Prevalence of Breathing Pattern Disorders: A Dissertation of Clinical Practice Improvement

A Dissertation

Presented in Partial Fulfillment of the Requirements for the

Degree of Doctor of Athletic Training

with a

Major in Athletic Training

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College of Graduate Studies

University of Idaho

by

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Authorization to Submit Dissertation

This Dissertation of Jena Hansen-Honeycutt, submitted for the degree of Doctor of Athletic Training with a Major in Athletic Training and titled "Prevalence of Breathing Pattern Disorders: A Dissertation of Clinical Practice Improvement," has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

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Abstract

A dissertation of clinical practice improvement (DoCPI) is a comprehensive document that will display the progress towards scholarly and advanced clinical practice. The DoCPI will include a narrative summary of the components of the document, three original manuscripts, and a culminating applied clinical research manuscript. The components highlight reflection, ability to collect and analyze evidence, and advanced knowledge in a focus area of breathing pattern disorders. This dissertation was essential to my growth as a scholar and clinician.

Acknowledgements

To my teachers, especially the remarkable Dr. Alan Nasypany and Dr. Jeffery Seegmiller, none of my successes would exist if I had not been fortunate enough to meet you: You changed my life, pushed me, encouraged me, and I will never forget it.

A special thank you to Dr. Russell Baker for your insight and feedback during this journey, it was instrumental to my success. Thank you Dr. Mark Van Riper for your support, knowledge, and discussions regarding patient care, I was able to shape and clarify my thoughts due to your feedback. Thank you Dr. Maria Perri for your insight on breathing, your knowledge is outstanding and I have learned so much from your expertise. I cannot thank my colleagues and classmates enough; our conversations and your feedback on my ideas were crucial to my development. I am forever grateful to all of those who have assisted in my growth and development during this journey.

Dedication

To my parents for their love, patience, and endless support. I am grateful for the opportunities you have provided me with to reach my goals and pursue my dreams. To my Grandma Nancy, not once did you doubt my abilities, thank you for believing in me every step of the way. To all my family and friends, thank you for your understanding and encouragement in my moments of doubt. Your friendship and support has enriched my life.

A thank you to my patients, your willingness to be open to new theories and techniques allowed me to learn. Without you, I would have not been able to start this journey and while you may not be aware, you made a difference in my life and I must say thank you.

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Chapter 1

Narrative Summary

Academic doctoral degrees are generally designed to prepare students for work in academia or research, the post-professional doctoral degree was initially developed to create an expert in the field or workplace. The expertise is demonstrated by a clinician's ability to transfer theory to clinical practice.[1] For many athletic trainers (AT), one way to continue their education is to complete an academic degree (e.g., PhD); however, the differentiation between academic and post-professional doctoral degrees is not always recognized and aligned with the reasoning for an individual's pursuit of a doctoral degree.[2] Due to my exposure to the University of Idaho's faculty while completing my undergraduate education, I was aware of variances between graduate education options. After graduating, I decided to pursue a post-professional masters degree in AT, but after completion, I still had a desire to continue my formal learning. Returning to the University of Idaho was an easy decision, as it was the first institution to offer a post-professional doctorate in athletic training (Doctor of Athletic Training, or DAT), with a clinical focus on developing athletic training-related skills.

The DAT program's philosophy and didactic course work aligned with my interests by placing an emphasis on developing AT clinical skills. Specifically the DAT's dissertation is designed to highlight and encourage progress toward advanced practice in AT. A professional practice dissertation is typically required for individuals who are completing a doctorate that is focused on developing advanced practice in the field or workplaces and on solving problems in professional practice.[2] The DAT requires students to complete a Dissertation of Clinical Practice Improvement (DoCPI) and is the their version of the professional practice dissertation.

There is a need for post-professional education to develop advanced practice in athletic training. In 2007, Jensen et al.[3] suggested that there are five components to developing clinical expertise: clinical reasoning, reflection, skill acquisition, knowledge, and professional affiliation or mentorship.[4] The components of clinical expertise are the foundation of the didactic coursework and DoCPI in the DAT program. Through a guided professional mentorship, students cultivate clinical expertise and move along the path toward advanced practice. Each chapter of the DoCPI covers many of the components of expertise in detail and allows the student to display evidence of his or her progress toward becoming an athletic trainer with advanced practice skills in a specific area while also producing scholarly work. Chapter 1 is my perspective on the DAT and the components necessary to develop into an advanced-practice clinician.

Transitioning from Novice to Expert

Unless the characteristics that separate a novice and an expert are identified, the process for becoming an expert will remain complicated, as there is no clear path for such. In athletic training, "time" spent in practice is generally used as the defining characteristic of advanced clinical practice and expertise.[5] Nevertheless, Benner, a clinical reasoning expert in the nursing profession, suggested that time is most often inversely related to advanced clinical practice.[6,7] During the first semester of the DAT program, I recognized that there were many steps necessary for me to take to become an expert in my field. Although I knew there would be challenges, I had the opportunity to choose to progress toward advanced practice.

Benner and Unsworth proposed a model (Table 1.1) for nurses and occupational therapists that identify key characteristics of practitioners from the novice level to that of the expert.[7,8] These characteristics include the ability to clinically reason as well as the ability to utilize and evaluate research to make medical treatment decisions for patients.[7,8] Athletic trainers could easily adopt the Benner-Unsworth model, because it shows the transition from novice to expert in terms of developed characteristics rather than time spent in the field. Health care professionals may move through five stages: [Novice, Advanced Beginner, Competent, Proficient (Advanced Practice), Expert] (Table 1.1). Skill acquisition, education, and experience all seem to play a role in the development from novice to expert; however, clinical reasoning is thought to easily distinguish a novice from an expert.[8–11] Clinical reasoning is defined as “a multi-factorial and complex mental process inclusive of multiple methods for diagnosis formulation; each with their own strengths, limitations, and context under study.”[10] Further, Benner suggests that a clinician’s skills will not improve if he or she cannot critically reflect on outcomes of interventions and allow for insight on what is effective and/or no longer effective for patients.[6]

Table 1.1. Stages and Key Characteristics of Clinician Skills, From Novice to Expert

Stage	Key Characteristics (based on Unsworth, 2001) [7,8,16]
1. Novice	• Has knowledge of theories, principles and specific patient attributes and is usually rigid in their application • Doesn't have experience in the clinical situations in which he or she will be involved
2. Advanced Beginner	• May begin to modify rules, principles, and theories so that they are adapted to specific situations; however, since AT has to concentrate on remembering the rules, he or she is less flexible in the application of those rules
3. Competent	• Has sufficient clinical experience to identify recurring themes and the information on which reasoning is based; however, may have difficulty acting in more unusual circumstances • Lacks the speed and flexibility of the proficient clinician
4. Proficient (Advanced Practice)	• Is flexible and able to alter treatment plans as needed • Has a clear understanding of the client's whole situation and has a perception of the situation that is based on experience rather than deliberation
5. Expert	• Anticipates and recognizes client strengths and weaknesses quickly, based on experiences with other clients • Does not need to rely on rules and guidelines to take appropriate action; rather, he or she has an intuitive grasp of the situation • Frequently finds it difficult to explain aforementioned intuition

The reflection component of student development was strongly emphasized in the DAT program. To understand my process for making patient care-related decisions, it was essential for me to explore my own clinical reasoning through the examination of patient outcomes and through self-reflection. Throughout my time in the DAT program, I was able to reflect on the knowledge, philosophies, and habits that I possessed that may have limited my ability to develop into the expert athletic trainer I was striving to become. The DAT faculty philosophically understands the stages of developing health care professionals; therefore, the faculty provided coursework to guide the student toward advanced practice.

Trends in Current Healthcare Research Concepts

In the early 1990s, there was a push for evidence-based medicine (EBM) to be incorporated into the practice of health care professionals.[12] Currently, EBM has various definitions. Sackett et al. defined it as, "the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients."[12] Recently, the definition of *EBM* has transitioned into the use of a "research-only model";[13] however this doesn't account for the many therapeutic interventions that provide pain relief to patients that have received limited scientific research through systematic reviews and randomized, controlled trials. This, in turn, led to the development of the term, *evidence-based practice* (EBP), in which emphasis is placed on the utilization of the best evidence available to provide quality patient care. The emphasis on EBP assisted me in making clinical decisions that previously seemed unprecedented due to lack of randomized controlled trial research.

The DAT program promotes the use of EBP and development of practice-based evidence (PBE), conducted through action research (AR).[14,15] Commonly, *action research* is defined as formally solving problems in one's clinical practice while incorporating research, intervention, data collection, data analysis, and reflection.[1] In action research, there is a focus on patient-centered care, which is shown through the collecting of patient-oriented evidence and disease-oriented evidence. The evidence is then used to guide a clinician's decision-making process and improve quality of patient care. Action research is a form of producing PBE in which the clinician uses patient outcomes to provide and publish data on real life phenomena. Furthermore, action research aids in producing clinical or translational research, which uses the best of EBP and PBE to ensure quality patient care.[1,13] Clinicians need to incorporate a blend of EBP and PBE into their clinical practice. For example, including basic science research and patient outcomes to make clinical decisions regarding patient care.

In Chapter 3 and 4, PBE is presented through patient outcomes, found in real-life clinical practice, which were documented through action research. These outcomes, some of which show success in the use of certain treatments, provide information that can support the use of these interventions and evolve theories. Basic science research can then add to the body of knowledge to substantiate or refute the use of various interventions that previously had limited research. The use of action research is thought to be crucial to filling the need for research to support EBP through producing PBE, which may be foundational to advanced clinical practice.

The use of action research in my clinical practice was vital to improving my ability to reflect on clinical decisions and measure patients' progress. Recognizing I could play a direct role in collecting data and publishing patient cases that could redirect and drive research was very inspiring. By incorporating action research I was able to efficiently support my clinical decisions. One of the most notable changes I saw in myself was how I viewed my patients. In a world where patient care takes into account the many uncontrollable factors influencing a patient's condition and does not occur in an isolated laboratory, the use of patient outcomes is essential to treating each patient as an individual. Utilizing patient-oriented and disease-oriented outcome measures facilitated my understanding of the many factors that influence and contribute to a patient's experience of pain. In my clinical practice, I realized how essential a balanced nervous system was to a patient's healing process. Specifically, I learned of the effect that stress had on a patient's ability to heal and manage musculoskeletal pain.

In action research and in an effort to understand the pattern of a specific condition, all of the factors that may contribute to a patient's condition are identified and explored. It is generally accepted that the human body is a complex system; and while it is easier to look at isolated factors and use a pathoanatomical model to identify causes of pain and/or injuries, the reality is that injuries are multifaceted and are often the effect of a "perfect storm." Therefore, highlighting the importance of a clinician understanding how all factors affect the human body and can contribute to a patient's current condition. The use of action research has provided me with the opportunity to use bench research and my own clinical practice to understand each patient's "perfect storm" and their musculoskeletal pain and injury. Incorporating action research has been foundational to improving my ability to provide quality, patient-centered care.

Summary

The DoCPI is a critical review of my progress toward advanced practice. Chapter 1 serves as a narrative of my perspective on the DAT. Chapter 2 is a review of current literature in recognizing and treating breathing pattern disorders demonstrates scholarship and an ability to understand and evaluate evidence. In Chapter 3, the action-research-related ability to collect evidence, utilize evidence in patient care to create an *a priori* plan for patient care in relation to my culminating research project is displayed. Chapter 4 is a case series displaying my ability to incorporate outcome measurements and assess patient progress. Patient outcomes collected during the clinical residency show planning, observation, action, and reflection in patient cases. Additionally it shows clinical reasoning and reflection in real-life patient care. The case series demonstrates an ability to transfer knowledge into clinical practice and analyze patient outcomes. Lastly, Chapter 5 is my culminating applied clinical research project that analyzes data and discusses meaningful findings that can be applied toward the advancement of the athletic training profession and the creation of a path for scholarly and future research as related to my area of focus, breathing pattern disorders. The chapters in this DoCPI serve as evidence of my progress toward advance practice and expertise. All chapters demonstrate improved skill acquisition, knowledge, reflection, and scholarly work, all guided with formal professional mentorship.

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Chapter 2

A Manuscript titled "A Clinical Guide to the Assessment and Treatment of Breathing Pattern Disorders in the Physically Active: Part 1"

Accepted for Publication, International Journal of Sports Physical Therapy, August 24, 2016

by Jena Hansen-Honeycutt, Erin B Chapman, Alan Nasypany, Russell Baker, Jim May

Introduction

The evaluation and treatment of breathing pattern disorders (BPDs) may be a missing component in the treatment of musculoskeletal pain.[1-3] Breathing mediates neuromusculoskeletal responses through its influence on the autonomic nervous system (ANS) and the central nervous system (CNS).[4-6] Breathing can be affected by biomechanical, biochemical, psychological, physiological, and/or unknown factors.[2,3,7,8] Various examination and treatment paradigms such as, dynamic neuromuscular stabilization, selective functional movement assessment, Buteyko method, and the Janda approach support the concept that breathing is the foundation of allostasis and functional movement. In a typical rehabilitation clinic, assessing breathing patterns may seem like a foreign concept due to the lack of emphasis placed on breathing in the traditional patient examination. However, breathing assessment may be an overlooked and essential tool to address a patient's primary complaint of musculoskeletal pain. The purpose of this clinical commentary is to demonstrate the integratration of a breathing pattern disorder (BPD) assessment into a standard clinical musculoskeletal orthopedic examination. Part II of this commentary will describe the assessment and treatment of patients with BPDs and its effect on their primary complaint of musculoskeletal pain.

A BPD is a dysfunction, not a disease, which in most cases is remediable through rehabilitation and neuromuscular re-education.[1,7,8] Symptoms of BPDs can mimic other diseases, often making diagnosis and treatment of BPDs challenging. Clinicians may not always be able to classify a patient into a specific BPD; therefore, must know the etiological features that can cause less than optimal breathing patterns.

Paradoxical breathing, where the abdomen draws in during inhalation and out on exhalation, is often considered the most severe BPD.[3] The theoretical result of this BPD is inadequate tidal volume and over activation of the scalenes and other accessory breathing muscles of the upper chest.[1,9] The subsequent insufficient exchange of gasses is thought to lead to respiratory distress and musculoskeletal imbalances.[9] Similarly, BPDs known as hyperventilation syndrome and tachypnea alters the body's pH producing respiratory alkalosis; which results in an array of symptoms including headache, dizziness, chest pain, trouble sleeping, breathlessness, light sensitivities, exhaustion, and cramps.[1,7,10,11] The cause of paradoxical breathing and hyperventilation syndrome is not always known, but can be associated with stress or an emotional response to a traumatic situation.[9,12] The secondary symptoms of BPDs, such as frequent yawning, inability to take a deep breath, fatigue and panic attacks,[8] may resolve with an appropriate intervention.

Functional Breathing

The CNS is immature in infants, allowing muscular and breathing patterns to develop sequentially in a genetically pre-determined pattern.[5] The diaphragm attains its position in the transverse plane between four to six months after birth, and costal breathing is fully established at six-months.[5] Once the position of the diaphragm is established it contributes to the development of stability of the spine and core, allowing the baby to roll, crawl, sit, stand, and begin to walk.[4,5] Breathing requires synchronized concentric activity of the diaphragm and pelvic floor, as well as eccentric activity of all muscles that insert into the thorax and abdominal wall muscles.[13,14] Improper sequencing during an abdominal breath can alter motor control patterns of postural muscles and spinal stabilizers resulting in pain and/or dysfunction.[5,6,15] Therefore, a functional breathing pattern can provide the clinician with a unique perspective into the coordination and maturation of the CNS.

Many muscles assist in the ability to take a breath. The primary and accessory muscles of inhalation and exhalation are listed in Table 2.1. The diaphragm is the primary muscle responsible for providing 70-80% of the inhalation force and is composed of the skeletal/costal and crural portions.[9] The diaphragm is evaluated from the perspective of vital functions such as breathing and metabolism.[16] Postural, visceral, and sphincter functions are important components that are often forgotten roles of the diaphragm.[1]

Table 2.1. Primary and Accessory Muscles Involved in Inhalation and Exhalation

The Primary and Accessory Muscles in Inhalation and Exhalation		
	Muscles of Inhalation	**Muscles of Exhalation**
Primary	Diaphragm Parasternal Internal Intercostals Upper and Lateral External Intercostals Levatores Costarum Scalenes (less active during normal breathing)	Elastic Recoil* Diaphragm Pleura and Costal Cartilage*
Accessory	Sternocleidomastoid Upper Trapezius Serratus Anterior Latissimus Dorsi Iliocostalis Thoracis Subclavius Omohyoid	Interosseous Internal Intercostals Abdominal Muscles Transversus Thoracis Subcostales Iliocostalis Lumborum Quadratus Lumborum Serratus Posterior Inferior Latissimus Dorsi

Listed above is a comprehensive list of the primary and accessory muscles that are associated with proper breathing patterns. When there is a BPD the accessory muscles replace the primary movers.[3]

* Primary non-muscular anatomic structures associated with breathing.

A normal breath at rest is referred to as a belly, diaphragmatic, or abdominal breath.[3,6,8,15,17] Upon inhalation the diaphragm should move caudally toward the pelvic floor with symmetry, while flattening and compressing the internal organs; the lower ribcage should move proportionately and symmetrically in a lateral, ventral and dorsal direction.[3] The abdominal walls should all expand equally in a cylindrical direction. The sternum will also move ventrally while the intercostal spaces between the ribs will expand minimally at the end of inhalation.[3]

Assessment of Breathing Patterns

The assessment of the patient's breathing pattern begins when the patient enters the clinic. During that time the patient is unaware that they are being observed, which reduces the possibility of conscious changes to breathing patterns.[6] The patient's posture should also be observed, as a slumped or hunched posture can limit the ability of the diaphragm to fully expand.[18] After the initial observational breathing pattern assessment and a full patient history, the clinician can start a comprehensive breathing examination.

Breathing is commonly assessed in a relaxed, supine position, but can also be observed in more challenging positions such as sitting, standing, or in positions that result in pain or discomfort.[6] During the Hi Lo assessment the patient is directed to place one hand on their chest, while the other hand rests on their abdomen (Figure 2.1). Once in this position the patient is not given any further instructions but the clinician may ask him or her questions regarding their history. The patient should breathe normally, and not be cued to take a deep breath during the assessment, as typically a prompted breath will result in the movement of the chest unless the patient has had previous training in abdominal breathing.[6]

Figure 2.1. The Patients Hand Position for Hi Lo Breathing Assessment

The assessment of breathing patterns is most often marked by the practitioner's observations, however standardized techniques are necessary to quantify a diagnosis. The Manual Assessment of Respiratory Motion (MARM) is a palpatory method that quantifies breathing patterns in a practical, inexpensive, and reliable manner.[19] Clinicians have used the MARM to assess diaphragm function since the 1980s to determine thoracic, abdominal and lateral breath. The MARM has good inter-examiner reliability (ICC = 0.85, p=.0001, CI 0.78, 0.89) as compared to plethysmography.[19] The MARM is performed by having the clinician positioned behind the seated patient and placing their hands on the posterior and lateral aspects of the 11th and 12th ribs.[6,19] While the patient breathes, the clinician measures perceived displacement and functional movement of the upper and lower rib cage movement, as well as abdominal expansion using two lines drawn on the patient to form a half of a pie chart and pressure placed through the clinician's hands (Figure 2.2).[19] The MARM values are calculated by measuring angle differences between the highest point of the inhalation (upper rib cage) and the lowest point (lower rib cage).[19] Each side of the body is considered its own entity and measurements should be between zero and 180 degrees. Positive values are indicative of chest breathing/vertical movement and negative values indicate abdominal/lateral movement.[19]

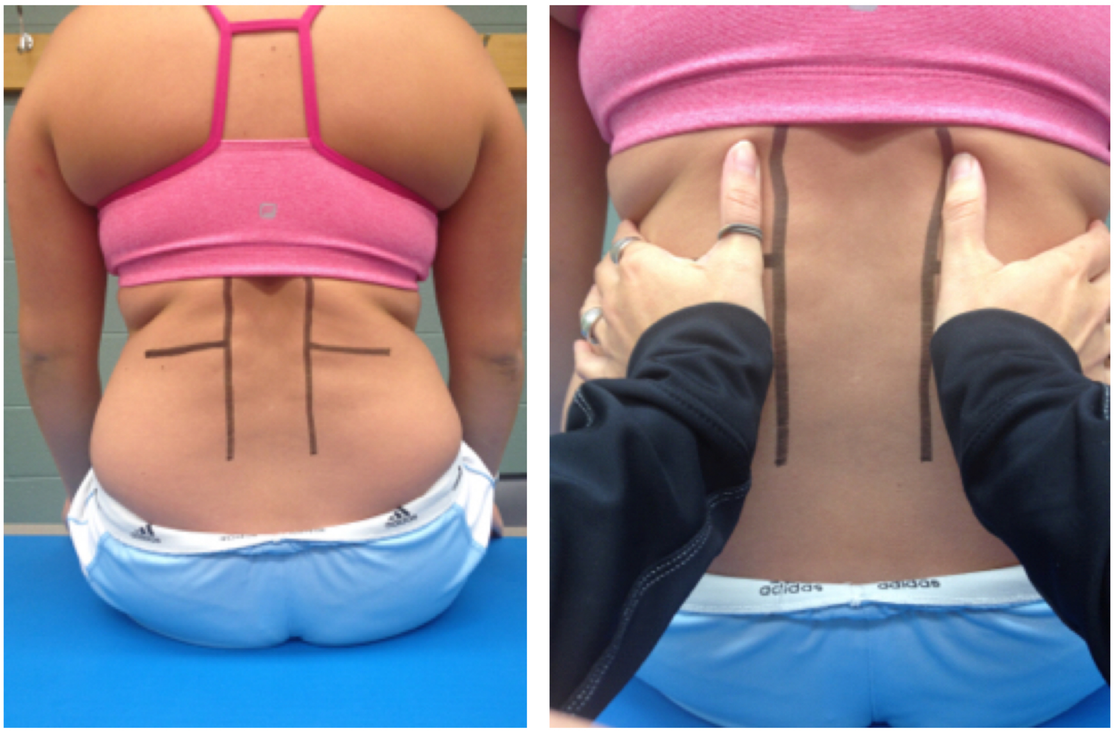

Figure 2.2. Clinicians Hand Placement to Classify and Quantify Respiratory Motion Using the MARM

Patients are assessed for tender areas, jump signs, or withdrawal reflexes upon palpation at the 1st/2nd, 7th/8th, or 11th/12th ribs unilaterally or bilaterally, as this may be a sign of faulty breathing patterns.[1,20,21] John Iams proposed that patients displaying increased sensitivity to normal palpation have an autonomic nervous system (ANS) that may be unable to balance the body's involuntary systems (i.e., parasympathetic and sympathetic nervous systems).[20-22] Theoretically, if the patient's body is functioning mainly in a protective state through activity of the sympathetic nervous system (SNS), a state of "up-regulation" may exist that presents as a startle or withdrawal reflex upon palpation.[21] If a patient presents with a startle reflex, or sensitivity to one or more of these locations, manual therapy could be used to "down-regulate" the area(s) or inhibit the pain cycle.[21-23] Therefore, assessing these specific locations with palpation may be important in clinical practice, as an "up-regulated" ANS could be a source of BPDs and musculoskeletal pain.

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Classification

There are many possible variations of classifications of BPDs, however, six primary dysfunctions found in the literature have become the foundation of the BPD assessment. A normal breathing pattern is classified as diaphragmatic or abdominal breathing.[6] Although this is considered a normal breathing pattern, it should be noted that a "normal" breathing pattern found in patients should not be considered the *ideal* functional breathing pattern. A few dysfunctional variations of an abdominal breath exist, including: asymmetrical with limited motion on one side of the abdomen; anterior movement only, without lateral or posterior movement; and adequate anterior and lateral movement, without posterior.

A chest or apical breather is characterized by excessive movement of the sternum and shoulder girdles toward the cranium, and minimal abdominal movement during inhalation.[6-8] Paradoxical breathing is when the chest expands during inhalation and the abdomen is drawn inwards and then during exhalation the abdomen is pushed outwards.[7,8] A new BPD classification, proposed by the authors of this commentary, is associated with a startle reflex. A startle reflex is when a patient elicits a withdrawal reflex upon palpation to the right or left 1st and 2nd ribs, anterior 7th and 8th ribs, and 11th and 12th ribs.[24] In part 2 of this series, three patient cases will be presented that display the short-term effects of treating a startle reflex BPD. Figure 2.3 is a visual representation of the classification of BPD in a rehabilitation clinic.

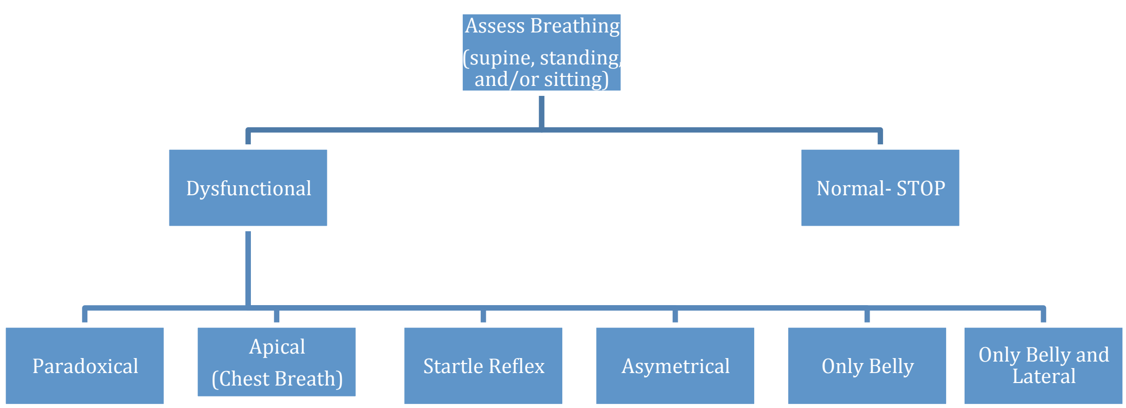

Figure 2.3. A Flow Chart of a Systematic Approach to Assess and Classify BPD in Clinic

Outcome Measures

Breathing pattern assessments, patient reported outcome measures, and other examination findings help to build a complete picture of BPDs.[6,7] Outcome measures identify minimal clinically important differences in patients with pain[25] and dysfunction to determine the effectiveness of a clinician's assessment and treatment.[19,26] A number of outcome measures can be used to quantify efficacy of evaluations and interventions in decreasing pain and correcting dysfunction in patients.[1] Measurement tools to evaluate musculoskeletal pain and/or dysfunction include the Numerical Pain Rating Scale[26] and the Disablement in the Physically Active scale.[27,28] The Nijmegen Questionnaire is a patient-reported outcome measure used to identify the presence of signs and symptoms associated with general and respiratory distress and higher values represent distress and dysfunction of the respiratory system.[1,11] These tools can easily be incorporated into an orthopedic examination without the addition of too much time.

Outcome measures should encompass both clinician and patient-reported evidence. Clinician-reported measures that may be useful in the collection of outcomes are the findings from the physical examination (functional impairments, range of motion, strength, asymmetry, MARM, Hi Lo, etc.). Patient-reported measures that may be useful in the collection of outcomes are the Numerical Pain Rating Scale,[26] Disablement in the Physically Active scale,[27,28] and Nijmegen Questionnaire,[11] as well as specific patient-oriented evidence measures that can be used at the clinician's discretion.

All outcome measures can be used in conjunction with comprehensive examination and functional biomechanical assessment (e.g. Selective Functional Movement Assessment). The CNS allows for optimal positioning of posture and stability through functional movement patterns.[5,13] Through the use of a functional assessment, the clinician may be able to locate pattern deficiencies contributing to the chief complaint(s) or less than optimal movement patterns. The correction of breathing patterns in low level postures should occur first and be followed by integration of proper breathing into complex movement patterns.

Clinical Advantages

Breathing is an involuntary process thought to be an essential aspect of posture and core stability. Restoring proper breathing mechanics and motor control can result in decreased pain, improved patient outcomes, and improved patient health.[6,8] Evaluation of breathing patterns is an easy clinical technique to learn. Treating BPDs requires little to no equipment in the rehabilitation clinic and intervention techniques provided by the clinician can be structured as a home exercise program in approximately five minutes or less.

Discussion

The purpose of this clinical commentary was to illustrate how to assess and classify BPDs prior to or in conjunction with the treatment of musculoskeletal pain or dysfunction. Since a BPD is not a disease, it is usually not recognized until an assessment is performed.[6-8] The specific cause(s) of BPDs are unknown, and each patient may adapt individual neuromuscular patterns associated with faulty breathing patterns. Postural and structural adaptations could possibly result in pain and/or dysfunction of muscles, ligaments, or joints with no apparent organic source, possibly resulting in various BPD signs and symptoms. The three main contributing factors to BPDs are: biomechanical, biochemical, and psychological.[3,8,9,29]

The act of breathing is mechanical in nature as the diaphragm and primary muscles control most of the respiratory system.[3,5] Restriction of muscle length, muscle imbalances, and diaphragm expansion can modify posture and core stability as a result of the body's inability to return to optimal resting position.[3,5,8,15] The concept of regional interdependence suggests that if one part of the kinetic chain is unable to perform motor patterns sufficiently, another portion of the body compensates for the deficiency, resulting in dysfunction.[30] Breathing patterns may change as a result of altered motor control patterns and postural changes and if the imbalances are not addressed can lead to suboptimal function of the CNS and chronic pain.[5]

While the biomechanical factors are visible to the clinician it is important to remember biochemical components of the respiratory system as well. Changes in the body's pH level, allergies, dietary factors, hormone levels, or internal organ dysfunction can potentially lead to premature fatigue, breathlessness, dyspnea, and resultant muscle pain.[6,8] The mind and body work together to maintain homeostasis during times of stress and anxiety.[31,32] While research is limited in understanding the emotional factors contributing to BPDs, researchers have suggested that memories, past experiences, and emotional states can have an effect on breathing patterns.[33,34]

"If breathing is not normalized, no other movement pattern can be."[35] Frank et al[5] and Chaitow[7] suggest that abnormal stabilization patterns are associated with BPDs and should be the starting point for all orthopedic evaluations. The authors believe that correction or re-education of BPDs can result in new neural connections and restoration of normal motor control patterns in the CNS. Roussel et al[15] observed various dysfunctional breathing patterns and altered motor control patterns during functional testing in a group of patients with low back pain compared to a group of healthy individuals. Breathing patterns are established subcortically and often associated with an injury, pain, and/or movement dysfunction. The goal of restoring breathing patterns is to establish normal subcortical motor patterns.[7] An athlete with an abnormal breathing pattern during physical activity may experience premature breathlessness or muscle fatigue, resulting in decreased performance.

Summary

The assessment and classification of BPDs is important, as normal and abnormal breathing patterns affect movement. Once a breathing dysfunction is classified, finding appropriate exercises for muscle relaxation, re-education of motor control patterns, and normal breathing patterns at rest and during activities may help restore normal and physiological balanced breathing.[6] Breathing pattern assessments and interventions might improve patient quality of life, physical function, and decreased breathing signs and symptoms during activities of daily living and exercise.[3,7,8,15,17,19] Part II of this clinical commentary will provide a case series related to BPDs in an athletic population, the interventions associated with BPDs, and the effects of BPDs interventions.

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Chapter 3

A Manuscript titled "A Clinical Guide to the Assessment and Treatment of Breathing Pattern Disorders in the Physically Active: Part 2, A Case Series"

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Introduction

Musculoskeletal injury incidence is high among the physically active population; Hootman et al[1] reported an average rate of game injury of 13.79 per 1000 athlete-exposures in collegiate athletics. Physical activity increases the demands on the body and simultaneously the body is adapting to chemical, psychological, and biomechanical changes through the breath. Respiration and breathing patterns play a vital role in maintaining allostasis[2] and biomechanical stability and mobility of trunk and spine.[3] Therefore, breathing pattern disorders (BPDs) may cause or contribute to a variety of general health[4] and musculoskeletal conditions (e.g. inappropriate motor control patterns and/or compromised trunk stability).[5-7] An optimal breathing pattern is typically defined as a three-dimensional abdominal breath resulting in expansion of the lower ribs[2,6,8,9] and has been suggested as an essential component in maintaining allostasis, posture, and spinal stability.[9]

The autonomic nervous system (ANS) plays an essential role in maintaining allostasis and balancing the body's involuntary systems (e.g., endocrine, respiratory, circulatory, lymphatic, and muscular systems) by altering breathing, blood pressure, heart rate, muscle tone, and hormones.[10-14] The sympathetic nervous system (SNS) and parasympathetic nervous system (PNS), branches of the ANS, respond to experiences (e.g., emotions, pain, fear, or stressors) and adjust breathing, blood pressure, and heart rate.[10-14] A change or dysfunction in the ANS, operating mainly (i.e., biased) through the SNS is also considered “up-regulation,”[15] a continuous period of heightened arousal of the nervous system.[16] “Up-regulation” could alter breathing patterns to maintain allostasis, and change the recruitment of respiratory muscles and alter motor control patterns,[15,17-19] potentially causing acute or chronic musculoskeletal pain.

When the body functions in an “up-regulated” nervous system, there is an increased sensitivity to touch and increased pain perception to various tender areas in the body.[17,20-22] Hallman et al[12] found that patients in chronic pain presented with an “up-regulated” nervous system and suggested that patients with chronic neck-shoulder musculoskeletal pain may benefit from treating the ANS. The “up-regulated” nervous system can also be present in conjunction with a startle or withdrawal reflex.[8,21,23] A startle reflex is an abnormal response to normal palpation/stimulus causing the body to withdraw from an area or move in a pattern to protect itself (e.g., head jolting forward, shoulders flex, and reflex reactions down the body).[15,17,24] The presence of startle reflexes may be relevant to the ANS, thus theoretically explaining the cause and perpetuation of BPDs in patients reporting musculoskeletal pain without a pathoanatomical cause.[25] Further, abnormal sensitivity to pain pressure (e.g., palpation) and temperature is theorized to be caused by hypersensitivity of the CNS and is thought to contribute to chronic musculoskeletal pain.[26-30]

The Numerical Pain Rating Scale (NPRS) may be variable between subjects (e.g. minimal to very painful), but most importantly the patient reacts abnormally to normal palpation.[25] Palpation bilaterally to $1^{st}/2^{nd}$, $7^{th}/8^{th}$, and $11^{th}/12^{th}$ ribs are theorized to be associated with BPDs and a startle reflex.[6,17] Through palpation of the ribs, as described in

Part 1, the clinician can identify if a startle reflex is present during the breathing pattern assessment. It should be noted that following the initial trigger that initiated the SNS response, the dysfunctional movement patterns and BPDs may continue even after the stimulus has been eliminated. The inclusion of the one-minute nociceptive exam™ assists the clinician to establish the ANS role in changes in breathing patterns and consequently global movement patterns.

Many factors influence breathing patterns, therefore it is essential to have a multifaceted assessment, as described in Part 1, which includes observation, palpation for the presence of startle reflexes, and orthopedic tests to assess local and global motor control patterns. The causes of BPDs are typically compensatory for biochemical, biomechanical, psychosocial, and/or psychological, thus varying between individuals. Therefore, the assessment and intervention presented in this paper could be essential to improve effects related to the primary musculoskeletal complaint and/or overall health of patients.[4] The purpose of this *a priori* case series was to examine the effects of Primal Reflex Release Technique (PRRT) and breathing exercises in physically active individuals that presented with a primary complaint of musculoskeletal pain, a BPD, and startle reflexes.

Subject Descriptions

Initial Examination

The evaluating clinician performed a breathing pattern assessment prior to determining the source of a potential subject's primary complaint of musculoskeletal pain. Two different clinicians at their respective work locations examined patients in order to find subjects for this study. The clinicians had over four years of professional experience, with one year of focused experience evaluating and treating BPDs in the physically active population.

Inclusion criteria included patients that presented with musculoskeletal pain and a startle reflex to palpation at the $1^{st}/2^{nd}$, $7^{th}/8^{th}$, and/or $11^{th}/12^{th}$ ribs; if the patient presented with a startle reflex at any of the tender points they were then evaluated for a BPD via a the physical assessment described in Part 1. Participants that did not present with both a startle reflex and a BPD were excluded, 8 participants presented with a BPD but not a startle reflex. All included subjects provided written informed consent for participation in the case series.

The observation of the subjects breathing pattern began prior to the formal assessment, thus allowing the clinician to observe unaltered breathing patterns. Mentioning to a patient that you are observing their breathing has been noted to significantly alter their natural pattern.[8] Bilateral palpations assessed startle reflexes at $1^{st}/2^{nd}$, $7^{th}/8^{th}$, and $11^{th}/12^{th}$ ribs tender areas using the NPRS scale. The assessment of breathing patterns occurred in two positions: seated and supine. In a seated position, the clinician performed a modified version of the Manual Assessment Respiratory Movement (MARM)[2,31] and a Hi Lo assessment in a supine position,[2,5,8,31] both described in Part 1. Typically the respiratory motion is quantified by drawing perceived motion on a form and is calculated as an exact number. However, for the purposes of this case series, the MARM was recorded only as positive (apical) or negative (abdominal) perceived motions were indicated by using a modified MARM and compared the results of the Hi Lo assessment to classify respiratory motion. The examiner observed and denoted where the respiratory movement initiated in each of the patients' breath (e.g., paradoxical, apical, or abdominal) as described in Part 1. The clinician determined the subjects breathing patterns, normal or dysfunctional, from the outcomes of the modified MARM and Hi Lo assessment. The outcomes from the assessments above might provide varying degrees to further classify each subject's breathing pattern.

History and Examination

A summary of each subject's history is provided in Table 3.1. Each subject denied any history of a traumatic event or spinal pathology. Orthopedic special tests, specific to each subjects musculoskeletal injury were negative, manual muscle testing of the involved muscles were completed, however no weakness or pain was noted, therefore we performed the Selective Functional Movement Assessment[32] to identify muscle imbalances and motor control dysfunctions.

Table 3.1. Patient's Demographics and History

PATIENT HISTORY				
Patient Number	Age	Sex	Onset of Pain	Occupation/Activity
1	**21**	**F**	**1 year**	**Student/Collegiate Softball Participant**
2	**22**	**F**	**5 years**	**Student/Track Participant**
3	**16**	**F**	**2 years**	**Student/High School Softball Participant**

Subject #1 had been experiencing low back pain for over a year without resolution despite participating in a therapy routine including, interferential current electrical stimulation and a core stabilization program. The subject reported an increase in pain and discomfort following a long travel day (i.e., bus and airplane ride). The subject's NPRS was a 2/10 for her primary complaint of low back pain during daily and physical activities. Upon entry to the clinic, the subject exhibited excessive chest movement upon inhalation. The Hi Lo assessment revealed the subject's breathing pattern as an apical breathing pattern with limited movement of the abdomen. Palpations bilaterally at the $11^{th}/12^{th}$ ribs (Left-3/10 NPRS, Right-2/10 NPRS) determined startle reflexes. A positive modified MARM confirmed the apical breathing pattern with minimal lateral and no back breath at rest (Table 3.2).

Table 3.2. Clinical Evaluation of BPDs, Location of Startle Reflex, and Interventions

CLINICAL EVALUATION AND INTERVENTIONS			
Patient Number	BPD	Startle Reflex	Intervention
1	**Chest/lateral breath**	**11th/12th rib**	**PRRT/McGill Side Bridge**
2	**Chest breath**	**1st/2nd rib 11th/12th rib**	**PRRT/Clam Shell**
3	**Paradoxical**	**11th/12th rib**	**PRRT/Clam Shell**

Subject #2 had been experiencing a sharp pain in the middle back for a period of five years without resolution. During initial examination, using the Thoracic Ring Approach™ developed by Linda Joy Lee, during rest the 5th rib ring was laterally positioned to the right.[33] The subject's NPRS was a 6/10 for her primary complaints (i.e., pain during inhalation or physical activity). The Hi Lo assessment revealed the subject's breathing pattern as an apical breathing pattern with limited movement of the abdomen. The subject also presented with a bilateral startle reflex response upon palpation of the 11th/12th ribs (Left-3/10 NPRS, Right-4/10 NPRS) and 1st/2nd ribs (Left-5/10 NPRS, Right-6/10 NPRS). A positive modified MARM confirmed that the breathing pattern was apical with a rigid abdomen and limited anterior, lateral, and back movement at rest (Table 3.2).

Subject #3 had been experiencing intermittent, throbbing pain in her left knee for a period of two years. During evaluation, the subject presented with muscle pain and a tender point on her left medial knee proximal to the joint line. The subject's NPRS was a 6/10 for her primary complaint of muscle pain at insertion of gracilis. The Hi Lo assessment revealed a paradoxical breathing pattern with minimal abdominal movement. Upon palpation, the subject also presented with a startle reflex at the left 11/12th ribs (8/10 NPRS). A positive modified MARM confirmed that the breathing pattern was paradoxical with minimal abdominal movement (Table 3.2).

Intervention

The exercises used in this case series have been beneficial in the authors' clinical setting to address various BPDs (e.g., paradoxical, apical, and breathing lacking lateral or back motion).[21] The "clamshell" and/or PRRT were used to address BPDs in all three subjects in order to reset and re-establish motor control dysfunctions. While the concept of resetting a BPD is fairly uncommon, a reflex triggering exercise, the "clamshell" is a modified exercise proposed by the authors from Michael Grant White's "Optimal Reflex Triggering Ankle Raise" exercise.[21] The reflex triggering exercise elicits the subject's need to breathe by altering the intra-abdominal pressure at the end of a natural exhalation.[21] The subject was side-lying and instructed to complete a full natural exhalation, (not a forced exhalation), then hold their breath. While holding their breath, the subject abducted the top knee, keeping their heels together for a count of three for abduction and count of three for adduction movements of the leg (Figure 3.1). When the limb returns to the resting position, the subject relaxes the body and inhales normally. If the "clamshell" reset is needed, and done correctly, the subject will demonstrate a deep and normal (e.g., a three-dimensional abdominal) breath, or at least significant progress in that direction as compared to a "normal" breathing pattern. A common mistake is to either force the exhalation or to not follow all of the breath out, both would not trigger the need to breathe reflexively. The process can be repeated until normal breathing is established, but the subject should monitor a few breaths between each "clamshell" repetition in order to create awareness of the changes in their breathing pattern.

Figure 3.1. Reflex Triggering Breathing Exercise the "Clamshell"

The PRRT developed by John Iams, utilizes the one-minute nociceptive exam™ as a global assessment to identify startle reflexes and quick movements with specific body positioning for treatment.[16,17] The PRRT treatment techniques utilizes coughing in certain positions in order to eliminate startle reflexes and decrease pain upon palpation of the 1st/2nd and 11th/12th ribs. The PRRT technique for the 7th/8th ribs utilizes applying pressure with two fingers just below the costochondral cartilage angle during the pause between the exhalation and inhalation.[34]

Results

Subject #1: PRRT was used to correct the startle reflex and BPD. PRRT performed (2x) bilaterally to the 11th/12th ribs as a means to reduce the tender areas that elicited a startle reflex upon palpation. Following the intervention, the clinician reassessed the subject's breathing pattern using the MARM and Hi Lo assessment and identified a normal abdominal breath (abdominal, lateral and back breath). The startle reflexes were re-evaluated using the one-minute nociceptive exam™. The startle reflexes dissipated to an NPRS of 0/10 bilaterally. The "clamshell" was not included as part of this subject's intervention as the PRRT intervention re-established an abdominal breathing pattern. The subject's primary musculoskeletal complaint of low back pain was 1/10 NPRS following a single treatment session.

Subject #2: PRRT was used to correct the startle reflex and BPD. The PRRT was performed (1x) bilaterally to the 1st/2nd and 11th/12th ribs. Re-evaluation using the one-minute nociceptive exam™ determined that the startle reflexes dissipated and tender areas all had an NPRS of 0/10 bilaterally; however following re-assessment using the MARM and Hi Lo, the BPD was still present. The BPD was therefore treated using the "clamshell" exercise (5x) and following the exercise the subject was able to establish an abdominal breath with anterior and lateral movement, but still lacked back movement. The subject's primary musculoskeletal complaint of sharp pain in the middle of the back was 0/10 NPRS following a single treatment session.

Subject #3: PRRT was used to correct the startle reflex and BPD. The PRRT was performed (1x) to the left 11th/12th ribs. Re-evaluation using the one-minute nociceptive exam™ determined that the startle reflex dissipated, but the subject was still tender (NPRS score of 7/10) upon palpation at the left 11th/12th ribs. The MARM and Hi Lo assessment indicated that the BPD was still present. The BPD was then treated with the "clamshell" exercise (5x) and following the exercise the subject had established an abdominal breath with anterior movement, but still had limited lateral and back movement. The subject's primary musculoskeletal complaint of left knee pain was 4/10 NPRS following a single treatment session.

The outcomes of this case series demonstrate that subjects #1 and #2 presented a change on the NPRS[35] achieving the minimal clinically important difference (MCID) in the affected areas after treatment of the startle reflex using PRRT (Table 3.3). All three subjects reported a change on the NPRS related to their primary complaint of musculoskeletal pain (consistent with the MCID) after the breathing pattern interventions (Table 3.4). Subject #1 was the only participant to exhibit a normalized breathing pattern following the PRRT treatment of the 11th/12th startle reflex. Whereas subjects #2 and #3 needed the addition of the clamshell exercise to initiate the ideal abdominal breath.

Table 3.3. Startle Reflex NRS Pre and Post Treatment

STARTLE REFLEX PRE/POST NRS			
Patient Number	Startle Reflex Palpation Location	Pre NRS	Post NRS
1	11/12th Left	3/10	0*
	11/12th Right	2/10	0*
2	1/2nd Left	5/10	0*
	1/2nd Right	6/10	0*
	11/12th Left	3/10	0*
	11/12th Right	4/10	0*
3	11/12th Left	8/10	7/10

Table 3.4. Patient's NPRS for Primary Complaint Pre and Post Treatment

PATIENT PRIMARY COMPLAINT PRE/POST NPRS		
Patient Number	Primary Complaint Pre NPRS	Primary Complaint Post NPRS
1	2	1
2	6	0*
3	6	4*

Discussion

The assessment and treatment of BPDs in three physically active subjects presented in this case series was beneficial in decreasing pain and improving breathing patterns prior to a clinical orthopedic evaluation and subsequent interventions. Breathing pattern disorders can produce inappropriate motor control patterns and compromised trunk stability resulting in musculoskeletal pain.[5-7] Janda's approach to pain and dysfunction focuses on finding the cause of signs and symptoms, which is typically away from the site of the patient's primary complaint.[36] The Central Nervous System (CNS) and musculoskeletal system work together to create movement; pathology to one system may be reflected by adaptation of another.[36] The diaphragm is crucial to structural posture and core stabilization.[37] Elevation of the lower rib cage (caudally) during inspiration may be a result of a weak diaphragm or poor recruitment of deep spinal stabilizers that can contribute to musculoskeletal pain or dysfunction of the cervical, thoracic, or lumbar segments.[36,38] The diaphragm is responsible for initiating core stability by regulating intra-abdominal pressure[37] and works collaboratively with the transversus abdominis, multifidus, and pelvic floor to provide support.[2,38] If breathing is dysfunctional this may predispose the patient to muscular adaptations and/or musculoskeletal pain in various other regions. For example, the most extreme BPD, a paradoxical pattern, is often accompanied with cervical spine pain, muscle imbalances, and/or dysfunction.[2,8] Alterations or weakness of the pelvic floor muscles have been associated with low back pain, groin strains, iliotibial band syndrome, anterior knee pain, anterior cruciate ligament tears, and lateral ankle sprains.[36,38-41] In this case series, the focus was on treating the diaphragm, often overlooked as a contributing factor to core stability, in order to decrease the subject's musculoskeletal pain through reflexive exercises targeting the CNS and ANS. The variety of musculoskeletal pain complaints in this case series may be related to global muscle imbalances, motor control adaptations, and trigger points within the kinetic chain.

The decrease in pain may have been due to improvement in diaphragmatic function, and/or the ability to initiate core stabilization, restore movement patterns, and diminish tender areas associated with BPDs. The exact mechanism for positive effects in these three patients is unknown. Lucas et al[42] determined that altered muscle patterns within the kinetic chain had trigger points that may be associated with changes to breathing patterns or posture. Mehling et al[43] compared the effects of physical therapy (e.g., soft-tissue mobilization; joint mobilization; and exercises for postural righting, flexibility, pain relief, stabilization, strengthening, functional task performance, and back-related education) and breathing therapy (e.g., verbal intervention and tactile cueing for proper breathing mechanics) on patients presenting with chronic low back pain and found that patients undergoing breathing therapy had similar improvements in pain, function, and physical and emotional role as the physical therapy group even though breathing therapy or exercises are typically not viewed as effective as physical therapy. The results of this case series determined that early inclusion of breathing exercises were beneficial in decreasing musculoskeletal pain in three physically active individuals.

Breathing is influenced by emotional and psychological input, yet it is difficult to identify if these sources contribute to BPDs.[44] McNulty et al[45] reported that EMG activity increased over trigger points when a patient was placed in a stressful situation. Untreated trigger points could result in continuous disruption of motor patterns that can be "reset" and re-established through appropriate interventions, such as muscle re-education. If trigger points increase during stressful circumstances, it may explain the startle reflex response and decreased tolerance to palpation, as seen in this case series. The PRRT used in this study are proposed to address the startle reflexes associated with BPD by addressing the nervous system through "resetting" primal reflexes.[15,16,46] Theoretically, by stimulating the reflexes through a cough or quick palpation, neural input being sent to the spinal cord and brain and is temporarily overloaded and/or "reset," which restores normal neural input to the muscles being treated.[16,34] The inclusion of evaluating startle reflexes in primary and accessory respiratory muscles could assist in directing treatment intervention and explain how BPDs have an intimate connection to stress, emotions, and musculoskeletal pain.

Stress has been identified as a risk factor and contributor to musculoskeletal injuries and chronic pain.[47] Hallman et al[12] monitored participants with chronic neck and shoulder pain and found that during rest there was a decrease in PNS activation and increased SNS activation suggesting a mild ANS imbalance, when compared to the healthy control group.[48] Mehling et al[43] suggested that the breath therapy might teach coping skills and provide insight regarding the effect of stress on the body and chronic low back pain. It has been theorized that the presence of startle reflexes provides information regarding the state of the ANS, specifically an ANS imbalance, or “up-regulated” nervous system, however this supposition has not been studied. If restoration of an ideal breathing pattern and treatment using breathing exercises and PRRT created changes in the ANS, specifically an increase in PNS activation, such a change could provide an explanation for the decrease in musculoskeletal pain seen in these subjects. The authors hypothesize that the ANS, specifically an “up-regulated” nervous system contributes to the presence and perpetuation of BPDs in patients that present with a startle reflex.

Breathing pattern disorders in the general population are theorized to be more common than reported[2] and if prevalence is similar in the physically active population, the effects of BPDs could be multiplied due to the increased physiological and biomechanical demands during exercise. If the body is not able to appropriately recruit muscles then compensatory motor patterns may ensue. Therefore, it is the opinion of the authors that breathing should be assessed in all patients due to the bidirectional influence of the psychological, chemical, and biomechanical systems.

The limitations of the present case series include the small number of patients treated, the absence of a control group, and the clinicians only present the initial assessment and treatment of BPDs outcomes, which do not allow for the generalization of the results. Additionally, the clinician's reliability of assessing BPDs was not tested and only used two treatment techniques to improve breathing patterns out of several simple techniques that have been suggested in the literature. Research on the long-term effects of assessing and treating BPDs is necessary to see if patients maintain improvements in diaphragm function and musculoskeletal pain. Further research using a larger sample with a control group is needed to recognize if changes in breathing patterns actually occur and are due to interventions, and whether the changes alter motor control patterns sustain long-term improvements in pain and function throughout the body. Analyzing the connection between the ANS, startle reflex, breathing patterns and motor control is essential to understanding how these treatments impact a patient's well-being.

Summary

In this case series, following the PRRT and/or "clamshell" exercise, each subject presented with a clinically important change in NPRS scores in regards to their primary musculoskeletal complaint. In addition, all subjects displayed a change in their breathing pattern as well as a diminished or eliminated presence of a startle reflex. The current findings suggest that the occurrence of a startle reflex upon palpation may be a contributing factor associated with a BPD and musculoskeletal pain. Using PRRT and/or the "clamshell" exercise facilitated re-establishment of an optimal breathing pattern and theoretically, global motor control contributing to the why the participants primary complaint of pain decreased. No previous research has indicated that the presence of a startle reflex is a common occurrence in an athletic population with disordered breathing. Therefore, the assessment and treatment of

BPDs and startle reflexes might be an essential component to determine a potential cause or contributors to musculoskeletal pain.

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Chapter 4

A Manuscript titled "Treatment Utilizing a Muscle Energy Technique and The MyoKinesthetic System on Patients With a Diagnosed Disc Injury"

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by Jena Hansen-Honeycutt, Alan Nasypany, Russell Baker

Introduction

Low back pain (LBP) is a common musculoskeletal complaint from those participating in physical activity; with an incidence ranging between 1% and 30% of all athletic injuries.[1] A structural abnormality may be the cause of pain, but more often low back pain (LBP) is not associated with such findings.[2,3] For instance, faulty posture and an increased lumbar lordosis has been correlated to LBP.[1,4] Another potential cause of LBP is a disc abnormality; where the disc herniation or bulge places pressure on the nerves of the spinal canal. When this occurs, commonly, the nucleus protrudes out of the annulus fibrosis limiting the room for the spinal nerve thereby producing pain or symptoms. Disc abnormalities, however, do not appear to be fully predictive of the presence of low back pain; researchers have studied asymptomatic populations and found that 57 and 64 percent of the participants without a history of LBP had disc abnormalities when examined using magnetic resonance imaging (MRI).[2,5] Therefore, it is not unreasonable to suggest that LBP commonly attributed to a herniated disc or bulge could actually be stemming from another causative factor.

Exploring a variety theories and treatment options is imperative to help patients find relief from LBP given the multifactorial nature of LBP. Common options for conservative care are chiropractic, massage, pharmacological, rehabilitation, and physical therapy interventions.[6] Surgical interventions (e.g., microdiscectomy, spinal fusion, laminectomy) are typically considered if conservative care fails after 4 to 6 weeks.[1,7–9] Even in patients whose non-specific LBP resolves, it has been documented to have a recurrence rate up to 90%.[10]

A current and well-accepted theory suggests that the cause of LBP stems from the changes in motor control, postural control, or stability of the core and not from the structural abnormalities.[4,11,12] There has been an influx in clinicians utilizing this theory to support restoring core stability for patients reporting LBP.[4] However, the high recurrence rate of LBP suggests that the true source of the pain has not been identified.[1,4,10] The inconsistent patient outcomes in regards to traditional conservative care and high recurrence rates of LBP led the author to utilize a novel and uncommon treatment combination of a muscle energy technique (MET) and a MyoKinesthetic treatment.

The MyoKinesthetic (MYK) System is a postural assessment and treatment for nerve pain, muscle pain, muscle imbalances, and postural imbalances.[13,14] The treatment includes passive and active movement along with stimulation into each muscle, bilaterally, along a particular nerve pathway.[13–15] The goal of the treatment is to clear any irregularities in signals delivered by the peripheral nervous system (PNS) along a single nerve pathway, therefore having a specific impact on the central nervous system (CNS) which in turn restores proper postures.[15] Theoretically, by treating the muscles along one nerve pathway, the information is sent to the spinal cord and brain where the information is then reprocessed and delivered to the muscles clearing the previous compensations and imbalances.[15] The MYK treatment is proposed to target the CNS and PNS to restore motor control patterns and postural imbalances that may cause musculoskeletal pain. The purpose of the following case reports is to provide an example of a novel LBP treatment that provided immediate and long lasting results in restoring function and decreasing pain in two patients suffering from LBP who had previously been diagnosed with a herniated disc.

Patients

Two patients presented with a previous diagnosis of a herniated disc by another healthcare professional. The same clinician evaluated and treated the patients. Each patient provided written consent for participation. Both patients denied spinal trauma but had similar symptoms including radiating pain into the buttock or legs, sharp localized pain between the lumbar spine vertebrae 5 (L5) and sacrum. Upon examination, both patients presented with unremarkable leg length tests and had no obvious deformity or obvious edema. Both patients exhibited a dysfunction of the sacroiliac joint during the March test. A summary of each patient's history and initial physical examination is provided in Table 4.1.

Table 4.1. Initial History and Physical Examination of Each Patient

Initial History and Physical Examination			
Patient #	Age	Sex	Exam
1	26	Female	Patient #1 was a 26 year old female who reported low back pain with sudden onset after tumbling during a cheerleading practice nine years prior to this evaluation. Patient went to primary care doctor and was diagnosed with a herniated disc of L5. Patient received two MRIs over course of treatments and both were positive for a herniated disc at L5. Initial treatment included pharmacological interventions, two epidurals, chiropractic care, massage, and physical therapy all providing moderate relief. The physical therapy, chiropractic care, and massage provided pain relief for 2-4 weeks. The epidurals provided relief for eight months. Patient was point tender over bilateral posterior superior iliac spine, quadratus lumborum, and L4 and L5 transverse processes. Neurological exam had only a positive Slump test. Previously the patient reported experiencing radiating pain into the buttock with sitting or standing for prolonged periods of time, but was not currently experiencing this type of pain. The patient's primary complaint was constant dull pain 3 of 10 NRS at rest and inability to sit or stand for prolonged periods of time since initial injury. Range of motion and strength tests for the hip were unremarkable. MYK postural assessment indicated L5 imbalance.
2	23	Male	Patient #2 was a 23 year old male who reported not feeling right after sitting up after a set of bench presses. The following day he woke up with pain 6 of 10 NRS and inability to touch toes. Patient was diagnosed with a herniated disc by another athletic trainer, after the examination the patient reported to seek treatment from the researcher/author. Patient reported an increase in pain with trunk flexion. Patient was point tender bilaterally over, quadratus lumborum, erector spinae, and over L5 spinous process. Neurological exam was positive for only the Slump test and patient reported radiating pain into buttock. Patient reported that the pain felt deeper than the clinician could palpate and inability to complete activities of daily living such as, tying his shoes. Range of motion and strength tests for the hip were unremarkable. MYK postural assessment indicated L5 imbalance.

Intervention

After history and initial exam, both patients were initially treated with MET. Because a sacroiliac (SI) joint dysfunction has been identified as a source of LBP,[16] a muscle energy technique (MET) was utilized prior to the MYK treatment in attempt to restore SI joint function and decrease pain. The patient was side lying on the opposite side of the pelvic girdle/SI joint dysfunction, with hands across the chest. The leg was not in contact with the table was placed into hip and knee flexion. Once in this position, the patient was instructed to abduct hip against resistance, then pull the hip into extension against resistance. The patient was then asked to lie in a hook-lying position and complete isometric contraction of hip adductors (3x) and abductors (3x) for six seconds each. The MET did restore normal pelvic girdle function; however, the technique did not completely resolve their symptoms.

The patients reported that they continued to experience pain and difficulty with functional activities. This led the clinician/researcher to seek a treatment that would target the CNS and PNS that may be contributing to the patient's complaint of pain with functional activities; thus specifically a MYK treatment seemed to be indicated. Table 4.2 lists the muscles treated and movements associated with the MYK L5 treatment.[15] At the second visit, a MYK L5 treatment was used in both patients based upon the MYK posture assessment. The following appointment, the patient was instructed that the MYK treatment include stimulation/massage of all muscles innervated by the L5 nerve root level bilaterally while performing passive and active movements to decrease pain and improve function.

Table 4.2. Active and Passive Movements and Muscles Stimulated with MYK L5 Treatment

Active and Passive Movement	Muscles Stimulated by Palpation
Hip Adduction	Gluteus Medius Gluteus Minimus
Hip Extension/Adduction	Tensor Fascia Lata
Hip Flexion	Gluteus Maximus
Hip Abduction	Adductor Magnus
Knee Extension	Semimembranosis Semitendinosis Biceps Femoris
Torso Flexion	Iliocostalis Lumborum Intertransversarii Interspinals Multifidus
Hip Medial Rotation	Gemellus Inferior Gemellus Superior Obturator Internus Quadratus Femoris
Dorsiflexion with Inversion	Peroneus Longus Peroneus Brevis
Dorsiflexion with Eversion	Tibialis Posterior Flexor Hallucis Longus Flexor Digitorum Longus
Plantar Flexion with Inversion	Extensor Digitorum Longus Peroneus Tertius
Plantar Flexion with Eversion	Tibialis Anterior Extensor Hallucis Longus
Plantar Flexion	Extensor Hallucis Brevis Extensor Digitorum Brevis
Knee Rotation	Popliteus
Big Toe Adduction	Abductor Hallucis
Big Toe Abduction	Adductor Hallucis
Foot Dorsiflexion	Flexor Digitorum Brevis Lumbricals
Big Toe Extension	Flexor Hallucis Brevis

The pain-intensity Numerical Rating Scale (NRS) and Disablement in the Physically Active (DPA) scale were used as patient-oriented outcome tools to measure improvements.[17,18] The Global Rate of Change (GRC) (11-point scale) was used at the beginning of the appointment to measure global progress from previous treatment.[19] Orthopedic tests and functional movement were also used to measure progress of physical limitations. Below in Table 4.3, the NRS was collected pre and post treatment intervention and GRC was collected at baseline and at the beginning of each treatment to retrospectively monitor change between treatments. In Figure 4.1, DPA scale scores were collected at initial examination, one week, and one month.

Table 4.3. Patient Reported GRC and NRS Before and After Each Treatment

Patient #1				Patient #2			
Treatment #	GRC	NRS Pre	NRS Post	Treatment #	GRC	NRS Pre	NRS Post
1. MET	2	3/10	2/10*	1. MET	3	6/10	6/10
2. MYK L5	5*	2/10	0/10*	2. MYK L5	6*	6/10	3/10*
3. MYK L5	7*	0/10	0/10	3. MYK L5	7	4/10	1/10*
				4. MYK L5	7	1/10	0/10*

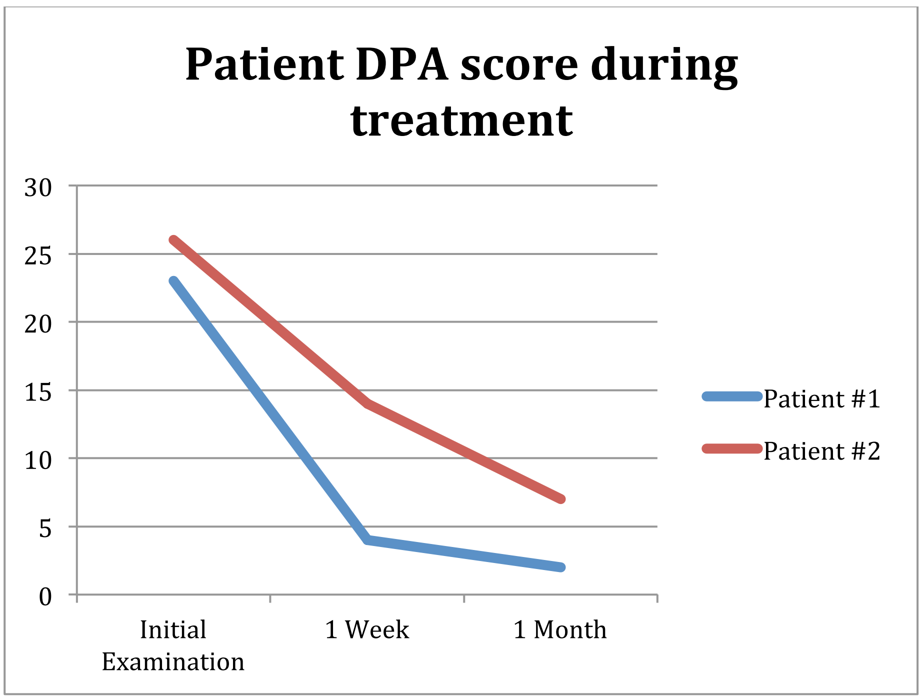

Figure 4.1. Patient Reported DPA Scores

Comparative Outcome

Patient #1 was initially treated with a MET to correct the pelvic girdle dysfunction and then presented with a negative March test. The patient reported a minimal clinically important difference (MCID) on the NRS after the MET treatment (Table 3). The patient returned to the clinic 2 days later and reported a 2 of 10 NRS score and a MCID for GRC (Table 4.3). When the patient was re-examined, she maintained normal pelvic girdle function and received a MYK L5 treatment to correct lingering complaints of pain and inability to stand for prolonged periods of time. Post-treatment the patient reported a MCID on NRS (0 of 10) (Table 4.3). At the one week follow up the patient reported a MCID for GRC and DPA scale (Table 4.3; Figure 4.1). Patient #1 continued to complain of "tightness where the pain used to be" and received another MYK L5 treatment, post-treatment there was no change in NRS (0 of 10). At a one month follow-up visit, patient #1 reported a MCID for GRC and DPA scale and was discharged (Table 4.3; Figure 4.1). At the patient's one year follow-up appointment, the patient reported a 0 of 10 NRS without any recurrences of LBP.

Patient # 2 was initially treated with MET to correct the pelvic girdle dysfunction and reported no change on the NRS, however presented with a negative March test. The patient returned to the clinic four days later and reported no change in NRS and upon re-examination maintained normal pelvic girdle function. The patient remained unable to touch his toes and received a MYK L5 treatment to decrease pain and improve function. After the MYK L5 treatment the patient a MCID was met for the NRS (3 of 10). The patient returned to the clinic after two days reporting a MCID on GRC and DPA scale (Table 4.3; Figure 4.1). The patient received another MYK L5 treatment. The patient's NRS pre-treatment was 4 of 10. Post-treatment a MCID was met on NRS (1 of 10) (Table 4.3). At the patient's one week follow up appointment, the patient complained of limited range of motion touching his toes and was experiencing intermittent pain (NRS 1 of 10). Figure 4.2 displays a picture of his toe-touch pre and post after the first MYK treatment. Figure 4.3 displays toe-touch pre and post after the second MYK treatment. A third MYK L5 treatment reduced the patient's pain from 1 of 10 to 0 of 10. At this time, the patient was discharged from treatment. At discharge the slump test was negative. At a one month follow-up the patient reported a MCID for GRC and DPA scale (Table 4.3; Figure 4.1). At a one year follow-up the patient reported a 0/10 NRS without any recurrences of LBP since treatments concluded.

Figure 4.2. Patient #2 Toe-Touch Pre and Post First MYK L5 Treatment

Figure 4.3. Patient #2 Toe-Touch Pre and Post Second MYK L5 Treatment

Discussion

The findings of the two patients within this Exploratory Clinical CASE Report presented unique patient outcomes compared to those experiencing LBP and presenting with a herniated disc. Each patient reported MCID for a variety of patient outcome measures and reported all symptoms resolved in 4 treatments or less. In another case study,[13] the MYK posture assessment and treatment produced similar positive patient outcomes in a patient that had failed typical conservative treatment and surgical interventions; the patient reported full resolution of pain in 7 treatments in two weeks and was discharged after 10 treatments.[13] The patient in the case study by Brody et al.[13] and the patients in this manuscript presents two separate examples of positive outcomes in improving function and decreasing pain by utilizing the MYK system.

In this Clinical CASE series, both patients received a MET first and it was beneficial in restoring normal pelvic girdle function when assessed using the March test. The effects of this unique treatment combination (i.e., MET and MYK) resulted in both patients reporting full pain and dysfunction resolution in two weeks from initial treatment for a herniated disc. Patient #2 far exceeded normal rehabilitation time frames for an acute onset of LBP, whereas if successful, patients completing traditional conservative care typically have resolution of symptoms in 4 – 8 weeks.[7,20] Additionally, depending on the results of diagnostic imaging, a patient reporting LBP for nine years (patient #1), who failed conservative care would most likely undergo surgery to decrease pain and improve quality of life. Nonetheless, long-term patient outcomes following a surgical intervention are unconvincing that surgery will decrease pain and/or improve quality of life.[21–24] It is unknown if only MYK treatments or a combination of MET and MYK treatments is necessary to produce comparable results in other patients who have similar symptoms.

It has been reported, that regardless of whether or not a patient successfully completes conservative care, up to 45 percent of patients go on to receive a surgical intervention.[7,23] The discouraging short and long-term success with typical conservative care and surgical options often leave patients looking for other options. Both patients reported no episodes of LBP between discharge and their one year follow up. Weinstein et al.[23] found that there was no difference in long-term outcomes when comparing surgery to conservative care options.[7] Furthermore, Parker et al.[9] reported that 22 percent of patients after a discectomy reported worsening of back pain or disability at a one year follow up; this in turn led to reporting a decrease in quality of life and general health state.[9] Additionally, patient #1 reported that this was the longest period of time since initial injury with no episodes of LBP. The MET and

MYK treatments provided positive short and long term results and could be a viable option for many patients experiencing LBP.

There are a variety of conservative care treatment options for those experiencing LBP, however the high recurrence rate of LBP suggests that the treatments might not appropriately target the source of pain.[10] Many patients are told that the source of their pain is from anatomical abnormalities such as a bulged or herniated disc, even though many patients who do not have any associated symptomology also have these abnormalities on magnetic resonance imaging.[2,5] In accordance with other proposed theories, the LBP in these patients could be stemming from changes in the CNS and PNS motor control and core stability patterns. Theoretically, the MYK treatment creates postural changes through the CNS and PNS and it appears that MYK might be a treatment to significantly decrease time loss from injury and aid patients in restoring optimal function.[14,15] It should be noted that even though both of the patients received a L5 MYK treatment, other patients should receive a MYK treatment based upon their postural assessment regardless of the location of structural abnormalities. The MYK postural assessment may indicate the same or different level of the structural abnormality.

Further research is needed to explore if a decrease in time loss from injury using MET and MYK treatments can be expected in others patients presenting with similar symptoms. Also it would be beneficial to understand if the same results could be produced using only the MYK system as seen in the Brody et al. case study.[13] Additional research is needed to identify if various anatomical abnormalities correlate to postural imbalances leading to specific MYK treatment suggestions. Lastly, it is essential that future research examines the current theory of anatomical abnormalities as always the source of LBP; this is crucial to improving patient outcomes.

Clinical Bottom Line

In two patients diagnosed with a herniated disc at L5, utilizing MET and the MYK system produced improvements in pain and function. Thus, it remains questionable whether the presence of a herniated disc was the cause, a contributor, or unrelated to LBP. The improvements in these two patients was clinically significant and utilizing a MET and MYK system and may be beneficial for other patients reporting similar symptoms.

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Chapter 5

Culminating Applied Clinical Research

A manuscript titled "The Prevalence of Breathing Pattern Disorders in Physically Active Individuals with or Without Musculoskeletal Pain"

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Introduction

An estimated 3-5 million injuries occur among those participating in physical activity and athletics.[1,2] Musculoskeletal pain is a major health concern because of the detrimental effects on quality of life and its excessive prevalence.[3] Breathing pattern disorders (BPDs) are known to cause persistent symptoms (e.g., musculoskeletal pain, altered motor patterns, dyspnea, anxiety, headaches, digestive disorders) that appear to have no causation and are often contributed to other general health factors (e.g., postural maladaptation's, congenital disorders, braced posture [post-operative], allergies, metabolic disorders, anxiety disorders, panic disorders, mental distress/ trauma).[4–6] Despite the possible connection between BPDs and musculoskeletal pain, clinicians do not consistently recognize that breathing plays a key role in maintaining optimal function of the neuromuscular system.[7–9]

The Central Nervous System (CNS) is the link connecting optimal breathing patterns to quality and functional movement, motor control, and core stability; "If breathing is not normalized no other movement pattern can be."[10] The genetically pre-determined predictable pattern for developing motor control is coordinated through the CNS.[11] Moving limbs, rolling, crawling, and walking are all developed from the fundamental motor pattern, breathing. It is agreed upon by experts that at birth, a healthy baby is provided with the necessary information from the CNS for learning optimal neuromuscular function in conjunction with breathing.[5,12,13] Therefore, if a patient-athlete presents with musculoskeletal pain and/or dysfunctional movement patterns, it is essential to assess the breathing mechanics, as this is the foundational component of the neuromusculoskeletal system. Under this developmental kinesiology philosophy, BPDs may be causing or contributing to dysfunctional movement patterns and/or musculoskeletal pain.

Compromised core stability is commonly associated with a variety of musculoskeletal injuries.[8,11] Sufficient core stability is essential for optimal physical performance, yet the commonly promoted core exercises ignore the role of breathing. The diaphragm modulates intra-abdominal pressure (IAP) and initiates core stability through the CNS.[5,11,14–17] Therefore, suboptimal breathing patterns should be corrected in conjunction with any musculoskeletal pain that may be associated with poor core stability.[8,11] In 2009, Roussel et al.[17] found that apically driven BPDs were observed in chronic low back pain (LBP) patients during motor control testing, while none of the healthy control changed their breathing patterns. While there could be many sources of LBP, one theory is that the respiratory musculature was not contributing to maintenance of core stability and posture.[8,11,17] Further, Hodges et al.[18] found that when respiratory demands increased the postural activity of the diaphragm and transverse abdominus decreased. The identification of BPDs may help explain the high incidence and recurrence of LBP and other injuries in the physically active population, especially when otherwise quality treatments have little to no effect on improving pain and/or dysfunction.[8,17]

The body uses the breath to adapt and compensate for any stressors while simultaneously influencing the biomechanical, chemical, and psychological systems.[13] Psychologically, the breathing rate and volume will adapt to thoughts, emotions, and experiences via the limbic and autonomic nervous system (e.g., stress, anxiety, anger, perceived threats) as a self-protective mechanism. For example, the sternocleidomastoid muscles will become taught, mouth will open, clavicles will rise cranially, the upper rib cage will expand, and the breath will be shallow and rapid. Similarly, when factors such as altitude, hormones, diet, allergies, and pharmacological drugs are introduced, the body will make various adaptations to maintain allostasis;[13] one adaption could be the rate or volume of the breath to maintain the acid-base balance (pH).[19] These examples of chemical and psychological triggers of suboptimal breathing patterns could result in muscular imbalances, motor control deficits, and altered movement patterns; this concept may explain musculoskeletal dysfunctions that lead to pain and/or injury.[7]

It is essential to recognize if the breathing pattern (BP) is normal at rest before it can be tested during functional activities. We developed the following definition from current research regarding the function of the neuromusculoskeletal aspect of the respiratory system.

> During a normal breathing pattern at rest, the abdominal and lower chest cavity should expand symmetrically, while the sternum moves ventrally.[5] Upon inhalation, the diaphragm contracts and flattens as organs are pushed caudally; functionally the diaphragm and pelvic floor concentrically contract, while muscles inserting into the thorax and abdominal wall eccentrically contract.[5,9,11,13] Intercostal spaces widen, and the lower part of the thorax expands in width and in an anterior-posterior direction. The thorax should expand equally in all directions, as the diaphragm and thorax are oval in nature allowing for symmetrical expansion.[20] The thoracic cavity's osseous and soft tissue should be elastic and compliant in functional movements.[12,13] At rest the breath should be through the nose, slow, and have a brief pause between breaths.

Any variation of an optimal abdominal breath should be classified as a BPD.[5,9,12,13,20,21] Table 5.1 proposes characteristics of BPD classifications.

Table 5.1. Direction and Quality of Respiratory Motion (DQRM) Breathing Pattern Classifications

Classification	**Description**
Paradoxical	Abdomen is drawn in upon inhale, chest expands anteriorly or laterally, and cranially
Apical High	Breath is in shoulders/clavicles
Apical Low	Breath is at breast point
Apical Lateral	Ribs are expanding laterally at xiphoid process
Apical Abdominal	Primary apical motion, with some abdominal motion secondary to chest motion
Abdominal Apical	Abdominal breath that secondarily has apical motion more than lateral or abdominal high/middle/ low motion
Abdominal High	2 inches above umbilicus normal breaths anterior motion, rib cage either flexed or extended
Abdominal Middle	Breath anterior at umbilicus(2inches +/-) anterior motion, rib cage either flexed or extended
Abdominal Low	2 inches below umbilicus anterior motion, rib cage either flexed or extended
Abdominal Lateral	Lateral and anterior motion of abdomen, rib cage in neutral position
Abdominal Posterior*	Abdominal expansion in 3 directions symmetrically with posterior motion and little 11th and 12th rib flare, rib cage in neutral position
* *Optimal BP according to proposed definition*	

The breath is accepted as playing an important role in sustaining life, but there is a dearth of research correlating the potential effects of BPDs in relation to the presence of various pathologies, injuries, and diseases. This lack of connection is due to absence of research and the complexity of measuring the seamless adaptations of breathing for the various demands of activities of daily living. In 2004, Perri and Halford[9] assessed breathing patterns in 94 local community members and found that 56.4 % of the participants had faulty breathing while in a relaxed state. Physical activity increases the demands on the body; therefore, it is possible that the consequences of BPDs may be multiplied and predispose the physically active population to various conditions (e.g., headaches, musculoskeletal pain, injuries, pseudo exercise-induced asthma, respiratory infections, digestive problems).[4,8,22] It is necessary to understand if BPDs are present in those complaining of musculoskeletal pain to recognize a potential source or contributor to chronic or acute pain. The purpose of this study was to explore the prevalence of BPDs in physically active participants presenting with and without musculoskeletal pain.

Methods

An observational research design was utilized to assess breathing patterns in a physically active population with and without musculoskeletal pain and/or injury.

Participants

Data was collected on a convenience sample of physically active college students in the Northeast United States who were participating in physical activity 3-5 times per week. Participants were excluded if they were not fit for physical activity (as assessed by a physician), had diabetes, kidney dysfunction, neurodevelopmental diseases, and/or were pregnant. The exclusion criterion was selected from factors which are known to cause non-mechanical changes in breathing patterns.[4,6,12] If participants reported asthma and/or exercise-induced asthma (EIA) (n=8) as a medical condition they were not excluded; as hyperventilation syndrome (a BPD) and asthma have similar symptoms.[23,24] The sample size was determined from an a priori power analysis from previously collected pilot data and it was determined that 26 participants were needed in each group with the significance level set to $p = 0.05$ and with a power of 80%. Participants without an injury in the last eight weeks were used as the control group ($n = 27$), while those who reported an injury in the last eight weeks were used as the experimental group ($n = 27$).

Procedures

After approval by the Institutional Review Boards, recruitment of participants began. The participants completed a general health questionnaire, which determined group (control vs. experimental). Breathing is extremely adaptive and as soon as the participant is aware that their breathing is being assessed the participant's natural and current breathing pattern may alter. To address this issue, participants were informed that they were to be partaking in a movement assessment. The participants were informed that the movement assessment (i.e., the breathing assessment) and questionnaire would not affect their evaluation or treatment for musculoskeletal pain and/or injury. The breathing assessment and questionnaires were completed in approximately 30 minutes. If a BPD was observed, the participant had the option to receive treatment and home exercises.

Breathing Assessment

Data was collected from the general health questionnaire, Depression Anxiety Stress Scale, Patient Well-Being questionnaire (Intra-Class Correlation; ICC = .931, 95% CI = .747, .982 [pilot study to assess instrument]), and the Breathing Assessment form. The breathing assessment included observation, breaths per minute (BPM), Hi Lo test, Direction and Quality of Respiratory Motion (DQRM), and the Manual Assessment of Respiratory Motion (MARM). The components of the breathing assessment were compiled from the best current literature regarding assessment of breathing patterns.

Observation of posture, resting position of mouth, and any prominent neck musculature were noted. The participant's breaths per minute (BPM) were calculated using a timer (Accusplit Inc., Pleasanton, CA; A601X model). The Hi Lo test was assessed in supine and sitting positions, previous inter-rater reliability was moderate (Kappa coefficient by

Roussel et al.,[25] κ= .42, .46).[7,25] The participant was directed to place one hand on their chest, while their other hand rests on their abdomen. The researcher was looking for which hand is moving first.

The Direction and Quality of Respiratory Motion (DQRM) is a tool used to measure the quality of primary and secondary respiratory motion (Table 1). The DQRM starts by having the clinician place their thumbs parallel to the spine and hands on the posterior and lateral aspects of the 11th and 12th ribs. While the participant breathes, the clinician identifies the primary direction of respiratory motion and the direction of secondary motion and then denotes if it was asymmetrical or symmetrical motion. The clinician also identified if the primary motion of abdominal breathing pattern was optimal or insufficient. Insufficient motion would be defined as motion in the direction but not the optimal motion to sustain a functional abdominal breathing pattern. The participant is instructed that the clinician is looking at their back and does not cue the participant to breathe. Preliminary reliability testing was conducted using a Cohen's Kappa coefficient and was fair (κ= .52; unweighted [pilot study to assess instrument]) and substantial (κ= .78; weighted [pilot study to assess instrument]). Table 5.1 displays the descriptions for the various breathing patterns identified using the DQRM.

The Manual Assessment of Respiratory Motion (MARM) was used to assess the participants breathing pattern in a sitting position (Intra-Class Correlation by Courtney et al.,[26] MARM balance; ICC = .850, p = .0001).The test uses a half circle and the clinician draws a line of perceived motion. The lines are then measured to identify direction and volume of motion into the abdomen or thoracic rib cage if the volume is predominantly an abdominal or apical breathing pattern. The MARM values are calculated by measuring angle differences between the highest point of the inhalation (upper rib cage) and the lowest point (lower rib cage).[13,26] Positive values are indicative of chest breathing and negative values indicate abdominal breathing.[13]

Data Analysis

Descriptive statistical analysis was performed to identify and assess differences in characteristics of BPDs between groups. A frequency test was used to analyze prevalence of BPDs in participants within the experimental and control group. Chi-squared tests were used to analyze associations in categorical variables between groups (i.e., Hi Lo, DQRM, MARM, observation, and area of injury). Correlation between DASS scores and PWB scores was analyzed using Pearson correlation coefficient. Statistical analyses were completed using SPSS 23 (Version 23.0 for Windows, SPSS Inc., Chicago, IL, USA) with an alpha level set at $p \leq .05$. To analyze effect size, phi (φ) was used for chi-squared analysis (small = 0.10, moderate = 0.30, large = 0.50).[27]

Results

Participants

A total of 54 male (n=11, 20.9 ± 1.51 years old) and female (n=43, 20.2 ± 1.53 years old) participants were included in the data analysis. Three participants indicated they had been diagnosed with scoliosis, but none reported back pain from this condition. An overlap in diagnosed asthma (n = 5) and/ or EIA (n = 7) by a physician was reported in a total of eight of the participants. In the experimental group, 52% reported a lower extremity injury (i.e., hip, thigh, knee, lower leg, ankle, and/or foot), 33% reported a spine injury (i.e., cervical spine, thoracic spine, lumbar spine, or pelvic girdle), and 15% reported an upper extremity injury (i.e., shoulder girdle, shoulder, elbow, forearm, wrist, and/or hand). Anatomical area of injury and BP classification for the experimental group are displayed in Table 5.2.

Table 5.2. Area of Injury and Primary Respiratory Motion for experimental Group

Breathing Assessment tool	Upper Extremity		Spine		Lower extremity	
Primary Breathing Pattern Motion (DQRM) and Hi Lo Assessment (seated)	Count	% of Group	Count	% of Group	Count	% of Group
Paradoxical	0	0.0%	0	0.0%	1	3.7%
Apical	2	7.4%	6	22.2%	9	33.3%
Abdominal	2	7.4%	3	11.1%	4	14.8%

Frequency of BPD classification between groups

The control group was found to have more participants with an abdominal BP (56%) compared to apical BP (44%). The experimental group displayed less participants with an abdominal BP (37%) to apical BP (63%). A statistically significant association was not observed (χ^2 (2) = 3.362, p = .186) and the effect size was small (φ = 0.25) with a high chance for a type II error(adjusted residuals <1.96);[28] however, a general trend of more apical BPDs was displayed in those with pain than those without pain. According to the DQRM and the proposed definition of an optimal breathing pattern (BP), a surprising 96.2% (n = 52) of the 54 participants were found to present with a BPD. Using the DQRM assessment tool, an optimal BP was found in only 7.4% (n = 2) of the control group and 0.0% (n = 0) were found in the experimental group. Table 5.3 displays frequency statistics regarding type of BPD based upon each assessment tool between the control and experimental group.

Table 5.3. Frequency of Breathing Pattern Classifications Derived from DQRM, Hi Lo, and MARM Between Control and Experimental Groups

Breathing Pattern Classification by Assessment tool	**Control** *(No pain or injury in the past 8 weeks)*		**Experimental** *(Pain or injury in the past 8 weeks)*	
	Count	% of Total	Count	% of Total
DQRM				
Paradoxical	0	0.0%	1	1.9%
Total Paradoxical	0	0.0%	1	1.9%
Apical High	4	7.4%	8	14.8%
Apical Low	4	7.4%	6	11.1%
Apical Lateral	1	1.9%	2	3.7%
Apical Abdominal	3	5.6%	1	1.9%
Total Apical	12	22.2%	17	31.5%
Abdominal Apical	2	3.7%	0	0.0%
Abdominal High	4	7.4%	0	0.0%
Abdominal Middle	2	3.7%	3	5.6%
Abdominal Low	3	5.6%	5	9.3%
Abdominal Lateral	2	3.7%	1	1.9%
Abdominal Posterior	*2	3.7%	0	0.0%
Total Abdominal	15	27.8%	9	16.7%
Hi Lo (Seated)				
Paradoxical	0	0.0%	1	1.9%
Apical	12	22.2%	17	31.5%
Abdominal	15	27.8%	9	16.7%
Hi Lo (Supine)				
Paradoxical	0	0.0%	1	1.9%
Apical	12	22.2%	16	29.6%
Abdominal	16	29.6%	9	16.7%
MARM +				
Apical	19	35.2%	23	42.6%
Abdominal	8	14.8%	4	7.4%

** Optimal BP according to proposed definition*
+ MARM Classification from balance calculation
All Percentages are of total participants (count/54)

DQRM = Direction and Quality of Respiratory Motion; MARM = Manual Assessment of Respiratory Motion

Associations between categorical variables

A chi-square test was performed to compare associations between categorical variables for the control and experimental group. A statistically significant association between the experiment and control groups and pain in the last year was observed (χ^2 (1) = 4.800, p = .028) with a moderate effect size (φ = .298). Additionally, there was a small association (p = .028) between groups and pain in the last year and moderate effect size (φ = .298,). A statistically significant association between the experiment and control groups and pain upon palpation was observed (χ^2 (1) = 8.963, p = .003) with a moderate effect size (φ = .407). No statistical significant association between groups and observation of mouth open or closed (χ^2 (1) = 2.700, p = .100), supine Hi Lo (χ^2 (2) = 4.267, p = .120), seated Hi Lo (χ^2 (2) = 3.362, p = .186), MARM Balance (χ^2 (1) = 1.714, p = .190), or DQRM primary respiratory motion (χ^2 (2) = 3.362, p = .186) was observed. Table 5.4 displays chi-squared associations between categorical variables.

Table 5.4. Chi-squared Values Between Categorical Variables and Groups (Control vs. Experimental)

	Variable	Value	df	2 side sig	Phi
	Mouth Open or closed	2.700	1	0.100	0.224
*	Hi Lo Supine	4.247	2	0.120	0.280
*	Hi Lo Seated	3.362	2	0.186	0.250
*	DQRM Primary Motion	3.362	2	0.186	0.250
	MARM Balance	1.714	1	0.190	0.178
	Pain with palpation	8.963	1	0.003	0.407
	Pain in Last year	4.800	1	0.028	0.298
*	DQRM apical	2.272	3	0.518	0.280
*	DQRM Abdominal	9.410	6	0.152	0.614
	* = cell count less than 5 increasing chance for error in statistical association				

Correlations

The PWB and DASS are designed to measure psychological factors that may be relevant to BPDs. A strong positive correlation ($r = .635$, $r^2 = .403$, $p \leq .01$ (2 - tailed)) between the DASS (95% CI (7.010, 11.323)) and PWB (95% CI (24.639, 30.768)) questionnaires was observed across both groups. Additionally, the model explains 40.3% ($r^2 = .403$) of the variability in differences between the PWB scores and the DASS scores.

Discussion

The Hi Lo assessment is designed to only differentiate between the primary direction of respiratory motion (i.e., paradoxical, apical, and abdominal) and is most commonly used in research. The information gathered from the Hi Lo is not sufficient to distinguish between a dysfunctional and an optimal abdominal breathing pattern, as it does not account for rib cage position in relation to the pelvis, asymmetrical lateral expansion, and/or three-dimensional expansion of abdomen. The MARM was designed to quantify distribution of motion and improve assessment of breathing patterns;[26] yet, during data analysis in this study, the specificity of the balance, volume, and percent of rib cage motion were difficult to compare to the anatomical classifications of BPDs. The measurements gathered from the MARM may display other information rather than BP classifications. The DQRM was designed to recognize primary and secondary respiratory motion (e.g., abdominal high, abdominal middle, abdominal low, etc.) allowing for further distinction of an optimal or suboptimal abdominal BP. The DQRM and Hi Lo assessment tools were used in this study and reported similar percentage of primary BP motion between groups (Table 3). Whereas, the MARM balance, volume, and percent rib cage motion measurement did not present with similar percentage of primary BP between groups (Table 3).

The definition of a BPD is paramount in analyzing prevalence of BPDs. If the Hi Lo test (seated position) and classification of abdominal motion is identified as an optimal breathing pattern, 55% (apical and paradoxical BPDs) of all the participants would be diagnosed with a BPD. However, using the proposed definition in this manuscript of an optimal BP (Table 5.1), an overwhelming 96.2% of all the participants would be classified as presenting with a BPD. Using the DQRM the clinician can recognize and include other factors such as rib cage position, asymmetrical lateral expansion, and three-dimensional expansion, which contribute to the classification of BPDs and subsequently lead to different treatment prescriptions. Consequently, the inclusion of these factors in the classification of BPDs increased the rate of diagnosis in this study's participants. The high prevalence of BPDs using the DQRM and our proposed definition in the control (92.5%) and experimental (100%) group most likely contributed to the lack of statistically significant difference between groups.

In contrast, if the Hi Lo test (seated position) (i.e., apical and paradoxical classification) was the only allocating factor to differentiate and classify breathing patterns, 56% of the control group and 63% of the experimental group displayed BPDs. The comparable percentages of apical and paradoxical BPDs to abdominal BPDs between groups would likely contribute to the lack of statistically significant difference. If a test or classification system points to a dysfunction percentage nearing 100%, one must always consider the likelihood that the tests or classifications were too sensitive. In this study, however, it is unlikely when considering the evidence that across all body areas, previous injury and inadequate rehabilitation are a predominate risk factor for injury.[2,29,30] Additionally, from a clinical relevance standpoint the BPDs classifications may lead to different treatments (e.g., Hi Lo findings of an apical BPD may use a different treatment vs. findings of an abdominal breath with loss of lateral breath BPD).

In this study, a statistically significant association (p = .028) between previous injury within the past year and experiencing an injury in the past eight weeks was observed. Only 29.6% (n = 16) of the participants in this study had not sustained an injury in the past year or past eight weeks and all were in the control group. Furthermore, half (n = 8) of those participants presented with some variation of an abdominal breathing pattern using the Hi Lo and DQRM assessment. Finding a population with no previous injury is necessary to accurately depict BP in physically active population as the control group. Analogously, patients who do not complete adequate rehabilitation for motor control after an ankle sprain are at an increased risk of developing chronic ankle instability.[31] The same increased risk could occur in patients with BPDs as the body does not consistently re-establish motor control following an injury. Therefore, injuries stemming from poor core stability (e.g., LBP), where breathing is not re-trained should be considered inadequate rehabilitation and may predispose the patient to re-injury. It is unknown how long BPDs may persist after an injury without proper intervention; the apparent cause could be several years removed from the assessment.

A major difference between the general population and the physically active (PA) population is the consistent increase of demands on the body through exercise that athletes place on their body. The definition used in this study is very specific and the threshold at which BPDs becomes symptomatic in patients is unknown. Is an abdominally driven BP "optimal enough" to not cause symptoms in the PA population? In this study, a 33% incidence of LBP, thoracic spine, and/or cervical spine injury in the experimental group indicates otherwise. Similarly, Boyle et al[8] theorized that the high recurrence rate of injuries in the PA population may be indicative of a missing component, and suggested that incorporating the diaphragm into traditional core stabilization exercises might be beneficial to improve LBP outcomes.[32] Additionally, In 2010, Cook et al.[33] proposed that, if the end range of movements caused unwarranted bracing, breathing difficulties, and breath holding, then the movement indicated a motor control dysfunction and should be corrected prior to local or global stabilization patterns were addressed. The theories above emphasize the importance of motor control, quality movement, and the impact breathing patterns could have on the biomechanical system to improve performance, decrease risk of injury, and/or improve rehabilitation protocols to decrease the risk of injury due to experience with previous injury.

Psychological Influences

The cortical and subcortical input from the brain adds a complex twist in understanding breathing patterns.[9,34,35] Ivarsson et al.[36] reported that psychological factors (e.g., stress, irritability, and anxiety) were significantly higher in those who later sustained an injury and potentially predict injuries in elite soccer players.[37] Additionally, the study by Ivarsson et al.[36] findings recommend teaching coping and stress management skills to decrease risk of injury. However, there is currently no proposed theory as to the cause for increased risk of injury in those under psychological stressors. A potential theory for the increased risk of injury may be associated with the Autonomic Nervous System (ANS); it controls various adaptations (i.e., breathing rate, cardiac output, chemical responses, and neural outputs) to meet the demands of every situation and can elicit the sympathetic or parasympathetic nervous system based up factors, such as sight, smell, touch, temperature, thoughts, memories, and/or emotions.[34,35,38–40] For example, mouth breathing is suggested to be indicative of a patient in the sympathetic response and consequently would alter breathing pattern, heart rate, heart rate variability, subjective units of distress scale, and decreased tolerance to normal palpation.[9,20,35,40] As a breathing pattern is altered by the ANS, the CNS (e.g., postural and movement patterns) will adapt, therefore changes are often unnoticed by the conscious mind.

The PWB and DASS questionnaires were included in this study to measure the aspects that influence psychological factors and BPDs. A strong positive correlation (r= .635) indicates that the PWB questionnaire may be useful in measuring depression, anxiety, and stress as it relates specifically to BPDs. The PWB was designed to measure factors that specifically relate to BPD symptoms (e.g., emotions, sleep, pain, respiratory issues, memory, and focus).[4,20,41] In contrast, the DASS is intended to measure overall depression, anxiety, and stress.[42,43] The PWB questionnaire is targeted towards BPD symptoms was significantly higher (p = 0.024) in the experimental group that also presented with more apical (n = 17) and paradoxical (n = 1) BPDs versus the control group, apical (n=12).

In 1940, human participants were exposed to a brief painful stimulus (pinprick to hand), after the pain dissipated, the participants were asked to recall the painful stimulus, and an increase in respiration happened upon recalling the event.[34,38] Simply by remembering a painful event, the participants breathing rate was altered, which demonstrates a profound connection between physical pain, respiration, and cognition.[13,34,35,44] The high prevalence of BPDs found in this study and other populations may further be explained by the classical conditioning theory and adaptability of the breath to physical musculoskeletal injury and/or pain. Therefore, a maladaptive breathing pattern, from cognitive thoughts (e.g., thinking of pain from previous injuries), might lead to dysfunctional motor patterns and predisposition for musculoskeletal injury.

Limitations

This study had a few limitations: the participants were a sample of a small community and it may have been known that breathing was being assessed rather than global movement patterns; the participants could have altered their breathing pattern if they knew breathing was being assessed. The BPD assessment tools have limited intra-rater and inter-rater reliability research, thus clinical relevance should continue to be examined, and may have affected the results. The results from this research were collected on a physically active population with a small age range and small amount of male participants. Therefore, the results may not be appropriate for generalization to all physically active patients.

Future Research

Future research should explore prevalence and classification of breathing patterns (inhalation and exhalation) in other populations (e.g., infants, children, adolescents, athletes), and this would significantly contribute to our understanding and definition of an optimal breathing pattern. Currently, the threshold at which a BPD becomes symptomatic is unknown, therefore future research should explore when BPDs become a major contributor or cause of musculoskeletal injury and/or general health conditions. Other factors besides primary direction of respiratory motion, such as rib cage position, asymmetrical lateral expansion, and three-dimensional expansion should be explored as they appear to be major contributors to defining and classifying BPDs. Additionally, research exploring short-term and long-term effects of treatment for BPDs on musculoskeletal pain and general health are also necessary.

Conclusion

Breathing is rarely assessed during an orthopedic evaluation regardless of the extensive list proposed regarding BPDs effect on the neuromusculoskeletal system.[4,7,9,17,25] In this observational research study, 100% of the experimental group and 92.6% of the control group presented with a BPD according to the proposed definition. Among experts it is agreed that a normal abdominal breathing pattern is rare and BPDs are more common,[9,13,21] and the results found in this study support this conclusion in a physically active population.

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