and one male, the mean age of participants was 54 years. All participants have been consistent with their rehabilitative training during their time at Body Synergy. However, all have some minimal to moderate musculoskeletal, spinal pain remaining.

Introducing the MrEMG System. Designed and built-in conjunction with this MProfPrac journey.

Figure 4: MrEMG device. Sourced from the author.
Figure 5: MrEMG sensors, 6 mm electrodes, sticker, Sourced from the author.
MrEMG App welcome screen.

Figure 6: Sourced from the author

The MrEMG App screen ready to record data.

Figure 7: Sourced from the author.
SEMG recording of a participant using a bike testing quadriceps from the study.

![SEMG recording](image)

*Figure 8: Sourced from the author.*

For this research project to begin, I had to develop the SEMG device and build the App with a team of leading engineers and a biomedical software specialist. What has transpired is a SEMG device of high quality and accuracy, explicitly designed with the clinician and patient in mind. The data files obtained for analysis are clear and precise, empowering to the test participants and clinician. Eight SEMG electromyograph files were obtained for all nine participants, measuring muscle outputs throughout their journeys. All files are available for review if necessary. The biofeedback provided participants with motivation for exercise, empowerment of their physical being, confidence in what exercises work the best, and muscle function clarity. All participants responded well and positively to the biofeedback; all wanted reports on their findings after every session.

The device provided an accurate measure of muscle outputs and data files, with pictures of movements and muscle outputs recorded in microvolts, which could be analysed in immense detail. This quality of SEMG data provides value to this research project.
SEMG Sensor placement sites used during research.
The diagrams below show the muscle sites SEMG can be used. These sites recognised within the SEMG industry. The muscles I tested on each participant were dependant on being the most beneficial for each participant.

Anterior sensor placement sites

*Figure 9: Sourced from Basics of Surface Electromyography Applied to Physical Rehabilitation and Biomechanics (Florimond, 2009), (p.14). REDACTED*
Posterior placement sites

Figure 10: Sourced from Basics of Surface Electromyography Applied to Physical Rehabilitation and Biomechanics (Florimond, 2009), (p.15). REDACTED

The muscles tested in this research project included:

<table>
<thead>
<tr>
<th>Upper Trapezius</th>
<th>Gluteus Maximus</th>
<th>Vastus Medius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Trapezius</td>
<td>Gluteus Medius</td>
<td>Vastus Lateralis</td>
</tr>
<tr>
<td>Latissimus Dorsi</td>
<td>Transverse Abdominus</td>
<td>Pec Major</td>
</tr>
<tr>
<td>Lumbar Paraspinals</td>
<td>Rectus Abdominus</td>
<td>Rear Deltoids</td>
</tr>
</tbody>
</table>

Table 1: Sourced from the author.
Methods of Data Collection

Methods of data gathering included quantitative and qualitative, matching it to each person's story.

As I worked through my investigations, I implemented the process of Triangulation. (Killam, 2013) acknowledges Triangulation includes numerous methods, both quantitative and qualitative, to answer research questions. (Killam, 2013) also states, "there are challenges to achieving triangulation, the results are arguably more comprehensive" (l.279). I used Triangulation to check and establish validity by analysing my research question from multiple perspectives. I am deeply interested in each participant's journey and how they reflect and comment on the research in their self-assessments. I am curious to see how their comments relate to their SEMG muscle engagement results and pain levels. I used Triangulation to uncover more profound meaning in the data. B2B Whiteboard (2013) conveys Triangulation allows for innovative ways to understand the phenomenon; it provides the opportunity to reveal unique findings or theories that may clarify the problem. Triangulation increases researcher confidence, giving clarity to understanding.

SEMG biofeedback and analyses comparing the client's muscle activity pre versus post-rehabilitation were recorded; each data-gathering session took 30 minutes. Examples of the testing will be provided. MrEMG device was used for each test; muscle sensor sites prepared using an alcohol swab to clean the skin surface before sensor placement, ensuring clean electrode contact. The device electrodes are 20 mm apart; electrodes are circular, made from 5n silver.

Muscle tests performed during initial consultation included:

- Upper trapezius muscle activity standing and walking.
- Lumbar paraspinal muscle activity standing and walking.
- Standing isometric muscle contractions of the Latissimus dorsi and gluteus maximus muscles.
- Gluteus maximus muscle activity during walking gait.
- Latissimus dorsi muscle activity during walking gait.

It took 31.5 hours in total to gather the data and perform all tests. Participants used the MrEMG device at home and work for nine self-assessments; I did the remaining 45 recordings at Body Synergy in the clinical rehabilitative environment. SEMG electromyography was recorded from each session to an iPad, measuring muscle outputs during various activities and matched with pictures of movements assessed during testing. Each recording was associated with a participant's self-reflection analysis, a well-being questionnaire was
completed post every second test, and a pain questionnaire completed pre-and post-
experiment. Data were collected over 18 weeks, from October 2020 to February 2021.

During the SEMG biofeedback sessions, I observed how participants responded to the
feedback they saw of their muscles.

The Oswestry Low Back Pain Disability Questionnaire was used. It was first published by
Fairbanks et al., (1980). This self-report questionnaire will be completed by participants pre-
and post-experiment. As stated by Physiopedia (2021), Oswestry Disability Index, the
"Questionnaire examines perceived level of disability in 10 everyday activities of daily living".
Six statements are scored from 0 to 5 and then calculated to provide a percentage score.

Scores below from Physiopedia (2021), Oswestry Disability Index, Interpretation section are
as follows:

0% to 20%: **minimal disability**: The patient can cope with most living activities. Usually, no
treatment is indicated, apart from advice on sitting, lifting and exercise.

21%-40%: **moderate disability**: The patient experiences more pain and difficulty with sitting,
lifting, and standing. Travel and social life are more difficult, and they may be disabled from
work. Personal care, sexual activity and sleeping are not grossly affected, and the patient can
usually be managed by conservative means.

41%-60%: **severe disability**: Pain remains the main problem in this group, but activities of
daily living are affected. These patients require a detailed investigation.

61%-80%: **crippled**: Back pain impinges on all aspects of the patient's life. Positive
intervention is required.

81%-100%: These patients are either bed-bound or exaggerating their symptoms.

Participants were encouraged to keep a personal journal of their progress during their
rehabilitation. This was a simple one-page self-assessment form completed each SEMG
session. At the outset, I requested access to their self-assessment as insight into their journey
was enlightening. I developed this questionnaire; I intended to make the questionnaire quick
and straightforward to complete. The sense was powerful, this questionnaire worked well,
and the participants' data was excellent. Participants completed all 54 questionnaires.
**Week 1 to 6 Self-Assessment form**

- How are your pain levels? (Please tick emoji)

- Is the SEMG device user friendly?

- Do you prefer to use the SEMG at work, home, or both?

- How helpful is SEMG biofeedback in your movement education?

**Weekly self-reflection Summary**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Well-being scale

A well-being scale will be used to measure the impact of a positive outlook on the SEMG biofeedback rehabilitative process. I have been approved to use The Warwick-Edinburgh Mental Well-being Scale (WEMWBS). The WEMWBS was created in 2006-2007. Stewart-Brown et al., (2008) state, "WEMWBS is a 14-item scale of mental well-being covering subjective well-being and psychological functioning, in which all items are worded positively and address aspects of positive mental health" (p. ii). The 14-item scale has five response categories, summed to provide a single score. The WEMWBS is used in various settings, including public health, workplaces including occupational health and clinical.

This well-being scale below will be completed by participants every two weeks throughout the experiment, as recommended by its authors.
The Warwick Medical School (2020), Interpretation section, recommend using the scoring system as follows:

- 40 points or less = probable depression
- 41 to 44 = possible depression
- 45 to 59 = average mental well-being
- 60 or more = high mental well-being

The following diagram shows the process I underwent throughout the research journey, from start to completion. The steps were followed by me meticulously.
**SEMG recordings**

One-third into the data gathering process, SEMG sensors were damaged by the participants at home or work, unbeknown to them. This was a valuable learning experience; more robust sensors were made. One participant had difficulty using the device at work, which they found stressful and time-consuming. These reasons combined forced the decision for me to conduct the data gathering at Body Synergy. Making this decision ensured more significant quality data and SEMG testing for participants, which benefited them and this project. I concluded that SEMG biofeedback analysis needs to be done by a clinician who can place sensors correctly on the skin, interpret the biofeedback data, and make informed movement and muscle engagement recommendations.

The SEMG device I used for this research has an App, which is available downloaded from the iTunes App store. The research participants all received their SEMG data recordings, enabling them to analyse and process their biofeedback at home. This action mitigated any stress from the testing and made their experience more valuable. As Kessels (2003) suggested, there is a significant difference in memory retention between spoken and visual medical instructions. With verbal instructions, 14% of the information is retained, compared to over 80% when pictographs used. Graphic pictures associated directly with meaning are most effective for the recipient’s memory retention. For this reason, the MrEMG Application was developed to record images directly related to the SEMG data recorded on the screen. This bought meaning to the participant's data as without pictures to show the activity tested, the on-screen SEMG data means nothing.

Two examples of SEMG biofeedback are presented here; I have the participant’s full consent to offer their data. The images provided show the depth of SEMG data obtained from each session and allow for the tests performed within this research to be replicated by other researchers. The pre- and post-assessments contained 10 SEMG tests for each participant. The research data SEMG biofeedback sessions included 10 to 20 tests each time, depending on each participant’s muscle groups assessed. Maximal voluntary contraction (MVC) muscle microvolt outputs were recorded and compared against other muscle outputs from different exercises. Explanations are provided with each picture to provide my insight into the SEMG recording. As the researcher, I will explain what I am observing with each test.

![MrEMG App](sourced-from-the-author)
Pre and post SEMG assessment (example)

**Test one** (MVC) of the upper Trapezius muscles, performed over three contractions, with the average output recorded. Left upper Trapezius is green, and yellow is right. Muscle outputs measured in microvolts—pictures were taken using the MrEMG App with each test to match the data.

**Note:** I am assessing for significant variances between sides to indicate the participant’s muscular awareness and an insight into what activities they have done in their life to create muscle output variances. Here the left upper Trapezius output is much larger than the right.

*Figure 13: Sourced from the author.*

**Test two** assessment is upper Trapezius muscle activity during walking gait. The average muscle activity recorded over 18 to 20-second duration.

**Note:** This test assesses muscle hyperactivity walking (Cinderella Syndrome) of the upper Trapezius muscles. This participant has very relaxed upper Trapezius muscles walking. This result is negative for Cinderella Syndrome.

*Figure 14: Sourced from the author.*
Test three **MVC** of the Latissimus Dorsi muscles. Performed over three consecutive contractions, with an average microvolt output recorded. Left Latissimus Dorsi is green, and the right is yellow.

**Note:** I am assessing the participant’s ability and awareness to engage these muscles. A good result here. Some people with back pain have a limited understanding of the Latissimus Dorsi muscles and find it challenging to engage them.

*Figure 15: Sourced from the author.*

Test four assessment of Latissimus Dorsi engagement during walking gait. Average microvolt muscle output recorded over 16 to 20 seconds.

**Note:** Active engagement of the Latissimus Dorsi muscles walking provides active trunk bracing for the spine. This participant has outstanding attention to their Latissimus Dorsi muscles walking.

*Figure 16: Sourced from the author.*

Test five **MVC** Lumbar Paraspinal muscles, recorded over three consecutive contractions, with average muscle output recorded. The left lumbar is green, right lumbar yellow.

**Note:** I am assessing for significant variances between sides, as is seen here in this picture. Providing insight into activities the participant may have done in their life to cause this difference.

*Figure 17: Sourced from the author.*
Test six  Lumbar Paraspinals engagement during walking gait. Average microvolt muscle output recorded over 16 to 20 seconds.

Note: This test is a measure assessing for Lumbar muscle hyperactivity. This subject has normal levels of muscle activity walking. The left Lumbar Paraspinal is more active than the right, however, within normal parameters.

Figure 18: Sourced from the author.

Test seven  flexion/relaxation phenomenon

Note: This is a test of lumbar spinal muscle activity when flexing the trunk. This participant shows a negative result. People with chronic lower back pain can have a positive result on this test. In a positive test, the spinal muscles do not relax when the participant flexes forward. Instead of a flat line, the activity seen would be more significant.

Figure 19: Sourced from the author.

Test eight  MVC of lumbar Paraspinals in a prone lying position. Enabling comparisons from standing lumbar MVC to prone lying lumbar MVC.

Note: I am assessing for significant variances between sides, as is seen here in this picture. Providing insight into activities the participant may have done in their life to cause this difference.

Figure 20: Sourced from the author.
**Test nine** MVC of the gluteus Maximus muscles, recorded over three consecutive contractions, with average muscle output recorded. Left Glute is green, right Glute yellow.

**Note:** I am assessing for the ability of the participant to engage their glutes actively. The glute output is outstanding in this picture, indicating a high level of muscle awareness for this participant.

*Figure 21: Sourced from the author.*

**Test 10** Gluteus Maximus engagement during walking gait. Average microvolt muscle output recorded over 16 to 20 seconds.

**Note:** Active engagement of the gluteal muscles helps reduce lower back stress in some people. This participant has outstanding gluteal engagement walking. Notice the alternating glute contractions of the walking gait.

*Figure 22: Sourced from the author.*

Summarising this analysis, this participant has a significant variance in their spinal muscles. MVC; the left upper Trapezius and Lumbar Paraspinal muscles have a much larger output. However, they are within the expected parameters of walking. This variance, in this case, is not an issue. If the spinal muscles were hyperactive walking, I would consider this muscle activity problematic. This participant's muscle output variance is from playing the Cello from the age of seven years old. I discovered this variance in muscle activity using SEMG biofeedback while this participant was paying Cello. This participant has a negative flexion/relaxation test, exceptional muscular engagement, awareness, and today are pain-free. They previously had severe chronic pain for several years.
SEMG biofeedback data recordings (data recording example).

The following example displays the precise steps taken for each SEMG biofeedback session performed at Body Synergy. All SEMG data recordings were clear, removed of any signal disturbance or artefacts. An artefact is a SEMG signal interruption during a muscle recording. Artefacts created by poor electrode contact with the skin.

Below is an example of a signal artefact during a recording: You can see the muscle signals are clean initially until the yellow sensor loses skin contact, causing the enormous signal disruption. Signal disruptions, such as this, must be removed from the data as they do not represent muscle activity.

\[\text{Figure 23: Sourced from the author.}\]

Once again, as the researcher, I will explain what I am observing with each test.

The test performed for this participant was on their Quadricep muscles.

I will summarise findings besides the SEMG biofeedback images, as this provides insight into the recordings.

Summarising this assessment, this participant presents with reduced right Quadriceps muscle outputs following a fracture of the right femur, an injury that required surgical repair with plates and screws; recovery was 12 months. What is positive for this participant is knowing the Quadriceps muscles function well after the injury when performing various exercises. When this participant applies more significant effort during an activity, such as using weight resistance machines, the right Quadriceps muscle outputs match the left leg. This example shows how powerful and positive SEMG biofeedback is for people recovering from injury.
Test one MVC of Quadriceps. The left Quadriceps is the top two lines; the right Quadriceps are the bottom two lines. Three contractions performed with average MVC recorded.

Note: As stated previously, this participant has reduced MVC levels on her right thigh muscles because of breaking her right femur in an accident. I will observe if this difference is present during other test comparisons. Pain reduces muscle outputs.

Figure 24: Sourced from the author.

Test two assessment of quadriceps muscle activity during walking gait. With an average recorded over 5.5 seconds.

Note: Muscle outputs walking are very balanced between legs. The MVC difference is not present here, which is positive feedback for this participant.

Figure 25: Sourced from the author.

Test three assessed Quadriceps muscles output using Concept 2 Bike erg over 8.6 seconds, comparing left versus right quadriceps muscles.

Note: Right thigh muscle output is reduced here compared to left. MVC recordings match muscle activity reduction here for the right Quadriceps. Not problematic, just an observation.

Figure 26: Sourced from the author.
Test four assesses Quadriceps muscles output using a Cybex Sparc trainer over 3.9 seconds and comparing left versus right quadriceps muscles.

Note: Right Quadricep reduction also presents with this activity, matching MVC contractions. It is not problematic as the right Quadriceps muscle output is acceptable.

![Figure 27: Sourced from the author.](image)

Test five assesses Quadriceps muscles output using a Vertex treadmill trainer over 2.9 seconds and comparing left versus right quadriceps muscles.

Note: Right Quadricep reduction also present with this activity matching initial MVC testing.

![Figure 28: Sourced from the author.](image)

Test six assessment of Quadriceps muscles output performing a Goblet squat and comparing left versus right quadriceps muscles.

Note: Right Quadriceps muscle output is more significant than left on this exercise, making this exercise a vital rehab exercise for this participant. Positive feedback for this participant as it shows the right Quadriceps are functioning well post their thigh fracture.

![Figure 29: Sourced from the author.](image)
**Test seven** assesses Quadriceps muscles output, performing an 18-kilo leg extension and comparing left versus right quadriceps muscles.

**Note:** The Quadriceps outputs balanced with this exercise—positive feedback and encouragement for this participant.

*Figure 30: Sourced from the author.*

**Test eight** assessment of Quadriceps muscles output using an Impulse Cross-trainer at level 10 over 4.7 seconds and comparing left versus right Quadriceps muscles.

**Note:** In this test, there is a slight reduction in muscle output from the right Quadriceps matching initial MVC testing.

*Figure 31: Sourced from the author.*

**Test nine** assessed Quadriceps muscles output using a Cybex Arc Trainer at level 40, over 5.8 seconds. Comparing left versus right, Quadriceps muscles

**Note:** A slight reduction in right Quadriceps muscle output with this machine, matching initial MVC testing.

*Figure 32: Sourced from the author.*
**Test 10** assessment of the left Quadriceps muscles output using a reverse leg press with 10 kilos resistance. I will be comparing left versus right, Quadriceps muscles.

*Figure 33: Sourced from the author.*

**Test 11** assessment of the right Quadriceps muscles output using a reverse leg press with 10 kilos resistance.

*Note:* The variance continues with this test, as seen previously. The right Quadriceps output is slightly reduced compared to the left below.

*Figure 34: Sourced from the author.*

**Test 12** assessment of the left Quadriceps muscles output using a leg press with 20 kilos resistance.

*Figure 35: Sourced from the author.*
**Test 13** assessment of the right Quadriceps muscles output using a leg press with 20 kilos resistance. Comparing left verses right, Quadriceps muscles

**Note:** The variance continues with this test, as seen previously. The right Quadriceps output is slightly reduced compared to the left.

*Figure 36: Sourced from the author.*

**Test 14** assesses the Quadriceps muscles using a spin bike in a seated position with medium resistance over 5.7 seconds.

**Note:** The variance continues with this test, as seen previously. The right Quadriceps output is slightly reduced compared to the left; however, muscle output levels are favourable.

*Figure 37: Sourced from the author.*

**MVC comparisons analysis begin:**

**Test 15** split screen assessment of the Quadriceps muscles activity walking on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess the volume of Quadriceps muscle output walking compared to MVC. Muscle outputs here are encouraging for this participant.

*Figure 38: Sourced from the author.*
**Test 16** split screen assessment of the Quadriceps muscles activity riding a Concept 2 Bike erg on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess the volume of Quadriceps muscle output cycling compared to MVC. Muscle outputs here are suitable for this participant, which for them is encouraging biofeedback.

*Figure 39: Sourced from the author.*

**Test 17** split screen assessment of the Quadriceps muscles activity using a Cybex Stex Cross-trainer on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess Quadriceps muscle output volume using a Cybex Sparc Trainer compared to MVC. Muscle outputs here are encouraging for this participant.

*Figure 40: Sourced from the author.*

**Test 18** split screen assessment of the Quadriceps muscles activity using a Vertex treadmill on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess Quadriceps muscle output volume pushing on a Vertex Treadmill compared to MVC. A reduction in right Quadriceps, however, relative to initial MVC. Muscle outputs here are encouraging for this participant.

*Figure 41: Sourced from the author.*
**Test 19** split screen assessment of the Quadriceps muscles activity performing a Goblet squat on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess Quadriceps muscle output volume performing a Goblet squat compared to MVC. Muscle outputs here are encouraging for this participant.

*Figure 42: Sourced from the author.*

**Test 20** split screen assessment of the Quadriceps muscles activity performing an 18-kilo leg extension on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess Quadriceps muscle output volume performing a leg extension compared to MVC. Muscle outputs here are encouraging for this participant.

*Figure 43: Sourced from the author.*

**Test 21** split screen assessment of the Quadriceps muscles activity using an Impulse cross-trainer at level 10 on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess Quadriceps muscle output volume using an Impulse Cross-Trainer compared to MVC. Muscle outputs here balanced for this participant relative to MVC.

*Figure 44: Sourced from the author.*
**Test 22** split screen assessment of the Quadriceps muscles activity using a Cybex Arc Trainer at level 40 on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess Quadriceps muscle output volume using a Cybex Sparc Cross-trainer compared to MVC. Muscle outputs here are encouraging for this participant.

*Figure 45: Sourced from the author.*

**Test 23** split screen assessment of the left Quadriceps muscles performing a reverse leg press, using 10 kilos on the right, compared to Quadriceps MVC on the left.

*Figure 46: Sourced from the author.*

**Test 24** split screen assessment of the right Quadriceps muscles performing a reverse leg press, using 10 kilos on the right, compared to Quadriceps MVC on the left.

**Note:** In this comparison, I assess the volume of Quadriceps muscle output using a Reverse Leg Press compared to MVC. Muscle outputs here are encouraging for this participant.

*Figure 47: Sourced from the author.*
Test 25 split screen assessment of the left Quadriceps muscles performing a leg press, using 20 kilos on the right, compared to Quadriceps MVC on the left.

Note: In this comparison, I assess Quadriceps muscle output volume using a Leg Press compared to MVC. Muscle outputs here are encouraging for this participant.

Figure 48: Sourced from the author.

Test 26 split screen assessment of the right Quadriceps muscles performing a leg press, using 20 kilos on the right, compared to Quadriceps MVC on the left.

Figure 49: Sourced from the author.

Test 27 split screen assessment of the Quadriceps muscles using a spin bike with medium resistance on the right, compared to Quadriceps MVC on the left.

Note: In this comparison, I assess Quadriceps muscle output volume using a Spin bike compared to MVC. Muscle outputs here are encouraging for this participant.

Figure 50: Sourced from the author.
Chapter 4 Data analysis

SEMG data were analysed using the MrEMG App for each participants session. Muscle outputs were measured in microvolts; this provided instant feedback for participants during the data gathering process.

AYOA Mind map software was used to transcribe each participant's data and progression throughout the study. Colour coding and note-taking were used to identify categories and establish themes as they emerged from the data.

Each category identified related themes during the analysis of the data. During the SEMG biofeedback sessions, it was resourceful to explore aspects of testing that benefitted the research, adding insight into the findings.

I implemented Triangulation, using multiple approaches, including quantitative and qualitative methods, to answer research questions.

The work of Miles et al., (2020) guided the data analysis. As stated by Miles et al., (2020), "we believe that coding is deep reflection about and, thus, deep interpretation about the data's meanings. In other words, coding is analysis" (p.63).

Mind mapping

Mind map analysis of participant B, journey example.
To measure each participant's journey throughout this 18-week research project, I used AYOA mind mapping software. This enabled me to precisely record what testing each participant had received, the date, and the exact time I entered the information.

Their participation was entered, including muscle outputs, pre-and post-testing, Oswestry pain scale scores pre and post. WEMWBS well-being scores pre- and post-every second SEMG data recording, SEMG testing records of each session, and self-reflection notes after every testing. Insights along the way from the participants and emerging themes for each participant. This process of data gathering enabled accurate colour coding and data analysis for each participant. Nine mind maps in total were generated. Mind maps provided clarity and were a good fit for how my brain processes data. Colour coding provided motivation and structure for task completion.

**Mind map documentation exported into the table** *(example)*

**Participant B imindmap exported document.**

**Oswestry low back pain scale and WEMWBS Well-being scores**

<table>
<thead>
<tr>
<th>Oswestry pain scale pre 20% (minimal disability) pre.</th>
<th>Oswestry pain scale post scores 18% (minimal disability).</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEMWS Pre scores 45 (Average mental well-being) pre.</td>
<td>WEMWBS 4 Post score 43 (probable depression).</td>
</tr>
</tbody>
</table>

*Table 2: Sourced from the author.*

**Week 1 SEMG testing and self-assessment (home and work).**

<table>
<thead>
<tr>
<th>Participants' self-reflection:</th>
<th>Participants' comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate pain levels: Device extremely user-friendly: Used both home and work: Biofeedback extremely helpful:</td>
<td>Very helpful, makes you more conscious of your body and positioning.</td>
</tr>
</tbody>
</table>

*Table 3: Sourced from the author.*

**Week 2 SEMG testing and self-assessment (home and work).**

<table>
<thead>
<tr>
<th>Participants' self-reflection:</th>
<th>Participants' comments:</th>
<th>WEMWBS 2 scores 40 (Probable depression)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor pain levels: Device extremely easy to use: Used both home and work: Biofeedback extremely helpful:</td>
<td>It was interesting how bad my body posture and traps were driving.</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4: Sourced from the author.*
Week 3 SEMG testing and self-assessment (gym)

**Clinical testing:** Tested upper traps and lower traps at the gym. Tested ring rows, triceps pushdowns, close grip lat pull down, low pulley row, cross trainer, walking gait, isometric contractions, ski erg, leg extensions, air dyne, lying hamstring curls, press-ups, straight arm pulldowns, workplace computer use, sitting in a comfortable chair, walking, spin bike seated, spin seated grind, spin standing climb.

*Table 5: Sourced from the author.*

<table>
<thead>
<tr>
<th>Participants' self-reflection:</th>
<th>Participants' comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor pain levels: Device extremely easy to use: Used at the gym: Biofeedback extremely helpful.</td>
<td>Tough week emotionally, great to check in with what my body is doing.</td>
</tr>
</tbody>
</table>

*Table 6: Sourced from the author.*

Week 4 SEMG testing and self-assessment (gym)

**Clinical testing:** Tested lateral quads and glutes at the gym. Isometric squeeze, cross-trainer, Cybex cross-trainer, impulse bike, impulse bike high resistance, fire hydrants, Cybex stex, air dyne bike, Concept 2 bike erg, isometric squeeze, spin bike seated, spin bike standing, walking, reverse leg press, supine hip extension, four-point leg extended behind, hack squat, self-awareness leg extension, leg extensions, box step-ups, cross trainer.

*Table 7: Sourced from the author.*

<table>
<thead>
<tr>
<th>Participants' self-reflection:</th>
<th>Participant's comment:</th>
<th>WEMWBS 3 scores 38 (probable depression)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor pain levels: Device extremely user-friendly: Used at the gym: Biofeedback extremely helpful.</td>
<td>Incredibly interesting to see the different exercises and my muscle reacting. Another tough week, family illness, conflicting demands on time.</td>
<td></td>
</tr>
</tbody>
</table>

*Table 8: Sourced from the author.*

Week 5 SEMG testing and self-assessment (gym)

**Clinical testing:** Tested abdominals at the gym, rectus abdominus and TVA. Walking activation, curl-ups, four-point TVA, abdominal brace, hanging leg raise, ski erg, air dyne bike, side bride, dead bug, supine hip extension flexed, prone hold, curl-ups, close grip pull down, matrix chest press, swiss ball hamstring curls, supine hip extensions, curl-ups, swiss ball crunches, reverse leg press, isometric abdominal brace, bike erg.

*Table 9: Sourced from the author.*
**Participants' self-reflection:** Moderate pain levels: Device extremely user-friendly: Used at the gym: Biofeedback extremely helpful.

**Participants' comments:** Really interesting week with testing in the gym, seeing what exercises work for my body.

| Table 10: Sourced from the author. |

**Week 6 SEMG testing and self-assessment (gym).**

**Clinical testing:** Tested rear deltoids and lats, then sensors 3 and 4 moved to TVA at the end. Testing is done at the gym. Isometric contractions, close grip lat pulldowns, seated low pulley row, ski erg, Cybex arc trainer, straight arm pulldowns, triceps rope pushdowns, bent over rows, spin bike seated, spin bike seated grind, spin bike climb, walking, ring rows, chin up, underhand lat pulldown, wide grip lat pulldown, air dyne bike, rower, four-point TVA to finish.

| Table 11: Sourced from the author. |

| Participants’ self-reflection: Moderate pain levels: Device extremely user-friendly: Used at the gym: Biofeedback extremely helpful. | Participant’s comment: Busy first week back at work. Discovered right lat lazy, with the biofeedback the right lat came to life with improved concentration. We discovered what exercise ignites the right lat, cable rows, ring rows, underhand pulldowns, and the rower. | WEMWBS 4 score 43 (probable depression). |

| Table 12: Sourced from the author. |

**Emerging themes from SEMG data and subject reflection:**

<table>
<thead>
<tr>
<th>The device very easy to use every time.</th>
<th>Noted daily time restrictions and impact that has on life stress.</th>
<th>Mother in hospital has cancer needing care, causing stress.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biofeedback extremely helpful, Improved muscle and movement awareness in daily activities.</td>
<td>Used device at home, in-car driving and at work.</td>
<td>A confirmed connection between stress levels, well-being, and pain present with this subject.</td>
</tr>
</tbody>
</table>
A greater understanding of the most effective concentric exercises for overall fitness at the gym.

Loved the biofeedback in the gym.

SEMG biofeedback did not improve well-being score in this subject.

Biofeedback did not improve mental well-being but improved pain.

Clear link between stress levels and pain

A 2% reduction on the Oswestry pain scale

External muscle groups activity improved; lower back activity dropped.

Isometric maximal muscle voluntary contractions went up.

Other lifestyle factors causing this subject pain.

**Table 13: Sourced from the author.**

**Insight:** Your data shows a correlation between stress levels and physical pain. Do you feel this is correct? Yes, I feel the stress has a major impact on my pain levels.

**Table 14: Sourced from the author.**

**SEMG upper Trapezius muscle pre vs post**

| Pre. Left UT MVC 44uv. Walk 20 s, (10) UV 22.7% | Post. Left UT MVC 299.9uv. Walk 20 s, (17.4) UV 5.8% |
| Pre. Right UT MVC 183.03uv. Walk (15.2) UV 8.3% | Post. Right UT MVC 249.3uv. Walk (13.4) UV 5.37% |

(Increase in MVC, walking % decreased activity during gait).

**Table 15: Sourced from the author.**

**SEMG analysis pre vs post Latissimus dorsi muscle pre vs post**

| Pre. L Lat MVC 44.9uv. Walk 20 s, (9.5) UV 21.15% | Post. L Lat MVC 59.4uv. Walk 20 s, (12.3) UV 20.70% |
| Pre. R Lat MVC 74.96uv. Walk (27.5) UV 36.68% | Post. R Lat MVC 63.56uv. Walk (21.2) UV 33.35% |

Comments on findings: (No significant change)

**Table 16: Sourced from the author.**
**SEMG analysis pre vs post Lower back muscles pre vs post**

<table>
<thead>
<tr>
<th></th>
<th>Pre. L LB MVC 23.33uv. Walk 20 s, (9.6) UV 41.14%</th>
<th>Post. L LB MVC 20.4uv. Walk 20 s, (7.9) UV 38.72%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre. R LB MVC 30.03uv. Walk (13.7) UV 45.21%</td>
<td>Post. R LB MVC 17.6uv. Walk (7.9) UV 44.88%</td>
</tr>
</tbody>
</table>

Comments: (Reduce MVC)

*Table 17: Sourced from the author.*

**SEMG analysis pre vs post glutes muscles pre vs post**

<table>
<thead>
<tr>
<th></th>
<th>Left Glute MVC 34.4uv. Walk 20 s, (6.1) UV 17.73%</th>
<th>Left Glute MVC 41.66uv. Walk 20 s, (4.7) UV 11.28%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right Glute MVC 26.83uv. Walk (9.3) UV 34.66%</td>
<td>Right Glute MVC 36.6uv. Walk (5.8) UV 15.84%</td>
</tr>
</tbody>
</table>

Comments: (Increased MVC, reduced walking %)

*Table 18: Sourced from the author.*

Many insights emerged as each SEMG biofeedback session went by; participants grew confident with their movements and understood SEMG biofeedback measured effort intensity. They understood the more significant their efforts while testing, the more critical personal discovery and knowledge benefit from the biofeedback. At the end of each SEMG session, I gave participants time to reflect and test any exercises or movements they wanted, intending to capture any emerging thoughts and enquiries of biofeedback they may find beneficial. This data extraction process from imindmap enabled precise analysis. This process highlighted Triangulation, allowing me to analyse the data from multiple perspectives, both quantitative and qualitative. Data analysis had to be accurate to gain insight into categories allowing themes to emerge.
CHAPTER 5: Research Findings

In the previous chapter, I described my methodology and styles that inform the change in my work-based practice towards a clinician specialising in SEMG biofeedback. This chapter describes the first steps to understand the need for a biofeedback modality in a clinical setting that benefits the client and clinician when assessing and treating clients with long-term spinal pain. The motivation for this research and this specific topic is considered in terms of a practical contextual application. The work is then evaluated in terms of the overall practice change process and its impact on my emergent professional practice framework. My findings have offered a somewhat different picture than my expectations.

From the research conducted in this investigation, I recognised the need for services we were not offering our clients at Body Synergy. This research leaves no doubt that better client screening, by implementing pain and well-being questionnaires is required. Regular SEMG analysis and movement coaching, combined with our current treatment practices, will result in better pain management outcomes for our clients.
How did the research impact the participants?

The benefits of SEMG biofeedback are immense and similar for each participant. Similarities emerged from the data, concluding that:

- SEMG biofeedback is extremely helpful for obtaining improved muscle awareness and confidence in movement. A participant said, "The result of the SEMG leads to more self-efficacy and self-motivation giving a sense of control".

- SEMG biofeedback can reduce low back pain for some people. A participant said, "So, enjoying life again after being SEMG tested. Back pain is not part of my life. If any pain comes back, I am reminded to turn my back off, stand properly, and it is gone. I would never have known this without SEMG."

- The SEMG device was extremely user friendly, encouraging its use and application. A participant said, "One can witness their success or improvement immediately from the biofeedback, which in return gives one confidence and motivation".

- Muscle outputs are subjective and only applicable to each person individually. An extreme variation in muscle outputs was seen between participants.

- Regular use of SEMG biofeedback improved isometric maximal voluntary muscle contractions, measurable from biofeedback data pre vs. post-analysis.

- A correlation between stress levels and feelings of well-being was discovered. A participant said, "I feel stress has a major impact on my pain levels".

- SEMG biofeedback accelerates learning time regarding improving postural modifications and exercise techniques. A participant said, "Learning takes place instantaneously and saves months or years of frustration".

- SEMG biofeedback provides hope and guidance to people with low back pain. A participant said, "SEMG showed me how to switch off back muscles. Was totally unaware that these muscles were working so hard causing my pain. I am rapt that now I know what to do to relieve my back pain".

- SEMG biofeedback is insightful and provides access to muscle function, which is unattainable through self-analysis. SEMG biofeedback provides clarity on muscle activity or inactivity, causing postural issues. A participant said, "It was interesting how bad my body posture and traps were driving".

It was insightful to witness the impact of improved muscle awareness and control for the participants. They grasped the biofeedback benefits and discovered daily activities impacting their muscle hyperactivity, and actions, to their surprise, were not. Improved muscular and movement awareness via SEMG biofeedback helps reduce exercise fear avoidance and enhances motivation to exercise.
Feedback from research participants was positive:

The following themes emerged from participant’s feedback:

**Self-awareness**

The SEMG biofeedback enhanced participants' self-awareness by encouraging them to slow down and think about how they felt their muscles engage when moving.

“Even with good self-awareness seeing the biofeedback increases the quality of the movement instantly, resulting in improved/higher muscle engagement. I can match my perception of what plus how much I do with what I actually do”.

**Muscle usage**

SEMG biofeedback shows how intensely muscles are working when exercising. Participants gained improved mind-muscle coordination and motivation to exercise.

*EMG made me understand by seeing the biofeedback about when the abdominals and lower abs are engaged with different exercises pulling or pushing. It increased my awareness of more than the main muscle group responsible for movement in coordination. I could feel how it increased power and speed accuracy.*

“Incredibly interesting to see the different exercises and my muscle reacting”.

“Excellent- I learned so much in this one session and got an appreciation of how my core is working well on particular exercises”.

**Understanding of body during exercise**

Participants were encouraged to exercise more intensely, from a deeper understanding of which exercises work best for them.

“The insight I gain from the testing accompanied by instruction/explanation seems unlimited. I understand much better what muscles are responsible for which movements and how much. e.g. that and how much the biceps contract when lifting arms”.

“Discovered right lat lazy, with the biofeedback the right lat came to life with improved concentration. We discovered what exercise ignites the right lat, cable rows, ring rows, underhand pulldowns and the rower”.

**Building confidence**

SEMG biofeedback encourages resilience by empowering recipients to have confidence in their body and muscles. Back pain can make some people feel physically fragile; SEMG biofeedback reduces this feeling by encouraging muscular control.

“Bloody interesting, you know why some things do not feel right”.

“Really interesting week with testing in the gym, seeing what exercises work for my body”.

52
“The adjustment to effective movement is small and subtle and made a huge difference. Not noticeable without the device”.

“Was surprised that my right leg was as good as my left as since my accident, I thought otherwise”.

Impact of everyday activities

Daily activities can be a source of pain for some individuals; SEMG biofeedback can expose these activities and encourage confidence in modified movement.

“It was interesting how bad my body posture and traps were driving”.

“Very helpful makes you more conscious of your body and positioning”.

I did my home yoga practice, breakfast, and I sat for three hours at the computer with EMG on. It was good to confirm that the yoga half-hour sequence was fine for my traps (apart from what you would expect with moving arms up). Also, time in front of the computer fine too.

“I wore it while driving the car to the gym, then later in the day while cooking. Both tasks were fine with the expected engagement of traps when reaching for things, as part of cooking”.

Pain management

SEMG biofeedback enhances muscle control, providing confidence in movement, assisting with pain reduction and pain management.

“Extremely pleased SEMG showed me how to switch off back muscles. I was unaware that these muscles were working so hard causing my pain. I am rapt that now I know what to do to relieve my back pain”.

“Great feedback about when I am using my neck. I need to be more aware of my right side when walking and carrying my bag. Interesting which exercises work well for me”.
My research question was:
Can long term musculoskeletal, spinal pain improve with movement education using SEMG biofeedback?

The answer to this question is complicated. Eight of the nine participants scored initially within the 0% to 20% rating of the Oswestry pain scale, indicating minimal disability:

Description: The patient can cope with most living activities. Usually, no treatment is indicated, apart from advice on sitting, lifting and exercise.

One participant rated in the following category of 21%-40%: moderate disability:

Description: The patient experiences more pain and difficulty with sitting, lifting, and standing. Travel and social life are more difficult, and they may be disabled from work. Personal care, sexual activity and sleeping are not grossly affected, and the patient can usually be managed by conservative means.

Post experiment, seven participants remained within the minimal disability rating. Included in the seven was the one participant who began in the moderate disability category. As explained previously, two participants developed pain outside of the study’s parameters, resulting in a significant percentage increased Oswestry pain scale score for both, moving them into the moderate disability category.

The Oswestry Pre vs post scores, the percentage change in pain levels, gym training sessions per participant throughout the four months of the study, and disability rating as follows:

<table>
<thead>
<tr>
<th>Participant</th>
<th>Pre score</th>
<th>Post score</th>
<th>Change %</th>
<th>Workouts</th>
<th>Disability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2%</td>
<td>10%</td>
<td>8% increase</td>
<td>21</td>
<td>minimal</td>
</tr>
<tr>
<td>B</td>
<td>20%</td>
<td>18%</td>
<td>2% decrease</td>
<td>22</td>
<td>minimal</td>
</tr>
<tr>
<td>C</td>
<td>8%</td>
<td>24%</td>
<td>16% increase</td>
<td>61</td>
<td>moderate</td>
</tr>
<tr>
<td>D</td>
<td>20%</td>
<td>28%</td>
<td>8% increase</td>
<td>35</td>
<td>moderate</td>
</tr>
<tr>
<td>E</td>
<td>26%</td>
<td>8%</td>
<td>18% decrease</td>
<td>34</td>
<td>minimal</td>
</tr>
<tr>
<td>F</td>
<td>12%</td>
<td>12%</td>
<td>0% change</td>
<td>19</td>
<td>minimal</td>
</tr>
<tr>
<td>G</td>
<td>10%</td>
<td>6%</td>
<td>4% decrease</td>
<td>50</td>
<td>minimal</td>
</tr>
<tr>
<td>H</td>
<td>4%</td>
<td>6%</td>
<td>2% increase</td>
<td>17</td>
<td>minimal</td>
</tr>
<tr>
<td>I</td>
<td>8%</td>
<td>2%</td>
<td>6% decrease</td>
<td>67</td>
<td>minimal</td>
</tr>
</tbody>
</table>

Table 19: Sourced from the author.

Essential observations from two participants:

Participant C – 8% to 24% = 16 % increase in pain caused by arthritic right hip degeneration. Participant quoted, “my pain is all hip-related”. (21%-40%: moderate disability). Observation: Pain did not reduce exercise intensity. Even though the participant was in pain, they had 61 gym sessions and exercised intensely during SEMG biofeedback sessions.

Participant D – 20% to 28% = 8% increase in pain was due to knee and wrist pain. Participant quoted, “my knee and wrist have been sore for around six weeks. Wrist is feeling better, knee still gives me pain walking upstairs”. (21%-40%: moderate disability). Observation: Pain did
not reduce exercise intensity. Although the participant was in pain, they had 35 gym sessions and exercised intensely during SEMG biofeedback sessions.

Minimal to moderate levels of back or musculoskeletal pain does not stop motivated people from exercising regularly. Tissue load tolerance levels when exercising are subjective to the individual; one can exercise five times per week and feel less pain; one can exercise five times per week and feel more pain. For some individuals, less is more.

The research indicated that levels of spinal pain could fluctuate daily within the minimal disability percentage parameters of the Oswestry pain scale for low back pain. I had not considered this before the experiment, knowing this information will enhance my professional practice framework.

SEMG biofeedback is a valuable tool to assist clinicians from many fields in the musculoskeletal area, combined with scales to measure pain and well-being. Not having access to a user-friendly SEMG device has been a limiting factor for its inclusion in clinical consultations and treatment plans. This positive participant feedback has identified a new service that can be implemented within my professional practice framework. On-going SEMG biofeedback sessions are essential for the continual progression of pain reduction for clients at Body Synergy. The motivation, belief and encouragement obtained from these sessions are necessary moving forward and something I overlooked as the clinic practitioner. A participant said,

> With the EMG feedback, I am surprised with the amount of control I am able to sustain. This gives me much more confidence to progress in my exercise. It reduces my fear to move correctly without causing pain. It improves my understanding of the relationship between awareness, control and pain and the influence of stress.

Monthly SEMG biofeedback sessions may encourage clients to exercise longer and prevent them from falling away from regular exercise.

The implementation of SEMG biofeedback during client/patient consultations and physical assessments as part of an ongoing rehabilitative motivation tool for clinicians fits well with Lin et al., (2020). Their objective was to identify high-quality care recommendations for the most common musculoskeletal conditions encountered by clinicians.

They established and put forward 11 recommendations for clinical practice guidelines. I believe SEMG biofeedback fits well with four of their 11 recommendations and would benefit both clinician and patient. I discuss the four here; these include:

"5. Undertake a physical examination, which could include neurological screening tests, assessment of mobility and/or muscle strength.

6. Patient progress should be evaluated including the use of outcome measures.

7. Provide patients with education/information about their condition and management options.
8. Provide management addressing physical activity and/or Exercise" (p.6).

MrEMG data example: Addressing recommendation number five. “Undertake a physical examination, which could include neurological screening tests, assessment of mobility and/or muscle strength”. This biofeedback system can be used effectively for physical examination, addressing muscle function, muscle hyperactivity and inactivity.

*Image 52: Sourced from the author*
MrEMG data example: Addressing recommendation number six, “Patient progress should be evaluated including the use of outcome measures”. SEMG biofeedback enables outcome measures to be easily measured, as shown in this example. MrEMG can evaluate patient progress from one consultation to their next using the biofeedback electromyograph recordings.

*Image 53: Sourced from the author*
MrEMG data example: Addressing recommendation number 7. “Provide patients with education/information about their condition and management options”. MrEMG being used to measure the flexion/relaxation phenomenon test of lumbar spinal muscles. MrEMG can provide immediate biofeedback on the flexion/relaxation phenomenon. As described by Nougarou et al., (2012), the flexion relaxation phenomenon is the silence or relaxing of the lumbar paraspinal muscles when a person flexes their trunk, such as bending forward to touch their toes. In patients with chronic low back pain, this relaxation of the lumbar back muscles is typically absent.

Image 54: Sourced from the author
MrEMG data example: Addressing recommendation number 8. “Provide management addressing physical activity and/or Exercise”. MrEMG being used to provide patient management by addressing feedback on the effort of physical activity. This biofeedback is very motivating to recipients.

Image 55: Sourced from the author

The examples shown show how MrEMG can enhance the clinical experience for the clinician and patients. Clinicians and patients can benefit from this technology through clear, precise feedback of muscle excitement.
My research aimed to investigate the following information:

- **Understand which SEMG biofeedback modalities work most effectively for our clients when rehabilitating spinal pain.**

All participants found the SEMG biofeedback extremely helpful, as recorded from the self-reflection questionnaires obtained at the end of each recording session. Of the 54 sessions undertaken, all participants scored the biofeedback to be “extremely helpful”. The research showed SEMG biofeedback is best performed in a clinical environment by a trained clinician efficient in musculoskeletal assessment and movement coaching. For example, a Physiotherapist, Osteopath, Chiropractor, Clinician of occupational health or personal rehabilitative trainer. One must understand muscle anatomy, sensor placement on the skin, skin preparation, data recording, data interpretation and effective communication of the data to be transcribed to the recipient for this process to be fully effective.

The answer to this question came from the initial commencement of participants using the SEMG device at home and to work to perform their biofeedback. 50% of the participants were confident using technology, and 50% were not. I had no way of knowing what tests each participant had performed or how long they used the device. It was not working. Some participants were good at using the App and saving their data; others were not. One participant took the device home for three days two times and never used it due to personal family commitments. Three EMG sensors were also damaged early on; this slowed my research as I had to have new sensors produced. The unique engagement early on with the device by participants was not as I hoped. I took the tech capabilities using the device for granted, which impacted my research. I had to reflect and Segway, establishing a more effective, efficient, and clinical testing protocol moving forward. This action enhanced the research quality, and the data gathered was more beneficial to the participants and me, the researcher. The benefit to the participants was immense, concluding rehabilitation using SEMG biofeedback needs to be done by a clinician, guiding the process of testing, and providing clear feedback in a favourable clinical setting. Appointments were made for all participants to have their testing done at Body Synergy; not one of the 45 appointments were missed.

- **Find which SEMG processes make clients feel comfortable within their bodies.**

All participants were very comfortable with the testing protocols. The discovery of information via biofeedback overshadowed any feelings of discomfort. The application of sensors on the skin, underclothing ensures comfort. The plastic the new sensors are made from contains antistatic qualities; this prevents artifacts from clothing by reducing friction on the sensor and enables participants to remain fully clothed during testing.
Discover which biofeedback modalities cause clients the least stress, physically and mentally.

I investigated this with the use of the WEMWBS well-being questionnaire. I experienced an increased awareness of the level of depression of my participants when they first completed the questionnaire at the beginning of this project. Having known these participants as customers for a minimum of three years, I had no idea of the internal personal battles some faced. The use of the SEMG device at work and home for three participants caused stress. The sensors not syncing to the iPad App and not transmitting EMG signal were problematic. Our prototype stickers that held the sensor to the skin could give way due to clothing rubbing on the sensor case; body sweat reduces the stickers’ adhesive qualities. The 3d printed shells of the early prototypes also created artifacts in the data when clothing rubbed on the sensor, making data interpretation difficult for participants.

The WEMWBS well-being scores pre versus post from participants, definitions, and change were as follows:

<table>
<thead>
<tr>
<th>Participant</th>
<th>Pre</th>
<th>Definition</th>
<th>Post</th>
<th>Definition</th>
<th>Well-being</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>57</td>
<td>Average</td>
<td>68</td>
<td>High</td>
<td>Increase</td>
</tr>
<tr>
<td>B</td>
<td>45</td>
<td>Average</td>
<td>43</td>
<td>Probable depression</td>
<td>Decrease</td>
</tr>
<tr>
<td>C</td>
<td>51</td>
<td>Average</td>
<td>54</td>
<td>Average</td>
<td>Increase</td>
</tr>
<tr>
<td>D</td>
<td>50</td>
<td>Average</td>
<td>48</td>
<td>Average</td>
<td>Decrease</td>
</tr>
<tr>
<td>E</td>
<td>48</td>
<td>Average</td>
<td>53</td>
<td>Average</td>
<td>Increase</td>
</tr>
<tr>
<td>F</td>
<td>42</td>
<td>Possible depression</td>
<td>51</td>
<td>Average</td>
<td>Increase</td>
</tr>
<tr>
<td>G</td>
<td>58</td>
<td>Average</td>
<td>50</td>
<td>Average</td>
<td>Decrease</td>
</tr>
<tr>
<td>H</td>
<td>65</td>
<td>High</td>
<td>61</td>
<td>High</td>
<td>Decrease</td>
</tr>
<tr>
<td>I</td>
<td>52</td>
<td>Average</td>
<td>53</td>
<td>Average</td>
<td>Increase</td>
</tr>
</tbody>
</table>

*Table 20: Sourced from the author.*

Mental health was consistent throughout the study for participants. Participant A and F had improved mental health, and participant B had family health issues impacting their mental well-being levels. Most changes were within the parameters of the well-being scale the participant stated within.

There was a direct correlation between levels of mental stress during the study and pain for some participants.

Comments included:

“Tough week emotionally, great to be able to check-in with what my body is doing”.

“Another tough week, family illness, conflicting demands on time”.

“Yes, I feel the stress has a major impact on my pain levels”.

61
“There is a clear correlation between my anxiety caused by the situation at my work and my pain”.

I discovered that mental well-being could fluctuate daily, life can cause stress and stress can influence pain levels.

I was shocked that only one of my participants scored with high mental well-being. I thought they all were of increased mental well-being. I could not have been more wrong. What learning this was. Several participants maintained a constant level of mental well-being; others went up and down, depending on what was happening in their personal lives.

A clear correlation between stress levels and pain emerged—the participants who suffered anxiety due to stress recorded increased pain levels when their stress levels increased.

- Understand physiological trigger complexities seen through SEMG biofeedback underlying musculoskeletal pain, such as hot flushes, stress, anxiety, past experiences, and how they present themselves during SEMG biofeedback sessions.

This question arose from me using another model of SEMG for the past six years, a Delsys Trigno wireless system. I now understand the biofeedback activity I was seeing with this device and thought to be high anxiety levels, to be a skin contact and an electrode issue, with the electrodes reacting to sweat particles on the skin. Using the MrEMG device, with more excellent quality electrodes, medical-grade stickers, and signal filters, I never witnessed physiological triggers on the biofeedback. MrEMG sensors have a different layout and better filtering and dynamic range. As Sperlich et al., (2018) point out, to take caution in interpreting short bursts of muscle excitation via SEMG biofeedback, it is challenging to know what these signals represent.

A correlation was seen between stress levels and pain, as discussed earlier. No participant throughout the study mentioned hormonal changes or feelings of overheating during data gathering. No participants described or showed any stress seeing their SEMG biofeedback. Of the 54 self-reflection questionnaires completed, all participants marked the biofeedback as extremely helpful and the device extremely user friendly. I concluded from these findings that feelings of anxiety or stress during SEMG biofeedback need to be assessed and interpreted cautiously.

- Understand the impact of back pain rehabilitation in a motivating, supportive, caring environment.

The power of clear communication via SEMG biofeedback during consultations impacted the participant’s experience and recollection. One participant said, “Great to figure out what needs to be done at the gym to sort out issues caused by general work activities”. In a study by Kessels (2003), he describes the difficulty for patients to remember what is discussed from a clinical setting. He recognises that almost 50% of the information patients provided is not retained correctly. He offers three reasons the forgetful have difficulty retaining information. These include the clinician using medical, technical jargon to explain information; secondly, the recipient or patient having low levels of education or preconceived expectations before
consultation; thirdly, the delivery of information not in a format most suited to the recipient, such as spoken or written formats.

My research has identified the importance of a professional, welcoming, and caring environment that stimulates the client experience. The feeling of having something done as a participant, witnessing smart-looking sensors and an iPad with a bright biofeedback display, as well as someone taking time out to help, are all factors that can make one’s experience better.

A qualitative research study conducted by Slade et al., (2009) titled ‘Listen to me, tell me: had the objective of investigating exercise programs’ experience for people with non-specific back pain. They measured exercise participation and engagement from various clinicians, including Physiotherapists, Yoga instructors, medical specialists, and general practitioners. The study consisted of three different groups of participants; adults aged more than 18 years. The results of this investigation indicated there is a preference for partnership in care. They concluded patients with back pain desire to have an active role in their rehabilitation. The participants felt frustrated with the service and level of care they received during the research. They were angry and frustrated at not being listened to, disappointed at the level of information provided, and disappointed with clinician explanations regarding their back-pain conditions. They also complained of not being given credit for knowing their own bodies. During the data gathering process of my research, I ensured all participants had a voice. I listened carefully to them and focused intently on providing a positive, caring experience.
How did the research process impact me, the clinician?

Reflecting, I understood from the initial testing that SEMG analysis and biofeedback needs to be conducted by a clinician. Accuracy of sensor placement and interpretation of the data is essential for positive outcomes. One participant reported,

*In order to be effective, the results from the testing must be accompanied by explanation, interpretation, feedback, and instruction by a trained practitioner to enable the person to make the necessary and correct adjustments. They can witness their success or improvement immediately from the biofeedback, which in return gives them confidence and motivation.*

I was surprised at the low to average level of the mental well-being of the participants. I expected and did discover the impact of how mental stress contributes to pain. This new knowledge created a professional practice transformation for me. In 32 years as a clinician, I have never measured mental well-being; this has been an error of judgment. There will have been clients who sought my help, who suffered from poor mental health contributing to back pain, for which I did not screen. Because of this error of judgment, they did not get the assistance from my clinic they needed and did not get better. In the future, I will implement a mental well-being scale as part of our customer management processes to ensure we are catering and responding appropriately to mental health needs as part of a holistic approach to client’s programmes.

A greater understanding of pain emerged from the data. Individuals who suffer back pain live with some discomfort on most days. Pain levels are personal to the individual; we do not know what someone else's pain level is. An individual may experience subjectively low pain levels; however, the pain level is immense to them. This new knowledge created a practice framework transformation. Moving forward, I will have all clients complete Oswestry Low Back Pain questionnaires to gain insight into how levels of pain are personal to them. I have been oblivious to measuring pain throughout my career.

Furthermore, I had not considered my participants’ mean age (54 years), youngest 27 years, the oldest 64 years, and the implications. I never recognised the impact pathological pain could have during the research period, which would affect my project's outcome. Two participants developed musculoskeletal problems, one an arthritic hip joint and another a wrist and knee complaint. Neither commented on their symptoms until the end of the research data gathering process. I was off-guard, reflecting; this was another professional practice transformation. I needed to include a brief discussion post each SEMG testing regarding their physical health and identify any musculoskeletal issues outside the study's parameters.
CHAPTER 6: Critical reflective commentary

As an introduction to this section, I review the insights into SEMG biofeedback movement education to treat long term musculoskeletal, spinal pain that has emerged during this work. Each stage is explored in terms of the changes this research will have on my professional practice.

So, what did I find out?

Everyday life and stress have an impact on the human musculoskeletal system. Spinal muscles can become hyperactive and overloaded, and this excessive muscle activity can contribute to pain, physical and mental stress. Large muscle groups such as the Quadriceps, spinal muscles and Gluteal muscles can atrophy over time and weaken, forcing pressure on the spinal tissues. Tasks such as preparing food in the kitchen, computer use, housework, gardening and poor exercise techniques can contribute to spinal muscle stress.

SEMG biofeedback is a powerful tool; it opens the user's eyes to how their muscles react to stress and exposes movements in everyday life or the gym contributing to pain levels. SEMG can be extremely user friendly; it makes the user conscious of their body and positioning. SEMG biofeedback is empowering to both clinicians and patients and bridges clinician/patient communication through visual feedback. SEMG biofeedback can encourage people with back pain to exercise. If an individual's muscles outputs are low, those muscles are likely not strong enough to provide efficient support for their musculoskeletal structure. The only way to improve one's muscles output levels is to exercise. SEMG is a useful measuring tool for reading muscle excitement. SEMG biofeedback can have an immediate positive impact on reducing spinal pain. The visual calming of spinal muscle hyperactivity makes some recipients feel better quickly.

This experiment showed a gap between exercise rehabilitation in a facility and guided rehabilitation using SEMG, which needs to be filled. Suppose individuals with back pain are diligent in their attendance weekly to a clinic and still have some residue pain. In that case, the pain may be caused by muscle overload from poor exercise techniques or stress from an activity at home or work they are unaware of.

Mental stress from the worry of which movements or activities are causing pain is a factor SEMG biofeedback can extinguish. Some participants were empowered to discover their spinal muscles were calm, driving a car, using the computer, eating, and performing exercise routines at the gym and home. For other participants, these movement habits were not so good; the biofeedback encouraged new learning and improved movement confidence.

It is usual for people with a history of low back pain to experience mild discomfort daily. Very rarely is their pain completely gone. Understanding this as a clinician is very important. It is essential information that needs to be conveyed to individuals with back pain, emphasizing the importance of regular strength training as a treatment option.

There is a direct correlation between mental well-being and pain. When practitioners assist individuals with long term pain, addressing the whole person from a mental well-being standpoint and physical standpoint is more beneficial than physical alone.
During the early phase of my study, I discussed my research's purpose and the motivations based on my previous experiences. There is no doubt that my personal experience as a clinician with a desire for innovative technologies formed my current assumptions that have inevitably set up how I have worked in this area. Insight is enlightening and offers me the opportunity to review my prior assumptions with the goal of re-framing my way of working in the musculoskeletal space.

Key learnings, at this point, have developed to reflect my research findings and then further informed by the literature. This guides me to recognise that SEMG biofeedback is involved; however, it is beneficial to people suffering long-term back pain. Successful welcoming of such technologies into clinical practices such as Physiotherapy, Osteopathic, Chiropractic and Occupational Health will require an introduction. MrEMG has developed with the clinician forefront, quick and easy to use with powerful display and data storage. Applying these critical learnings to my research findings collectively enable me to propose a new client management treatment plan for Body Synergy and confidence to encourage clinicians to use the MrEMG device.

Exploring the following essential suggestions for Body Synergy and MrEMG:

- Customers fill out an Oswestry Low Back Pain Questionnaire at initial consultations and at the start of every month.
- Customers complete a well-being questionnaire at initial consultations and at the start of every month.
- SEMG biofeedback consultations are available for clients to encourage exercise confidence and prevent customers from falling away from regular exercise.
- Provide MrEMG device demonstrations to clinicians.
- Present SEMG biofeedback diversity to encourage use in 15-minute clinical consultations.
- Create and edubits qualification with Otago Polytechnic to ensure consistent MrEMG product knowledge use.

Chapter 6 explained specific findings. I have referenced the current literature throughout this thesis and offered a brief commentary at each chapter's end. Those findings represent my overall analysis. I have provided quotes and observations from the project where applicable; the following content tells the story that eventually unfolded for me during my research discovery and informed future professional practice recommendations.

This chapter has introduced my practitioner project's background and development as a professional leader in the exercise rehabilitation space. I have briefly described my findings in the practitioner project that influence my future practice framework as a practitioner treating long-term musculoskeletal and spinal pain. My research findings indicate SEMG biofeedback as a valuable tool in discovering daily activities or gym activities that contribute to an individual's long-term spinal pain. My results indicate specific use of SEMG biofeedback is most suited to clinical environments, where it can enhance the current practice methodologies of Physiotherapy, Chiropractic, and Osteopathy.
Described in my introduction chapter were some clear goals for undertaking this professional practice research. My first intention was the dream of making a positive difference in the world by fulfilling my desire to be an innovator within the musculoskeletal industry. I wanted to expand my practice framework, develop new skills, and obtain more profound knowledge. Finally, I had to figure out how to encourage practitioners to embrace the latest SEMG science into their practice.

This research produces the following recommendations for further investigation:

Based on my findings in chapter 6, the definitions for acute and chronic back pain need to be revised. My research showed individuals could suffer from a minimal disability level of back pain that can go on for years. The pain will not stop them from exercising or enjoying everyday activities. If this pain has been present for more than three months with current recommendations, it is termed chronic; this research indicates this is incorrect. I recommend the definitions of back pain be revised as follows:

**Acute back pain** - is when it causes severe symptoms, including sciatic nerve pain in buttocks or legs, pain on coughing or sneezing, inability to work and sit, or drive a vehicle. Symptoms may last from a few days to four weeks.

**Chronic back pain** – Severe pain, lasting more than four weeks, neurological symptoms affect buttocks or legs. Nerve pain is present below the knee. Symptoms are not responding to medications or conservative treatments, possible pathology present requiring imaging investigations and Orthopaedic assessment immediately.

**Moderate back pain** – low-level backache present, limited mobility throughout the day and pain standing from sitting. Mild sciatic nerve symptoms above the knee, which reduce with exercise, can work performing light duties and sit for up to 30 minutes without pain. Symptoms felt most days.

**Minimal back pain** – low-level backache present or limited mobility early morning or nighttime. Pain goes away with movement and exercise, can work full-time performing all duties. Some backache symptoms when sitting for more than 45 minutes. Some days every week without back pain.

My research suggests a place for a SEMG biofeedback modality in assessing and treating individuals who suffer minimal to moderate levels of back pain. Recipients find biofeedback motivating and helpful. SEMG biofeedback may reduce pain for some people with back pain by encouraging them to exercise and implement movement modifications.

The research findings' richness suggests an analysis of mental well-being and back pain levels at the initial consultation and as part of a rehabilitative plan beneficial. Empowering individuals with feedback can be helpful as the whole person is supported and not backache alone.

This chapter reviews SEMG biofeedback findings to improve movement education and its impact on long-term musculoskeletal, spinal pain. My research has also contributed to my
clinical framework as a practitioner. I have developed a deeper understanding of how long-term back pain affects people in different ways, physically and emotionally.
CHAPTER 7: Reflective Summary

My professional practice learning outcomes.

1. **Research competency** - as an outcome of the learning project.
   All participants completed the project. I performed 63 SEMG data assessments on participants in 18 weeks, collecting much qualitative and quantitative data. Participants enjoyed the research process, obtaining personal insights into back pain, mental well-being and SEMG biofeedback. Research does not always go as planned when humans are involved. Participants did not carry the same passion for my project as I. Urgency and competency from participants is not always present, causing me to intervene and change SEMG testing to the clinical setting.

2. **Analysis competency** - as an outcome of conducting the research process.
   I have learnt to analyse data objectively without bias. I found richness within the analysis process using multiple methods to extrapolate themes using MrEMG App software, mind mapping and colour coding.

3. **Improved practice** – A leading expert in the use of SEMG.
   I am now an expert in SEMG. I understand the processes of sensor manufacture, design, and implementation. I have worked tirelessly with a specialised team to create a SEMG device of high quality. Through this process, I am self-motivated, well planned, focused, intent and goal orientated.

4. **Enhanced understanding** - of client needs and the interactions between the physical and emotional.
   I am a better clinician—a greater depth of understanding of the complexities of human behaviour. Strategies now implemented to provide support and understanding clients pain levels and emotional well-being.

5. **Development** - of a new rehabilitation model.
   This project has evolved me as a clinician, a business owner, and an employer. Body Synergy has implemented a new 13-week Rehabilitation Plan of Well-Being for clients with spinal pain. Our goal is to address the whole person, not just back pain. We provide regular SEMG biofeedback from initial consultation and ongoing Oswestry pain scale analysis and well-being monitoring for mental health throughout the membership term.
CONCLUSION:
In this thesis, I have described developing a work project using SEMG biofeedback to help long term musculoskeletal, spinal pain through improved movement education in the context of my professional practice as a manual and movement clinician.

These conclusions are reached in the context of established literature and practice, reflecting on my learnings, and validating my findings.

My professional practice framework is a manual and movement clinician leading a rehabilitative clinic, helping people with pain. SEMG biofeedback is an intrinsic component of this practice. My aim in completing this work was to develop a deeper understanding of how SEMG biofeedback and mental well-being can influence back pain. My application of this new knowledge serves three purposes: enhanced therapeutic knowledge of pain and mental well-being for my clients. Understanding how SEMG biofeedback helps people with back pain and intrinsic knowledge of SEMG enhances me as the clinician to take MrEMG to the musculoskeletal industry.

During this work, I have read extensively and searched to identify literature that supports my findings; I have also identified shortfalls in the literature. I have noted the evolving changes throughout this project; I have commented on my research’s limitations and strengths.

There is room for further exploration of this study. Individuals suffering from long-term musculoskeletal, spinal pain require assistance and guidance both physically and mentally in supportive environments. Back pain can be debilitating for some sufferers, so devices such as SEMG can provide a platform to assist in educating those in distress on how to regain confidence in movement again. SEMG biofeedback is a win/win for all involved, clinicians and patients. SEMG enables direct assessment of muscle function, which is impossible through palpation and observation.
REFERENCES:


