Investigation of the Rosenbaum Concussion Knowledge and Attitudes Survey in Collegiate Athletes: A Dissertation of Clinical Practice Improvement

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with a

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by

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Authorization to Submit Dissertation

This dissertation of Erin B. Chapman, submitted for the degree of Doctor of Athletic Training with a Major in Athletic Training and titled "Investigation of the Rosenbaum Concussion Knowledge and Attitudes Survey in Collegiate Athletes: A Dissertation of Clinical Practice Improvement," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

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Abstract

The capstone project of the Doctor of Athletic Training program is a Dissertation of Clinical Practice Improvement (DoCPI). The DoCPI demonstrates my athletic training growth toward an advanced practitioner in my area of focus. Included in this project is my Narrative, which analyses my DAT journey toward advanced practice. Reflective practice is used throughout my DoCPI to demonstrate my clinical residency growth and clinical-reasoning improvement. My clinical practice growth is highlighted through my understanding of action research and evidence-based practice through patient outcomes, analysis of data, and dissemination of findings through scholarship. Evidence to support my growth toward advanced practice in the assessment and treatment of breathing pattern disorders is demonstrated in two manuscripts titled, "A Clinical Guide to Recognizing Breathing Disorders in the Physically Active: Part 1" and "Breathing Pattern Disorder and Interventions: Part 2." Lastly, a manuscript titled, "Investigation of the Rosenbaum Concussion Knowledge and Attitudes Survey in Collegiate Athletes" demonstrates an advanced *a priori* statistical analysis design to assess the validity and reliability of this outcome measure in a collegiate population.

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Dedication

To my mother and father, who have supported me through out my career with unconditional love. Thank you for listening and being a consistent support system with each step in my life. To Michael and my close friends, especially Jena and Patti, who have loved and supported me to not give up on my dreams. Thank you for showing me what true friendship is and that it is possible.

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Chapter 1

Narrative Summary

In 1990, athletic training (AT) was recognized as an allied health profession and has continued to evolve alongside the growing educational and clinical demands of healthcare (Delforge & Behnke, 1999). Initially, the minimum educational requirement for an athletic trainer was an undergraduate degree, but growing advancements in the profession led to the development of AT graduate programs. At that time, a terminal degree was considered a Master's degree in any given focus area (Nasypany, Seegiller, & Baker, 2013). Athletic trainers wanting to pursue a doctorate degree had limited options within the AT field requiring them to choose between becoming an expert in advanced educational strategies or basic research techniques by obtaining a Doctor of Science (D.Sc.), Doctor of Education (Ed.D.), or a Doctor of Philosophy (Ph.D.) degree. Further, AT practitioners who desired a program that combines both advanced knowledge and advanced clinical practice skills were without options. To fill this need, the Doctorate of Athletic Training (DAT) post-professional degree at the University of Idaho was developed in 2011 to foster improved foundational knowledge, introduce many novel assessment and intervention techniques, while utilizing patient outcomes and the best available evidence to improve clinical practice (Nasypany et al., 2013).

As a culminating end experience of the DAT program, a Professional Practice Dissertation (Willis, Inman, & Valenti, 2010) known as a Dissertation of Clinical Practice Improvement (DoCPI) is developed to assemble evidence of scholarship, outcome collection, reflective practice, and original research. The purpose of the DoCPI is to compose a portfolio that is relevant and applicable to the AT professional's clinical experiences and highlights their clinical evolution toward advanced practice (Nasypany et al., 2013; Willis et al., 2010). An advanced practitioner in AT is defined as a "board certified athletic trainer who has developed a focused area of clinical practice through the attainment of knowledge and skills both academically and through critical reflection of their patient care outcomes" (Nasypany et al., 2013). In this chapter, I will discuss the principles of evidence-based research, the impact evidence-based practice has had on my clinical practice, the application of evidence-based practice to my patient care, and the lessons I have learned on my journey toward a Doctorate of Athletic Training post-professional degree.

Scholarly practitioners must comprehend, analyze, and process the founding principles of evidence-based research to become successful in the DAT program (Nasypany et al., 2013). Evidence-based practice (EBP) was developed from evidence-based medicine and is "the process by which decisions about clinical practice are supported from research using scientific models and theoretical paradigms" (Hurley, Denegar, & Hertel, 2011, p.30). The integration of EBP into a practitioner's clinical setting requires the incorporation of their own clinical expertise, patient values, and the best available clinical research (Raab & Craig, 2015; Sackett, Rosenberg, Gray, Haynes, & Richardson, 1996). Therefore, the purpose of EBP is to improve the quality of care through a patient-centered approach. Values of the patient are incorporated in patient-centered care and patient-rated outcome measures (PROMs), which are often comprised in questionnaires or surveys, to quantify a patient's perception of their injury or illness; thus, bridging the gap between the patient's views and the treating clinician to tailor individual treatment plans (Michener, 2011).

Patient-rated outcome measures are designed to assess a wide range of health-related factors, such as physical function, symptoms, global health, psychological and social well-being, cognitive function, activities, personal constructs, and sensitivity to care (Fitzpatric, Davey, Buxton, & Jones, 1998; Michener, 2011). To evaluate change in a patient's health status (e.g., support short- and long-term goals), PROMs are collected consistently along with disease-specific outcome measures (DSOMs). Disease-specific outcome measures are included as not to ignore a practitioner's clinical judgment and assess the signs and symptoms of an injury or illness from their perspective (Fitzpatric et al., 2011). Disease-specific outcome measures may be misinterpreted and therefore should not be the only representation of a patient's progression. Without the inclusion of PROMs, along with DSOMs, clinical experiences and analysis of clinical research, athletic trainers cannot successfully incorporate EBP in their patient care or demonstrate the effectiveness of intervention techniques.

Practitioners integrate EBP to emphasize patient-centered care, develop critical thinking skills, and continually evolve the AT profession by improving the standard beliefs of athletic training and providing scientific support of athletic training methods (Steves & Hootman, 2004). Similarly, patients have their own goals and beliefs when seeking medical care. The primary concerns of a patient are often to reduce pain, improve function, and/or return to previous level of activity. Therefore, as a practitioner developing an EBP I had to learn how to interpret best current evidence from systematic research in relation to individual patients, including individual preferences, environment, culture, and values regarding health and well-being. The inclusion of PROMs in my clinical practice enhanced my awareness of a patient's perception of pain and/or a dysfunction, improved my evaluation of best practice, identified gaps in my injury assessments and interventions, and improved my clinical decision-making skills.

The term, EBP, cannot be deliberated without mentioning action research (AR) (Koshy, Koshy, & Waterman, 2010). Action research is defined as "healthcare practitioners conducting systematic enquiries in order to help them improve their own practices, which in turn can enhance their working environment and the working environments of those who are part of it – clients, patients, and users" (Koshy et al., 2010, p.1). The purpose of AR in an AT setting is to facilitate a specific change in patient outcomes by utilizing assessment and treatment techniques to improve patient care (Koshy et al., 2010). Action research is a continuous self-reflective cycle involving the assessment, action, critical reflection, and implementation of changes (Koshy et al., 2010). In the DAT program, students learn how to apply the concepts of AR to solve local problems (e.g., treatment for low back pain) rather than generate a global theory.

One of the first lessons I learned in my clinical residency was how to identify a local problem. I initially set out to improve my clinical practice by developing my skills in the assessment and treatment of chronic low back pain. Low back pain is a common injury in my clinical practice that often took months to alleviate. Therefore, I developed research questions to present the highest level of evidence to support an assessment that would identify the source of a patient's low back pain as well as a treatment paradigm that would immediately reduce pain and increase function. I then searched academic databases for the best evidence in the assessment and treatment of low back pain and incorporated it with my clinical experiences to develop an AR model. Following the assessment and treatment of this patient population, I analyzed the PROMs. The patients in this subset of my population did not have positive changes in their disablement as I lacked a strong foundational knowledge in clinical research and application of new treatment techniques. I was able to determine this shortcoming through continuous reflective practice of my AR model and patient-centered care. Reflective practice is an active learning skill used by practitioners to develop self-awareness and critically evaluate clinical decisions (Thorpe, 2004). In my patient care, I utilized reflective practice to identify gaps and improvements in my orthopedic assessments, intervention choices, and patient outcomes as well as provide further evidence of my progression toward advanced practice.

Additionally, continuous reflection of my patient care identified my inability to be mindful or present during patient interactions. I was not listening to my patients' concerns, missing key components of their medical history and injury assessments, and not applying the best treatment options based on their pain and/or dysfunction. Rather, I was simply operating under prior clinical communication experiences I encountered throughout my undergraduate education and employment. To correct this habit, I adapted the concepts of mindfulness; the practice of being consciously aware of one's experiences to promote positive changes (Rakel, Fortney, Sierpina, & Kreitzer, 2011; Shapiro, Carlson, Astin, & Freedman, 2006). The practice of mindfulness along with the tools (i.e., Tapping, Sensory Flow, and Traumatic Release Exercises) I have learned in the DAT program has taught me to be more aware of individual patient concerns and values.

The purpose of including mindfulness in my patient care was to develop a clinical environment that is non-judgmental and open-minded, to reduce clinical errors and immediately produce positive patient outcomes. The three concepts of mindfulness that I use on a daily basis to achieve the above goals are as follows: intention, attention, and attitude (Shapiro et al., 2006). The role of intention is to reflect upon the purpose of mindfulness (i.e., deepening practice, awareness, and insight) and my goals as a practitioner to address individual patient needs. Secondly, my attention is focused on a patient's moment-to-moment and internal and external experiences to direct my awareness and concentration during injury assessments and interventions. The last component and the most important aspect of my mindfulness practice is attitude. My attitude, positive or negative, affects the quality of my awareness of a patient's needs in a given situation. In my clinical practice, I use the three concepts of mindfulness concurrently with my clinical experiences, AR methods, and reflective practice to create a positive environment to treat a patient's physical and emotional well-being.

The DoCPI is a critical appraisal of my journey toward advanced scholarly practice supported by a detailed reflection and analysis of my evolution as an AT practitioner. My achievement of advanced practice begins with a clinical guide and corresponding *a priori* investigation of my clinical practice focus area: the assessment and treatment of breathing pattern disorders (BPD). A manuscript titled, "A Clinical Guide Recognizing Breathing Disorders in the Physically Active: Part 1" is included in Chapter 2 of my DoCPI and is a practitioner's guide to the assessment and classification of patients with a BPD in conjunction with musculoskeletal pain. The unique *a priori* investigation and AR method to determine the effectiveness of the assessment and treatment intervention, Primal Reflex Release Technique, in patients with a BPD and musculoskeletal pain is on the forefront of AT clinical research and illustrates my ability to incorporate advanced practice into my patient care. The patient outcomes from this *a* *priori* investigation is included in Chapter 3 of my DoCPI and is described in a second manuscript titled "Breathing Pattern Disorders and Interventions: Part 2" and provides further evidence of scholarship in my journey toward advanced practice. The results of my AR study subsequently provide fellow AT practitioners with a new assessment and treatment technique they can easily incorporate into their clinical practice to treat patients with chronic musculoskeletal pain that has not resolved using conservative treatment.

Finally, in Chapter 4, I provide evidence of increased knowledge about my chosen action research topic on the assessment of a concussion knowledge and attitudes survey through an *a priori* design. The National Collegiate Athletic Association's concussion mandate recommends all member institutions provide concussion education to their student-athletes, however at the present time the effectiveness of the guidelines is unknown. In addition, the efficacy of education programs cannot be determined without a psychometrically sound outcome measure. Multivariate statistical analysis of the Rosenbaum Concussion Knowledge and Attitudes Survey in a collegiate student-athlete population is described in Chapter 4 in an applied research manuscript, which offers scholarship in my progression toward advanced practice. The findings of my research study support the implementation of the Rosenbaum Concussion Knowledge and Attitudes Survey to quantify change in a collegiate student-athlete's concussion knowledge but not attitudes toward concussions. Through further analysis of the attitudes index, it may become an essential outcome measure in the development of an evidence-based concussion education program in a collegiate setting.

In my DoCPI, I demonstrate my scholarly journey toward advance practice with the understanding and application of EBP through the completion of manuscripts and an applied original research study. Through coursework and my clinical residency, I learned how to define clinically relevant questions pertaining to the daily demands of the athletic training clinic, search academic databases for the best evidence, critically appraise the latest research, apply the best evidence, and evaluate PROMs along with DSOMs to determine the effectiveness of intervention techniques. The knowledge and clinical experiences I acquired during this process were applied to my patient care through AR methods to not only improve my clinical practice but to also build a foundation in AT research.

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Chapter 2

Area of Focus Manuscript 1

Submitted to *International Journal of Sports Physical Therapy*

A Clinical Guide to Recognizing Breathing Disorders in the Physically Active: Part 1

Chapman E, Hansen-Honeycutt J, Nasypany A, Baker R, and May J.

The evaluation and treatment of breathing pattern disorders (BPD) may be essential in the treatment of musculoskeletal pain.[1-3] Breathing mediates neuromusculoskeletal responses through its influence of 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 paradigms such as, dynamic neuromuscular stabilization, selective functional movement assessment, Buteyko method, and Janda approach support the notion that breathing is the foundation of homeostasis and functional movement. In a typical athletic training clinic, assessing breathing patterns may seem like a foreign concept due to the lack of emphasis in the traditional patient assessment. However, this evaluation may be an overlooked and essential tool to improve a patient's primary complaint of musculoskeletal pain. The purpose of this paper is to demonstrate an easy way to integrate a BPD assessment into a standard clinical musculoskeletal orthopedic evaluation.

A BPD is a disorder, not a disease, which in most cases is remediable through rehabilitation and neuromuscular re-education.[1,7,8] Symptoms of BPD can mimic other diseases, often making the diagnosis and treatment challenging. Clinicians may not always be able to classify a patient into a specific BPD; therefore they must be knowledgeable of 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 accessory breathing muscles of the upper chest.[1,9] The insufficient gas exchange is thought to lead to respiratory distress and musculoskeletal imbalances.[9] Similarly, another BPD known as hyperventilation syndrome, or tachypneic, 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] Many of these secondary symptoms of BPDs may be resolved with suitable assessment and effective intervention.

Functional Breathing

The CNS is underdeveloped in infants, allowing muscle function 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 core stabilization, allowing the baby to roll, crawl, stand and begin walking.[4,5] Breathing requires synchronized concentric activity of the diaphragm and pelvic floor, as well as synchronized eccentric activity of all muscles that insert into the thorax and abdominal wall muscles.[13,14] Disruption of an abdominal breath can alter motor control patterns of postural muscles and spinal stabilizers.[5,6,15] The precise coordination and maturation of the CNS results in a unique perspective of a functional breathing pattern and movement.

Several muscles assist in the ability to take a breath. The primary and accessory muscles of inhalation and exhalation are listed in Table 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.

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 trapexius 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

Table 1. 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]

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 breathing patterns shifting.[6] The patient's posture should also be observed, as a slumped or hunched posture can limit the diaphragm's ability to fully expand.[18] After the breathing pattern observations and a full patient history, the clinician can start a comprehensive breathing assessment.

Breathing is assessed in a relaxed, supine position, but can also be observed in challenging positions such as sitting, standing, or positions that result in pain or discomfort.[6] The patient is directed to place one hand on their chest, while their other hand rests on their abdomen (Figure 1). The patient should 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]

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 plethysmograph.[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 breaths, the clinician measures perceived displacement and functional movement of the upper and lower rib cage movement, as well as abdominal expansion using two lines depicted on the patient to form a half of a pie chart and pressure placed on the clinician's hands (Figure. 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 1. The patient has been directed to place one hand on their chest and the other on their abdomen while in a supine position. As noted in the picture they are in a relaxed state and not focusing on their breathing. Placing the patient into a seated or standing position with the same handplacement can be challenging.

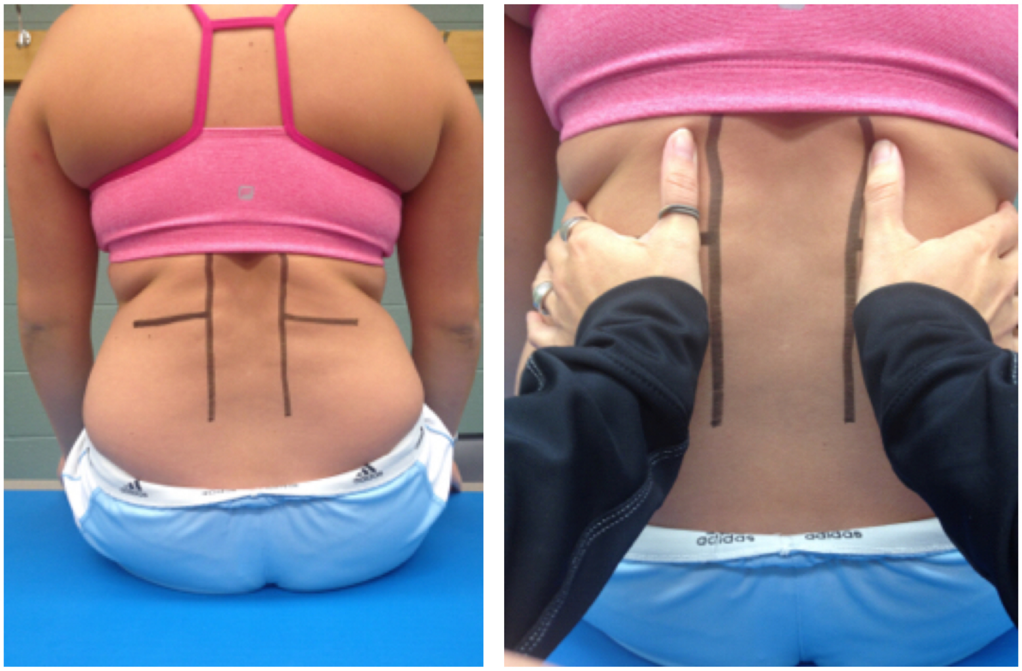

Figure 2. The lines drawn on the patient depict the MARM angles the clinician is using to classify and quantify lower rib movement.

Patients presenting with tender areas, jump signs, or withdrawal reflexes upon palpation at the $1^{st}/2^{nd}$, $7^{th}/8^{th}$, or $11^{th}/12^{th}$ ribs unilaterally or bilaterally, may be presenting signs associated with faulty breathing patterns.[1,20,21] It has been proposed that patients displaying increased sensitivity to normal palpation have an autonomic nervous system (ANS) that may not be appropriately balancing 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 the sympathetic nervous system (SNS), this person could be in a state of "up-regulation" and that present 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] Assessing specific locations with palpation may then be important in clinical practice, as the imbalance within the ANS could be the source of the BPD and musculoskeletal pain.

Classification

The variations of classifications of BPD could be infinite, however, the 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 the "normal" breathing pattern found in patients should not be considered the ideal functional breathing pattern. Further, there are a few dysfunctional variations of an abdominal breath. The abdominal breath may be asymmetrical with limited motion on one side of the abdomen, while another variation might only have anterior movement and no lateral or back movement. The last variation of a dysfunctional abdominal breath is one that lacks posterior movement, but has an adequate amount of anterior and lateral movement.

A chest or apical breather has excessive movement of the sternum and shoulder girdles toward the cranium, with 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 exhale the abdomen is pushed outwards.[7,8] A new BPD classification, proposed by the authors, is thought to be 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 manuscript three patient cases display the short-term effects of treating a startle reflex

BPD. Figure 3, is a visual representation of the classification of BPD in the athletic training clinic.

Breathing Pattern Assessment and Classification of Dysfunctions

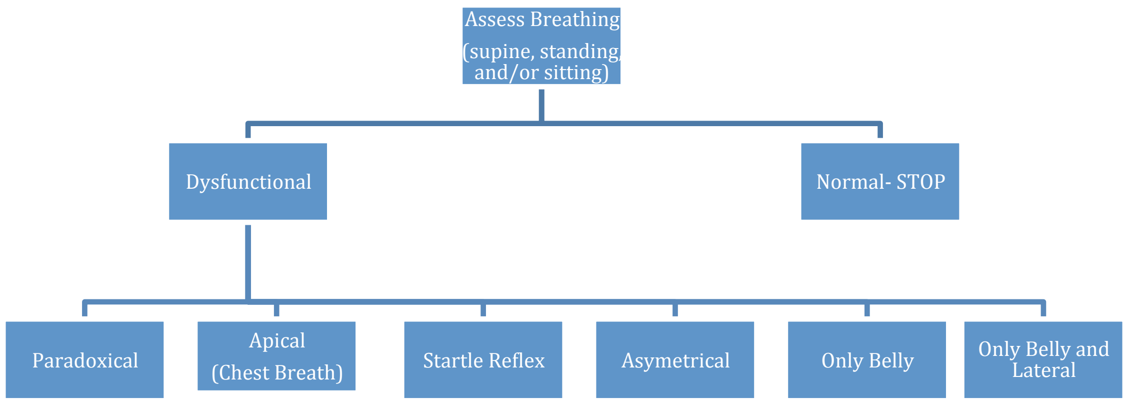

Figure 3. The flow chart is the systematic approach designed by the clinicians to effectively and efficiently assess breathing in the Athletic Training Clinic.

Outcome Measures

Breathing pattern assessments, outcome measures, and findings from an orthopedic assessment help to build a complete picture of BPDs.[6,7] Outcomes measures identify minimal clinically important differences in patients with pain[25] and dysfunction.[19,26] A number of scales 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 may include the Numerical Pain Rating Scale[26] and the Disablement in the Physically Active scale.[27,28] The Nijmegen Questionnaire is a self-assessment used to identify the presence of signs and symptoms associated with general and respiratory distress.[11] The assessment tools can easily be incorporated into an orthopedic evaluation without exceeding an appropriate amount of time for an evaluation.

Outcomes should encompass both disease-oriented and patient-oriented evidence. Disease-oriented 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, etc.). The Nijmegen Questionnaire[11] provides an overview of a patient's respiratory health where higher values represent distress and dysfunction of the respiratory system.[1] Patient-oriented 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 an orthopedic evaluation and functional biomechanical assessment (e.g. Selective Functional Movement Assessment). Functional movement patterns are a progression of neurodevelopmental postures that are predetermined by the CNS[4,9], that allow the body to maintain optimal positioning, stability and motion through active movements. Through the use of a functional assessment, it is thought that the clinician will be able to locate pattern deficiencies contributing to the chief complaint(s). The correction of breathing patterns should occur first and followed with integrating this into more 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 BPD requires little to no equipment in the athletic training clinic and intervention techniques provided by the clinician can be structured as a home exercise program in approximately 5 minutes or less.

Discussion

The purpose of this paper was to illustrate how to assess and classify BPDs prior to or in conjunction with the treatment of musculoskeletal pain or dysfunction. Since BPD is not a disease, it is usually not recognized until an assessment is performed.[6-8] The specific cause(s) of BPD are unknown, as each patient will adapt individual neuromuscular patterns. Postural and structural adaptations could possibly result in pain and/or dysfunction to the body, muscles, ligaments, or joints with no apparent organic source, possibly resulting in various BPD signs and symptoms. The three main attributing factors to BPD are: biomechanical, biochemical, and psychological.[3,8,9,29] Effective BPD interventions might be essential to improving global patient outcomes related to musculoskeletal complaints.

The act of breathing is mechanical by 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.[3,5,8,15] The concept of regional interdependence suggests that if one part of the kinetic chain is unable to recruit 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 (cross-syndrome).[5] While the biomechanical factors are visible to the clinician it is important to look deeper into the respiratory system since the chemical components of the system are just as important. Changes to the body's pH level, allergies, diet, hormone levels, or internal organ dysfunctions can potentially lead to premature fatigue, breathlessness, dyspnea, and muscle pain.[6,8] The mind and body work together to maintain allostasis during times of stress and anxiety.[31,32] While research is limited in understanding the emotional factor of BPD, 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"[8,9 (p3)] Frank et al.[5] and Chaitow[7] suggest that abnormal stabilization patterns will be associated with BPD and should be the starting point for all orthopedic evaluations. Correction or re-education of BPD can result in new neural connections and restoration of normal motor control patterns in the Central Nervous System. Roussel et al.[15] observed dysfunctional breathing 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, or the body demanding to maintain homeostasis. The goal of restoring breathing patterns is to establish normal subcortical motor patterns.[7] An athlete with an abnormal breathing pattern during physical activity could possibly have premature breathlessness or muscle fatigue, resulting in decreased performance.

Matching the patient's expectations and clinical findings is important to provide the opportunity to create clear, measurable, and attainable goals. 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] Through the use of baseline and follow-up measurements the clinician can follow a patient's progress.

Summary

The assessment and classification of BPDs is important to create an awareness of normal breathing patterns effect on movement. Once established, 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] Part II of this paper will explore a case series related to BPD in an athletic population, the interventions associated with BPD, and the effects of BPD interventions.

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Chapter 3

Area of Focus Manuscript 2

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Breathing Pattern Disorders and Interventions: Part 2

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Musculoskeletal injury incidence is high among the physically active population; Hootman et al.[1] have reported an average rate of game injury of 13.79 per 1000 athlete-exposures in collegiate athletics. Physical activity increases the demands of 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 and biomechanical stability and mobility of trunk and spine. Therefore, breathing pattern disorders (BPD) may cause a variety of general health[2] and musculoskeletal conditions (e.g. inappropriate motor control patterns and/or compromised trunk stability).[3-5] An ideal breathing pattern is typically defined as a three dimensional abdominal breath[4,6-8] and accepted as an essential component in maintaining allostasis, posture, and spinal stability.[8]

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.[9-13] 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.[9-13] A change or dysfunction in the ANS, operating mainly (i.e., biased) through the

SNS is also considered “up-regulation”,[14] a continuous period of heightened arousal of the nervous system.[15] “Up-regulation” could alter breathing patterns to maintain allostasis, and change the recruitment of respiratory muscles and alter motor control patterns.[14,16-18] Therefore, potentially causing acute or chronic musculoskeletal pain.

When the body is functioning in primarily an “up-regulated” nervous system, there is an increased sensitivity to touch and increased pain perception.[16,19-21] Hallman et al.[11] found that chronic pain patients presented with increased ANS activity, “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.[7,20,22] 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).[14,16,23] The presence of startle reflexes may provide insight to the ANS, thus theoretically explaining the cause and perpetuation of BPDs in patients reporting musculoskeletal pain without a pathoanatomical cause.[24] 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 widespread chronic pain.[25-29] The intimate relationship of the ANS and the CNS may provide another theory as to the cause of musculoskeletal pain.

The Numerical Rating Scale (NRS) may be high or low, but most importantly the patient reacts abnormally to normal palpation.[24] Palpation bilaterally to ribs 1st/2nd, 7th/8th, and 11th/12th are theorized to be associated with BPDs and a startle reflex.[4,16] Through palpation of the ribs, 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 after the stimulus has been eliminated. The inclusion of palpation to the ribs assist in establishing the ANS role in changes to the breathing patterns and consequently global movement patterns.

Many factors influence breathing patterns, therefore it is essential to have a multifaceted assessment which includes observation, palpation for the presence of startle reflexes, and orthopedic tests to assess local and global motor control patterns. Breathing plays an integral role in maintaining allostasis and core stability, and provides reason to look at its effect on musculoskeletal pain. The causes of BPDs are typically compensatory and vary between individuals, the assessment and intervention presented in this paper could be essential to improve effects related to the primary complaint and/or overall health of patients.[2] The purpose of this *a priori* case design was to identify startle reflexes in patients who present with musculoskeletal pain and a BPD; secondarily, pain and breathing patterns were assessed for change following manual therapy intervention.

Case Description

The evaluating clinician performed a breathing pattern assessment prior to determining the source of the participant's primary complaint of musculoskeletal pain. Two different clinicians at their respective work locations examined participants. The clinicians had over four years of professional experience, with one year of focused experience evaluating and treating BPDs in the physical active population. All participants provided written consent. Inclusion criteria included patients that presented with musculoskeletal pain and a startle reflex at the 1st/2nd ribs, 7th/8th ribs, and/or

11th/12th ribs; if the patient presented with a startle reflex at any of the tender points they were then evaluated for a BPD established through a physical assessment. 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.

The observation of the participants 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.[7] The formal 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)[6,30] and a Hi-Lo evaluation in a supine position.[3,6,7,30] Bilateral palpations were used to assess startle reflexes at 1st, 2nd, 7th, 8th, 11th, and 12th ribs tender points using the NRS scale.

The MARM hand placement is demonstrated in Figure 1. The clinician placed their hands on the patient's low back; thumbs were placed parallel to the spine, while the 4th and 5th phalanges lightly palpated the 11th and 12th ribs (just reaching the anterior abdominal muscles).[30] During this assessment the clinician observed and palpated for lateral and symmetrical movement of the rib cage while the participant went through several breathing cycles. Increased upper rib cage motion (positive range of motion) indicated an apical or paradoxical BPD, while increased lower rib cage motion (negative range of motion) identified a normal breathing pattern (i.e., abdominal and back breath).[30] Typically the respiratory motion is quantified by drawing perceived motion on a form and is calculated as an exact number. However, in this assessment only positive or negative perceived motions were indicated by using a modified MARM and compare the Hi-Lo test to classify respiratory motion.

The Hi-Lo hand placement is demonstrated in Figure 2. The participants placed one hand on their chest and the other on their abdomen.[7] The examiner observed and denoted where the respiratory movement initiated in each of the patients' breath (e.g., paradoxical, apical, or abdominal). The clinician determined the participants breathing patterns, normal or dysfunctional, from the outcomes of the MARM and Hi-Lo evaluations.

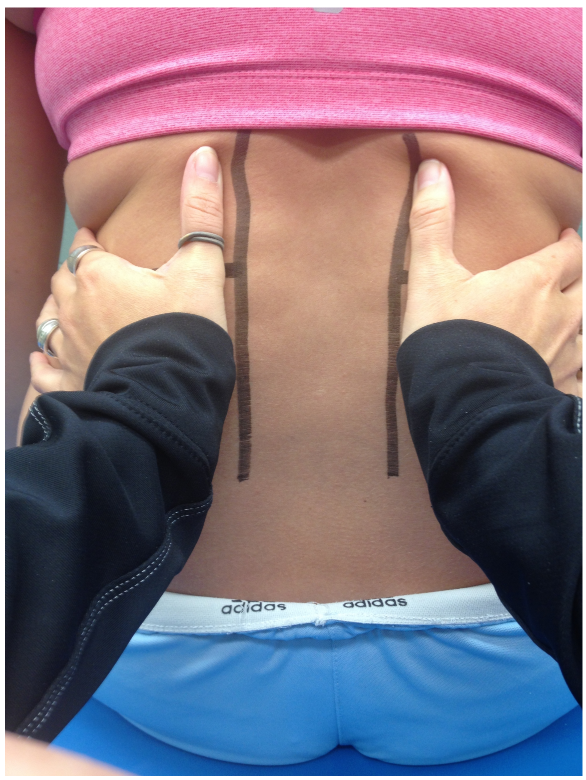

Figure 1. The clinician is demonstrating the hand placement for the MARM to establish rib movement, back breath, and lateral movement during breathing. The lines that are down represent the MARM graph for visualization of a novice clinician in establishing breathing patterns.

Figure 2.

History and Examination

A summary of each participant's history is provided in Table 1. Each participant denied any history of a traumatic event or spinal pathology. Orthopedic special tests were negative, manual muscle testing of the involved muscles were completed, however no weakness or pain was noted, therefore we performed functional movement testing to identify muscle imbalances and motor control dysfunctions.

TABLE 1. 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**

Participant #1 had been experiencing low back pain for over a year without resolution despite participating in a therapy routine including, electro-stimulation and a core stabilization program. The patient reported an increase in pain and discomfort following a long travel day. The participant's numerical pain rating scale (NPRS) was a 2/10 for her primary complaint of low back pain during daily and physical activities. The initial observation established excessive chest movement upon inhalation. The Hi-Lo assessment revealed the participant'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 NRS, Right-2/10 NRS) determined startle reflexes. A positive modified MARM confirmed the apical breathing pattern with minimal lateral and no back breath at rest (Table 2).

Participant #2 had been experiencing a sharp pain in the middle back for 5 years without resolution. During initial examination, the 5^{th} rib appeared to be laterally positioned to the right. The participant's NPRS was a 6/10 for her primary complaints (i.e., pain during inhalation or physical activity). The Hi-Lo assessment revealed the participant's breathing pattern as an apical breathing pattern with limited movement of the abdomen. The participant also presented with a bilateral startle reflex response upon palpation of the $11^{th}/12^{th}$ ribs (Left-3/10 NRS, Right-4/10 NRS) and $1^{st}/2^{nd}$ ribs (Left-5/10 NRS, Right-6/10 NRS). 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 2).

Participant #3 had been experiencing throbbing intermittent pain in her left knee for two years. During evaluation, the participant presented with muscle pain and a tender point on her left medial knee proximal to the joint line. The participant'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 participant also presented with a startle reflex at the left 11/12th ribs (8/10 NRS). A positive modified MARM confirmed that the breathing pattern was paradoxical with minimal abdominal movement (Table 2).

TABLE 2. 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**

Intervention

Manual therapy interventions were used in all three participants to reset and re-establish motor control dysfunctions. While the concept of resetting a BPD is fairly uncommon, a reflex triggering exercise, the "clamshell," an alteration by the authors from the " Optimal Reflex Triggering Ankle Raise" exercise by Michael Grant White, elicits a need to breath by altering the intra-abdominal pressure at the end of a natural exhale.[20] The exercise has been beneficial in the clinical setting to address various BPDs (i.e., paradoxical, apical, and breath lacking lateral or back motion).[20] The "clamshell" was performed with the participant side-lying. Following the completion of a full natural exhale, not a forced exhale, the patient was instructed to hold their breath. While holding their breath, the participant abducted the top knee, keeping their heels together for a count of three abduction (i.e., up) and three adduction (i.e., down) movements of the leg (demonstrated in Figure 3). At the completion of the last count, the participant relaxes the body and takes a normal inhalation. If the clamshell reset is needed, and done correctly, the patient will demonstrate a very big and normal (e.g., 3 dimensional abdominal breath), or at least significant progress in that direction. 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 reflex. The process can be repeated until normal breathing is established, but the participant should monitor a few breaths between each "clamshell" exercise to create awareness of the changes in their breathing pattern. The Primal Reflex Release Technique (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.[15,16] The PRRT treatment techniques utilized coughing in certain positions to eliminate startle reflexes and decrease pain upon palpation for the 1st/2nd and 11th/12th ribs. The PRRT technique for the 7th/8th ribs utilized a quick palpation of the abdomen at a certain time in the respiration pattern.[31] The PRRT techniques used in this study addressed the startle reflexes associated with BPD through addressing the nervous system through "resetting" primal reflexes.[15] Theoretically, by stimulating the reflexes through a cough or quick palpation neural input is sent to the spinal cord and brain and are temporarily overloaded and/or "reset", which restores normal neural input to the muscles being treated.[15,31]

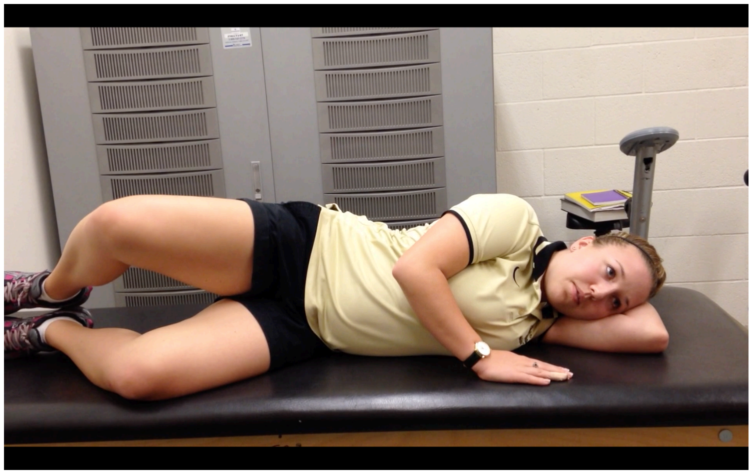

Figure 3. The clamshell exercise is completed in a side lying position (as seen in picture). Following the completion of an exhale the patient was instructed to hold their breath. While holding their breath, the participant abducted the top knee, keeping their heels together for a count of three abduction (i.e., up) and three adduction (i.e., down) movements of the leg. At the completion of the last count, the participant inhales.

Results

Participant #1, PRRT was used to correct the startle reflex and BPD. PRRT performed (2x) bilaterally to the $11^{th}/12^{th}$ ribs to reduce the tender areas eliciting a startle reflex upon palpation. Following the intervention the participant's breathing pattern normalized, establishing a normal abdominal breath (abdominal, lateral and back breath) and dissipated the tender areas with an NRS of 0/10 bilaterally. The participant's primary complaint of low back pain was 1/10 NRS following the intervention.

Participant #2, PRRT was used to correct the startle reflex and BPD. PRRT was performed (1x) bilaterally to the $1^{st}/2^{nd}$ and $11^{th}/12^{th}$ ribs. Following the intervention the startle reflexes dissipated and tender areas all had an NRS of 0/10 bilaterally; however the BPD was still present. The BPD was treated with the clamshell exercise (5x) and following the exercises the participant was able to establish an abdominal breath with anterior and lateral movement, but still lacked back movement. The participant's primary complaint of sharp pain in the middle of the back was 0/10 NRS following the interventions.

Participant #3, PRRT was used to correct the startle reflex and BPD. PRRT was performed (1x) to the left 11th/12th ribs. After the intervention the startle reflex dissipated, but the participant was still tender (NRS score of 7/10) upon palpation at the left 11th/12th ribs and the BPD was still present. The BPD was then treated with the clamshell exercises (5x) and following the exercises the participant had established an abdominal breath with anterior movement, but still had limited lateral and back movement. The participant's primary complaint of left knee pain was 4/10 NRS following the interventions.

TABLE 3. 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

The outcomes of this case series found that participants #1 and #2 presented a minimal clinically important difference (MCID) on the NRS[32] after treatment of the startle reflex using PRRT techniques. All three participants reported a MCID on the NRS after the breathing pattern interventions on their primary complaint of musculoskeletal pain. Participant #1 was the only participant to exhibit a normalized breathing pattern following the PRRT treatment of the 11th/12th startle reflex. Whereas participants #2 and #3, the clamshell exercise initiated the ideal abdominal breath but still lacked motion in one or two directions. Following the BPD treatments, participants were assessed and treated for their primary complaint if pain was still present. All participants returned to activity without limitations.

TABLE 4. 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

In this case series, the assessment and treatment of BPDs in a physically active population in conjunction to a clinical orthopedic evaluation was beneficial. Breathing pattern disorders can produce inappropriate motor control patterns and compromised trunk stability resulting in musculoskeletal pain.[3-5] 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.[33] The Central Nervous System (CNS) and musculoskeletal system work together to create movement; pathology to one system is reflected in adaptation to another.[33] The diaphragm is crucial to structural posture and core stabilization.[34] Elevation of the lower rib cage (caudally) during inspiration is a result of a weak diaphragm or deep spinal stabilizers that cause musculoskeletal pain or dysfunction of the cervical, thoracic, or lumbar segments.[33,35] The diaphragm is responsible for initiating the core stability process through regulating intra-abdominal pressure[34] and works with the transverse abdominus, multifidus, and pelvic floor,[6,35] if breathing is dysfunctional this may predispose the patient to muscular adaptations and/or musculoskeletal pain. For example, the most extreme BPD, a paradoxical pattern, is often accompanied with cervical spine pain, muscle imbalances, and/or dysfunction.[6,7] Alterations or weakness of the pelvic floor muscles are associated with low back pain, groin strains, iliotibial band syndrome, anterior knee pain, anterior cruciate ligament tears, and lateral ankle sprains.[33,35-38] In our case series we focused on treating the diaphragm, often overlooked as a contributing factor of core stability, to decrease the participant'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 also been due to improvement in the diaphragms function, ability to initiate core stabilization, restore movement patterns, and diminish tender areas associated with BPDs. Lucas et al.[39] determined that altered muscle patterns within the kinetic chain had trigger points that may be associated with changes to breathing patterns or posture. In 2005, Mehling et al.[40] compared the effects of physical therapy and breathing therapy on patients presenting with chronic low back pain; patients undergoing breathing therapy had equal results as the physical therapy group even though breathing therapy or exercises are typically not viewed as effective as physical therapy.[41] Our results determined that early inclusion of breathing exercises were beneficial in decreasing musculoskeletal pain.

Breathing is influenced by emotional and psychological input, yet it is difficult to identify if they contribute to BPDs.[42] McNulty et al.[41] 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 decrease tolerance to normal palpation, as seen in this case series. The change in breathing rate and volume were able to become a conditioned response to painful stimuli and emotions, in as little as 8 breaths, and may explain the perpetuation of trigger points and BPDs after the initial stimuli of musculoskeletal pain.[17] The inclusion of evaluating trigger points 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.[43] In 2012, Hallman et al.[11] 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.[44] Mehling et al.[40] 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 is unknown, but theorized that the presence of startle reflexes provides information regarding the state of the ANS, specifically an ANS imbalance, or "up-regulated" nervous system. 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, this could provide an explanation for the decrease in musculoskeletal pain seen in these participants. 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 thought to be more common than absent[6] 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, this will lead to compensatory motor control patterns, and because breathing has a bidirectional influence with the psychological, chemical, and biomechanical systems it should be assessed in all patients. In this case series, following the breathing exercise and PRRT treatments each participant presented with a MCID in their NRS in regards to their primary complaint of musculoskeletal pain. In addition, all participants displayed a change in their breathing pattern as well as a diminished or eliminated presence of a startle reflex. Our findings suggest that the occurrence of a startle reflex upon palpation might be a contributing factor associated with a BPD and musculoskeletal pain. Using manual therapy and a reflex triggering exercise(s) diminished startle reflexes and facilitated the participant's re-establishment of an optimal breathing pattern and theoretically, global motor control contributing to the why the participants primary complaint of pain decreased.

Limitations of this case series is that only the initial assessment and treatment of BPDs outcomes were presented and the clinician's reliability of assessing BPDs was not tested. Additionally, the researchers only used two treatment techniques to improve breathing patterns out of several simple techniques. 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 is needed to recognize if the ANS alters motor control patterns and contributes or causes musculoskeletal pain through changes in breathing patterns.

Summary

The participants in this case series exhibited positive outcomes associated with their primary complaint of musculoskeletal pain by treating the startle reflexes and BPD using a reflex triggering exercise and specific PRRT techniques prior to directly addressing patients' primary complaint. No previous research, that we are aware of, has indicated this is a common occurrence in an athletic population with disordered breathing. The breath's seamless ability to maintain allostasis and biomechanical stability of the trunk and spine is often overlooked as a potential cause or contributor to musculoskeletal pain. Using manual therapy and the reflex triggering exercise to treat BPDs, diminished the startle reflex and allowed the participant to re-establish optimal breathing patterns and motor control.

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Chapter 4

Applied Clinical Research

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Investigation of the Rosenbaum Concussion Knowledge and Attitudes Survey in Collegiate Athletes

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The National Collegiate Athletic Association's (NCAA) concussion mandate reflects best practice for concussion diagnosis and management as outlined in the consensus statement of the 4th International Conference on Concussion in Sport.[1,2] All active NCAA members are required to have a concussion management plan for student-athletes on file.[2] As part of the management plan and of primary interest to the present study, the guidelines recommend member institutions "provide student-athletes with educational material on concussions."[2] Concussion education is a preventative strategy thought to enhance student-athletes' knowledge and attitudes toward concussions as well as improve reporting behavior. The lack of evidence-based research supporting concussion education raises the question as to whether or not collegiate student-athletes have an improved awareness of concussions through education.

The NCAA publishes a Sports Medicine Handbook annually to provide the most current sports medicine guidelines to its member institutions. The handbook references three educational resources in the concussion management section designed to educate coaches and student-athletes on what a concussion is, the signs and symptoms, and the short-and long-term effects.[2] The three resources include the NCAA's Concussion Fact Sheet and video for coaches and student-athletes as well as the Heads Up: Concussion Tool Kit and video;

however, no evidence-based research supports these resources. The development and establishment of evidence-based concussion education require practitioners to quantify (i.e., patient-rated outcome measures) student-athletes' knowledge and attitudes toward concussions before and after participation in an instructional program.

Outcome measures (e.g., surveys and questionnaires) are designed to serve a wide range of purposes in a variety of healthcare settings. In sports medicine, outcome measures quantify the effects of treatments as well as improvements following educational interventions.[3] Various outcome measures have been developed to evaluate high school and collegiate student-athletes' knowledge and attitudes toward concussions. Livingston and Ingersoll[4] designed a survey to measure concussion knowledge of collegiate student-athletes, while Sye et al.[5] focused on assessing concussion attitudes in high school student-athletes. The surveys identify knowledge gaps and unsafe attitudes in athletics but lacked psychometric analysis.[4-6] Psychometric analysis is the analysis of outcome measures to ensure validity and reliability in the measurement of human behaviors, attitudes, and personal characteristics.[7]

Limited data analysis was also reported by the developers of two other surveys measuring knowledge and attitudes toward concussions: the College Football Head Injury Survey[8] and the Knowledge and Attitudes about Sports Concussion Questionnaire (KASCQ-24).[9] The small sample sizes and lack of psychometric analyses do not reflect quality statistical data to suggest these surveys can adequately quantify student-athletes' knowledge and attitudes toward concussions. As a result, Rosenbaum & Arnett[6] developed the Rosenbaum Concussion Knowledge and Attitudes Survey (RoCKAS).

Extensive psychometric examination of the RoCKAS determined it is a fairly valid and reliable survey in the measurement of high school student-athletes' knowledge and attitudes toward concussions.[6] The survey is comprised of the Concussion Knowledge Index (CKI) and the Concussion Attitudes Index (CAI). To determine the reliability of the CKI over a period of time the variables were analyzed using test-retest reliability (intraclass correlation [ICC]). The ICC reached an adequate level of .67 ($p < .001$) but did not attain at least .70 to be considered a stable measure.[6] Rosenbaum & Arnett[6] theorized that the CKI ICC fell slightly below an acceptable level potentially due to the close proximity between test days (two) and participants not knowing or guessing the answers. A cluster analysis of the CKI items demonstrated diverse and discrete groups based on the level of difficulty with no underlying constructs; therefore the CKI is considered an adequate measurement of knowledge.[6] The CAI items were deemed an appropriate measure of attitudes through correlation analysis ($r = -.09$, $N = 367$, $p > .05$, $d = 0.008$), test-retest reliability ($ICC = .79$, $p < .001$), and exploratory factor analysis (58.9% of the total variance).[6]

Currently, Kroshus et al.[10] and Kroshus et al.[11] use the RoCKAS as the main outcome measure in their perspective studies to assess the effectiveness of the NCAA's concussion guidelines and reporting behavior. A limitation of these studies is the survey has not been determined to be an appropriate outcome measure in quantifying knowledge and attitudes toward concussions in a collegiate population, thus potentially drawing incorrect conclusions from the data. Therefore, it is important to subject the RoCKAS to extensive psychometric analysis for two reasons: (a) to establish a standardized outcome measure that bridges the gap between knowledge and attitudes in collegiate student-athletes; and (b) to establish a measure that can quantify change in concussion knowledge and attitudes of collegiate student-athletes to potentially produce best practice in concussion education.

Informed by the current RoCKAS findings and the importance of an evidence-based approach to concussion prevention in a collegiate student-athlete population, the aim of the present study is: (a) to provide a multivariate statistical analysis of the data to determine the underlying constructs of the attitudes indices; (b) to determine internal consistency of the attitudes indices; and (c) to determine the construct validity and reliability of the knowledge indices in a collegiate setting.

Methods

The researcher recruited all athletic teams (n = 21) at a Division III institution to participate in this study. The Institutional Review Board at the university approved this study and all participants consented prior to beginning the survey. A convenience sample was obtained from the student-athlete population. A total of 433 student-athletes completed the RoCKAS for a response rate of 78% (n = 555 total student-athletes). Inclusion criteria were student-athletes participating on an NCAA collegiate athletic team and 18 years of age. The demographics of the participants are illustrated in Table 1, separately by studies. Pearson's chi-square showed no statistical significance in the demographics between the participants in both Studies 1 (n = 226) and 2 (n = 207).

Table 1.
Demographics

Participants: N = 433	Study 1 (N = 226)	Study 2 (N =207)	Chi-square
Sex			
Male	128 (56.6%)	111 (53.6%)	p = .938
Female	98 (43.4)	96 (46.4%)	
Age	19.43+/- 1.426	19.53 +/- 1.417	
18	78 (34.5%)	62 (30%)	
19	51 (22.6%)	53 (25.6%)	
20	45 (19.9%)	40 (19.3%)	
21	35 (15.5%	33 (15.9%)	p = .540
22	11 (4.9%)	12 (5.8%)	
23	4 (1.8%)	5 (2.4%)	
24	1 (.4%)	2 (2.4%)	
26	1 (.4%)	0	
Collegiate Year			
Freshman	73 (32.3%)	65 (31.4%)	
Sophomore	59 (26.1%)	54 (26.1%)	p = .182
Junior	60 (26.5%)	55 (26.6%)	
Senior	34 (15.0%)	33 (15.9%)	
Athletic Team			
Baseball	24 (10.6%)	19 (9.2%)	
Lacrosse (W)	6 (2.2%)	7 (3.4%)	
Lacrosse (M)	15 (6.6%)	11 (5.3%)	
Softball (W)	12 (5.3%)	8 (3.9%)	
Gymnastics (W)	12 (5.3%)	12 (5.8%)	
Swimming/Diving (M/W)	7 (3.1%)	9 (4.3%)	
Wrestling (M)	7 (3.1%)	7 (3.4%)	
Basketball (W)	5 (2.2%)	9 (4.3%)	
Basketball (M)	8 (3.5%)	8 (3.9%(	
Ice Hockey (M)	12(5.8%)	15 (7.2%)	p = .061
Track and Field (M/W)	18 (8%)	21 (10.1%)	
Football	34 (15%)	33 (15.9%)	
Field Hockey	8 (3.5%)	10 (4.8%)	
Soccer (M)	10 (4.4%)	5 (2.4%)	
Soccer (W)	17 (7.5%)	15 (7.2%)	
Volleyball (W)	8 (3.5%)	8 (3.9%)	
Cross Country (W)	8 (3.5%)	3 (1.4%)	
Cross Country (M)	4 (1.8%)	4 (1.9%)	
Tennis (W)	6 (2.7%)	3 (1.4%)	
Prior Concussion Education			
Yes	121 (53.5%)	116 (56%)	p = .947
No	105 (46.5%)	91 (44%)	
Concussion Knowledge Index	19.57 +/- 2.00	19.7 +/- 2.195	p = 1.00
Concussion Attitude Index	57.11 +/- 7.32	58.62 +/- 7.95	p = .597

Descriptive measures by study groups. There is no statistical significance association between the study groups and demographic variables.

Outcome Measure

The instrument used in this study was an established outcome measure, the RoCKAS. Prior to the completion of the RoCKAS, participants completed a brief demographics section that asks sex, age, athletic team, eligibility year, and prior concussion education. The RoCKAS is comprised of two subscales with five sub-sections within those subscales, totaling 40 items. The first subscale of RoCKAS is the CKI. The CKI is comprised of 25 items for a total of 25 possible points, which are divided into three sub-sections: section 1 (14 true-false items), section 2 (3 true-false items), and section 5 (symptom identification; 8 items). The second subscale of RoCKAS is the CAI. The CAI is comprised of 15 items for a total of 75 possible points, which are divided into two sub-sections: section 3 (5 five-point Likert scale items, ranging from strongly disagree to strongly agree) and section 4 (10 five-point Likert scale items, ranging from strongly disagree to strongly agree). Higher scores on CKI and CAI indicate a greater knowledge and safer attitudes toward concussions, respectively.

Procedure

The participants for this study were recruited during pre-season meetings in the fall of 2014. The researcher distributed the paper-based RoCKAS. An unbiased assistant, with no affiliation to the study, monitored participants completing the survey. The researcher was not present during the completion of the survey to allow participants to answer honestly such that any potential bias (i.e., coercion) was prevented.

Data Analysis

A missing values analysis was conducted in IBM SPSS Version 23.0[12] and identified that none of the CKI and CAI items were missing more than 2.1% of the data.[13] The missing value rates were within acceptable ranges of 5% and were imputed by a group mean of each item.[13] As the validity of RoCKAS has never been established for the target population, the current study randomly split respondents into two studies: Study 1 for Principal Components Analysis (PCA) and Study 2 for Confirmatory Factor Analysis (CFA). The PCA was conducted in Study 1 using IBM SPSS Version 23.0[12] to uncover the underlying factor structures of the CAI and identify relationships among the measured variables.[14] The scree plot was used to select the number of factors, whose eigenvalue is over 1. The final factor solution was established through a PCA with varimax rotation. Varimax rotation was utilized to aid the interpretation of the chosen factors, and identify the amount of variance in components explained by variables.

Confirmatory factor analysis (CFA) was then conducted in Study 2 using IBM SPSS Amos Version 21.0[15] to establish the goodness of fit of the factor model identified by the final PCA to explain the relationship between observed variables and underlying latent constructs.[16] Three models were examined to confirm the measurement theory. Several fit indices assessed which CFA model best fit the data: (a) the significance of χ^2, (b) root mean square error of approximation (RMSEA), (c) the goodness of fit index (GFI), and (d) consistent akaike information criterion (CAIC). The RMSEA measures the average of the residual variance and covariance; best fit models have RMSEA values of 0.05 or less.[16] The GFI index falls between 0 and 1, with values greater than 0.90 indicating good fitting models.[16] The CAIC represents a best fit model with smaller values.[17]

Internal consistency analysis, Cronbach's Alpha[18], of both studies evaluated the reliability of the CAI as a whole and between factor levels. The correlations between factors (r) are interpreted as poor (below 0.50), moderate to good (0.51- 0.75) or good to excellent

(0.76 and higher).[18] A cluster analysis[19] of the CKI items in both Studies 1 and 2 was performed to examine the homogenous solution of the variables. Comparing the clusters evaluates the construct validity and repeatability across datasets. The alpha level was set at 0.05.

Results

Descriptive Statistics

The means, standard deviations, and percentage of participants within groups are reported in Table 1. The means and standard deviations of the CKI and CAI are also reported in Table 1.

Principal Components Analysis (PCA) of CAI Items - Study 1 Data

Two PCAs varying rotation methods were conducted to determine the final solution: (1) an unconstrained PCA with proximal rotation and (2) PCA with varimax rotation. The factors for each PCA were selected based on eigenvalues greater than or equal to 1[20] and assessment of a scree plot.

The first one was an unconstrained PCA with proximal rotation (15 items). A proximal rotation was initially completed to examine the component correlation matrix. The median intercorrelation among the factors was .183 (range = .041 to .375). Additionally, the five-factor solution contained several items that displayed multicollinearity[21] between factors and contained less than two items.

Table 2
Study 1 Principal Components Analysis: Concussion Attitudes Index

	Kaiser-Meyer-Okin	Bartlett's Test	Number of Factors	Variance
Unconstrained: Varimax rotation (15 variables)	.722	x^2 = 824.498 p = .000	5	61.303%
Constrained 5 factors: Varimax rotation (12 variables)	.691	x^2 = 586.230 p = .000	5	68.785%

Therefore, due to the low correlations among factors, it was decided to conduct a second PCA with a varimax rotation. An unconstrained PCA with varimax rotation reduced the number of linear variables (Table 2). The loadings improved with the exception of three CAI items. The multicollinearity variables were removed and the remaining 12 were re-analyzed. The final PCA, a constrained five-factor analysis with varimax rotation (12 variables) determined the final factor solutions (Table 3).

Table 3
Varimax-Rotation Rotated Component Matrix and Communalities

Component Coefficient						
Variable	PRTP	RTP	ORTP	COACH	ATC	h^2
S3 Q1	.762	.090	.041	.075	-.079	.603
S4 Q9	.615	.216	.029	.067	.334	.542
S4 Q5	.606	.191	.484	.062	.054	.645
S3 Q2	.394	.282	.086	-.015	.305	.335
S3 Q5	-.015	.853	.034	.074	-.058	.737
S3 Q6	.299	.631	.161	-.010	.060	.518
S4 Q1	.180	.573	.222	.130	.286	.509
S3 Q7	.182	.381	-.271	.054	.256	.320
S4 Q4	-.050	.038	.822	.237	-.001	.736
S4 Q3	.274	.258	.655	-.214	.228	.669
S4 Q6	.286	.028	.551	.542	-.026	.680
S4 Q2	-.143	.280	.271	.757	.057	.748
S4 Q10	.484	-.084	-.133	.662	-.003	.697
S4 Q7	.058	.102	.117	-.140	.852	.772
S4 Q8	.042	.027	-.046	.473	.674	.683

Note: Highlighted Rows = multicollinearity, items were removed from analysis; h^2 = communalities; S = Survey Section (Concussion Attitudes Index); Q = Question Number; RTP = return-to-play; PRTP = personal return-to-play; ORTP = other's return-to-play; ATC = Athletic Trainer management; COACH = coach management

The final factor solutions were simplified. Factor 1 (eigenvalue = 3.334; 27.78%) consisted of three items pertaining to personal attitudes toward a teammate's concussion and was labeled Personal Attitudes towards a Teammate's Return-to-Play (RTP). Factor 2 (eigenvalue = 1.340; 11.17%) consisted of three items pertaining to personal attitudes about return-to-play guidelines and was labeled RTP Attitudes. Factor 3 (eigenvalue = 1.277; 10.64%) consisted of two items pertaining to the views of others' attitudes about return-to-play guidelines and was labeled Others' RTP Attitudes. Factor 4 (eigenvalue = 1.226;

10.21%) consisted of two items pertaining to a coach's management of concussions and was labeled Coach's Management. Finally, Factor 5 (eigenvalue = 1.078; 8.98%) consisted of two items pertaining to an athletic trainer's management of concussions and was labeled Athletic Trainer Management.

Confirmatory Factor Analysis- Study 2 Data

Confirmatory factor analysis assessed the factor solutions identified in the final PCA with the data collected from the participants in Study 2. Three CFA models, represented in Table 4, determined if a best model fit could be established in the five-factor solution. Model 1 includes all 12 CAI items and is loaded on a single attitudes factor (Figure 1). The single factor model has the smallest number of statistical constraints and a comparison for the remaining models. Each CFA model should improve its overall goodness of fit as constraints are added.

Table 4
Study 2 Confirmatory Factor Analysis: Concussion Attitudes Index

	df	x^2	CAIC	RMSEA	GFI
Model 1: One Factor	54	305.560	457.545	.150	.823
Model 2: Hierarchical (General Attitudes)	53	214.500	372.817	.122	.863
Model 3: 5 factor (Intercorrelated/Primary Model)	49	207.902	391.550	.125	.868

Three CFA models were used to establish goodness of fit indices of the primary mode (i.e., identified from the EFA constructs) using the Study 2 dataset.

Model 2 is a second-order model and includes the five factors identified by the final PCA and a general attitudes theme. This model is also known as a hierarchical model and is represented in Figure 2. The purpose of this model is to determine if each CAI item can be loaded onto the general attitudes factor and the five-factor solution from the final PCA.

Model 3 is the primary model and the first iteration of the five-factor solution from the PCA and is represented in Figure 3. The CAI items are distributed among the factors based on the data and include correlations among the factors. The results of the CFA indicated a poor model fit and improper correlations between factors.

Internal Consistency of CAI Factor Solutions - Studies 1 and 2

The CAI showed good to excellent internal consistency in Study 1's (α = .746) and Study 2's (α = .821) RoCKAS outcomes (Table 5). In Study 1, the internal consistency of the factor levels revealed moderate [factors 1 (α = .611), 2 (α = .626), 3 (α = .618), and 5 (α = .558)] to poor relationships [factors 4 (α = .465)]. Below average internal consistency is potentially associated with the low number of items (two) in the final factor solutions. In Study 2, the findings were better but similar to Study 1's internal consistency: factors 1 (α = .637), 2 (α = .642), 3 (α = .689), 4 (α = .660), and 5 (α = .674).

Table 5
Internal Consistency: Concussion Attitudes Index

	Cronbach's Alpha	Factor Level of Cronbach's Alpha (Constrained 5 factors: Varimax rotation)
Study 1: 12 variables	.746	1. .611 (PersonalRTP) 2. .626 (RTP) 3. .618 (OthersRTP) 4. .465 (CoachMan) 5. .558 (ATCMan)
Study 2: 12 variables	.821	1. .637 (PersonalRTP) 2. .642 (RTP) 3. .689 (OthersRTP) 4. .660 (CoachMan) 5. .674 (ATCMan)

RTP = return-to-play, ATC = Athletic Trainer, and Man = Management

Cluster Analysis

A hierarchical cluster analysis using binary measurement of squared Euclidean distance was conducted to visually estimate the number of clusters in the CKI.[22,23] Using all

25 CKI items, a two to five cluster solution was identified. A second cluster analysis, K-means, examined and evaluated the appropriate number of clusters.[22] A two-cluster solution was selected because of the relationship among the data. The binary data required us to identify the distribution[23] of the CKI items based on the percentage of participants who answered them correctly or not. Cluster 1 contains items of low difficulty, while cluster 2 contains items of high difficulty. The findings are reported in Table 6. Similar findings (i.e., z tests) were noted between Study 1 and Study 2.

Discussion

The purpose of this study was to determine if the RoCKAS is an appropriate outcome measure to assess knowledge and attitudes toward concussions in collegiate student-athletes as determined through validity and reliability testing. To date, there are a limited number of concussion knowledge and attitudes surveys designed specifically for collegiate student-athletes, and most only assess knowledge.[6] The increased awareness of concussions in collegiate athletics has led to the development of concussion education guidelines, which are not supported by an evidence-based approach, creating the need for an outcome measure to assess improvements in knowledge and attitudes. The RoCKAS was subjected to extensive psychometric analysis, determining that the CKI is a valid and reliable measure in collegiate student-athletes. However, the results of the CFA indicated a poor model fit and improper correlations between attitude items. Therefore, the CAI may not be a sound outcome measure of collegiate student-athlete's attitudes toward concussions.

Concussion knowledge is the most common focus of education programs.[24,25] The CKI is designed to assess the specific knowledge gaps and/or improvements in a given population. In this study, the cluster analysis and standard score of the CKI consistently measured knowledge and were similar to Rosenbaum and Arnett's[6] reporting. For the current population, the findings were placed into two constructs based on the percentage of correctly answered items (Table 6). The collegiate population identified two constructs, low and high difficulty, as compared to three constructs (i.e., low, moderate, and high) recognized in the high school population. The collegiate sample did not have a moderate difficulty construct as more than 65% of the participants in both study groups answered the low difficulty items correctly. However, the collegiate population had one additional high difficulty item compared to the findings of Rosenbaum & Arnett[6], thus potentially identifying a gap in this collegiate population's concussion knowledge. Based on these findings, we conclude that the CKI is a stable measure and adequately represents the population among the measured variables between Studies 1 and 2.

An effective assessment of attitudes is important to understand individuals' beliefs about concussions, however the focus on attitudes in concussion education is limited and not well represented in existing outcome measures. The development of concussion education programs to address one's beliefs, views, and approach to concussions may improve knowledge and reporting behaviors in collegiate student-athletes.[11] Building on the theory that attitudes may influence a student-athlete's knowledge and reporting behavior[26], the CAI is thought to identify the attitudes of the participants' views on concussions and management. In this study, the PCA identified a five-factor solution and included the views of the collegiate study population: personal attitudes toward a teammate's return-to-play guidelines, others' attitudes about return-to-play guidelines, personal attitudes about return-to-play guidelines, a coach's management of concussions, and an athletic trainer's management of concussions. To further establish a relationship between the attitude items, Cronbach's alpha determined the reliability of the CAI as a whole as well as between factors (Table 5). However, the findings via CFA do not validate our hypothesis that similar constructs identified in the PCA (Study 1) will be observed in Study 2 as it does not approach goodness of fit (Table 4). Therefore, we conclude that the CAI may not be a valid and reliable measure to quantify change in collegiate student-athletes' attitudes toward concussions. The failure of this model to establish best fit may be the result of several factors, such as the social, physical, and emotional differences in a collegiate population, a participant's prior concussion education, a participant's prior concussion history, potential data sampling error and/or sample size of Studies 1 and 2.

In prior collegiate student-athlete samples, misconceptions about the CAI are present. Kroshus et al[10] proposes using the Theory of Planned Behavior (TPB) model to help design and evaluate concussion education. While environmental constraints may influence behavior and attitudes toward concussions in a collegiate population our findings suggest the CAI may not be sensitive enough to assess a collegiate student-athlete's concerns about reporting concussions, reporting norms, and confidence to report concussions in challenging situations. Therefore, the TPB model may not distinguish reporting behaviors. Similarly, a second study by Kroshus et al[11] determined there was no statistically significant difference between CKI and CAI scores following five different education programs. Based on our findings, we concur that the education strategies used did not produce knowledge transfer, however we are unable to draw conclusions about each programs' influence on attitudes as the CAI may not effectively and consistently quantify changes in this population. As a result, we cannot determine the effectiveness of the NCAA's concussion education guideline. Given that the RoCKAS is the only survey that has gone through extensive psychometric analysis, it is understandable why this survey was the primary outcome measure in these studies; however, their findings should be assessed at face value for future research.

The lack of consistency and repeatability of this survey in a collegiate population is potentially due to the small number of CAI items in the constructs. The internal consistency findings provide additional support for the possible addition of CAI items. In both Studies 1 and 2, the internal consistency of 12 items had a good to excellent relationship while between factor levels ranged from poor to good (Table 5). The factor levels fall slightly below the adequate threshold, potentially due to the small number of items (two) in the constructs, thus influencing the relationship between the observed variables and underlying latent constructs.

Limitations

A potential limitation of this study is participants were recruited from only one collegiate institution, limiting generalization to other colleges. Future research in several collegiate settings is encouraged to evaluate the accuracy and consistency of the RoCKAS in measuring knowledge and attitudes toward concussions.

Conclusion

The main purpose of concussion education is to improve knowledge and reporting behavior, thus it is imperative that an evidence-based program that can effectively change or reinforce positive behaviors is developed. This type of program should involve the development and analysis of an outcome measure that can consistently and effectively quantify change in a collegiate student-athlete’s knowledge and attitudes toward concussions. The current study is an important step toward this goal and our findings suggest that the CKI is a valid and reliable outcome measure to assess concussion knowledge in collegiate student-athletes. However, the CAI was shown not to be a valid and reliable measure in our sample.

We suggest adding additional attitudes items to potential strengthen the relationship between the observed variables and underlying latent constructs to measure collegiate student-athletes' attitudes as well as improve its ability to identify gaps in reporting behavior. New attitude items would potentially focus on what influences a student-athlete's reporting behavior and situations unique to the collegiate setting.[26] Following the addition and validation of CAI items, the implementation of the RoCKAS prior to concussion education would allow practitioners to learn about their audience and identify area(s) needing improvement. These improvements in the RoCKAS would transform it into an essential outcome measure in the development of an evidence-based approach to collegiate concussion education.

Table 6
Cluster Analysis of Concussion Knowledge Index

Clusters:	
1: Low difficulty	2: High difficulty
There is a possible risk of death if a second concussion occurs before the first one has healed. (91%; 95%; z = - 1.65, p = 0.101)	After a concussion occurs, brain imaging (e.g., CAT scan, MRI, X-ray, etc.) typically shows visible physical damage (e.g., bruise, blood clot, etc.) to the brain. (26%; 21%; z = 1.31, p = 0.1902)
People who have had one concussion are more likely to have another concussion. (82%; 88%; z = - 1.75, p = 0.08)	After a concussion, people can forget who they are and not recognize others but be perfect in every other way. (31%; 32%; z = - 0.204, p = 0.841)
In order to be diagnosed with a concussion, you have to be knocked out. (98% 97%; z = 0.4533, p = 0.653)	An athlete who gets knocked out after getting a concussion is experiencing a coma. (18%; 21%; z = - 0.692, p = 0.490)
A concussion can only occur if there is a direct hit to the head. (86%; 81%; z = 1.314, p = 0.190)	After 10 days, symptoms of a concussion are usually completely gone. (28%; 29%; z = - 0.256, p = 0.795)
Being knocked unconscious always causes permanent damage to the brain. (73%; 74%; z = - 0.316, p = 0.749)	
Symptoms of a concussion can last for several weeks. (96%; 98%; z = - 1.249, p = 0.211)	
Sometimes a second concussion can help a person remember things that were forgotten after the first concussion. (78%; 82%; x (1) = 2.26, p = .324)	
If you receive one concussion and you have never had a concussion before, you will become less intelligent. (96%; 95%; z = 0.431, p = 0.667)	
Concussions can sometimes lead to emotional disruptions. (92%; 92%; z = 0.095, p = 0.928)	
There is rarely a risk to long-term health and well-being from multiple concussions. (85%; 86%; z = - 0.305, p = 0.764)	
It is likely that Player Q's concussion will affect his long-term health and well-being. (65%; 71%; z = - 1.329, p = 0.184)	
It is likely that Player X's concussion will affect his long-term health and well-being. (93%; 92%; z = 0.444, p = 0.660)	
Even though Player F is still experiencing the effects of the concussion, her performance will be the same as it would be had she not suffered a concussion. (91%; 85%; z = 1.975, p = 0.05)	
Headache (99%; 98%; z = 0.931, p = 0.352)	
Sensitivity to light (93%; 97%; z = - 1.98, p = .05)	
Difficulty remembering (95%; 91%; z = 1.765, p = 0.078)	
Drowsiness (83%; 85%; z = - 0.522, p = 0.603)	
Feeling in a "fog" (82%; 84%; z = - 0.607, p = 0.541)	
Feeling slowed down (86%; 84%; z = 0.512, p = 0.603)	
Difficulty concentrating (96%; 93%; z = 1.289, p = 0.197)	
Dizziness (95%; 95%; z = - 0.0176, p = 0.984)	

Comparative percentage of participants that answered the CKI items correctly (Study 1; Study 2). Proportional difference z-test were used to illustrate that there was no statistical significance between the study populations.

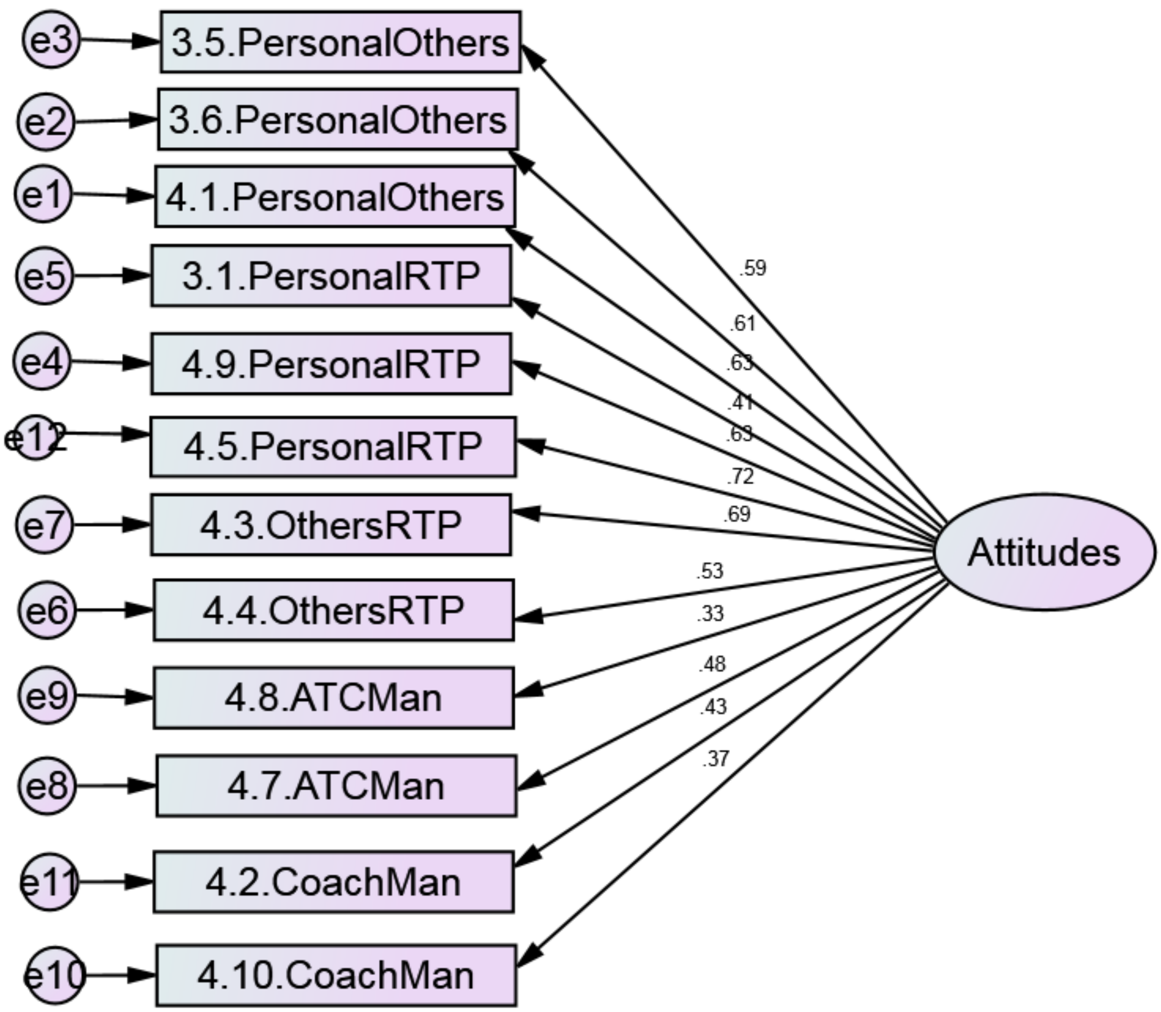

Figure 1. Model 1: One factor Confirmatory Factor Analysis- the general attitudes factor is represented on the right and the Study 2 dataset is denoted using the survey section (3 or 4) and the corresponding questions (1-10).

RTP = return-to-play, ATC = Athletic Trainer, and Man = Management

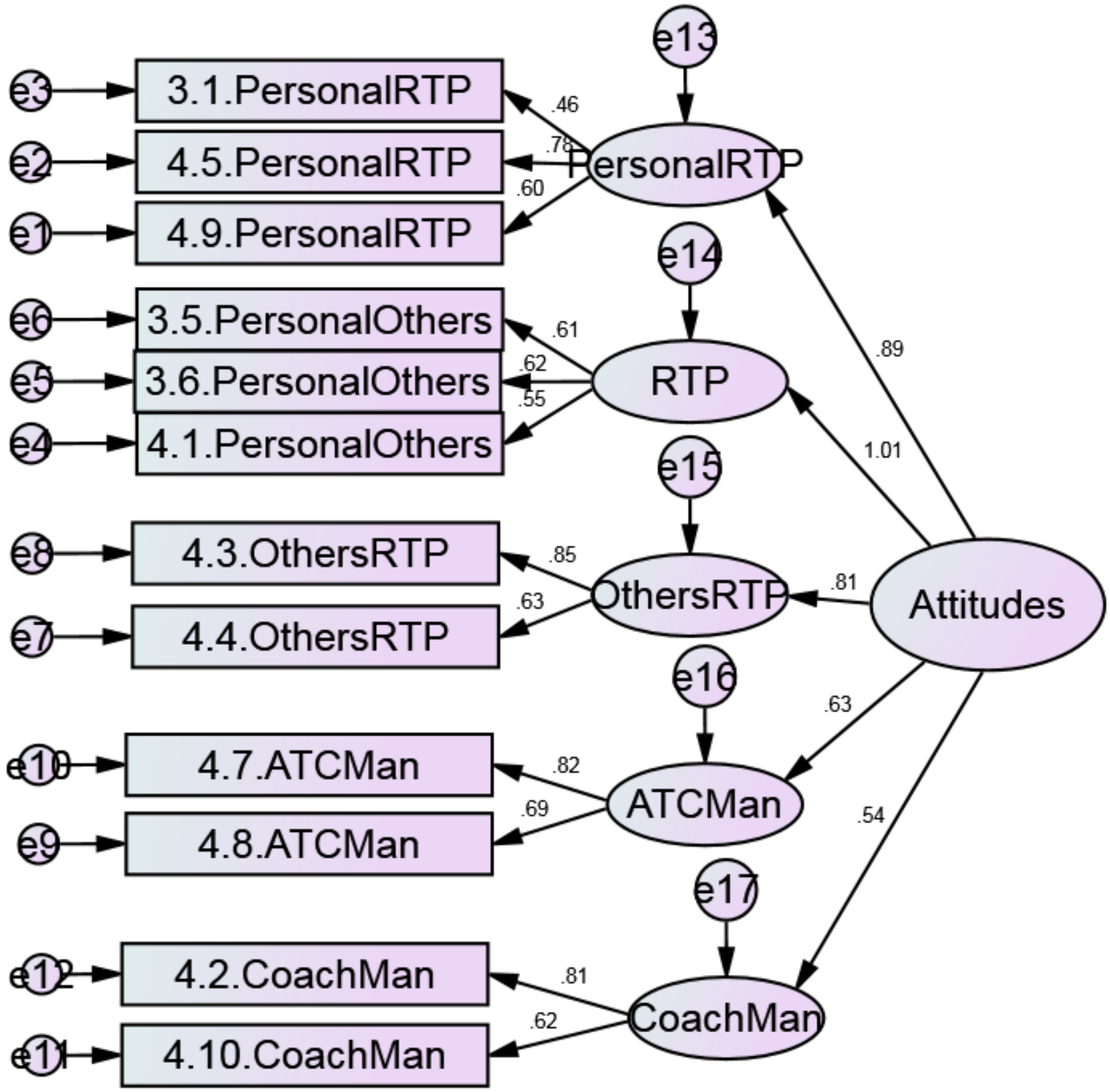

Figure 2. Model 2: Hierarchical (general attitudes) Confirmatory Factor Analysis- the factor constructs identified in the EFA are represented in the circles to the right and the Study 2 dataset is denoted using the survey section (3 or 4) and the corresponding questions (1-10).

RTP = return-to-play, ATC = Athletic Trainer, and Man = Management

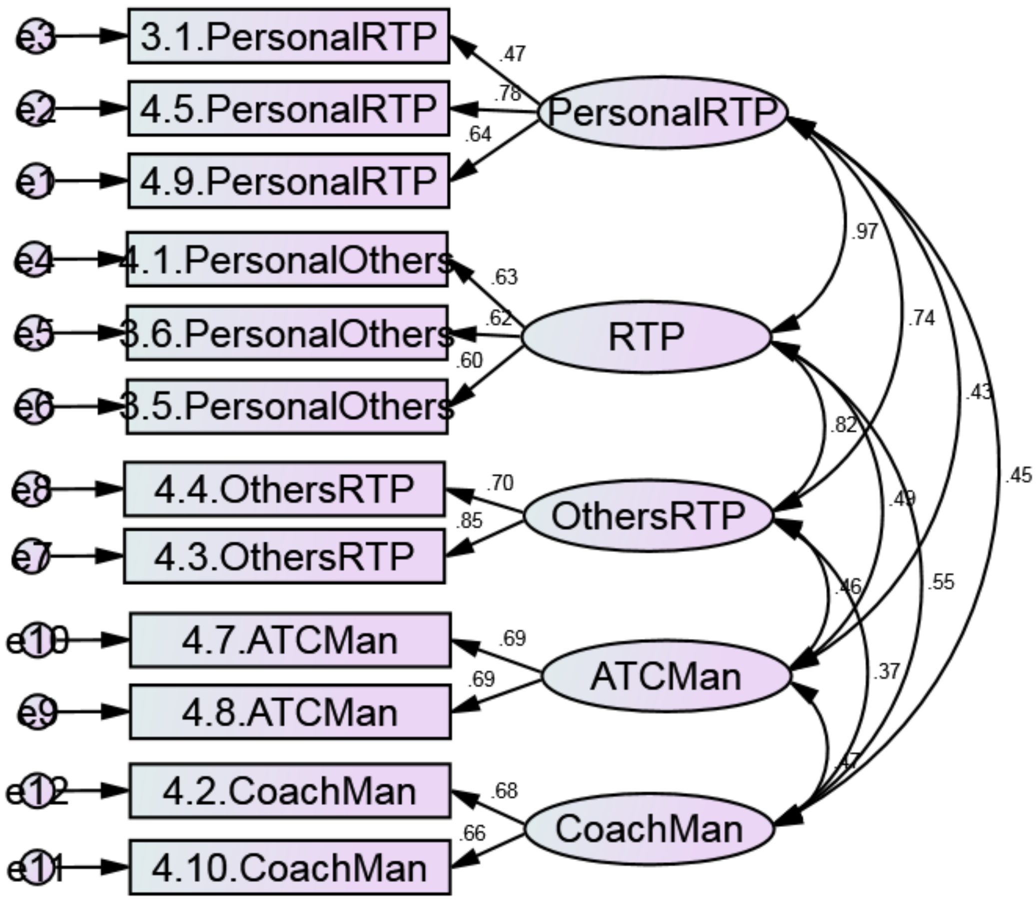

Figure 3. Model 3: Intercorrelated/Primary Confirmatory Factor Analysis- the factor constructs identified in the EFA are represented in the circles to the right and the Study 2 dataset is denoted using the survey section (3 or 4) and the corresponding questions (1-10).

RTP = return-to-play, ATC = Athletic Trainer, and Man = Management

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