Effects of kinesiotaping on symptoms, functional limitations, and underlying deficits on individuals with rotator cuff tendinopathy

Thèse

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Thesis

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RÉSUMÉ

Le kinesiotape est une ressource complémentaire largement utilisée dans les cliniques pour le traitement de nombreuses pathologies musculosquelettiques, qui a été suggéré comme un traitement efficace pour diminuer la douleur et les limitations fonctionnelles chez les individus avec une tendinopathie de la coiffe des rotateurs (TCR) par l'augmentation du retour proprioceptif, qui contribuerait à l'amélioration du contrôle neuromusculaire de l'épaule. L'objectif de cette thèse était de déterminer si le kinesiotape engendre des gains supplémentaires à la réadaptation des individus avec TCR à moyen et long terme.

L'efficacité du kinesiotape à moyen et long terme a été étudiée lorsqu'utilisé en association avec un programme de réadaptation de six semaines, basé sur l'entraînement sensorimoteur pour restaurer le contrôle neuromusculaire de l'épaule. Pour atteindre nos objectifs, 52 individus diagnostiqués avec une TCR unilatérale ont participé à un traitement composé de 10 séances de physiothérapie et d'exercices à la maison. Les participants ont été assignés, aléatoirement, à l'un des deux groupes (KT [expérimental] ou No-KT [contrôle]), dans lesquels le groupe KT a reçu une application thérapeutique de kinesiotape, spécifique pour la TCR, en plus du programme de réadaptation, alors que le groupe No-KT a reçu seulement le programme de réadaptation. Le programme de réadaptation était le même pour les deux groupes, incluant un entraînement sensorimoteur, la rééducation du patient, des exercices résistés pour le renforcement musculaire, de la thérapie manuelle, et des étirements. Un plan de traitement individuel a été personnalisé et mis en place pour chaque participant. Les techniques utilisées variaient en fonction des besoins spécifiques de chacun.

Le niveau de symptômes et les limitations fonctionnelles ont été évalués avec le questionnaire Disabilities of the Arm, Shoulder, and Hand (DASH), le Brief Pain Inventory (BPI), et le Western Ontario Rotator Cuff (WORC) à cinq moments (évaluation initiale, 3, 6 et 12 semaines, et 6 mois), alors que les amplitudes de mouvement (ADM) de l'épaule, sans douleur et complète, et la distance acromio-humérale (DAH) au repos et à 60° d'abduction active de l'épaule, ont été évaluées avant (évaluation initiale) et après le traitement (semaine 6). De plus, l'effet immédiat du kinesiotape sur l'augmentation de la DAH et sur l'amélioration de la capacité de repositionnement articulaire actif des individus avec TCR a également été évaluées avant la première séance de physiothérapie chez les participants du groupe KT (devis transversal).

Globalement, 78.8% des participants ont rapporté un changement positif significatif de leur condition à la fin du traitement. Les résultats de l'essai randomisé contrôlé (ECR) montrent que les deux groupes ont présenté une amélioration similaire et significative de leurs symptômes et limitations fonctionnelles au fil du temps. Par conséquent, le kinesiotape n'a apporté aucun bénéfice

supplémentaire au processus de réadaptation pour réduire les symptômes et les limitations fonctionnelles chez les individus avec TCR à moyen et long terme. De plus, les résultats de l'étude transversale ont montré que le kinesiotape seul a entraîné une augmentation immédiate de la DAH chez les individus avec TCR alors qu'aucun changement immédiat de la capacité proprioceptive chez ces mêmes individus n'a été observé.

ABSTRACT

Kinesiotaping, an adjunct resource widely used in clinics for treating several musculoskeletal disorders, has been suggested to be effective in immediately reducing pain and functional limitations in individuals with rotator cuff tendinopathy (RCTe) through improvement of the proprioceptive feedback, which may contribute to improving shoulder control. The objective of this thesis was to determine whether kinesiotaping provides additional benefits for the rehabilitation of individuals with RCTe in the mid and long-term.

The effectiveness of kinesiotaping in the mid and long-term was investigated when used in conjunction with a 6-week rehabilitation programme based on sensorimotor training for the restoration of shoulder neuromuscular control. To reach our objectives, 52 individuals diagnosed with unilateral RCTe took part in a treatment composed of 10 physiotherapy sessions and home exercises. Participants were randomly assigned to one of two groups (KT [experimental] or No-KT [control]), in which KT group received a therapeutic kinesiotaping application, specific for RCTe, in addition to the rehabilitation programme, whereas No-KT group received only the rehabilitation programme. The physiotherapy rehabilitation programme was the same for both groups, including sensorimotor training, patient re-education, resisted exercises for muscular strengthening, manual therapy, and stretching exercises. An individual rehabilitation plan was customized for each participant. The techniques used varied according to the specific needs of each participant.

The level of symptoms and functional limitations were assessed using the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, Brief Pain Inventory (BPI) scores, and the Western Ontario Rotator Cuff (WORC) index, in five-time points (at baseline, week-3, week-6, week-12 and 6-months follow-up), whereas pain-free and full shoulder active range of motion (ROM), and acromiohumeral distance (AHD) at rest and at 60º of active shoulder abduction were evaluated before (baseline) and after the treatment (week-6). In addition, the immediate effect of kinesiotaping in increasing AHD and improving the active joint repositioning ability of individuals with RCTe was also assessed before the first physiotherapy session in the participants of the KT-group (cross-sectional design).

In general, 78.8% of the participants reported a significant positive change in their shoulder condition at the end of the treatment. The results of the randomized controlled trial (RCT) show that both groups presented a similar and significant improvement of their symptoms and functional limitations over time. Therefore, kinesiotaping did not provide additional benefits to the rehabilitation process for reducing symptoms and functional limitations of individuals with RCTe in the mid- and long-term. In addition, the results of the cross-sectional study showed that kinesiotaping alone provided an

immediate increase of AHD in individuals with RCTe, whereas no immediate changes in the proprioceptive ability of these individuals were observed.

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LIST OF ABBREVIATIONS

ADM	Amplitude de mouvement
AHD	Acromiohumeral distance
ANOVA	Analysis of variance
BPI	Brief Pain Inventory
CI	Confidence interval
CID	Clinically important difference
CIRRIS	Centre for interdisciplinary research in rehabilitation and social integration
CIUSSS-CN	Center Integrated University Health and Social Services (*Centre intégré universitaire de santé et des services sociaux de la Capitale Nationale*, in French)
CNS	Central nervous system
DAH	Distance acromiohumérale
DASH	Disabilities of the Arm, Shoulder, and Hand questionnaire
ECR	Essai randomisé contrôlé
EMG	Electromyography
ER	External rotation
ES	Effect size
FL	Functional limitations
GRC	Global Rating of Change
ICC	Intraclass correlation coefficient
IC	Intervale de confiance
IRDPQ	Institut de réadaptation en déficience physique de Québec
IR	Internal rotation
ISEK	International Society of Electrophysiology and Kinesiology
KT	Kinesiotaping
MDC	Minimal detectable change
RC	Rotator cuff
RCTe	Rotator cuff tendinopathy
RCT	Randomised controlled trial or randomized controlled trial
RMS	Root mean-square
ROM	Range of motion
SEM	Standard error of measurement
SENIAM	Surface EMG for Noninvasive Assessment of Muscles
SRM	Standardized response mean
TCR	Tendinopathie de la coiffe de rotateurs
WORC	Western Ontario Rotator Cuff index

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DEDICATION

This thesis is dedicated to my mother (*in memoriam*) that, despite we have passed not much more than eight years living together, taught me how to persevere even with adversities and that the real objectives are achievable, but only with hard work they could be achieved.

I also dedicate this doctoral thesis to my grandmother, Hercília de Oliveira Machado (*in memoriam*), who was the main responsible for my growth. Thank you for your hard words and actions that, at the right time, shaped me with important teachings such as character and solidarity. No doubt, I owe you everything! Both of you are unforgettable and will always be in my heart and in my prayers!

Lastly, but not least, a special dedication to my lovely daughter (Gabriela). Although she did not agree in most of the time, even so, she realized that daddy had to work a little more instead of going to play. Because of you, daddy had to take some forced breaks, which, after all, were always very helpful for renewing my energies. Thank you for brightening up my hazy days with your smile, and your sincere, naïve and funny words. My love, I dedicate to you not only this thesis but every day of my life. I love you more than everything in this life!

The faith in the victory has to be unshakeable!
Anjos (Pra quem tem fé). O Rappa

Dedico esta tese à minha mãe (*in memoriam*) que, apesar dos poucos mais de oito anos vividos juntos, me ensinou como é possível perseverar mesmo com as dificuldades e que os reais objetivos são alcançáveis, mas somente com muita luta eles poderiam ser alcançados.

Também dedico esta tese de doutorado à minha avó, Hercília de Oliveira Machado (*in memoriam*), que foi a principal responsável pela minha criação. Obrigado pelas duras palavras e ações que, no momento certo, me moldaram com importantes ensinamentos, tais como caráter e solidariedade. Sem dúvidas, eu devo tudo a você! Vocês são inesquecíveis e estarão sempre no meu coração e nas minhas orações!

Finalmente, porém não menos importante, uma dedicatória especial à minha adorável filha (Gabriela). Embora ela não tenha concordado na maioria das vezes, ela compreendeu que o papai precisava trabalhar mais um pouco ao invés de ir brincar. Graças a você, o papai teve que fazer algumas pausas forçadas, que, no final das contas, sempre foram muito úteis para renovar as energias. Obrigado por alegrar os meus dias mais nebulosos, com o seu sorriso e suas sinceras, ingênuas e engraçadas palavras. Meu amor, dedico a você não apenas esta tese, mas todos os dias da minha vida. Eu te amo mais do que tudo nesta vida!

A fé na vitória tem que ser inabalável!
Anjos (Pra quem tem fé). O Rappa

ACKNOWLEDGMENTS

First of all, I thank God, our father, and Lord of all the universe, for enlightening my paths and giving me the opportunity to be enrolled in a Ph.D. programme. Thank you, my Lord, for the faith that increases every day, the patience, health, and all friendship provided to me throughout this journey.

I thank greatly, Dr. Jean-Sébastien Roy to accept me in his team and for teaching me all aspects of scientific rigor. I also thank him for all encouragements to go further in search of answers. Undoubtedly, his guidance was crucial for me to overcome the hard path along these last three years. I could write a book of acknowledgments to him.

Thanks to Dr. Laurent Bouyer for his expertise, critical and assertive comments, always aiming at improving our work.

Thanks to Dr. Benoît Pairot de Fontenay, for all exchange, friendship, and advice. His engagement in this project was elementary.

I express my gratitude to all CIRRIS members for their backstage support. Special thanks to Mr. Steve Forest and Dr. Jean Leblond, whose availability contributed immensely to this project.

Finally, my sincere thanks also go to every funding source for this project. All my gratitude to the CAPES Foundation that provided me a generous grant for pursuing my doctoral studies.

PREFACE

This thesis is composed of four scientific manuscripts, divided into seven chapters, based on aspects related to the rehabilitation process of individuals with a rotator cuff tendinopathy (RCTe). In here, you will find an introduction to the subject (**chapter I**), where the rationales behind the articles included in this thesis are presented, followed by four publications, which were extracted from the data collected over the last three years on the journey in search of my doctorate in clinical and biomedical sciences. They are presented in **chapters II to V**.

The first manuscript (**chapter II**) is a systematic review synthesizing the evidence on muscle activation of the rotator cuff (RC) muscles in symptomatic individuals with RCTe. Published in the *Journal of Electromyography and Kinesiology* on June 07th, 2017, this study allowed us to identify important aspects of the RC muscle activity as a possible trigger source of painful symptoms of RCTe and to understand its association with impairments observed in this population. Findings from this review gave us a notion about how and which muscles could be targeted in a clinical research protocol (second manuscript) to determine the effects of kinesiotaping added to a rehabilitation programme for symptoms and functional limitations associated with RCTe. This research protocol was published in the *British Medical Journal Open* on September 1st, 2017 and it is presented in **chapter III** with detailed information on the methodology applied in our research protocol.

To address some underlying aspects related to RCTe, a third manuscript, presented in **chapter IV**, investigated the immediate effects of kinesiotaping on the acromiohumeral distance (AHD) and active shoulder joint repositioning ability, as a part of proprioception, in symptomatic individuals with RCTe. This study was published in the *Clinical Biomechanics* on November 10th, 2018. Finally, **chapter V** brings the central study of this doctoral project (fourth manuscript). It is a randomized controlled clinical trial aiming to identify whether the kinesiotaping add some advantages when included in a rehabilitation programme for individuals with RCTe. This manuscript was submitted to the *Journal of Physiotherapy* in October 2018.

As the primary author of all these studies, I participated directly in the conception of the study, designing, and preparation of the procedures. Additionally, I was responsible for the data collection, recruitment, interpretation, data analyses, implementation of the rehabilitation programme, and writing the manuscripts. All works were greatly supervised by Dr. Jean-Sébastien Roy, co-supervised by Dr. Laurent Julien Bouyer and had a very important assistance from Dr. Benoît Pairot de Fontenay. Both supervisors participated directly in the studies, contributing to the conception of the study, design, preparation of the procedures, equipment selection and acquisition, interpretation and data

analyses, and supervision of the manuscripts writing. I would like to take advantage of this opportunity to thank you all co-authors involved in these research: Amanda Ager, who was a partner in evaluating the articles for the systematic review (manuscript 1); Dr. François Desmeules, who collaborated in the conception and revision of the main study of this doctoral research (manuscript 2 and 4); and Dr. Benoît Pairot de Fontenay, who participated directly in the preparation of the procedures, data collection, outcomes assessments, interpretation and data analysis, and he has commented several versions of the manuscripts extracted from this research project (manuscript 2 to 4).

Following the presentation of these manuscripts, a discussion is provided in **chapter VI**, and a general conclusion (**chapter VII**), based on the studies composing this thesis.

CHAPTER 1. INTRODUCTION

The shoulder is one of the most affected joints in humans. It is estimated that one out of three people in the general population will have, or already had, an episode of shoulder pain. One of the most common causes of shoulder pain is the rotator cuff tendinopathy (RCTe) that can generate long-lasting symptoms and limitations affecting the capacity to work. A high absenteeism or presenteeism rate and an increased loss of productivity, caused by the RCTe, provide an important socioeconomic impact for societies and governments.[1,2] According to the Quebec workers' compensatory board (CNESST), the estimated annual expenses for work-related shoulder injuries in the province of Quebec (Canada) exceeded $ 128 000 000 between 2013 and 2015. Therefore, effective treatments for RCTe is a priority.

Among several methods of treatment described in the literature, rehabilitation is the main choice for managing shoulder disorders[3-5] and shoulder control exercises are the basis of a rehabilitation programme for an RCTe due to its effectiveness in reducing shoulder motor deficits.[3,4] Previous studies have demonstrated that a rehabilitation based on sensorimotor training is very effective for restoration of the shoulder neuromuscular control.[6,7] Notwithstanding, because not all individuals with RCTe present motor abnormalities,[8] and due to long-lasting motor deficits and the limitations generated by RCTe, new approaches for the treatment of this injury are encouraged to optimize the effects of a rehabilitation programme based on a sensorimotor training. Understanding the shoulder functioning in normal and pathological conditions as well as the abnormalities that affect the shoulder girdle joints during arm elevation are important for building an efficient rehabilitation strategy for individuals with RCTe.

This introduction section provides a review of the shoulder functioning, followed by a brief approach on RCTe and the conservative methods of treatment commonly used for this injury, prior to dive into a specific topic on the kinesiotaping as a promising therapeutic resource for providing a new approach for individual with RCTe, besides its effects on the population with RCTe.

1.1. The shoulder

The shoulder, the most mobile joint of the human body, is composed of three bones (humerus, scapula, and clavicle) that form three joints (glenohumeral, acromioclavicular, sternoclavicular)[9,10] and one pseudo-joint (scapulothoracic).[11]

The clavicle, through the acromioclavicular and sternoclavicular joints, concatenates the upper limbs and the trunk[10]. Both the acromioclavicular and the sternoclavicular joints contribute to scapulothoracic upward rotation,[12] and possibly to the overall scapulothoracic motion. The coordination between these joints results in an adequate scapulohumeral rhythm.[13] Although the scapulothoracic joint is not a true joint, due to the absence of joint capsule and ligamentous stability, it articulates the ribs and scapula,[9,10] having, therefore, an important role in the scapular movements during upper limbs motion. Serving as a site for attachment of several muscles, an adequate scapular movement is crucial for the proper functioning of the shoulder.[14] The scapula glides over the ribs 2 through 7 during the arm elevation movements, whereas the scapulothoracic joint contributes to maintaining the glenohumeral joint properly aligned throughout arm elevation.[9] The synchronous rhythm between the scapula and the glenohumeral joint is essential for a normal shoulder kinematics. For instance, during a 30º arm elevation, the scapula is required to move slightly, whereas, in higher movements of the upper limbs in abduction, the scapula is required to rotate counterclockwise in 2:1 ratio from glenohumeral to scapulothoracic joint motion,[15,16] throughout the entire movement. This means that for each 2º of glenohumeral motion, there is 1º of scapulothoracic motion contributing for arm elevation in the frontal plane.[17] Thus, in the horizontal abduction at 90º, 30º came from scapulothoracic joint and 60º from glenohumeral joint.

Known as the shoulder joint, the glenohumeral joint is formed by the humeral head and the glenoid fossa of the scapula.[9] The glenohumeral joint has a special role in the shoulder kinematics and functionality of the upper limbs.[9] Its dynamic stability is provided by glenohumeral muscles, which control the dynamic centralization of the humeral head in the glenoid fossa during arm movements.[9,12,18-20] As the glenoid fossa is shallowly concave, with a joint surface smaller than the humeral head, which has a hemispheric and convex format, this articulation has great mobility and poor congruency.[9,10] Factors such as the loose connection capsule, the limited bony contour and the lack of ligamentous support makes the glenohumeral joint more susceptible to instability,[21] resulting in loss of shoulder stability.

1.1.1. Shoulder stability

Great mobility accompanied by potential instability is the main characteristic of the shoulder.[22,23] The shoulder stability is related to a proper glenohumeral joint functioning through an adequate intersegmental control of the humerus, scapula, and clavicle, and this stability is assured by the cooperation among bony architecture and soft tissues such as muscles, ligaments, tendons and joint

capsule.[22] The elements necessary to ensure glenohumeral joint stability and, hence, a normal functioning of shoulder, include the adequate size of the glenoid fossa and proper mobility of the scapula, retroversion of the humeral head, an intact joint capsule and glenoid labrum, and, finally, a proper functioning of RC muscles in terms of force, endurance, flexibility and integrity.[22-25]

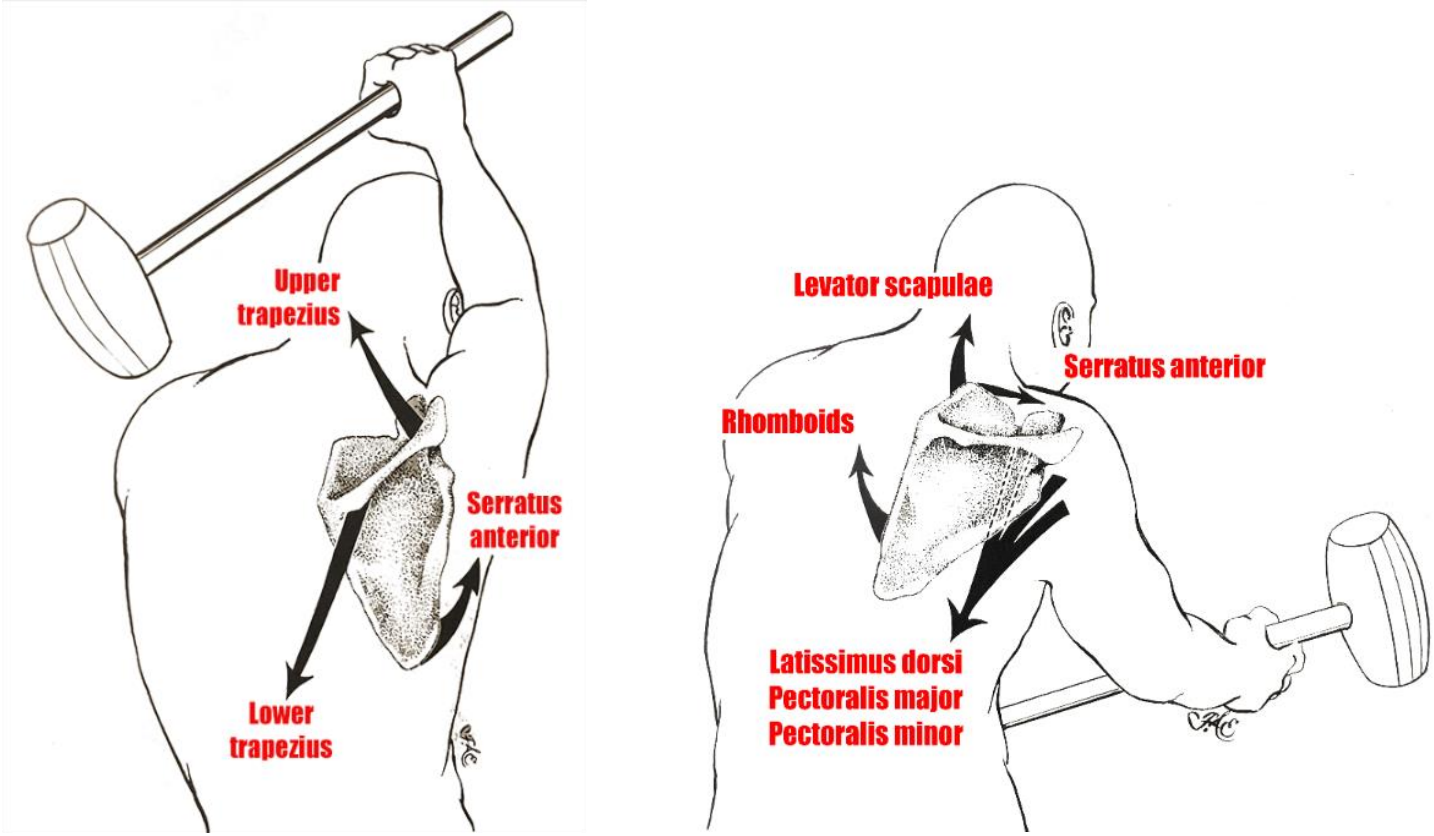
According to the principles of the stability as described by Panjabi,[26] there are three subsystems working together to create a joint stability: passive, active, and neural control.[26] In the shoulder, the stability is provided by static and dynamic contenders[17,22,27] corresponding to passive and active subsystems, respectively. Passive or static joint stability is provided by bony structures, ligaments, and glenoid labrum, whereas active or dynamic stability is provided by the RC (supraspinatus superiorly, subscapularis anteriorly, infraspinatus and teres minor inferiorly), deltoid and biceps brachii muscles. Additionally, both long heads of the biceps and triceps brachii also participated in the stability mechanism of the shoulder, reinforcing the shoulder joint capsule. The long head of the biceps brachii, for instance, acts in the stabilization against a superior translation of the humerus, contributes for anterior glenohumeral joint stability, and resists to humeral torsion force when the shoulder is abducted and externally rotated.[17,27]

The scapulohumeral and scapulothoracic muscles are the main responsible for the dynamic stability being categorized into three groups: glenohumeral muscles, including the deltoid, pectoralis major, teres major, and the four RC muscles; scapulothoracic muscles, including trapezius (upper, middle, lower fibers), serratus anterior (superior, middle, inferior), rhomboids (major and minor), pectoralis minor, levator scapulae, and subclavius muscles; and multi-joint muscles, including the pectoralis major, latissimus dorsi, biceps and triceps brachii.[28] Multi-joint muscles contribute to the motion and forces generated on the glenohumeral joint during movement, whereas the scapulothoracic muscles play an important role in the shoulder control due to the close relationship between scapulothoracic and glenohumeral joints,[29] allowing smooth gliding motion of the scapula over the thoracic cage during arm movements. Notwithstanding, the glenohumeral muscles are the primary source of stability for the shoulder since only the RC muscles and the three portions of the deltoid play a significant role to maintain congruency between the scapula and humeral head[17] during static and dynamic activities.

Although the muscles are categorized into groups, the adequate shoulder functioning is dependent on a harmonic and synergistic cooperation among muscles or group of muscles, to generate movement, also called force-couple relationship (Figure 1.1).[30] The RC muscles participate in arm elevation and rotation of the shoulder in many directions. The lateral arm elevation is initiated by the supraspinatus

that raises the arm up to 30º. Thereafter, the arm is raised by the middle deltoid, which also participates in the shoulder stabilization and provides the strength necessary to lift the arm higher than 30º. When the arm approaches 90º of abduction, the external rotators muscles (infraspinatus, teres minor) rotate the humerus externally, in an attempt to avoid impingement of the structures placed in the subacromial space.[30,31] In this context, a dynamic interplay among RC muscles is essential for the stability of the glenohumeral joint since it maintains the humeral head tightly in the glenoid fossa, avoiding impingement of the subacromial structures throughout the arm elevation movement.[32] Simultaneously, the acromion raises and moves in posterior tilting, whereas the superior angle of scapula moves downward, and the inferior angle of the scapula moves laterally, in upward rotation.[12,14] The scapula can also move into protraction, abduction, and elevation when the shoulder is in normal condition, depending on the direction of the movement.[14] These scapular movements require an effective activation of the scapulothoracic muscles and result in clavicular movements, which contributes to important rotational and tipping adjustments of the scapula during movements.[33] The scapula is stabilized through a synchronized combination of forces in two planes: the balance between upper trapezius, levator scapulae muscle, and the arm weight, in the frontal plane; and pectoralis minor, rhomboids, and serratus anterior muscles, in the sagittal and transverse planes. A dysfunction in any of these muscles added to a laxity of the joint capsule may affect the shoulder muscle synchronism, which compromises the shoulder stability and the scapular kinematics, resulting in an important alteration in the shoulder neuromuscular control.[34] It is well accepted that all these above-mentioned mechanisms are regulated by the central nervous system (CNS) to ensure an adequate shoulder neuromuscular control through activation or co-activation of muscular system to produce a coordinated movement, without compensation or excessive mobility, and without painful symptoms.

Figure 1.1. Contribution of scapulothoracic muscles for shoulder functioning through scapular force couple.



Source: Burkhead WZ. Rotator cuff disorders. Michigan, USA: Lippincott Williams & Wilkins; 1996.

1.1.2. Shoulder neuromuscular control

1.1.2.1. Internal model

Proper neuromuscular control is based on the interaction between the central and peripheral nervous system, besides motor and sensory systems.[35-38] The internal model principle of control theory[39] is often used to describe the neuromuscular functioning. This theory suggests that all movements once learned, have a model built in the CNS. This pre-structured representation is exploited every time that a known motor task is required. In this context, the intern model builds the movement and triggers the peripheral structures necessary to perform the task properly. Therefore, motor learning plays an important role in the creation and maintenance of built models.[35,39] The internal model's theory includes two components: an inverse and a forward model. The inverse model is based on the determination of the motor command required to achieve the desired movement trajectory. The forward model predicts the sensory feedback that may result from a movement and the consequences of a specific motor command.[35] When a command does not result in a proper movement, the command is updated. However, neuroanatomical abnormalities, such as a proprioceptive deficit, may result in malfunctioning of the internal model.[40]

As the shoulder neuromuscular control relies, in part, on the efferent responses related to the proprioceptive afferent impulses, proprioception has been proposed to assist building the internal representation of the limbs, acting in the conversion of kinematic information to motor commands, resulting in suitable forces to perform a movement.[41]

Impairments in a mechanical or sensorial structure involved in the shoulder functioning may lead to inadequate movement patterns and functional instability, indicating an improper shoulder neuromuscular control. Previous studies have demonstrated that impairments, such as altered muscle activation of RC[30,42,43] and scapulothoracic muscles,[25,44-47] associated with a reduced proprioceptive input[48] and contributing for decreasing shoulder neuromuscular control, are often observed in individuals with RCTe.[49,50]

1.1.2.2. Proprioception

Proprioception is an essential part of shoulder stability and neuromuscular control.[38,51] For a movement production, a very fast, complex and important exchange of sensory information is accomplished between the peripheral structures and the CNS.[36-38] Proprioceptive information originates at the level of mechanoreceptors[48] that are present in muscles, tendon, fascia, ligament,

skin and joint capsule,[48,52] such as Meissner's corpuscles (touch-sensitive nerve receptor), Ruffini corpuscle (pressure-sensitive nerve endings), Pacinian corpuscles (vibratory pressure, touch and stretch sensitive receptor), Merkel's disks (tactile sensory nerve-endings), and free nerve endings (afferent and efferent endings) and are responsible for providing proprioceptive feedback to the CNS. Muscle spindles located in the skeletal muscles,[36,53] also plays an important role in the transmission of proprioceptive feedback to the CNS. They respond to changes in the skeletal muscle length.[36] Additionally, Golgi tendon organs, located in the musculotendinous junction of skeletal muscles, also participate in the proprioceptive feedback mechanism acting in conjunction with muscles to ensure a proper interconnection between the CNS and the peripheral structures (afferent[38] and efferent endings[36]). This mechanism ensures a proper agonist, antagonist and synergistic muscle activation and, thereafter, provides a synchronous shoulder control.[54] Injuries in the joint capsules, ligaments or muscles may also affect the proprioceptive input, resulting in muscular imbalance and impaired shoulder neuromuscular control, triggering a series of problems that can generate an RCTe.

1.2. The Rotator Cuff Tendinopathy (RCTe)

The RCTe is a broad term encompassing several diagnoses related to painful signs and symptoms at the subacromial structures (RC tendon, long head of the biceps, bursa)[3,4,55-57] combining pain and impaired performance.[58,59] Subacromial structures are involved with inflammation and degeneration in the context of an RCTe. RCTe is frequently termed subacromial pain (impingement) syndrome, based on the underlying mechanism that includes encroachment of the subacromial space soft tissues underneath the coracoacromial arch as the arm is elevated secondary to a dynamic narrowing of the subacromial space.[60,61]

1.2.1. Epidemiology of rotator cuff tendinopathy

The RCTe is the commonest pathology of the shoulder[62-66] and the second most common cause of musculoskeletal complaints in humans.[64] According to the systematic review of Luime *et al*.,[67] shoulder pain has an incidence of 0.9% to 2.5% in the general population, and a prevalence rate as follows: wide-ranging point (7% to 26%), monthly (19% to 31%), annual (5% to 47%), and estimated lifetime (7% to 67%).[67] In other words, it is estimated that one out of three people will have at least one episode of shoulder pain within their lifetime.[67,68] More recently, Littlewood *et al*.[69] grouped studies determining the prevalence, incidence, risk and prognostic factors related to RCTe.[69] Results

from this study shown an incidence of 0.3% to 5.5%, and point prevalence from 2.4% to 21%.[69] In the working-age population, the prevalence was 2.4 to 14%, with a monthly prevalence of 2.8% and annual ranging from 0.5% to 7.4%.[69] Although more frequent in men,[70] the symptoms of an RCTe seem to be more incapacitating in women.[71] Men are likely more affected than women possibly since most of the awkward[72] and physically strained works,[73] requiring high physical workload,[73] are occupied by men. This may contribute to increase the occurrence of RCTe in this population. Previous literature[67,71,74] on the prevalence of RCTe have reported that women present more severe pain and worse shoulder function than men. Hill *et al*.[71] compared the SPADI scores between men and women and found a difference of 9.6 points for pain and stiffness suggesting that women are 40% more likely to have more severe shoulder pain and impaired function than men (41.6 SPADI points vs.32.0 SPADI points, respectively). According to Ge *et al*.,[75] gender differences in pain modulation is pointed out as a possible explanation for the higher severity of pain observed in women.[75] For the authors, women feel more pain than men due to greater susceptibility in developing temporal summation mechanisms of muscle pain, besides having different motor control strategies to adapt to an injured condition,[76] generating a different circuit of pain interpretation in the women compared to the men.

The RCTe has a very important socio-economic impact on the societies, contributing to increasing the rate of absenteeism and sick leave as the limitations caused by an RCTe may remain for 12 months or more[64] in up to 40% of the cases[77] involving manual workers. Considering these long-lasting remaining limitations, efficient methods of treatment are strongly needed. Howbeit, an effective treatment is dependent on the accuracy of the diagnosis and the identification of the causes of RCTe, which is a troublesome challenge.

1.2.2. Main causes of the rotator cuff tendinopathy

1.2.2.1. Intrinsic and extrinsic factors

The RCTe may originate from multiple factors and many theories have emerged as a possible explanation of RCTe, including tension overload, degeneration of the RC tendons, abnormal anatomy of the coracoacromial arch or humeral head, and shoulder control impairments.[78] Extrinsic, intrinsic, or a combination of both mechanisms are classically described as factors playing an important role in generating an RCTe (Figure 1.2).[79]

Intrinsic factors are directly related to degeneration of the substance of the tendon, which is commonly caused by genetic,[80] aging,[81] insufficient vascularity,[82] alterations in the biological production or concentration of collagen,[83] and mechanical overload in the RC tendon.[84] Defined as structural alterations in the tendon, a degeneration, particularly of RC tendons, is inevitable and inexorably progressive.[17] Even though the human body has a high capacity to withstand mechanical stress, an excessive level of stress such as overuse and overload, may provide a tissue breakdown, generating structural degeneration.[79] Considering the concept stated by Meyer[85] that establishes that shoulder tendon is doomed to degeneration[85] based on the wear-and-tear effects, aging could contribute to the appearance of an RCTe since the degeneration process occurs slowly. However, limited evidence exists to support this theory that aging is related to the onset of an RCTe.[4]

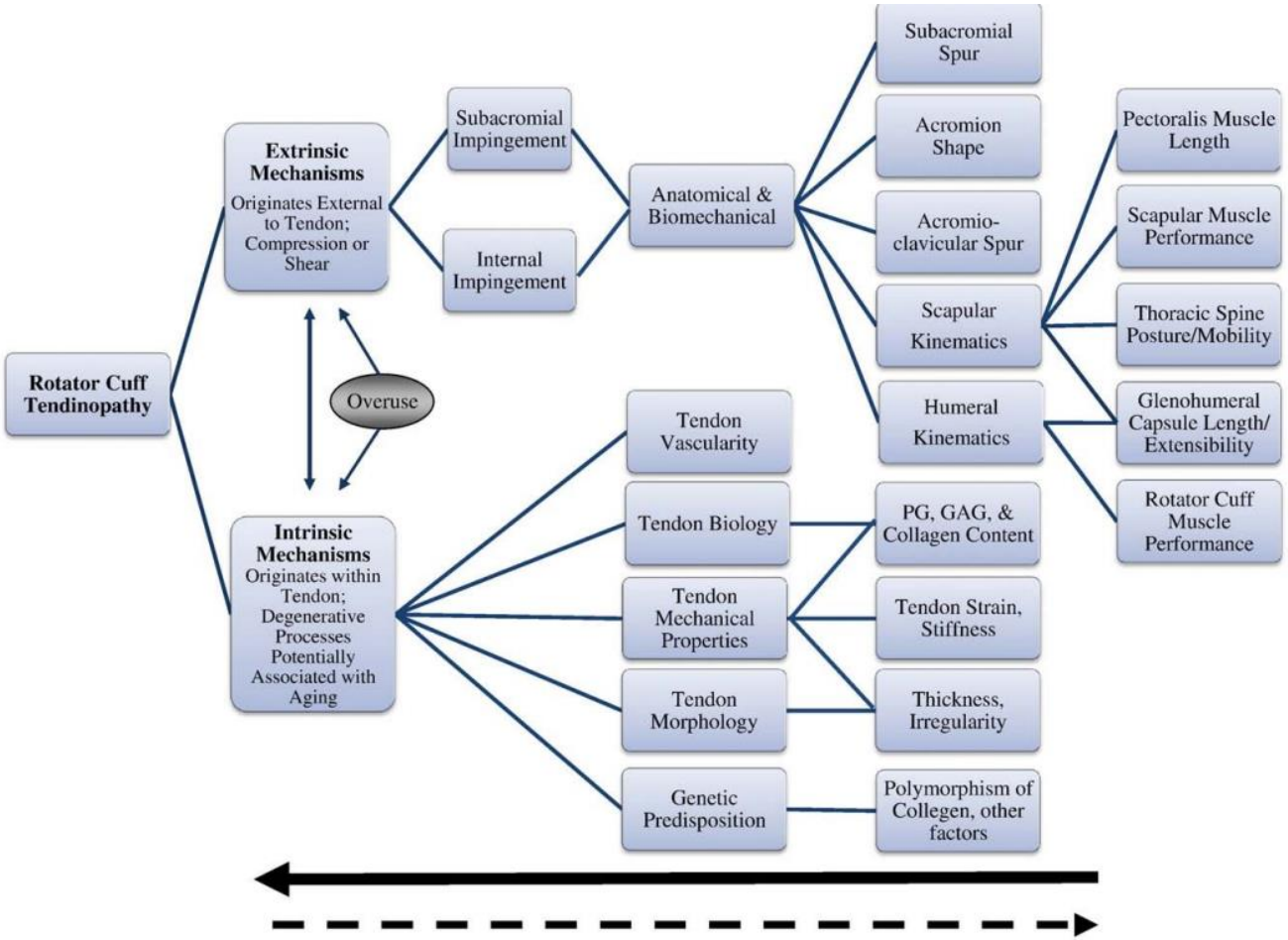
The supraspinatus tendon is the most affected tendon in an RCTe. Because it crosses the subacromial space close to the undersurface of the coracoacromial arch, the supraspinatus tendon can possibly be pinched when the arm is elevated over the shoulder level. Due to very poor vascularization of the area where the supraspinatus tendon is constantly pinched, this area is considered critical.[13,86] Therefore, it is likely that repeated bouts of hypoxia in the critical zone may induce degeneration of the RC tendon.[87] The prompt response for all the repetitive encroachment is a chronic irritation, followed by inflammation, which generates swelling and thickening of the tendon. Combination of these inflammatory events reduces the subacromial space and hampers the passage of the supraspinatus tendon.[88,89]

The extrinsic factors are those in which structures outside the tendon contribute to repetitive subacromial compressions,[61] such as subacromial and acromioclavicular joint osteophytes, pectoralis minor shortening, anatomical variations in the shape of the acromion, inadequate posture and reduced thoracic spine mobility, glenohumeral joint capsule stiffness, shoulder kinematic alterations, RC and scapular muscle impairments, and pathological conditions, such as arthritis in the acromioclavicular joint, that trigger degenerative changes[17,79] of the tendon fibers. Abnormalities in the acromion, which is classified according to its shape (type I, flat; type II, curved; and type III, hooked undersurface),[90] have been suggested as contributors to the extrinsic mechanism of RCTe. Despite prior studies have documented a relationship between the acromion shape and severity of RCTe,[91-93] abnormalities in the acromion shape as a cause of RCTe is very controversial. Balke *et al.*[94] investigated the correlation of the acromial morphology with RCTe and no association between the type of acromion to RC injury was found. This study also suggested that alteration in the acromioclavicular joint, more specifically the low lateral acromial angle and the large lateral extension of the acromion, is significantly correlated to RCTe.[94] This alteration in the acromioclavicular joint is more likely to affect the scapula

kinematics, contributing to mechanical impingement,[61,95] than the shape of the acromion. Therefore, the acromial morphology alone, without combination with any other factor, may not be necessarily a definitive factor causing RCTe.[79]

It is suggested that an interaction between intrinsic and extrinsic factors exist, as both factors produce alterations resulting in compression of subacromial structures. Although there is no consensus on etiological mechanisms of RCTe,[96,97] both intrinsic and extrinsic factors result in impairments in the proprioceptive feedback, compromising the connection between CNS and peripheral structures[49,98] and then, contributing to the progression of RCTe.

Figure 1.2. Mechanisms of rotator cuff tendinopathy.



Source: Seitz AL, McClure PW, Finucane S, Boardman ND 3rd, Michener LA. Mechanisms of rotator cuff tendinopathy: intrinsic, extrinsic, or both? *Clin Biomech*. 2011;26(1), 1-12.

1.2.2.2. Central changes related to a rotator cuff tendinopathy

Individuals with RCTe often report lasting pain. Studies have demonstrated that this long-lasting pain may be associated with alterations in the central motor representations affecting the movements,[99,100] such as changes in the corticospinal excitability of shoulder muscles. The presence of persistent pain can lead to changes in the daily habits of individuals with RCTe, such as alterations of the pattern of movements,[101] in an attempt to protect the injured tissue from further damage. These changes seem to be positive in the short-term, but in the mid- and long-term, they generate important abnormalities in the motor pattern of shoulder movements.[102] Among these possible abnormalities, it can be highlighted the alterations in the level of activation and coordination of RC and scapulothoracic muscles and glenohumeral joint kinematics, which affect the shoulder stability, resulting in progression of motor deficits, and contribute to the recurrence of an RCTe. Recently, Ngomo *et al.*[100] investigated the motor representations of the infraspinatus muscle in 39 individuals with RCTe, using transcranial magnetic stimulation. The authors found that the affected shoulder presented an active motor threshold larger than the unaffected shoulder, suggesting a lower cortical excitability of the infraspinatus in the affected shoulder compared to unaffected shoulder, in the targeted population.[100] Interestingly, a moderate correlation (r=.45, *p*=.005) between the asymmetry in the cortical excitability and the duration of pain was observed. Thus, these alterations in the central motor representations may, partially, explain the chronicity of symptoms[100] and the motor deficits[100] caused by an RCTe. They may also be responsible for the lack of effectiveness of treatments of individuals with chronic RCTe.[22,103]

Another interesting point that may play an important role in pain complaints reported by individuals with RCTe, is the central sensitization. Described by Woolf *et al*.[104] as *"an amplification of neural signaling within the CNS that elicits pain hypersensitivity"*, central sensitization has been reported as a hypersensitivity generator (i.e., reduction of the pressure-pain threshold)[105] in individuals with RCTe.[106] Thus, nociceptors become hypersensitized,[104] reducing the pain threshold of individuals with RCTe.[106,107] The consequence is an amplified and misrepresented response from the CNS to little (nociceptive) or normal (non-nociceptive) somatosensory input.[108]

Even supposing that a minority of individuals with RCTe presents predominant central sensitization, evidence has supported the clinical importance of the hypersensitivity in chronic musculoskeletal pain since these individuals often present a poor prognosis and outcomes, not responding adequately to peripheral treatment.[108]

Although most of the current treatments for RCTe has focused in interventions for the peripheral structures,[16,109-116] specific interventions for reversing this maladaptive reorganization, such as pain education and sensorimotor training, have been demonstrated to be effective for reducing painful symptoms and motor deficits associated with RCTe.[7,103,117]

1.2.3. Impairments observed in individuals with rotator cuff tendinopathy

Based on the all above-mentioned information, one can suppose that the shoulder motor deficits may explain part of the progression or even the severity level of the RCTe. Among these impairments, alterations in the muscle activation of the glenohumeral and scapulothoracic muscles during arm elevation as well as the kinematic alterations of glenohumeral, scapulothoracic, and sternoclavicular joints, are pointed out as strong indications of motor deficits.[19,20,45,118] In the next subsections, the main motor deficits observed in individuals with RCTe will be approached, followed by the description of two clinical outcomes that can be used for evaluating the shoulder motor deficits in this population.

1.2.3.1. Muscle activation during dynamic movements

Alterations in muscle activation patterns of the RC muscles could explain, in part, the dynamic narrowing of the subacromial space and the alterations in upper limb kinematics that have been observed in individuals with RCTe during arm elevation.[7,8,19] These alterations, along with shoulder mechanical alterations, are consistent indicative of motor deficits.[19,20,45,118,119]

As the shoulder is an inherently unstable joint, activation of RC muscles plays an important role in the shoulder stability since it increases glenohumeral joint stiffness, thereby maintaining a stabilizing congruency between the humeral head and the glenoid fossa. Therefore, the harmonic functioning of the shoulder is dependent on synchronous activation among RC muscles.[30,42,120] The RC muscles are activated alongside other muscles, such as scapulothoracic muscles to properly align the humeral head with respect to the glenoid fossa,[30] thereby preventing the impingement of the subacromial structures during arm elevation.[32] Thus, scapulothoracic muscles also play an exceptional role in the shoulder functioning.[12] Given these arguments, the dynamic interplay among RC and scapulothoracic muscles is essential for the proper glenohumeral function and it appears to be compromised in the presence of an RCTe.[12,19,30,42] Abnormalities in the scapulothoracic muscle activation, including lack

of coordination of trapezius and serratus anterior, may partially explain the scapular kinematics impairments observed in individuals with RCTe.[121,122] Because alterations in the muscle activity of scapulothoracic muscles can provide alterations in scapular position, an optimal dynamic interplay among deltoid, scapulothoracic and RC muscles is crucial for maintaining or restoring shoulder function.[7,8] The neuromuscular impairments, such as muscle activation of RC muscles, have been targeted by several investigations.[7,123-126] Systematic reviews of EMG activity of the shoulder complex[25,43,44] have concluded that individuals with RCTe may present an altered muscle activity such as increased muscle activity in upper trapezius,[25,44] and reduced muscle activity in the lower trapezius and serratus anterior.[25] A delayed onset of activation in lower trapezius[43,44] and serratus anterior[43] has been also reported. As most of the systematic reviews have addressed the EMG activity of scapulothoracic muscles, examination of RC muscle activation is constitutive for a thorough evaluation of shoulder neuromuscular control. In chapter 2, we present a study,[42] published in the *Journal of Electromyography and Kinesiology* in June 2017, that synthesized the evidence on the EMG activity of the RC muscles in healthy compared to individuals with RCTe. This study reports that RC muscle activity of individuals with RCTe may be altered; however, analyses involving isometric, isotonic and isokinetic contractions do not expose these alterations. In contrast, dynamic motion analysis favors the identification of the EMG deficits.[42]

1.2.3.2. Mechanical alterations during arm elevation

As stated in previous studies, mechanical alterations of the shoulder, especially in the glenohumeral and scapulothoracic joints,[19,31,127-129] are one of the main causes of symptoms of individuals with RCTe. A superior translation of the humeral head occurs during arm elevation, even in healthy people. In a normal shoulder, the humeral head remains centered in the glenoid fossa, throughout the movement. On the other hand, several mechanical alterations have been observed at the glenohumeral joint and in the scapular motion in a presence of an RCTe. In this condition, the superior translation of the humeral head is increased, resulting in loss of congruency between the humerus and glenoid fossa and, hence, in impingement by compression of the subacromial structures.[20] This alteration could be, therefore, the main cause of impairments observed in individuals with RCTe.

Among the kinematic alterations observed in individuals with RCTe, it is highlighted the decreased scapular posterior tilting,[19] associated with decreased activation of the serratus anterior;[19,118] decreased upward rotation,[19,129] which may keep the acromion in a lower anterolateral position[20] as a result of reduction in the lower trapezius muscle activation;[19,45] increased internal rotation[20,119]

associated with a reduced infraspinatus activation[30,130,131] and increased subscapularis activation;[30,132,133] and excessive elevation of the shoulder girdle[134] associated with an increased upper trapezius muscle activation.[19,135] Restrained scapular motion results in impossibility of the acromion moving away from the humeral head during arm elevation, leading to a dynamic narrowing of the subacromial space[7] and compression of subacromial structures.[20]

In addition to scapular neuromuscular impairments, shortening of the pectoralis minor,[19,119,136,137] posterior shoulder tightness,[138] and an increase in thoracic spine flexion[19,116] are possible factors that could be responsible for the scapular alterations. Thoracic kyphosis has been suggested to contribute to RCTe since it diminishes the scapular posterior tilt, impacting directly the width of subacromial space [139] and reduction of the AHD.

1.2.3.3. Acromiohumeral distance (AHD)

Faulty shoulder neuromuscular control in individuals with RCTe often includes hampered contribution of RC and scapulothoracic muscles[30] in keeping the subacromial space intact. The width of subacromial space is estimated through the AHD, which is defined as the tangential distance between humeral head bony landmarks and acromion inferior edge,[140] usually determined using magnetic resonance imaging (MRI),[141-143] ultrasonography,[140,144-146] and radiographs.[143,147-149]

Previous studies have stated that the AHD varies between 9 and 12 mm in asymptomatic subjects,[150,151] however, it is reduced in individuals with RCTe[7,141,142,152] during arm elevation or compared to healthy.[7,140,152-154] Recently, Navarro-Ledesma *et al.*[152] compared the AHD of 76 individuals with RCTe to 40 healthy subjects. Their results indicated that, at 60º of shoulder abduction, the AHD reduced by 0.33 mm in the symptomatic shoulder in comparison to asymptomatic shoulder, whereas the reduction in comparison to the healthy subjects corresponded to 0.51mm.[152] As a reduced subacromial space may compromise the shoulder functioning, methods contributing to increasing the AHD are always welcome. In this context, we tested the effectiveness of the kinesiotaping, as a promising adjunct therapeutic resource, in increasing the AHD. The results can be consulted in chapter 4.

The reduction of AHD is associated with mechanical alterations such as insufficient scapular upward rotation during arm elevation,[155] which, theoretically, affect the shoulder ROM due to posterior shoulder stiffness.[135] However, this is a controversial topic since more recent study have identified a poor correlation between ROM and AHD.[156]

1.2.3.4. Range of motion (ROM)

The ROM is the maximal amount of movement produced within a joint,[157] without compensation. In this context, the shoulder has the largest ROM of the body with a maximal elevation amplitude of approximately 180º.[157] However, muscular or kinematic abnormalities of the shoulder functioning may compromise this large amplitude. For this reason, evaluation of the ROM is important for determining the strategy for an effective rehabilitation of an RCTe.

In individuals with RCTe, the ROM is often reported to be reduced due to several factors such as joint stiffness and posterior capsule tightness.[157,158] Thus, limited ROM is one of the most common impairments observed in this population. A significant moderate relationship (r=-.50, p=.006) between loss of internal rotation ROM and the increased posterior capsule tightness has been previously reported.[158] Therefore, the presence of posterior shoulder tightness in the glenohumeral joint along with the reduction of glenohumeral internal rotation may explain the impaired ROM observed in individuals with RCTe.[157]

Tyler *et al.*[158] quantified alterations in the shoulder ROM of dominant and non-dominant upper-limbs of 31 individuals with RCTe compared to 33 healthy controls. Their findings indicated that individuals with RCTe presented an increased posterior capsule tightness and decreased internal rotation ROM compared to healthy controls. The more expressive decrease of ROM was observed in individuals with RCTe in the nondominant upper-limbs in comparison to those who had the dominant upper-limbs affected.[158]

The presence of a posterior shoulder tightness is indicative of asymmetric tension within the capsule[158,159] that, in turn, leads to arthrokinematics alterations[157] such as anterior and superior migration of the humeral head during forward flexion of the shoulder[158] and limited posterior translation of the humeral head when the arm is raised in abduction. Both limiting the normal shoulder ROM. In addition, a study using cadaveric shoulder models[160] demonstrated that a posterior capsular contracture associated with a glenohumeral internal rotation deficit may restrain the humerus to externally rotate when the arm is elevated in abduction resulting in impingement and, consequently, restricted ROM due to mechanical alterations in the glenohumeral joint and pain, which is the main symptom of this population.

1.2.4. Symptoms caused by rotator cuff tendinopathy

In general, individuals with an RCTe may present a series of symptoms such as joint stiffness, weakness, and functional limitations observed as difficult to reach objects requiring arm elevation. However, pain is the main symptom associated with RCTe.[3,161] In this section, the most common symptoms observed in individuals with RCTe are presented in detail.

As the main symptom reported by individuals suffering from an RCTe, pain usually occurs when the arm is elevated in forward flexion and vertical abduction, especially at a higher level than 60º, but it can also occur in lower amplitude. In general, pain is manifested during dynamic activities requiring overhead movements; however, studies have demonstrated that pain at rest and at night[162] are also important complaints of people with RCTe.

Individuals suffering from an RCTe have also difficulties in performing repetitive activities requiring arm elevation, not necessarily at shoulder levels or overhead, throwing, pushing, pulling, or swinging the arm. Littlewood *et al*.[69] reported strong evidence that these functional limitations are often related to the pain caused by an RCTe.[69] These findings were related to studies determining the prognostic factors relating to shoulder pain,[163-165] and the impairments caused by pathological shoulder conditions such as RCTe. The consequences of these impairments are important functional limitations that incapacitate to work by restraining overhead movements and to perform the daily activities as dressing or combing hair by limiting reaching behind the back, lifting loads, and sleeping on the injured shoulder.

Several methods are used in clinics to control pain caused by RCTe. In the next section, we present full details on the methods and therapeutic resources used to relieve pain and improve function as well as the level of evidence on their effectiveness in the treatment of individuals with RCTe.

1.3. Treatments for rotator cuff tendinopathy

Several recommendations for treating RCTe have been provided in systematic reviews and meta-analysis; however, there is no specific rehabilitation protocol for guiding clinicians or physiotherapists about how to treat this injury. Although surgery is widely performed in individuals with symptomatic RCTe in working age,[166] the conservative approaches remain the primary choice for treating an RCTe as it is less likely to provide side effects. In addition, the cost is lower and similar results can be achieved with exercise program[167-170] compared to the operative treatments. Therefore,

conservative rehabilitation should be a priority for the treatment of RCTe, whereas surgical treatments should be used only when conservative interventions have failed.[161]

Several types of conservative interventions have been tested to obtain better results for the impairments associated with RCTe. All these treatments have similar goals, which are the reduction of common pain-related impairments,[5] and improvements of upper limbs and shoulder function.[161] However, different level of evidence exists for each modality. The modalities are classified as active (exercise programs) and passive modalities (medication such as anti-inflammatory non-steroids and corticosteroids injections, electrotherapy, manual therapy, and kinesiotaping). Reviewing all these modalities exceed the objective of this thesis, therefore evidence on passive modalities are summarized in Table 1.1, whereas the current section will focus on interventions demonstrating clinical effectiveness in treating an RCTe such as therapeutic exercises.

Evidence has shown that rehabilitation programme based on exercises is as effective as surgery in the long-term (1-, 2-, 4-, 5-, up to 10-year follow-up)[169,171,172] for reducing pain and improving functional limitations, with the advantages to be cheaper and providing very little or no risk of post-intervention complications. Hanratty *et al*.[3] reviewed systematically 16 studies that investigated the effects of therapeutic exercises for treating symptoms and functional limitations of 1162 individuals with RCTe. The authors reported strong evidence that exercises reduce pain and improve function in the short-term for this population, with specific exercise providing better results than non-specific exercises.[5] Dong *et al.*[161] concluded that exercise-based programs are one of the most important types of treatment for individuals RCTe, whereas a systematic review conducted by Steuri *et al*.,[5] reported that exercises are more effective than the conventional physiotherapy that not include exercises.

Many other interventions, such as mobilization with movements[173,174] and with exercises,[175,176] movement training,[7] and strengthening exercises,[6] have targeted the RCTe impairments in rehabilitation programme[19,121,122,135,177] to decrease symptoms, disability, and functional loss.[126,178] However, as impairments observed in individuals with RCTe, are associated with inadequate motor control, restoration of shoulder neuromuscular control is the key to the success of the rehabilitation process.[22,179] Therefore, treatments that might correct the shoulder neuromuscular control using movement training to reduce motor deficits are considered a good option for treating this population.

In this context, the sensorimotor training emerges as a solution since it can optimize the scapular motion and re-educate muscular recruitment, resulting in improvements of the activation of RC muscles and maximization of the synchronism among RC muscles.[6,7] Studies using programs of exercises based on motor training for correcting scapular kinematic and glenohumeral joint control

have demonstrated that sensorimotor training corrects motor deficits associated with RCTe,[6,7,117] which lead to a reduction of symptoms. Recently, Savoie *et al*.[7] investigated the effects of a treatment based on movement training on symptoms, functional limitations and AHD in 25 individuals with RCTe. Although based on shoulder control exercises, the rehabilitation programme also included strengthening of scapulothoracic and scapulohumeral muscles, patient education regarding posture, shoulder positioning and body mechanics, manual therapy consisting of passive mobilization and manipulation techniques, and stretching exercises for pectoralis minor and stiffness of inferior and posterior glenohumeral capsule. Their results were satisfactory as all outcomes analyzed improved significantly after the treatment.

Several techniques and adjunct resources have been included in the exercise-based rehabilitation programme in the attempt to optimize the treatment for RCTe. Manual therapy has been evidenced to provide immediate effects in reducing pain and improving function on individuals with RCTe.[117,126,180] When combined with exercises, the effectiveness of manual therapy is increased compared to exercises alone in the short-term.[5,115,180,181] Pieces of evidence also indicate that laser therapy provides more prominent effectiveness in reducing pain on symptomatic individuals with RCTe, when combined to exercises compared to exercises alone or sham laser,[5,182] whereas current evidence is insufficient to support or discard the use of shockwave therapy combined with exercise on this population.[5] Based on the above-mentioned information, exercises have been reported to be optimal at the early stage of RCTe.[161] Kinesiotaping is also often included in the exercise-based rehabilitation programme in clinics. Although the kinesiotaping, which is the central element of this thesis, is reported to be superior to placebo or sham taping,[5] the evidence are still insufficient to draw conclusions on its effectiveness alone or in combination with other interventions for reducing pain and improving shoulder function of individuals with RCTe.[183,184]

Table 1.1. Summary of evidence on the effectiveness of interventions (passive modalities) used for improving pain and functional limitations.

Modalities	Summary of evidence
Electrotherapy	
Therapeutic ultrasound	The ultrasound does not provide greater benefits than a placebo in terms of pain reduction and functional improvements.[56] The ultrasound in conjunction with exercise is not superior to exercise alone in terms of pain reduction and functional improvements.[56] The ultrasound is not superior to laser therapy in terms of pain reduction.[56] Long duration ultrasound (8 minutes) is more effective than short duration ultrasound (4 minutes) for reducing pain and function.
Percutaneous electrolysis	Not enough evidence for or against the use of ultrasound-guided percutaneous electrolysis and eccentric exercises.[5]
Laser therapy	Low-level laser therapy provides pain relief alone or in conjunction with physiotherapy.[185] Laser therapy provides greater benefit than the ultrasound in terms of pain relief.[56] The laser is superior to the sham laser for reducing pain.[5] Laser combined to exercise is superior to exercise plus sham laser for reducing pain.[5]
Transcutaneous electrical neurostimulation (TENS)	No conclusion can be drawn on the efficacy of TENS for treating RCTe due to a small number of studies.[186] TENS is not superior to corticosteroid injections for pain reduction in the short-term. [186] TENS is not superior to heat or pulsed radiofrequency. [186]
Microcurrent electrical stimulation	Insufficient evidence for or against the use of microcurrent electrical stimulation.[5]
Microwave	Insufficient evidence for or against the use of microwave.[5]
Interferential light therapy (ILT)	Insufficient evidence for or against the use of interferential light therapy.[5]
Pulsed electromagnetic field (PEMF)	Insufficient evidence for or against the use of the pulsed electromagnetic field.[5]
Extracorporeal shockwave therapy (ECSWT)	High-ECSWT improves pain and shoulder function in chronic calcific tendinitis compared to low-ECSWT and placebo.[187-190] ECSWT is superior to sham ECSWT for reducing pain.[5]
Medical and Surgical interventions	
Platelet-rich plasma (PRP)	Evidence does not support the use of platelet-rich plasma for reducing pain associated with RCTe as laboratory studies are not feasible to be translated to clinical practice.[191,192] Insufficient evidence for or against the use of platelet-rich plasma therapy.[5]
Surgery (acromioplasty)	Surgery is effective for reducing pain and improving shoulder function. Operative treatments such as open and arthroscopic acromioplasty are not superior to exercises in terms of shoulder function[5,193,194] and return-to-work outcomes.[193]
Nerve block	Nerve block was superior to control for pain and shoulder function.[5]
Myofascial trigger point	Insufficient evidence for or against the use of myofascial trigger point therapy.[5]
Hyaluronate acid	Insufficient evidence for or against the use of hyaluronate.[5]

Corticosteroid injections	Corticosteroids injections are effective for reducing pain and shoulder function in the short-term.[195] Corticosteroids injections are not more effective than placebo in reducing pain intensity in the mid-term.[196] Corticosteroids injections are superior to physiotherapy modalities in the short-term.[5] Corticosteroids injections are superior to no treatment in terms of pain, shoulder function and ROM.[5] Corticosteroids injections are superior to TENS for reducing pain in the short-term.[186] Corticosteroids injections are as effective as AINES in the short-term in terms of pain reduction and shoulder function.[195] Local corticosteroids injections are superior to systemic steroids for improving active ROM.[5] Corticosteroids injections are superior to local anesthetics in relieving pain in the short-term.[5]
Anti-inflammatory non-steroids (AINES) and other anesthetics medications than corticosteroids	AINES provides pain relief in the short-term compared to placebo.[5,195] AINES does not improve function in the short-term compared to placebo.[195] AINES is superior to placebo medication for reducing pain and active ROM.[5] AINES has similar efficacy to corticosteroids injections in the short-term in terms of pain reduction and shoulder function.[195] Local anesthetics are inferior to corticosteroids injections in relieving pain in the short-term.[5] There is no comparison between the effects of AINES and exercise.[5]
Therapeutic resources	
Diacutaneous fibrolysis	Insufficient evidence for or against the use of diacutaneous fibrolysis.[5]
Myofascial trigger point	Insufficient evidence for or against the use of myofascial trigger point therapy.[5]
Acupuncture	Insufficient evidence for or against the use of acupuncture.[5]
Massage	Insufficient evidence for or against the use of massage.[5]
Manual therapy	Manual therapy is superior to wait-and-see policy for reducing pain.[5] Manual therapy is superior to placebo for reducing pain.[5] Manual therapy combined with exercise is superior to exercise alone for reducing pain and improving shoulder function, in the short-term.[5] Manual therapy combined with exercise is superior to sham ultrasound and placebo gel for improving shoulder function.[5]

1.4. The Kinesiotaping

Kinesiotaping is a therapeutic bandage method, designed by Dr. Kenzo Kase,[197] developed in the late 1970s. Although its first international exposure was in the 1988 Seoul Olympics, only recently it has received widespread attention. The popularization among world-renowned athletes boosted the attention given to this new therapeutic resource.

Although kinesiotaping seems similar to conventional athletic tape, it is very different. Not only due to its characteristics of manufacturing, but the philosophy of application. According to the creator of the method,[197] the kinesiotaping was developed to minimize the loss of the benefits gained during a physiotherapy session. Therefore, the kinesiotaping was developed to help muscles and other tissues to achieve an auto-healing and, hence, their homeostasis when the patient is not under treatment in clinics.

Current clinical observations reveal that the kinesiotaping is a safe technique,[197] widely used for the rehabilitation of several types of injuries, including musculoskeletal disorders such as RCTe. Producing minimal side effects,[197] the satisfaction of patients with the use of kinesiotaping in their treatments in clinics has contributed to the growing up of this method in rehabilitation. Based on its concepts, the kinesiotaping is an adjunct therapeutic resource to be used in conjunction with a conventional physiotherapy intervention. However, this treatment resource is still very recent, and several aspects are still unknown and unexplored.

1.4.1. Characteristics of the kinesiotaping

Kinesiotaping is an adhesive elastic tape, free of latex and sensitive to the heat. It is thinner and more compliant than the rigid athletic taping and other types of bandage, with a unique texture and recoil characteristics.[198,199] In addition, it is designed to allow longitudinal extension of its length, not restraining motion. With an elasticity similar to the human skin, the kinesiotaping may be extended to 40-60% of its original length. Its application is classified according to the tension of the tape applied over the skin (Table 1.2);[198] however, to date, there is no scientific support for this classification. Recently, Lemos *et al.*[200] investigated the effects of directions (origin to insertion and insertion to origin) and tension (0%, 10%, and 75%) of the kinesiotaping application on the skin over the rectus femoris muscle and over the knee of 42 healthy subjects. Their data indicated that the direction and tension of kinesiotaping application did not provide different effects on rectus femoris muscular strength and knee ROM.[200] The same results were found by Luque-Suarez *et al.*,[154] who did not find differences in the AHD when compared the directions (origin to insertion and insertion to origin) of kinesiotaping application.

Table 1.2. Classification of kinesiotaping according to the tension applied (by percentage).

Tension	Classification	Clinical indication
None (paper off)	No tension or normotension	Acute muscular condition.
10 to 15%	very light tension	Edema, lymphedema.
15% to 25%	Light tension or paper-off	Acute conditions, sensitive reactions, support contraction (insertion to origin).
25% to 50%	Medium or moderate tension	Chronic condition, functional correction.
50% to 75%	Severe tension	Mechanical functions (support or correction).
75% to 100%	High or full tension	Mechanical functions (support or correction).

Source: Lemos TV, Kase K, Dias EM. Kinesio Taping®: Introdução ao método e aplicações musculares. 3ª ed. São Paulo, SP: Editora Andreoli; 2015.

1.4.2. The rationale behind the kinesiotaping functioning

As kinesiotaping is still very recent, the functioning mechanism has not been yet established. Therefore, the rationale behind the efficacy of kinesiotaping is based on hypotheses centered on the lifting effects generated by convolutions on the epidermis layers and papillary dermis (dermal function).[201] The wrinkles formed by the kinesiotaping recoil applied over the skin, when the skin goes back to resting position, are believed to increase the interstitial space by lifting the epidermis, which may lead to an increase in blood and lymph flow, while facilitating the pressure release on soft tissues underneath the skin (Figure 1.3). Consequently, vascular networks in deep vessels under the skin are increased, reducing swelling and inflammation in injured tissues.[78,198,202-209]

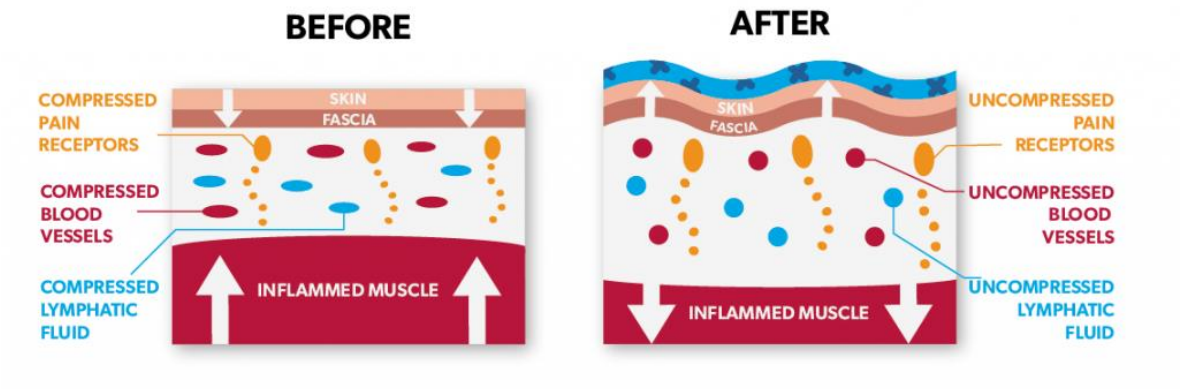
The fingerprints texture present on the kinesiotaping is believed to provide a smooth massage in the tissues during motion, acting therefore as a lymphatic drainage.[199] This action may facilitate removal of fluids and other substrates presented in an injured area by facilitating the flow of fluids such as blood and lymph, while it helps the drainage of exudate removal of waste products and, then, decreasing pain (lymphatic function).

Based on the gate control theory established by Melzack & Wall,[210] the increase of the interstitial space seems to be the primary source of analgesia provided by the kinesiotaping since decompression of interstitial space contribute to pressure relief in the five cutaneous mechanoreceptors that are sensitive to mechanical pressure: Pacinian corpuscles, Ruffini endings, Meissner corpuscles, Merkel's discs, and Free nerve endings (analgesic function). This pressure relief improves the

mechanoreceptors functioning resulting in best communication between the CNS and damaged peripheral structures, which, in turn, can stimulate the recruitment of motor units for the contractions (called "facilitation") or simply adjust the muscle activation to ensure a proper coordination between muscles (agonist and antagonist) involved in a movement (called "inhibition"). Considering that restoration of the muscle balance among agonists, antagonists, and synergists (muscular function) may facilitate the movement control in pathological conditions, the kinesiotaping is also argued to contribute to joint alignment (articular function).

Again all these arguments are theoretical hypotheses not scientifically proven.[204,211-213] Therefore, these considerations should be viewed with caution.

Figure 1.3. Hypothetical effects of kinesiotaping underneath the skin (lifting effects).



Source: http://www.wpphysio.capetown/kinesiotaping/image-7/

1.4.3. Current knowledge about kinesiotaping for rotator cuff tendinopathy

Several studies have examined the effects of kinesiotaping on musculoskeletal disorders[154,214-220] including shoulder injuries.[78,173,175,201,202,209,212,213,217,221-225] However, systematic reviews[184,228-232] have concluded that the current evidence does not support the use of kinesiotaping for individuals with RCTe.

This section provides a summary of the current evidence on the outcomes investigated in the studies that comprise this thesis (pain and functional limitations, proprioception, acromiohumeral distance, and range of motion).

1.4.3.1. What is currently known about the effects of kinesiotaping on pain and functional limitations?

Pain and functional limitations are the main impairments associated with RCTe and, therefore, the most investigated outcomes in research on the effects of kinesiotaping. Still, only a few studies have examined the effects of kinesiotaping on these outcomes.[175,176,209,212,213,226] While some studies have suggested that kinesiotaping is effective in reducing pain[78,175,176,212,227] and improving disabilities,[78,175,176,213] others have reported no effects compared to sham-taping.[209,226] As one of the most cited studies related to the effectiveness of kinesiotaping, Thelen *et al.*[209] reported that kinesiotaping is not more effective than sham-kinesiotaping in providing immediate and short-term (3 and 6 days) improvements on pain during arm elevation and functional limitations for patients with RCTe.[209] However, this study addressed young college students (mean age of 20.6 years), and the presence of underlying pathologies that could cause similar symptoms than RCTe such as instability, was not evaluated. Kocyigit *et al.*[226] also compared the effects of kinesiotaping on pain and functional limitations to sham-taping in 41 individuals with RCTe in the short-term (12 days).[226] Although both groups improved significantly their symptoms of pain and functional limitations, kinesiotaping was not superior to sham-taping.[226] In contrast, Shakeri *et al.*[213] reproduced the kinesiotaping application used by Thelen *et al.*[209] to investigate the effects of kinesiotaping on pain[212] and functional limitations[213] in individuals with RCTe compared to a placebo taping. Their results[213] were different than those reported by Thelen *et al.*[209] and Kocyigit *et al.*[226] The authors found an immediate (time not precisely reported) significant reduction in pain intensity at night and during activity,[212] besides a significant improvement in the level of symptoms and functional limitations in the short-term (seven days).[213]

Concerning the effectiveness of kinesiotaping used in conjunction with another intervention, the evidence is also insufficient to recommend its use for improving pain and disabilities.[183] However, positive findings have been reported for both pain and functional limitations.[175,176] Simsek *et al.*[176] reported that kinesiotaping added to an exercise programme based on shoulder stabilization (Hughston's exercises) provided better results than the same exercise programme alone.[176] The authors found that despite no changes in the pain level at rest, a significant reduction of pain level during activity and improvements in disabilities were observed in short-term (5 to 12 days). Kaya *et al.*[175] compared the mid-term effects of kinesiotaping added to an exercise programme to manual therapy with exercise, in 54 individuals with RCTe.[175] The authors reported that both groups provided similar significant improvements in pain at rest or during activity and disabilities after six weeks of treatment. However, the kinesiotaping group provided a superior improvement on pain at night.[175]

Systematic reviews[183,184] and meta-analyses[183] have concluded that evidence on the efficacy of kinesiotaping on pain and functional limitations are inconclusive,[183] contradictory[184] or still insufficient to support or reject the use of kinesiotaping for reducing pain and improving functional limitations associated with RCTe. Given these controversial results, it is likely that the proprioceptive stimulus provided by the kinesiotaping may not be enough to provide changes in these outcomes.

1.4.3.2. What is currently known regarding the effects of kinesiotaping on proprioception?

As the proprioceptive feedback is the basis of the kinesiotaping functioning, positive results observed on other outcomes suggest that kinesiotaping may also provide changes in the proprioceptive feedback. Proprioceptive deficits can be termed as the incapacity to identify consciously a limb position, movement or the forces imposed and produced by body segments.[36,37,54]

Few studies have addressed the effects of kinesiotaping on shoulder proprioception. In addition, most of them have tested only healthy subjects. Aarseth *et al*.,[202] assessed the proprioceptive ability with and without kinesiotaping using joint position sense at 50º, 90º, and 110º of arm elevation in scapular plane to determine the immediate effects (time not precisely reported) of kinesiotaping on shoulder proprioception in healthy subjects. The authors found that kinesiotaping had no effects on the variable errors in any angle tested and no differences were observed in the absolute errors with and without kinesiotaping at 50º and 110º. In contrast, the authors reported that kinesiotaping reduced acuity at 90º of elevation. The fact that the sample was composed of healthy athletes may have influenced the results. Burfeind and Chimera[228] investigated the immediate (time not precisely reported) effects of kinesiotaping on shoulder proprioception of healthy athletes using a joint repositioning sense task. Proprioceptive ability was tested in flexion, extension, internal and external rotation of the shoulder. The authors reported that kinesiotaping provided a significant reduction of the absolute error in flexion and external rotation of shoulder compared to the control group. In contrast, no effects were observed in extension and internal rotation. In theory, individuals without injury are likely less susceptible to the potential effects of kinesiotaping since they possibly have a proprioceptive level near optimal ability and, therefore, they do not need any improvements in the function of mechanoreceptors.

Lack of research testing symptomatic population with proprioceptive deficits hampers determination of the effectiveness of kinesiotaping in improving proprioceptive feedback as theorized by Kenzo Kase.[198] A single and recent study investigated the shoulder proprioception in a symptomatic population. Keenan *et al*.[229] used a threshold to detect passive motion method to evaluate shoulder proprioception in the internal and external rotation. The authors compared the immediate (time not

precisely reported) effects of kinesiotaping in symptomatic individuals with RCTe to placebo taping and healthy subjects.[229] No significant differences were observed in the absolute errors between and within groups, suggesting that kinesiotaping has no effects on shoulder IR and ER proprioception of individuals with RCTe.

Because most studies have investigated shoulder proprioception in an asymptomatic population, there is no evidence to draw conclusions on the effects of kinesiotaping on the proprioceptive ability of individuals with RCTe. Thus, further studies need to be conducted on this symptomatic population.

It is necessary to highlight that proprioceptive deficit is an important determinant of disability[49] having a relevant connection to the alterations in the shoulder kinematics[12,19] that, in turn, are consistent to the reduction of the subacromial space.[20]

1.4.3.3. What is currently known regarding the effects of kinesiotaping on acromiohumeral distance?

Reduction of the AHD is a common characteristic of symptomatic individuals with RCTe.[79,230] This deficit is potentialized by alterations in the shoulder kinematics[20] that requires an adequate sensorimotor control.[36,54] Due to the hypothetical mechanical effects of kinesiotaping on joint alignment,[198,199] the kinesiotaping emerged as a promising resource for contributing to the increase of the AHD and, hence, to restore a proper width of subacromial space.

Currently, studies addressing the effects of kinesiotaping on AHD in a population with reduced subacromial space such as individuals with RCTe is scarce. In fact, three studies have been published reporting effects of kinesiotaping on AHD; all of them addressing asymptomatic subjects, who in theory may less benefit functionally of an increase of AHD. Luque-Suarez *et al.*[154] investigated the immediate effects of kinesiotaping on AHD at 0º and 60º in the scapular plane in asymptomatic individuals. The authors found an increase of 1.16mm immediately after kinesiotaping application, which was argued to be related to a change in the muscle activation of external rotators muscles or to a mechanical correction provided by the kinesiotaping.[154] Mechanical correction provided by the kinesiotaping was also the explanation used by Harput *et al.* to justify the immediate increase of the AHD at 60º of abduction (0.69 mm) in asymptomatic volleyball players five minutes after kinesiotaping application.[231] More recently, Lyman *et al.* compared the effects of three different kinesiotaping techniques, used for shoulder pain: 1- taping over supraspinatus from insertion to origin; 2- taping surrounding the deltoid muscles from insertion to origin; and 3- combination of both techniques.[232] Results from this experiment indicated a significant increase in the AHD (0.79 mm) with kinesiotaping applied surrounding the deltoid muscles, whereas the other techniques also

increased slightly the AHD, but not in a significant level. Again, it is very important to point out that only the neutral position (0º) was tested and that the sample comprised only healthy subjects.

Despite these findings, there is still a lack of studies addressing the effects of kinesiotaping on the AHD in individuals with symptomatic RCTe. This population can really benefit from an increased AHD as they have demonstrated an AHD smaller than the healthy population,[151,230] compromising the mobility of the shoulder.[20]

1.4.3.4. What is currently known regarding the effects of kinesiotaping on the range of motion?

The effects of kinesiotaping on the ROM have been frequently investigated since shoulder ROM is often compromised secondarily to other impairments affecting the functioning of the glenohumeral joint.[20,157] Current evidence on the use of kinesiotaping on shoulder ROM demonstrates that individuals with RCTe can benefit from the usage of kinesiotaping for improving their shoulder ROM.[173,176,183,209] Despite this optimist circumstance, only immediate and very short-term effects of kinesiotaping have been explored.

Thelen *et al.*,[209] compared the immediate and short-term (3 and 6 days) effects of kinesiotaping on active pain-free ROM between therapeutic kinesiotaping and sham-taping applied to symptomatic individuals with shoulder pain.[209] Because individuals using therapeutic kinesiotaping presented more revealing improvements in abduction movement throughout the treatment, the authors concluded that kinesiotaping may contribute to improving pain-free ROM in individuals with RCTe. Further studies corroborate these findings.[173,176] Djordjevic *et al.*[173] evaluated the short-term (5 and 10 days) effects of kinesiotaping plus mobilization with movements on active pain-free ROM in flexion and abduction, compared to a supervised exercise programme, in individuals with RCTe.[173] The individuals receiving intervention with kinesiotaping presented faster and more pronounced improvements in their flexion and abduction ROM than those who did not.[173] Therefore, kinesiotaping was considered more effective than an exercise programme alone in increasing ROM in individuals with RCTe. In another study examining the shoulder ROM, Simsek *et al.*[176] compared the short-term (5 and 12 days) effects of therapeutic kinesiotaping plus an exercise programme to sham-taping with the same exercise programme. Active pain-free ROM and active and passive full ROM were assessed in this experiment. Results from this study demonstrated that all combinations of conditions x movements increased their amplitude over time, except for active full IR ROM, which remained similar than baseline values.[176] Kinesiotaping was superior to sham-taping in the active pain-free abduction and passive full ROM abduction.[176] For all other combinations, kinesiotaping presented

similar improvements than sham-taping, except for active and passive full flexion ROM, where sham-taping was superior.[176]

Kocyigit *et al.*[226] assessed the short-term (12 days and 4 weeks) effects of kinesiotaping on active full ROM in flexion and abduction, in individuals with RCTe. No significant differences were observed within and between groups, indicating that kinesiotaping was not effective to improve ROM in individuals with RCTe.[226] Therefore, it is likely that the effects of exercise, which have been reported to be effective in improving several impairments related to RCTe, including ROM, may have influenced the results.

Since few are the studies addressing the effects of kinesiotaping on ROM of individuals with RCTe, further studies should be conducted to ascertain its effects on this symptomatic population. In addition, research investigating its mid- and long-term effects is also encouraged as only immediate and short-term results are currently available.

In general, most of the evidence on the above-mentioned outcomes is based on trials that examined the kinesiotaping as an isolated method of treatment instead in conjunction with physiotherapy as used in clinics. In addition, only immediate and very short-term effects have been addressed. This makes it difficult to ascertain causation and may compromise the evidence of the real effects of kinesiotaping. Therefore, mid- and long-term effects of kinesiotaping on RCTe still need to be evidenced.

1.5. Objectives and hypotheses

Based on all the above-mentioned evidence on the RCTe and kinesiotaping, we can recognize that kinesiotaping may have a great potential for the treatment of musculoskeletal disorders, in general, including RCTe. However, most studies on the effects of kinesiotaping in individuals with RCTe have presented a low level of evidence, suggesting a high risk of bias, besides that only the immediate, short-term or isolated effects of kinesiotaping have been tested. These facts indicate the real need of an additional high-quality evidence to better guide clinicians and physiotherapists on the use of kinesiotaping for the rehabilitation of individuals with RCTe. Therefore, the main objective of this thesis was to determine whether kinesiotaping provides additional benefits for the rehabilitation of individuals with RCTe in the mid- and long-term.

1.5.1. Pattern of EMG activity of RC muscles in individuals with RCTe (manuscript 1)

The objective of the first study of this thesis was to synthesize the evidence concerning the pattern of EMG activity of RC muscles in individuals with RCTe. The general hypothesis was that data synthesized would permit us to confirm that individuals with RCTe present alterations in their RC muscular activation.

1.5.2. Research protocol for determining the effects of kinesiotaping used in conjunction with a conventional physiotherapy programme for individuals with RCTe (manuscript 2)

The second manuscript aimed to present the clinical research protocol for determining the effects of kinesiotaping added to a rehabilitation programme for improving symptoms and functional limitations in individuals with RCTe. Because this manuscript is a research protocol, no clinical or outcomes hypotheses were defined for it.

1.5.3. Immediate effects of kinesiotaping on subacromial space and shoulder proprioception (manuscript 3)

The aspiration of the third study was to determine whether the kinesiotaping provide an immediate increase in the AHD and improvements in the active joint repositioning ability in this population. As kinesiotaping has been reported to increase the AHD and it is believed to improve shoulder proprioception in healthy people, in the short-term, we hypothesized that individuals with RCTe would also benefit from these improvements.

1.5.4. Benefits of kinesiotaping for the rehabilitation of individuals with RCTe in the short, mid- and long-term (manuscript 4)

As the main research of this thesis, the primary objective of the fourth manuscript was to assess the short, mid- and long-term effects of kinesiotaping added to a 6-week conventional rehabilitation programme, based on sensorimotor training, in improving symptoms and functional limitations for individuals with RCTe using a randomized controlled clinical trial. The secondary objective was to evaluate the effects of kinesiotaping on outcomes related to shoulder control such as pain-free and full ROM, and AHD, in individuals with RCTe.

Because the proposed physiotherapy programme, based on exercises and techniques that were demonstrated to be effective in improving deficits of RCTe, was provided identically to both

experimental and control group, our general hypothesis was that both groups would present significant improvements in their shoulder condition over time. In addition, based on previous studies reporting that kinesiotaping may provide immediate and short-term improvements to all outcomes analyzed in this study, we hypothesized that individuals using kinesiotaping would have faster and more meaningful improvements, described as increased pain-free ROM and increased AHD, than those who do not.

CHAPTER 2. ELECTROMYOGRAPHIC ANALYSIS OF ROTATOR CUFF MUSCLES IN PATIENTS WITH ROTATOR CUFF TENDINOPATHY: A SYSTEMATIC REVIEW

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Article published in the ***Journal of Electromyography and Kinesiology*** on June 10, 2017.

2.1. Résumé

L'épaule est, par nature, une articulation instable qui compte fortement sur l'activation neuromusculaire du complexe de la coiffe des rotateurs (CR) pour assurer sa stabilité lors des mouvements. Actuellement, il n'y a pas de consensus sur la façon dont l'activité des muscles de la CR est affectée chez les individus avec une tendinopathie de la CR (TCR). Cette étude a effectué la critique de l'ensemble des études ayant comparé l'activité électromyographique (EMG) des muscles de la coiffe des rotateurs d'épaules avec une TCR symptomatique à celle d'épaules asymptomatiques. Huit bases de données ont été consultées. Les données de 343 participants (201 épaules symptomatiques et 209 asymptomatiques) ont été analysées à partir de 10 études incluses sur 402. De fortes évidences suggèrent que l'activité musculaire du sous-épineux et du sus-épineux pendant les contractions isométriques n'est pas altérée chez les individus avec une TCR, alors que les évidences sont limitées pour ces muscles lors de contractions isotoniques. Des évidences très limitées indiquent une activité musculaire réduite du sous-épineux et du sous-scapulaire en présence d'une TCR lors de contractions isotoniques, et aucune altération pour le sus-épineux et le petit rond. Enfin, des évidences contradictoires à modérées suggèrent des altérations de l'activité des muscles de la CR au cours de mouvements sans contrainte, ainsi que pendant la nage. Ces résultats indiquent que les déficits EMG associés à une TCR peuvent être mieux évalués lors de mouvements sans contrainte.

2.2. Abstract

The shoulder is inherently an unstable joint which heavily relies on the neuromuscular activation of the rotator cuff (RC) complex for stability during movement. Currently, there is no consensus regarding how the activity of RC muscles is affected among individuals with a RC tendinopathy (RCTe). This study reviewed the evidence of studies comparing the electromyographic (EMG) activity of any RC muscle of shoulders with a symptomatic RCTe to asymptomatic shoulders. Eight databases were searched. Data from 343 participants (201 symptomatic and 209 asymptomatic shoulders) were analyzed from 10 out of 402 included studies. Strong evidence for the infraspinatus and supraspinatus during isometric contractions and limited evidence for the supraspinatus and infraspinatus during isokinetic contractions suggest that the muscular activity is not altered among individuals with an RCTe during these types of contraction. Very limited evidence indicates reduced muscle activity for the infraspinatus and subscapularis in the presence of an RCTe during isotonic contractions, and no alterations for the supraspinatus or teres minor were identified. Lastly, conflicting to moderate evidence suggests alterations in RC muscle activity during unrestrained movements and swimming. These findings indicate that EMG deficits associated with an RCTe can best be appreciated during unrestrained movements.

(As published at the ***Journal of Electromyography and Kinesiology***)

2.3. Introduction

Shoulder disorders are very common (point prevalence ranging from seven to 66.7%)[67] and are associated with substantial functional limitations that tend to increase with age. Rotator cuff tendinopathy (RCTe) is the most common source of shoulder pain[233] and represents an estimated 66 to 85% of all shoulder cases.[234] RCTe is an umbrella term, which encompasses several diagnoses related to various tendon signs and symptoms (e.g. tendinosis/tendinitis, supraspinatus tendinopathy/tendinosis/tendinitis, subacromial impingement, subacromial bursitis),[3,56] combining pain and impaired function.[235]

While there is no consensus regarding etiological mechanisms,[96,97] several factors have been suggested to explain the persistence of symptoms and functional limitations in individuals with an RCTe. Among these factors, a lack of coordination[236-238] and neuromuscular balance[96,239] between the RC muscles, which includes the supraspinatus, infraspinatus, subscapularis, and teres minor, has been identified. Proper RC musculature activation is crucial for shoulder stability control, as it increases glenohumeral joint stiffness, thereby maintaining a stabilizing congruency between the humeral head and the glenoid fossa. In addition, RC muscles are activated together with other scapulothoracic and scapulohumeral muscles to properly align the humeral head with respect to the glenoid fossa, thereby preventing the impingement of the subacromial structures during arm elevation that would otherwise result from superior migration of the humeral head.[32]

Changes in muscle activation patterns of the RC muscles could explain, in part, the dynamic narrowing of the subacromial space and the alterations in upper limb kinematics that have been observed in individuals with RCTe during arm elevation.[7,8,19] In fact, the neuromuscular deficits of RC muscles have been targeted by several investigations evaluating the effects of rehabilitation intervention for RCTe.[7,123-126] Examination of RC muscular activity is, therefore, essential for a thorough evaluation of shoulder neuromuscular control. A recent systematic review addressing the EMG activity of the shoulder complex[44] concluded that individuals with an RCTe may present with altered EMG activity; however, this review was inconclusive due to inconsistencies during data retrieval, and inclusion of studies only evaluating scapulothoracic and middle deltoid muscles (evidence related to the EMG activity of RC muscles was not included). To our knowledge, there are currently no published systematic reviews compiling evidence of RC muscles activity in patients with an RCTe. Thus, the aim of this study was to review systematically the evidence concerning the EMG activity of RC muscles in individuals with RCTe. Presentation of this systematic review follows the recommendations outlined by PRISMA.

2.4. Methods

2.4.1. Identification and selection of studies

Bibliographical searches were performed in eight databases (Medline/PubMed, Science Direct, Scopus, EMBASE, ISI Web of Science, PSYCInfo, CINAHL, and Scielo) from their inception to August 2016 addressing three concepts (outcomes, patients/symptoms, and anatomical site/muscles) with the following search strategy: (EMG OR electromyograph* OR "musc* activity") AND (tendinopathy* OR impingement OR "subacromial pain") AND (infraspinatus OR supraspinatus OR "teres minor" OR subscapularis OR "rotator cuff muscles"). This strategy was adapted for each database using the appropriate truncation and medical subject heading (MeSH) (see Appendix A for an example of a search strategy). Reference lists of the retrieved studies were also searched to identify additional relevant publications. Published studies written in English, Spanish, French or Portuguese were included. After removal of duplicates, two reviewers (FCLO, JSR) independently screened the study titles and abstracts using a blinded standardized protocol. The selection criteria for the full-text review were: a) reporting on the EMG activity of any RC muscles, b) including individuals with RCTe, and c) comparing impaired shoulder to unimpaired (painful to pain-free shoulders in the same individuals or individuals with a painful shoulder to asymptomatic individuals). Thereafter, the same two reviewers scrutinized the full-text of all potentially eligible studies, independently, to decide on their inclusion. Disagreements concerning study eligibility were resolved by consensus. If no consensus was reached, a third reviewer made the final decision (LJB).

2.4.2. Assessment of characteristics of studies

2.4.2.1. Qualitative analysis (critical appraisal)

The *Standard Quality Assessment Criteria for Evaluating Primary Research Papers* (QualSyst), a quality appraisal tool developed by Kmet *et al*.[240] was used. It evaluates methodological quality and risk of bias of quantitative and qualitative studies. Items 5, 6 and 7 (random allocation and blinding) were excluded to tailor the QualSyst to the studies included (Table 2.1).

Two raters (FCLO, ALA) independently evaluated each article using the QualSyst checklist. After each independent evaluation, the pair of raters met to discuss each article. Each specific domain was openly discussed to reach a consensus. A pre-consensus inter-rater agreement was calculated for the final scores with an intraclass correlation coefficient (ICC). As summary scores were not yet associated with different qualitative categories, the following index was used: "high quality" (HQ) representing scores greater than 80.0%, "good quality" (GQ) for scores between 70 and 80.0%,

"moderate quality" (MQ) for scores between 50.0% and 69.9%, and "low quality" (LQ) for scores less than 50.0%.

Table 2.1. Assessment of methodological quality (critical appraisal) after a consensus between the researchers.

	Item number and corresponding score															FS_{qual}
	1	**2**	**3**	**4**	**5***	**6***	**7***	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Points**	**Score**
Bandholm *et al*. (2006)	Y	Y	Y	P	n/a	n/a	n/a	Y	P	Y	Y	P	Y	Y	19	0.86
Clisby *et al*. (2008)	Y	P	Y	Y	n/a	n/a	n/a	Y	P	Y	Y	P	Y	Y	19	0.86
Lopes *et al*. (2015)	Y	Y	Y	Y	n/a	n/a	n/a	Y	Y	Y	Y	Y	Y	Y	22	1.00
Michaud *et al*. (1987)	Y	Y	Y	P	n/a	n/a	n/a	P	P	Y	P	P	P	P	15	0.68
Myers *et al*. (2009)	Y	Y	Y	Y	n/a	n/a	n/a	Y	Y	Y	Y	P	Y	Y	21	0.95
Pink *et al*. (1993)	Y	P	P	Y	n/a	n/a	n/a	P	Y	P	P	P	Y	Y	16	0.73
Reddy *et al*. (2000)	Y	P	P	P	n/a	n/a	n/a	Y	P	P	N	P	P	P	12	0.55
Roy *et al*. (2008)	Y	P	Y	Y	n/a	n/a	n/a	Y	Y	Y	Y	Y	P	Y	20	0.91
Ruwe *et al*. (1994)	Y	Y	P	P	n/a	n/a	n/a	Y	P	P	P	P	P	P	14	0.64
Skolimosvski *et al*. (2009)	Y	P	Y	Y	n/a	n/a	n/a	Y	Y	Y	Y	N	N	P	16	0.73

Studies presented in alphabetic order. Y: yes (2 points); P: partial (1 point); N: no (0 points); n/a: not applicable.
Points mean the sum of scores for each item. Score are the points divided by the maximum possible score (22).
FS_{qual} was calculated dividing the total sum (TS) of rates by the maximum possible score (PS).
TS = *"number of yes"* x 2 points + *"number of partial"*.
PS = (22) – *"number of not applicable"* * 2.
1) Question/objective sufficiently described? 2) Study design evident and appropriate? 3) Method of subject/comparison group selection or source of information/input variables described and appropriate? 4) Subject (and comparison group, if applicable) characteristics sufficiently described? 5) If interventional and random allocation was possible, was it described? 6) If interventional and blinding of investigators was possible, was it reported? 7) If interventional and blinding of subjects was possible, was it reported? 8) Outcome and (if applicable) exposure measure(s) well defined and robust to measurement/misclassification bias? Means of assessment reported? 9) Sample size appropriate? 10) Analytic methods described/justified and appropriate? 11) Some estimate of variance is reported for the main results? 12) Controlled for confounding? 13) Results reported in sufficient detail? 14) Conclusions supported by the results?
Kmet LM, Lee RC, Cook LS. Standard quality assessment criteria for evaluating primary research papers from a variety of fields. Alberta Heritage Foundation for Medical Research; 2004.
* Items removed to make the QualSyst tailored for this research.

2.4.2.2. EMG scale of assessment

A critical appraisal scale for reporting EMG was developed for this study (Appendix B). This scale is based on the *Unit, Terms, and Standard for Reporting EMG Research*, reported by the Ad Hoc Committee of the International Society of Electrophysiological Kinesiology to guide the reporting of EMG research. The scale is composed of 13 items, evaluating the reporting of electrodes type and position, raw signal processing (amplification, filtering, sampling, normalization), and crosstalk. Again, two raters (FCLO, JSR) independently evaluated each article with the EMG scale, followed by a meeting where a consensus was reached (Table 2.2). A pre-consensus inter-rater agreement was also calculated for the final scores with reported ICC values.

Table 2.2. Scores of EMG scale of assessment after a consensus between the researchers.

	Types of electrodes	Electrodes technical information	Amplification procedure	Amplification reports	Band pass filters and filter types	Frequency range (ISEK standards)	Wave rectification	EMG processing	Nyquist theorem	A/D Board information	Preliminary training (MVC)	Details of contraction analysis	EMG crosstalk	**Total (0 to 26)**	**Final Score**
Bandholm *et al*. (2006)	Y	Y	P	Y	N	Y	N	Y	Y	N	Y	P	P	17	0.65
Clisby *et al*. (2008)	Y	Y	P	P	P	P	N	Y	P	P	Y	Y	P	17	0.65
Lopes *et al*. (2015)	Y	P	P	Y	P	P	Y	N	Y	N	Y	Y	N	16	0.62
Michaud *et al*. (1987)	Y	Y	P	N	P	P	P	Y	Y	N	Y	Y	P	17	0.65
Myers *et al*. (2009)	Y	Y	Y	Y	Y	P	N	Y	Y	N	Y	Y	N	19	0.73
Pink *et al*. (1993)	P	N	N	N	N	N	N	P	N	N	N	Y	N	4	0.15
Reddy *et al*. (2000)	Y	P	N	P	P	P	N	P	Y	P	P	P	P	13	0.50
Roy *et al*. (2008)	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	25	0.96
Ruwe *et al*. (1994)	Y	Y	N	P	P	N	N	Y	Y	P	Y	P	P	15	0.58
Skolimosvski *et al*. (2009)	Y	P	N	N	P	N	N	P	N	N	N	N	N	5	0.19

ISEK: International Society of Electrophysiology and Kinesiology. Studies presented in alphabetic order. Y: yes (2 points); P: partial (1 point); N: no (0 points); n/a: not applicable.
Points mean the sum of scores for each item. Score are the points divided by the maximum possible score (26).
FS_{EMG} was calculated dividing the total sum (TS) of rates by the maximum possible score (PS).
TS = *"number of yes"* x 2 points + *"number of partial"*.
PS = (26) – *"number of not applicable"* * 2.

2.4.2.3. Data extraction

A first reader extracted the data (FCLO). A second reader (JSR) then corroborated or completed the extraction if data was found to be missing. A third reader (LB) with an expertise in EMG analysis verified all extracted EMG parameters. Data were extracted for participants' characteristics, task/intervention, EMG technique, EMG variables, muscles evaluated, detection and processing of EMG data, and normalization.

EMG activity was the main outcome of this systematic review. It included any variable examined during EMG analysis (e.g. muscle activation profile, coactivation ratio, as well as maximal and submaximal amplitudes). Parameters extracted included types of electrodes and their position, sampling rate, amplification, gain, analog-to-digital conversion and processing, high and low-pass cut-off frequencies, filter type, noise processing, signal rectification, and EMG processing.

2.4.2.4. Data analysis

Studies included in this review could not be pooled into a meta-analysis due to differences in the type of EMG analyses performed in each study. Therefore, a qualitative review of the evidence was conducted.

Following the qualitative review, the body of evidence and the strength of our recommendations were established after considering four domains (number of studies/participants [imprecision], methodological quality [risk of bias], methodological and outcomes similarities [indirectness], and direction of results [inconsistency]). Thereafter, the level of evidence was classified as strong, moderate, conflicting, limited, and very limited.[241,242]

Strong evidence: multiple HQ studies with consistent results, regardless of methodological heterogeneity.

Moderate evidence: multiple studies, including at least one HQ study; or multiples MQ or GQ studies; or multiple LQ studies, homogeneous methodologies; always providing consistent results.

Conflicting evidence: multiple studies regardless of the methodological quality, with inconsistent results.

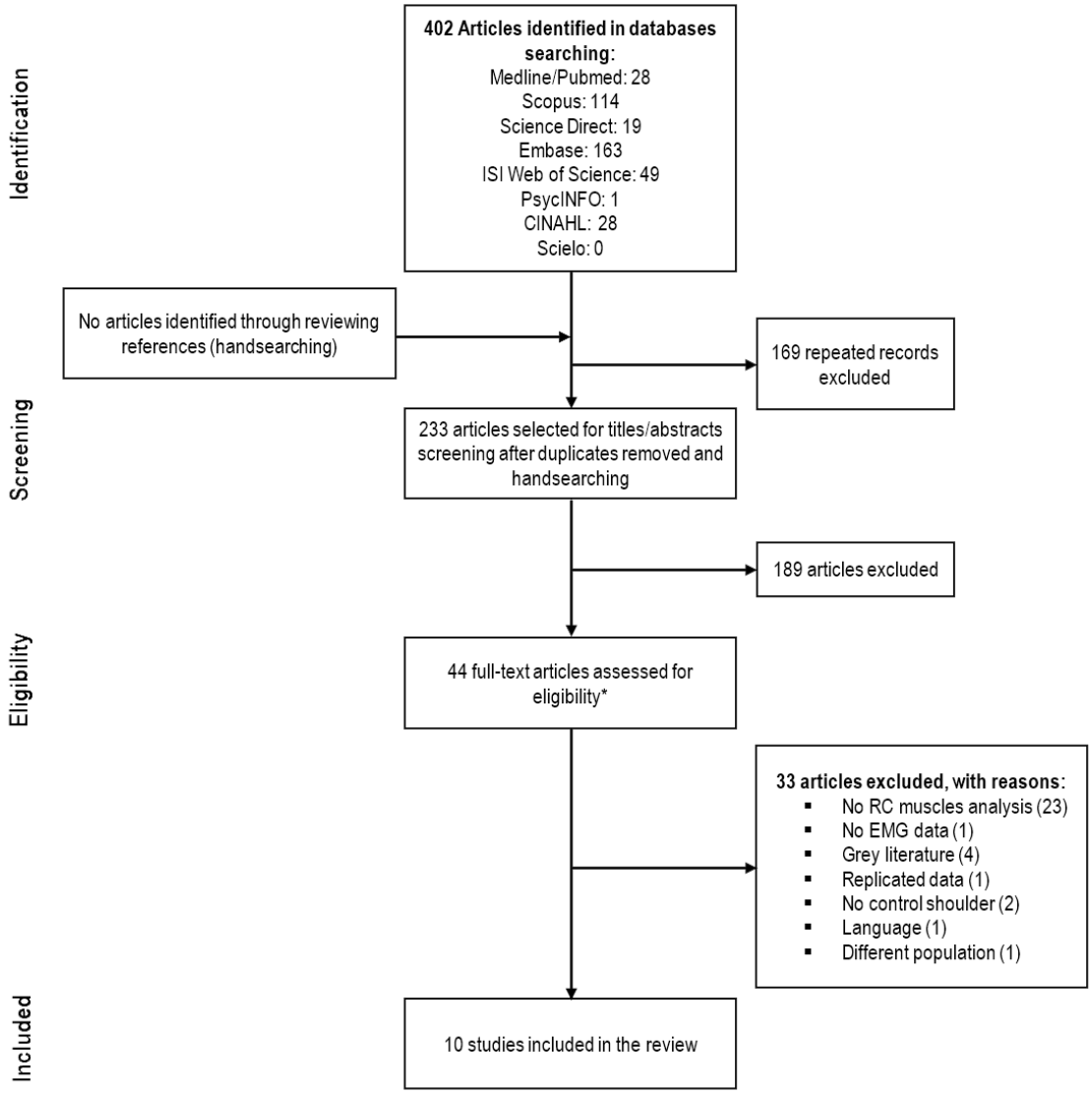
Limited evidence: multiple studies, with heterogeneous methodologies and/or inconsistent results; or single GQ study or higher.

Very limited evidence: results from single LQ or MQ study.

2.5. Results

Four hundred and two articles were retrieved. After removal of duplicates, title/abstract screening, and full-text analysis, 10 articles met the inclusion criteria (Figure 2.1). Summaries of the included studies are available in Table 2.3.

Figure 2.1. Flowchart describing the article selection process.



2.5.1. Characteristics of the studies

Outcomes measures addressed in the evaluated studies included muscle activation,[8,97,130-133,243,244] coactivation ratios,[30] and muscle contribution[236] (Table 2.4). The infraspinatus was the most investigated RC muscle as 9/10 studies investigated its activity. Supraspinatus was examined by seven studies, subscapularis by four, and teres minor by three (Table 2.5).

A single study used isokinetic (Bandholm *et al*., 2006) and isotonic contractions,[130] whereas four studies used isometric contractions to examine muscle activity.[131,236,243,244] Other six studies used unrestrained dynamic movements,[8,30,97,131-133] including two that examined aquatic sports movements.[132,133] EMG activity was collected using surface electrodes in seven studies, intramuscular fine wire in two, and Basmajian-needle technique in four. In total, 343 participants were investigated (196 with RCTe [unilateral or bilateral shoulder pain] and 205 with healthy shoulders), resulting in 201 symptomatic and 205 asymptomatic shoulders. Sample sizes of the included studies ranged from nine to 58 participants.

2.5.1.1. Diagnostic criteria and labeling

Clinical diagnostic tests (Hawkins-Kennedy, Neer, Jobe/Empty Can, arc of movement, isometric contractions) were performed in nine out of 10 included studies to determine the diagnosis of an RCTe. Three studies[130,236,244] also used diagnostic imaging (radiography, arthrography, and arthroscopy). The labeling of an RCTe was mostly homogenous across included studies as seven labeled them as subacromial or shoulder impingement, two simply as impingement,[132,133] and one as supraspinatus tendinitis.[244] Details on the diagnostic criteria and labeling are listed in Table 2.5.

2.5.1.2. Methodological quality

QualSyst scale (Table 2.1): Scores ranged from 12/22 (54.5%) to 22/22 (100.0%), with a mean score of 79.1 ± 14.7%. Five studies had methodological procedures classified as “high quality”, two as “good”, and three as “moderate”.

EMG Scale (Table 2.2): Scores ranged from 4/26 (15.4%) to 25/26 (96.2%), with a mean score of 56.8 ± 2.4%. Eight studies failed to provide important information on band pass filter or filter type. Seven studies did not fully respect the ISEK standards concerning frequency range (low and high-frequency cut-off). Most studies (70.0%) did not describe wave rectification, and information on the A/D conversion was absent in six articles. Lastly, four studies did not report the strategies used to determine or avoid EMG crosstalk contamination.

Pre-consensus inter-rater agreement on the total scores was high for both QualSyst (ICC = 0.96 [95% IC: 0.83–0.99]) and EMG (0.99 [95% IC: 0.96–1.00]) scales.

2.5.2. EMG activity of RC muscles in patients with RCTe

As the 10 included studies used different procedures to evaluate muscle activity with an RCTe, we decided to group them into four functional groups: isometric, isokinetic, isotonic, and unrestrained dynamic movements (including sporting movements).

2.5.2.1. Impact of RCTe on EMG activity during isometric contractions

There is strong evidence for the infraspinatus and supraspinatus, that their activation is not altered in individuals with RCTe during isometric contractions (Table 2.6), as four studies (n=128) that have looked at RC muscle activity during this type of contractions did not observe any significant differences between the symptomatic and asymptomatic shoulder.[131,236,243,244] Skolimowski *et al*.[131] reported no changes in both infraspinatus and supraspinatus muscle activity, as recorded by surface EMG, in 58 patients with unilateral RCTe compared to their healthy shoulder during isometric internal rotation, external rotation, and abduction contractions. EMG data were processed through Root Mean-Square (RMS). Michaud *et al*.[244] compared the EMG activity of supraspinatus muscle during isometric submaximal contraction at 0º and 45º of abduction of 20 patients suffering from RCTe to 20 healthy controls (surface electrodes, Z-score used for normalization, data processed through integrals EMG). Bandholm *et al*. also compared individuals with RCTe (n=9) to healthy controls (n=9) using surface electrodes during isometric submaximal and maximal voluntary contractions (MVC) at 45º and 90º of abduction (data expressed as relative muscle activity, normalized to MVC, and processed through RMS 1-s window). Both studies found that supraspinatus muscle activity was unaffected by RCTe during the isometric abduction contractions. Bandholm *et al*.[243] also reported no difference in infraspinatus muscle activity. Clisby *et al*. further support infraspinatus muscle activity to be unaffected by RCTe while comparing isometric contractions during external rotation in 14 symptomatic individuals to 18 healthy controls (surface electrodes, RMS at 32Hz to process EMG data, MVC as normalization method).

2.5.2.2. Impact of RCTe on EMG activity during isokinetic contractions

There is limited evidence that supraspinatus and infraspinatus muscle activity is not altered during isokinetic contractions in individuals with RCTe (Table 2.6). A single HQ study[243] found no changes

in EMG activity during either eccentric (110–95º and 55–40º) or concentric (40–55º and 95–110º) contractions of shoulder abduction for the supraspinatus and infraspinatus muscles in individuals with RCTe. The same parameters as described above for isometric contractions were used.

2.5.2.3. Impact of RCTe on EMG activity during isotonic contractions

Very limited evidence exists that infraspinatus and subscapularis muscle activity is reduced in individuals with an RCTe during isotonic contractions, whereas supraspinatus and teres minor muscle activity is not altered (Table 2.6). A single MQ study used the Basmajian technique to compare muscle activity of all four RC muscles during 30º-120º of scaption among individuals with RCTe (n=15) to healthy controls (n=16) (data normalized to MVC and processed by IEMG). No significant between-group differences for supraspinatus and teres minor were found. In contrast, a significant decrease in EMG activity in the 30º-60º movement range for infraspinatus and subscapularis and in the 60º-90º range for infraspinatus was reported.

2.5.2.4. Impact of RCTe on EMG activity during unrestrained active and sports movements

The strength of evidence within this functional group is either conflicting or moderate (Table 2.6). The conflicting evidence is for the impact of an RCTe on supraspinatus and infraspinatus muscle activity since important between-study differences were observed. Two studies[8,97] looked at infraspinatus muscle activity during arm movements and found no altered muscle activity in individuals with RCTe. In the study of Lopes *et al*.,[97] infraspinatus activity of 19 patients with RCTe was compared to 19 healthy controls during dynamic elevation of the arm in forward flexion (surface EMG, two reference trials for normalization). Roy *et al*.,[8] evaluated infraspinatus muscle activity in 33 individuals with RCTe and 20 healthy participants, during end-range reaching 90° of elevation (surface EMG, reference conditions used for normalization). By contrast, four studies[30,131-133] reported altered muscle activity in people with RCTe. Two of them[30,131] observed decreased muscle activity for infraspinatus during shoulder movements, whereas the other two[132,133] found increased subscapularis and infraspinatus muscle activity during swimming. Skolimowski *et al*.[131] observed a decreased infraspinatus muscle activity during unrestrained internal and external rotations in the involved shoulder (n=58) compared to their healthy shoulder (surface electrodes, processed by RMS). Myers *et al*.[30] reported similar findings when comparing coactivation ratio of RC muscles (surface and intramuscular EMG, maximal elevation torque used for normalization) of 10 individuals with RCTe to 10 healthy controls during unrestrained humeral elevation. They reported that individuals with RCTe exhibited altered muscular coactivation between RC muscles: less subscapularis-

infraspinatus and supraspinatus-subscapularis coactivation between 0º-30º, accompanied by an increase in middle deltoid activation when compared to the healthy group. Furthermore, supraspinatus-infraspinatus coactivation was reduced between 30º-60º, and accompanied by diminished infraspinatus activation, while subscapularis-infraspinatus and supraspinatus-infraspinatus coactivation were higher between 90º-120º.

Finally, moderate evidence suggests that the muscular activity of all four RC muscles is altered in individuals with RCTe during swimming, based on two studies[132,133] that have investigated symptomatic swimmers during the butterfly and breast swim strokes (Basmajian technique, MVC used for normalization) (Table 2.6). Pink *et al*.[132] indicated that all RC muscles had significant alterations in activation patterns, as evaluated during a butterfly stroke, in 14 painful shoulders compared to 20 pain-free shoulders of controlled participants. Using a similar design, Ruwe *et al*.[133] also found differences in muscle activity between swimmers with and without shoulder pain during breaststroke. In both studies, subscapularis and infraspinatus muscular activity was increased in shoulders with RCTe, whereas supraspinatus and teres minor were decreased.

2.6. Discussion

The goal of this study was to systematically review the evidence concerning the pattern of EMG activity of RC muscles in individuals with RCTe. Ten studies with a mean methodological score of 80.4% were included. Overall, very limited to strong evidence infers that muscular deficits vary according to the task performed. Undoubtedly, the most interesting findings came from studies showing alterations in muscular activity during unrestrained dynamic movements. Despite not presenting strong evidence, these findings contribute to the understanding of the mechanisms underlying the dynamic narrowing of the subacromial space, during movements, within this population.

RCTe is frequently labeled as impingement syndrome, based on the underlying mechanism, which includes encroachment of soft tissue underneath the coracoacromial arch as the arm is actively elevated. Therefore, deficits related to this injury tend to be more prominent during dynamic activities in elevated arm positions. For example, acromiohumeral distance (AHD) has been shown to be reduced at 45° and 60° of active shoulder abduction, but not in a neutral position.[7] Findings from this systematic review support this reasoning since alterations in muscular activity were mostly observed during movements when the arm was actively elevated. Yet, some between-study differences were found during dynamic movements. This can be explained by the choice of imposed movements, as

well as by the parameters used for EMG processing and analysis, including the normalization method, which will be further discussed in the following sections.

2.6.1. EMG activity of RC muscles in patients with RCTe

2.6.1.1. Normalization of EMG values in symptomatic patients

Lack of between-studies consistency may be explained by differing methodologies, outcomes measures, data acquisition techniques, and raw EMG data processing. Normalization methods, however, may hold the most important impact on the results. MVC is often used to normalize EMG data, although it can be problematic in symptomatic participants since pain may compromise the achievement of true maximal values, leading to an overestimation of relative EMG activity used during movement, and increased data variability. An alternative method to normalize EMG values in symptomatic population uses a reference condition, as described in Roy *et al*.[8] In their study, data were normalized by mean EMG activity collected while participants actively held their arm at 90° of elevation against a 1 kg load. This normalization approach also has some limitations, however. Indeed, as the muscular activity is impaired in this population and variable across participants, normalizing using this method may also lead to increased data variability. The lack of a standardized EMG normalization method, therefore, obscures comparison of muscle activation amplitude across studies.

It is important to point out that included studies are relatively dated since 50% of them were published more than 10 years ago.[130,132,133,243,244] In fact, only one study has been published within the last five years.[97] Therefore, it may have influenced the EMG parameters and processing used, especially, normalization and filtering for which guidelines have only been suggested in recent years.

2.6.1.2. Impact of RCTe on EMG activity during isometric contractions

The four included studies that explored EMG activity during isometric contractions show strong evidence for supraspinatus and infraspinatus, that the muscle activity of these two muscles is not altered during this type of contraction (Table 2.6), even in elevated arm positions. Shoulder control required during isometric contractions may not be demanding enough to expose sensorimotor deficits. However, it must be noted that during isometric contraction at 45º of abduction, deltoid EMG activity has been shown to be decreased within this population.[244] As the deltoid is one of the primary agonists during shoulder abduction, its inhibition could be a strategy to avoid pain by preventing the superior

translation of the humeral head during such contractions.[239] Details on this perspective should be further investigated.

2.6.1.3. *Impact of RCTe on EMG activity during isokinetic contractions*

As only a single HQ study[243] has examined the RC muscle activity during isokinetic contractions in individuals with an RCTe, the evidence showing no alteration in the supraspinatus and infraspinatus muscle activity is limited. During isokinetic movements, no alterations in the muscular length-tension relationship are observed. Given that, the absence of significant alterations in muscle activity during an isokinetic movement is not surprising. Further investigations are needed to provide definite conclusions during isokinetic contractions.

2.6.1.4. *Impact of RCTe on EMG activity during isotonic contractions*

During isotonic contractions, muscle tension remains constant, however the muscle length changes,[60] providing variation in the production of muscle force to overcome the resistance throughout the motion. Here again, a single MQ study[130] investigated RC muscle activity using this type of contractions and provided very limited evidence of a decrease EMG activity for infraspinatus and subscapularis. In our point of view, the reduction in EMG activity of infraspinatus and subscapularis during scaption, reported by Reddy *et al*.,[130] likely occurred due to an inhibition mechanism as a result of shoulder control disturbances generated by mechanical alterations. Possible physiological characteristics observed during isotonic contractions are also present during dynamic movements, especially in eccentric contractions. These common elements may contribute to understanding the changes in the RC muscle activity observed in unrestrained dynamic movements.

2.6.1.5. *Impact of RCTe on EMG activity during unrestrained active movements*

Due to a small number of participants, methodological heterogeneity, and the inconsistencies of the reported results, conflicting evidence was observed regarding the supraspinatus and infraspinatus muscle activity when unrestrained movements were used to evaluate the RC muscle activity. Indeed, alterations in RC muscle activity are not unanimous, as two studies did not report any change.[8,97] Between these two studies, we highlight that Roy *et al*.[8] used a reference condition as a normalization method. This could have increased data variability and limited the capacity to identify between-group differences.

Among the four studies[30,131-133] that found altered RC muscle activity during dynamic movement, two reported increased infraspinatus muscle activity, and the other two reported reduced activities. A possible explanation for these diverging results is that different shoulder movements were used, as the level of muscular activation differs when acting as a prime mover or not. In this case, studies reporting increased activity of infraspinatus muscle examined the muscle response during arm elevation (infraspinatus is not the prime mover), whereas reduced activity was found during unrestrained humeral external rotation (infraspinatus is the prime mover). The choice of different control subjects may also contribute to the divergences between these studies. Indeed, in one study reporting infraspinatus activity reduction (Skolimowski *et al*., 2009), the comparison was made between the symptomatic and the asymptomatic shoulders of individuals with a diagnosed RCTe, while the other studies compared the same shoulder in individuals with and without RCTe.

Findings from Myers *et al*.[30] highlight the importance of coactivation among RC muscles. Synchronous control between infraspinatus and subscapularis is required to maintain shoulder joint stability in the transverse plane; therefore, altered activation of one of these muscles requires an activation from its antagonist in the same direction. Results from Myers *et al*.[30] revealed that between 0º-30º, coactivation between infraspinatus-subscapularis and subscapularis-supraspinatus were reduced. Interestingly, after 90º of abduction, coactivation between infraspinatus-subscapularis and supraspinatus-infraspinatus increased above normal. This increase was likely a response mechanism triggered to counteract the superior migration of the humeral head, creating a force coupling to stabilize the humeral head in the glenoid fossa. These findings highlight that properly timed activity between RC muscles plays an important role in avoiding impingement. Despite the relevant findings, the evidence on alteration of subscapularis and teres minor muscle is considered moderate due to the small sample size and heterogeneous methodologies.

2.6.1.6. *Impact of RCTe on EMG activity in sports movements*

The literature showed that swimmers with RCTe had a significant increase in infraspinatus and subscapularis muscle activity, whereas supraspinatus and teres minor were decreased.[132,133] The level of evidence of these findings, however, was considered moderate due to the small sample size and methodological heterogeneity, as differing swimming strokes were used for two of the included studies. As several types of swimming strokes require repetitive medial rotation of the arm, subscapularis activity is likely increased during the initial phase of a movement aiming to improve swimming performance. In contrast, to prevent forward humeral head translation during swim-strokes, infraspinatus muscle activity could also be increased during the recovery phase. Therefore,

these studies propose that increased infraspinatus activity could be a response to decreased range of motion (ROM) in lateral rotation, resulting from a failure of the humeral greater tuberosity to pass under the acromion during arm elevation, or increased medial rotation. This requires attention when considering that subscapularis assists the latissimus dorsi in rotating the humerus medially,[132] whereas infraspinatus counteracts the effects of these muscles by rotating the humerus laterally. Because characteristics of athletes do not necessarily correspond to the profile of the general population, these findings should be analyzed with caution.

2.6.2. Strengths and limitations of the study

The strengths of this review include the use of a validated tool for the critical appraisal (QualSyst), the determination of the quality of evidence, a rigorous literature search in eight recognized databases and four different languages, as well as the development of a scale for the appraisal of reported EMG activity.

We are aware of some limitations of this review. First, non-scientific journals, unpublished, and gray literature were not included in data search. Thus, it is possible that relevant studies may have been missed due to these criteria. Next, despite analyzing the normalization procedures adopted in each study, this review was not able to identify a standardized manner to normalize EMG data of symptomatic patients with RCTe. Finally, three studies that have looked at infraspinatus EMG activity during unrestrained active movements[8,97,131] have used surface EMG. This may not be appropriate for infraspinatus recordings. As surface electrodes are attached to the skin and it is likely that it does not follow the infraspinatus muscle during scapular movements leading to the recording of other neighboring muscles.[245-247]

2.6.3. Future research directions

Future studies addressing the EMG activity of RC muscles should follow the ISEK standards to ensure higher quality recordings and reports. Based on some possible points of improvements identified among the included studies, the following recommendations are advised:

(1) Band-pass filter and filter type should be clearly reported, facilitating protocol reproduction.

(2) Procedures for the identification and reduction of crosstalk contamination should be clearly described to increase the confidence of the readers.

(3) Normalization methods not minimized by pain or other symptoms of RCTe should be developed.

Further studies are required to highlight the differences in EMG activity between patients with RCTe and healthy individuals, during dynamic contractions. Finally, most studies focused on the supraspinatus and infraspinatus; therefore, subscapularis and teres minor muscle activity should be further investigated.

2.7. Conclusions

According to the body of evidence summarized, there is strong evidence that individuals suffering from an RCTe have no alteration in the muscle activity of infraspinatus and supraspinatus muscles during isometric contractions.

The level of evidence regarding the impact of an RCTe on EMG activity of RC muscles varied largely (from conflicting to moderate evidence) during unrestrained dynamic movements. There is moderate evidence to suggest that the subscapularis and teres minor muscle activity is reduced, while there is conflicting evidence regarding a reduced muscle activity of the infraspinatus and supraspinatus muscles, during unrestrained movements among individuals with an RCTe. Notwithstanding, moderate evidence indicates that patients affected by RCTe may have the RC muscle activity altered during swimming strokes.

Altered RC muscles activity may compromise joint stability, resulting in increased shoulder dysfunction. Therefore, our results show the importance of evaluating muscle performance and shoulder motor control in individuals suffering from RCTe during dynamic tasks. Further investigations are required to define RC muscle activity of this population during dynamic movements.

2.8. Footnotes

2.8.1. Competing interests

Fábio Oliveira, Dr. Laurent Bouyer, Amanda Ager, and Dr. Jean-Sébastien Roy declare that they do not have a conflict of interests to declare.

2.8.2. Source(s) of support

The main researcher receives a doctoral scholarship from the Brazilian government through the Science without Borders programme in association with the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES.

Table 2.3. Evidence table of included studies.

Authors	Sample	Objectives / purposes	Diagnostic criteria and labeling	Task / intervention	EMG technique	EMG variables	Muscles evaluated†	Available information on detection and processing of EMG data	Normalisation	Results (EMG analysis)	Score QualSyst (classification)	Score EMG assessment (classification)
Bandholm *et al*. (2006)	Experimental: n = 9 (gender not informed) Age: 28.2 ± 5.3 yrs (21 - 38) Control: n = 9 (gender not informed) Age: 27.7 ± 4.2 yrs (22 - 37)	To examine the effects of SIS on shoulder sensory motor control, expressed as submaximal shoulder ABD force steadiness and related muscle activity, and maximal shoulder muscle strength.	Clinical evaluation: Painful arc of movement; Hawkins - Kennedy test. Labeling: Subacromial Impingement Syndrome (SIS).	Isometric contractions in 45º and 90º of shoulder ABD. Concentric contractions in 40-55º and 95-110º of shoulder ABD. Eccentric contraction in 110-95º and 55-40º of shoulder ABD.	Surface EMG; Intramuscular EMG.	Force steadiness in 20%, 27.5% and 35% of the maximum shoulder abductor torque.	Supraspinatus, Infraspinatus, Anterior Deltoid, Middle Deltoid, Upper Trapezius, Lower Trapezius, Serratus Anterior, Latissimus Dorsi.	Sampling rate: 1000 Hz Amplification: custom-built differential amplifier. HP filter: 10 Hz LP filter: 1000 Hz Noise processing: CMRR > 100 dB EMG processing: RMS 1-s window (10, no overlapping, 100-ms intervals).	MVC at 45º of isometric ABDs, ADDs, internal and external rotations of the upper arm. MVC at 90º of isometric ABD of the upper arm.	Muscle activity was unaffected by the SIS† Isometric contractions: No differences in any muscle activity. Concentric contractions: No differences in any RC muscles activity. Eccentric contractions: No differences in any muscle activity.	86% high	65% moderate
Clisby *et al*. (2008)	Experimental: n = 14 (5 men, 9 women) Age: 51.07 ± 11.06 yrs Control: n = 18 (6 men, 12 women) Age: 42.17 ± 7.64 yrs	To evaluate the conditions of resisted isometric ER that optimized the contribution of the IS and the load of ER at which ADD was most effective at reducing the DE contribution, in the	Clinical evaluation: Painful arc of movement; Hawkins - Kennedy test; 90° Scaption isometric resistance; Anterior and lateral	Isometric external rotation; ADD + Isometric external rotation.	Surface EMG	Muscle contribution at 10%, 40%, and 70% of MVC of isometric ER, with and without shoulder ADD.	Infraspinatus, Posterior Deltoid, Middle Deltoid, Pectoralis Major.	Gain: 1000x A/D processing: storage in a computer. HP filter: 20 Hz LP filter: 500 Hz EMG processing: RMS 32Hz	The average RMS over the middle 5s for each muscle at 10%, 40% and 70% MVIC.	Symptomatic x asymptomatic shoulders The activation patterns in the SAI sample were similar to those found in the asymptomatic shoulders† SAI: 8.239 ± 4.500 kg Asymptomatic: 9.856 ± 3.621 kg). IS: More active at 40% MVIC in ER and ER	86% high	65% moderate

		symptomatic shoulders of patients with SAI. To compare the IS and PD muscle activation between symptomatic and asymptomatic shoulders.	pain on the shoulder. Imaging diagnostic: Radiography. Labeling: Subacromial Impingement (SAI).							+ ADD. ADD did not change the infraspinatus contribution. No differences in the relative contributions at any load of ER with or without ADD for SAI and asymptomatic groups).		
Lopes *et al*. (2015)	Experimental: n = 19 (12 men, 7 women) Age: 40.2 ± 13.8 yrs Control: n = 19 (11 men, 8 women) Age: 46.4 ± 10.9 yrs	To characterize scapular kinematics and shoulder muscle activity in patients with SIS, with and without visually identified scapular DYSK.	Clinical evaluation: Painful arc of movement; Hawkins - Kennedy test; Jobe test. Labeling: Subacromial Impingement Syndrome (SAIS).	Ascending and descending shoulder flexion.	Surface EMG	Muscle activity during ascending and descending phases of weighted shoulder flexion in subjects with SIS (DYSK) and NODYSK.	Infraspinatus, Upper Trapezius, Lower Trapezius, Serratus Anterior.	Sampling rate: 960 Hz Gain: 10.000x A/D processing: storage in a computer. HP filter: 20 Hz LP filter: 400 Hz Filter type: Notch filter (59 - 61 Hz) Noise processing: CMRR >92 dB at 60 Hz Rectification: Full wave	For normalization, surface EMG data were collected during 2 trials while participants performed a reference contraction against resistance for 5 seconds at the midpoint of the testing motion at 90º of flexion in the sagittal plane.	Symptomatic x asymptomatic group No significant differences between groups (DYSK and NODISK) for IS. DYSK (Ascending): 30 - 60º : 10.7 ± 2.3% 60 - 90º : 12.8 ± 2.9% 90 - 120º : 16.3 ± 2.7% DYSK (Descending): 30 - 60º : 7.5 ± 1.5% 60 - 90º : 6.0 ± 1.2% 90 - 120º : 7.2 ± 1.7% NODYSK (Ascending): 30 - 60º : 15.8 ± 2.3% 60 - 90º : 10.8 ± 2.9% 90 - 120º : 18.7 ± 2.7%	100% high	62% moderate

										NODYSK (Descending): 30 - 60º : 8.4 ± 1.5% 60 - 90º : 4.5 ± 1.2% 90 - 120º : 13.1 ± 1.7%		
Michaud *et al*. (1987)†	Experimental: n = 10 (7 men, 3 women) Age: 28.8 ± 6.8 yrs Control: n = 10 (5 men, 5 women) Age: 29.7 ± 3.8 yrs	To investigate the EMG activity of both the SS and MD muscles in normal subjects and patients suffering from an ST.	Clinical evaluation: No details on tests used. Imaging diagnostic: Arthrogram. Labeling: Supraspinatus tendinitis.	Isometric ABD of the arm.	Bipolar electrodes (Needles). Surface EMG	Muscle activity in submaximal contraction of MVC, during ABD of the arm at 0º and 45º.	Supraspinatus, Middle Deltoid.	HP filter: 16 Hz LP filter: 1600 Hz (surface) / 3200 Hz (intramuscular wire) EMG processing: Integrals (16 voltage reset integrator).	Z-score.	SS:† No altered muscle activity between 0º and 45º in both groups (experimental and control). No different muscle activity between ST and healthy subjects, in both angles (0º and 45º).	68% moderate	65% moderate
Myers *et al*. (2009)	Experimental: n = 10 (5 men, 5 women) Age: 42.70 ± 10.61 yrs Control: n = 10 (5 men, 5 women) Age: 36.58 ± 7.61 yrs	To measure RC coactivation and MD muscle activation in participants with SIS and to determine if there is an abnormal coactivation in these muscles.	Clinical evaluation: Painful arc of movement; Hawkins - Kennedy test; Neer test; Jobe test. Labeling: Subacromial Impingement.	Humeral elevation and depression (ABD and ADD).	Surface EMG; Intramuscular EMG.	Muscle coactivation	Middle Deltoid, Infraspinatus, Supraspinatus, Subscapularis.	Sampling rate: 1000 Hz Amplification: Single Gain: 500x HP filter: 15 Hz LP filter: 500 Hz Filter type: Butterworth Noise processing: CMRR 130 Db	Maximal elevation torque was used to calculate the load (25%) to be held during subsequent functional elevation tasks.	SIS group; Control group 0–30◦ (↓ coactivation) SB-IS* (116.73 ± 25.60%; 143.74 ± 20.55%) SS-SB* (107.50 ± 20.99%; 133.28 ± 26.89%) 30–60◦ (↓ coactivation) SS-IS* (149.09 ± 17.84%; 170.25 ± 18.32%) IS* (92.00 ± 15.09%; 105.36 ± 13.00%) 60–90◦ No significant differences.	95% high	73% good

										90–120◦ (↑ coactivation) SB-IS* (191.28 ± 24.78%; 160.85 ± 35.36%) SS-IS* (204.95 ± 35.01%; 169.22 ± 32.52%)		
Pink *et al.* (1993)	Experimental: n = 14 (9 men, 5 women) Age: 31 yrs (19 - 48) Control: n = 20 (17 men, 3 women) Age: 39 yrs (20 - 67) (Pink *et al*., 1993b)	To compare the muscle firing patterns in competitive swimmers with painful and normal shoulders during the butterfly stroke.	Clinical evaluation: Hawkins - Kennedy test; Neer test; Speed test. Labeling: Impingement.	Butterfly swim stroke	Basmajian Needle technique.	Muscle activity	Anterior Deltoid, Middle Deltoid, Posterior Deltoid Serratus Anterior, Upper Trapezius, Rhomboids, Supraspinatus, Infraspinatus, Teres Minor, Subscapularis, Latissimus Dorsi, Pectoralis Major.	Sampling rate: 2500 Hz EMG processing: Integrals 20 ms	Maximal Manual Muscle Test (MMT)	Swimmers painful Shoulders x Swimmers with normal shoulder SS* (25 ± 24% x 52 ± 26%, EPT) (1 ± 1% x 5 ± 3%, MPT) (21 ± 19% x 47 ± 31%, LR) IS* (15 ± 17% x 4 ± 4%, MPT) (67 ± 32% x 35 ± 25%, LPT) (78 ± 35% x 46 ± 24%, LPT) TM* (9% to 20% x 28 to 80%, EPT) (6 ± 3% x 14 ± 9%, LR) (4 ± 3% x 14 ± 9%, LR) SB* (42 ± 19% x 21 ± 16%, MPT)	73% good	15% low
Reddy *et al*. (2000)	Experimental: n = 15 (12 men, 3 women)	To compare data on DE and RC muscle activity during	Clinical evaluation: No details	Isotonic scaption from 30 to 120º of arm elevation with the	Basmajian single-needle technique.	Muscle activity	Middle Deltoid, Infraspinatus, Supraspinatus,	Sampling rate: 2500 Hz A/D processing: storage in a computer. HP filter: 10 Hz	Within the 5-sec maximum MMT for each muscle,	General decreased muscle activity in SIS population. 30 - 60º	55% moderate	50% moderate

	Age: 53.5 yrs (40 – 66) Control: n = 16 (12 men, 4 women) Age: 29 ± 4 yrs (23 – 36)	scapular plane ABD (scaption) in subjects with known SIS with data obtained from subjects with normal shoulders.	on tests used. Imaging diagnostic: Radiography; Arthroscopy. Labeling: Subacromial Impingement	elbow extended and holding a load of 25% of their NMW.			Subscapularis, Teres Minor.	LP filter: 1000 Hz	the highest half-second interval of integrated EMG signal was selected as 100% effort.	MD: 62%; IS: 32%; SB: 18% 60 - 90º IS: 43% No significant changes in 90 - 120º. No significant changes for SS and TM.		
Roy *et al*. (2008)	Experimental: n = 33 (11men, 22 women) Age: 47.9 ± 8.7 yrs (26 - 59) Control: n = 20 (7 men, 13 women) Age: 46.6 ± 9.9 yrs (27 - 60)	To characterize upper limb motor strategies in individuals with and without shoulder impingement during reaching in natural speed and to evaluate their adaptation to higher speeds of movement.	Clinical evaluation: Painful arc of movement; Hawkins - Kennedy test; Neer test; Jobe test; ER isometric resistance. Labeling: Shoulder Impingement Syndrome.	Reaching towards two targets (frontal and oblique plane) in two speeds (natural and fast), both at 90º of arm elevation.	Surface EMG	Reaching speed, upper limb kinematics, and EMG activity.	Upper Trapezius, Middle Trapezius, Lower Trapezius, Serratus anterior, Infraspinatus, Anterior Deltoid, Middle Deltoid.	Sampling rate: 5000 Hz Gain: 4000x A/D processing: storage in the computer at 1000 Hz. HP filter: 10 Hz LP filter: 500 Hz Filter type: Butterworth Noise processing: CMRR 93 dB; input impedance 10^9 Ω, gain 23 Wave rectification: Full-wave EMG processing: Smoothing, threshold value > 2 SD beyond baseline for 25ms.	Percentage of reference condition (calculated by maintaining the arm at 90º elevation with a 1 kg load during 5s).	Patients with SIS x healthy controls IS† No significant differences in the EMG activity in all 3 phases, for both conditions (natural and fast speed) in both planes (frontal and oblique).	91% high	96% high

Ruwe *et al*. (1994)	Experimental: n = 14 (9 men, 5 women) Age: 31 yrs (19 - 48) Control: n = 25 (19 men, 6 women) Age: 39 yrs (20 - 67)	To describe and compare electrical activity patterns in 12 shoulder muscles during the breaststroke in competitive swimmers with normal and painful shoulders.	Clinical evaluation: Hawkins - Kennedy test; Neer test; Supraspinatus test. Labeling: Impingement.	Breast swim stroke	Basmajian single-needle technique.	Muscle activity	Anterior Deltoid, Middle Deltoid, Posterior Deltoid Serratus Anterior, Upper Trapezius, Rhomboids, Subscapularis, Supraspinatus, Infraspinatus, Teres Minor, Latissimus Dorsi, Pectoralis Major.	Sampling rate: 2500 Hz A/D processing: storage in the computer at 2500 Hz HP filter: 100 Hz LP filter: 1000 Hz EMG processing: Computer integration	Peak 1-s of Maximal isometric MMT in water.	Swimmers painful Shoulders x Swimmers with normal shoulder SB* (↑EMG activity for painful) 46 ± 36% x 19 ± 11%, EPT) 47 ± 31% x 22 ± 15%, EPT) 44 ± 18% x 23 ± 12%, MPT) 45 ± 17% x 19 ± 12%, MPT) 49 ± 21% x 13 ± 7%, MPT) 41 ± 22% x 9 ± 8%, TPT) 25 ± 22% x 7 ± 7%, TPT) SS * (↓EMG activity for painful) (15 ± 14% x 35 ± 11%, MR) (17 ± 13% x 39 ± 11%, MR) (14 ± 13% x 38 ± 14%, MR) (15 ± 14% x 41 ± 24%, LR) (16 ± 15% x 39 ± 22%, LR) (17 ± 15% x 34 ± 21%, LR) IS* (↑EMG activity for painful) (28 ± 25% x 9 ± 7%, MR) TM (trend to ↓EMG activity, PT)	64% moderate	58% moderate
Skolimovski *et al*. (2009)	Experimental:	To evaluate the changes of	No details on the	Maximum isometric contraction	Surface EMG	Bioelectric	Deltoid, Supraspinatus,	Filter type: Butterworth 4th order	No information on	SIS shoulders x healthy shoulders	73% good	19% low

	n = 58 (19 men, 39 women) Age: 56 yrs (24 - 85) Control: n = 58 (19 men, 39 women) Age: 56 yrs (24 - 85)	bioelectric activity of the chosen muscles in people with impingement syndrome and the effect they have on the functioning of the shoulder joint.	methods used to diagnose RCTe. Imaging diagnostic: Radiography; Arthroscopy. Labeling: Subacromial Impingement	(resisted) and unrestrained in the internal and external rotation, ABD, flexion, and extension.	muscular activity	Infraspinatus, Latissimus Dorsi, Pectoralis Major, Bíceps Brachii.	EMG processing: RMS	normalization.	IS: ER (unrestrained)* 0.038 ± 0.036 mV x 0.130 ± 0.115 mV (↓ EMG activity) ER and IR (isometric) 0.042 ± 0.029 mV x 0.077 ± 0.046 mV SS: ER and IR (unrestrained) 0.028 ± 0.020 mV x 0.017 ± 0.013 mV ER and IR (isometric) 0.030 ± 0.027 mV x 0.018 ± 0.016 mV ABD (unrestrained) 0.099 ± 0.074 mV x 0.092 ± 0.080 mV ABD (isometric) 0.053 ± 0.035 mV x 0.092 ± 0.056 mV

Ω: ohms; HP: high-pass filter; LP: low-pass filter; RC: rotator cuff; ROM: range of motion; ABD: abduction; ER: external rotation; IR: internal rotation; SAI: subacromial impingement; SIS: subacromial impingement syndrome; RT: rotator tendinosis; ST: supraspinatus tendinitis; DYSK: scapular dyskinesis; NODYSK: normal scapular motion; MMT: manual muscle test; NMW: normalized maximum weight; MVC: maximum voluntary contraction; ADD: adduction; ABD: abduction; IS: infraspinatus; SS: Supraspinatus; SB: Subscapularis; TM: Teres minor; DE: Deltoid; LD: Latissimus Dorsi, PM: Pectoralis Major; BB: Biceps Brachii; AD: Anterior Deltoid; MD: Middle Deltoid; PD: Posterior Deltoid; SA: Serratus Anterior; T: Trapezius; UT: Upper Trapezius; MT: Middle Trapezius; LT: Lower Trapezius; RB: Rhomboids; PT: pull-through; EPT: early pull-through; MPT: mid-pull-through; LPT: late pull-through; TPT: terminal pull-through; MT: mid-recovery; LR: late recovery; rcte: Rotator cuff tendinopathy.

* indicates significance ($p \leq 0.05$; †Results reported without clear details on values.

Only significant results, reported by each study, are described in Results (EMG analysis) column.

† Only rotator cuff muscles were analyzed in this study.

Table 2.4. Overview of the level of evidence for the outcomes.

Outcomes analyzed	Participants (studies)	Trials	Methodological quality	Level of evidence	Results
Coactivation ratio	n=20 (1 study)	Myers *et al*.	HQ	**Limited** due to imprecision	Muscle coactivation (SB-IS; SS-IS) affected by RCTe
Muscle contribution	n=32 (1 study)	Clisby *et al*.	HQ	**Limited** due to imprecision	No differences in the relative contributions
Muscle activation	n=311 (8 studies)	Bandholm *et al*.	HQ	**Conflicting** due to indirectness, inconsistency	SS, IS muscle activation unaffected by RCTe
		Skolimovsky *et al*.	GQ		
		Lopes *et al*.	HQ		
		Roy *et al*.	HQ		
		Pink *et al*.	GQ		
		Reddy *et al*.	MQ		Several methodological differences leading to various results (altered and unaltered muscle activation), concerning all RC muscles.
		Michaud *et al*.	MQ		
		Ruwe *et al*.	MQ		

The bold terms refer to the level of evidence, which did not consider the EMG quality. Imprecision: a single study or data from less than 100 participants. Risk of bias: methodological quality determined by the rating system adopted in this review. Indirectness: methodological heterogeneity between studies. Inconsistency: Results/findings in different directions.

Table 2.5. Muscle investigated and general findings of the included studies.

	Infraspinatus (IS)	Supraspinatus (SS)	Subscapular (SB)	Teres minor (TM)
Studies				
Bandholm *et al*. (2006)	x	x		
Clisby *et al*. (2008)	x			
Lopes *et al*. (2015)	x			
Michaud *et al*. (1987)		x		
Myers *et al*. (2009)	x	x	x	
Pink *et al*. (1993)	x	x	x	x
Reddy *et al*. (2000)	x	x	x	x
Roy *et al*. (2008)	x			
Ruwe *et al*. (1994)	x	x	x	x
Skolimosvski *et al*. (2009)	x	x		
Muscle activity altered/affected by RC tendinopathy				
Myers *et al*. (2009)*	x	x	x	
Pink *et al*. (1993)	x	x	x	x
Reddy *et al*. (2000)	x		x	
Ruwe *et al*. (1994)	x	x	x	x
Skolimosvski *et al*. (2009)	x			
Muscle activity non-altered/affected by RC tendinopathy				
Bandholm *et al*. (2006)	x	x		
Clisby *et al*. (2008)	x			
Lopes *et al*. (2015)	x			
Michaud *et al*. (1987)		x		
Reddy *et al*. (2000)		x		x
Roy *et al*. (2008)	x			
Skolimosvski *et al*. (2009)	x	x		
Increased muscle activity				
Pink *et al*. (1993)	x		x	
Ruwe *et al*. (1994)	x		x	
Myers *et al*. (2009)*	x	x	x	
Reduced muscle activity				
Myers *et al*. (2009)*	x	x	x	
Pink *et al*. (1993)		x		x
Reddy *et al*. (2000)	x		x	
Ruwe *et al*. (1994)		x		x
Skolimosvski *et al*. (2009)	x			

* Measurements of the coactivation of rotator cuff muscles.

Table 2.6. Overview of the level of evidence for the functional grouping.

Functional group	Participants (studies)	Trials	Methodological quality	Level of evidence	Results
Isokinetic contraction	n=18 (1 study)	Bandholm *et al*.	HQ	**limited** due to imprecision	SS, IS unaffected by RCTe (1)
Isotonic contraction	n=31 (1 study)	Reddy *et al*.	MQ	**very limited** due to imprecision	IS, SB affected by RCTe (1) SS, TM unaffected by RCTe (1)
Isometric contraction	n=96 (3 studies)	Michaud *et al*.	MQ	**strong**	**consistent findings** SS unaffected by RCTe (3)
		Bandholm *et al*.	HQ		
		Skolimovsky *et al*.	HQ		
	n=108 (3 studies)	Bandholm *et al*.	HQ	**strong**	**consistent findings** IS unaffected by RCTe (3)
		Clisby *et al*.	HQ		
		Skolimovsky *et al*.	GQ		
Unrestrained movements	n=222 (5 studies)	Roy *et al*.	HQ	**conflicting** due to inconsistency	IS unaffected by RCTe (2) IS affected by RCTe (3)
		Lopes *et al*.	HQ		
		Skolimovsky *et al*.	HQ		
		Pink *et al*.	GQ		
		Ruwe *et al*.	MQ		
	n=151 (4 studies)	Myers *et al*.	HQ	**conflicting** due to inconsistency	SS unaffected by RCTe (1) SS affected by RCTe (3)
		Skolimovsky *et al*.	GQ		
		Pink *et al*.	GQ		
		Ruwe *et al*.	MQ		
	n=93 (3 studies)	Myers *et al*.	HQ	**moderate** due to imprecision, indirectness	SB affected by RCTe (3)
		Pink *et al*.	GQ		
		Ruwe *et al*.	MQ		
	n=73 (2 studies)	Pink *et al*.	GQ	**moderate** due to imprecision, indirectness	TM affected by RCTe (2)
		Ruwe *et al*.	MQ		
Sporting movements	n=73 (2 studies)	Pink *et al*.	GQ	**moderate** due to imprecision, indirectness	All RC muscles affected by RCTe (2)
		Ruwe *et al*.	MQ		

The bold terms refer to the level of evidence, which did not consider the EMG quality. Imprecision: a single study or data from less than 100 participants. Risk of bias: methodological quality determined by the rating system adopted in this review. Indirectness: methodological heterogeneity between studies. Inconsistency: Results/findings in different directions.

CHAPTER 3. METHODOLOGY

This chapter describes in full details all the methodological procedures used to reach the objectives of this doctoral research. First, we present the research protocol designed for the randomized controlled trial as the main research of this project. This research protocol was published at the *British Medical Journal Open* and, therefore, the description in here follows the submission rules of this journal.

Afterward, we provide the methodology implemented in the cross-sectional study design to reach the secondary objective of this doctoral project. First, the characteristics of the participants are described with details on the method of recruitment implemented as well as the inclusion and exclusion criteria. Then, the study design is presented with all the technicalities necessary to replicate this investigation, including meticulous details on the variables of interest and procedures conducted for data collection. Finally, sample size calculation, procedures for data processing and analysis, and statistical analysis are presented next.

3.1. Manuscript 2 (Effects of kinesiotaping added to a rehabilitation programme for patients with rotator cuff tendinopathy: protocol for a single-blind randomised controlled trial addressing symptoms, functional limitations, and underlying deficits)

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Article published in the ***British Medical Journal Open*** on September 01, 2017.

3.1.1. Résumé

Introduction : La tendinopathie de la coiffe des rotateurs (TCR) est la cause la plus fréquente de douleurs à l'épaule, entraînant des pertes considérables pour la société et les ressources publiques. Les déséquilibres musculaires et le contrôle sensorimoteur inadéquat sont des déficits souvent associés à la TCR. Le kinesiotaping (KT) est largement utilisé par les cliniciens pour la réadaptation des TCR. Bien que certaines études ont évalué les effets immédiats du KT sur les blessures à l'épaule ou les effets du KT comme une méthode isolée de traitement, aucune étude publiée n'a évalué ces effets à moyen et long terme lorsque combiné avec un programme de réadaptation pour les patients avec TCR. L'objectif principal de cet essai randomisé contrôlé (ERC) sera d'évaluer l'efficacité thérapeutique du KT, ajouté à un programme de réadaptation, pour réduire la douleur et les incapacités chez les personnes atteintes de TCR. Les objectifs secondaires porteront sur les effets du KT sur les facteurs sous-jacents impliqués dans le contrôle de l'épaule, tels que l'activité musculaire, la distance acromio-humérale (DAH), et l'amplitude de mouvement (ADM).

Méthode et analyses : Un ERC à simple insu sera conduit. Cinquante-deux participants, répartis aléatoirement entre deux groupes (KT ou No-KT), participeront à un programme de réadaptation de six semaines. Le groupe KT recevra le KT en plus du programme de réadaptation, alors que le groupe No-KT ne recevra que le programme de réadaptation. Les mesures seront prises lors de l'évaluation initiale, à la semaine 3, 6, 12, et à 6 mois. Les résultats principaux seront les symptômes et les limitations fonctionnelles évalués par le questionnaire DASH. Les résultats secondaires incluront les ADM de l'épaule, la DAH au repos et à 60° d'abduction, et l'activité musculaire pendant l'élévation du bras. Les effets supplémentaires du KT seront évalués via une ANOVA à deux facteurs à mesures répétées.

Éthique et diffusion : L'approbation éthique a été obtenue du Comité d'éthique de l'Institut de réadaptation de Québec (IRDPQ) du Centre intégré universitaire de santé et des services sociaux (CIUSSS-CN). Les résultats seront diffusés par des publications dans des journaux scientifiques internationaux révisés par les pairs, en plus de présentations à des conférences internationales.

Numéro d'enregistrement de l'essai : Protocole enregistré sur ClinicalTrials.gov (NCT02881021) le 25 août 2016. Les données d'enregistrement des essais de l'Organisation mondiale de la santé peuvent également être retrouvées sous forme de fichier supplémentaire.

Mots-clés : bandes élastiques, bande kinésiologique, physiothérapie, coiffe des rotateurs, douleur à l'épaule, blessures tendineuses.

3.1.2. Abstract

Introduction: Rotator cuff tendinopathy (RCTe) is the most frequent cause of shoulder pain, resulting in considerable losses to society and public resources. Muscle imbalance and inadequate sensorimotor control are deficits often associated with RCTe. Kinesiotaping (KT) is widely used by clinicians for rehabilitation of RCTe. While previous studies have examined the immediate effects of KT on shoulder injuries or the effects of KT as an isolated method of treatment, no published study has addressed its mid- and long-term effects when combined to a rehabilitation programme for patients with RCTe. The primary objective of this randomised controlled trial (RCT) will be to assess the efficacy of therapeutic KT, added to a rehabilitation programme, in reducing pain and disabilities in individuals with RCTe. Secondary objectives will look at the effects of KT on the underlying factors involved in shoulder control, such as muscular activity, acromiohumeral distance (AHD), and range of motion (ROM).

Methods and analysis: A single-blind RCT will be conducted. Fifty-two participants, randomly allocated to one of two groups (KT or No-KT), will take part in a 6-week rehabilitation programme. The KT-group will receive KT added to the rehabilitation programme, whereas the No-KT group will receive only the rehabilitation programme. Measurements will be taken at baseline, week-3, week-6, week-12 and 6-months. Primary outcomes will be symptoms and functional limitations assessed by the DASH questionnaire. Secondary outcomes will include shoulder ROM, AHD at rest and at 60º of abduction, and muscle activation during arm elevation. The added effects of KT will be assessed through a 2-way ANOVA for repeated measures.

Ethics and Dissemination: Ethics approval was obtained from the Ethics Committee of Quebec Rehabilitation Institute (IRDPQ) of the Center Integrated University of Health and Social Services (CIUSSS-CN). Results will be disseminated through international publications in peer-reviewed journals, in addition to international conference presentations.

Trial registration number: Protocol registered at ClinicalTrials.gov (NCT02881021) on August 25, 2016. The World Health Organization Trial Registration Data Set can also be found as a supplementary file.

Keywords: elastic tape, kinesiology taping, physiotherapy, rotator cuff, shoulder pain, tendon injuries.

(As published at the ***British Medical Journal Open***)

3.1.3. Introduction

Shoulder pain is a very common musculoskeletal disorder affecting a large portion of the population. With point prevalence ranging from 6.9% to 26%,[248] it is estimated that one in three persons will have at least one episode of shoulder pain within their lifetime.[67,68] Rotator cuff tendinopathy (RCTe) is the most common pathology of the shoulder,[62,63] with up to 50% of rendered diagnoses.[62,249]

RCTe is a broad term encompassing several diagnoses related to painful signs and symptoms in the subacromial structures (subacromial bursa, rotator cuff [RC] tendons and long head of the biceps tendon).[3,4,55,56,77] It is frequently termed impingement syndrome, based on the proposed underlying mechanism that includes encroachment of the subacromial space soft tissues underneath the coracoacromial arch, secondary to a dynamic narrowing of the subacromial space, as the arm is elevated.[60,61] In addition, hormonal dysregulation and metabolic diseases have been suggested as a possible contributor for RC injuries due to a possible influence on the biology of tendons and, hence, in the biomechanical properties of the musculoskeletal system.[250,251]

While there is no consensus on the specific etiological mechanisms of RCTe,[96,97] glenohumeral and scapular kinematics alterations have been suggested as instigators of the dynamic narrowing of the subacromial space.[18,19,79,129] A lack of coordination and an imbalance between RC and scapulothoracic muscle activations could explain these kinematics alterations.[42] The muscular balance between deltoid and RC muscles is crucial to maintaining the glenohumeral joint function,[42,252] keeping a stabilizing congruency between the humeral head and the glenoid fossa; however, this dynamic interplay appears to be compromised in individuals with RCTe.[30,42]

Reduction of these deficits is the key to returning to a proper shoulder neuromuscular control leading to the resolution of pain and restoration of function.[22,179] Therefore, many rehabilitation programmes include interventions such as mobilisation with movements[173] and with exercises,[175,176] movement training,[7] and strengthening exercises.[6] These interventions improve the neuromuscular control of the shoulder and concomitantly decrease symptoms and functional limitations.[7,126,253] In addition, taping techniques have been considered an interesting option to improve shoulder control and hence to reduce the deficits associated with RCTe.[27] Taping techniques such as kinesiotaping (KT) are now widely used in clinical settings for rehabilitation of shoulder disorders. The proposed rationale behind its functioning is based on the lifting effects of epidermis layers and papillary dermis,[201] caused by micro-convolutions formed on the taped skin. Wrinkles generated by the KT are believed to increase the interstitial space, leading to an increase in blood and lymph flow, while facilitating pressure release on underlying soft tissues. Consequently, vascular networks in deep vessels under the skin are increased, reducing swelling and inflammation in injured tissues.[198,203] The KT is also argued to

contribute to pain relief by producing increased stimulation of cutaneous mechanoreceptors,[254] that likely improves the proprioceptive feedback and thereby provides muscle activation.[255] Combination of these effects is suggested to provide support to the joint during functional movements. Considering all of these potential benefits, the KT method has been widely used in clinical practice; however, its functional underlying mechanism is still hypothetical, and its clinical efficacy has not been thoroughly ascertained.

While some clinical trials have investigated the effects of KT on musculoskeletal disorders,[208,214,216,218,220,256-259] including shoulder injuries,[78,173,176,201,209,212,213,222,224,225,260] systematic reviews have consistently pointed out that not enough evidence is available to conclude on the efficacy of KT on musculoskeletal conditions.[183,261-265] Recently, Desjardins-Charbonneau *et al.*[183] examined six randomised controlled trials (RCT)[173,175,176,209,212,260] (n=360) specifically addressing RCTe. Their meta-analysis findings showed that KT might be effective in immediately increasing pain-free flexion and abduction range of motion (ROM). However, most published studies on KT have presented a high risk of bias, tested KT as an isolated method of treatment (when it is used in combination with other modalities in the clinics), or only looked at the immediate or short-term effects of KT.[78,176,209,212] Therefore, additional high-quality evidence is required to better guide health professionals on the use of KT in the rehabilitation of individuals with RCTe.

3.1.3.1. Objectives and hypotheses

The primary objective of this single-blind RCT is to evaluate the added effects of therapeutic KT to a rehabilitation programme focusing on sensorimotor training to reduce symptoms and functional limitations of individuals with RCTe. The secondary objective is to evaluate the effects of KT on variables related to shoulder control, such as muscular activity, AHD and ROM, in attempting to identify the underlying effects of KT. Our hypothesis is that both groups will possibly achieve a mean improvement superior to the clinically important difference (CID) of the Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH) after the rehabilitation programme, as both groups will receive the same programme that has been shown to be effective for this population.[7] However, based on findings of previous studies that have shown immediate and short-term effects of KT, it is likely that positive outcome of rehabilitation in terms of reduction in symptoms and functional limitations will be obtained faster for the patients allocated to the KT-group.

3.1.4. Methods and Analysis

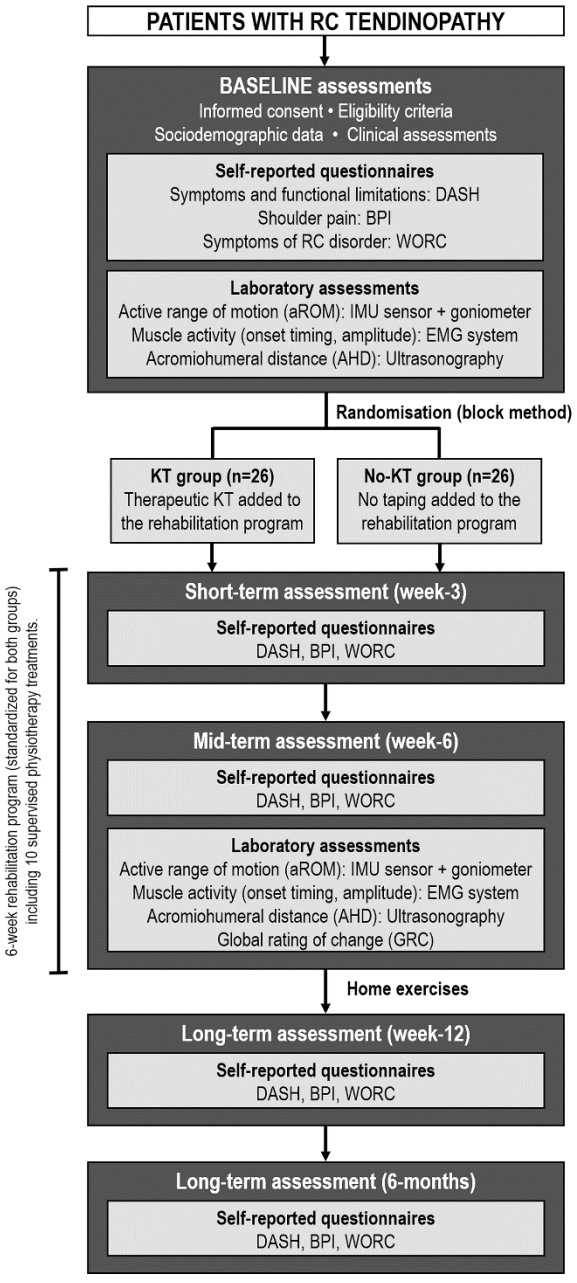
3.1.4.1. Study design

This single-blind parallel group RCT will include a 6-week rehabilitation programme and five evaluation sessions (baseline, week-3, week-6, week-12, and 6-months) over six months (Figure 3.1). All evaluations will be carried out at the Center for Interdisciplinary Research in Rehabilitation and Social Integration (CIRRIS) in Québec City, Canada.

Participants will take part in the baseline evaluation. After providing written informed consent, eligibility criteria will be assessed. Thereafter, eligible participants will complete a sociodemographic questionnaire, followed by the evaluation of the primary (DASH questionnaire), and secondary outcomes (Brief Pain Inventory [BPI] and the Western Ontario Rotator Cuff Index [WORC] questionnaires, shoulder ROM, AHD, muscle activity). Participants will then be randomly allocated to one of two groups (KT or No-KT) and take part in their assigned 6-week intervention: *experimental group* (KT-group - KT application will be added to the rehabilitation programme), and *control group* (No-KT group - only the rehabilitation programme, without any KT). An allergy testing to KT will be conducted by the treating physiotherapist specifically for patients allocated to the experimental group.

The three self-reported questionnaires (DASH, BPI, WORC) will be re-evaluated at week-3 (mid-point of the rehabilitation programme), week-6 (end of the rehabilitation programme), week-12, and 6-months after baseline evaluation. These follow-up evaluations are planned to assess progression in terms of symptoms and functional limitations throughout the study, allowing to establish whether an intervention leads to a faster and/or more lasting improvement than the other. Shoulder ROM, AHD, and muscle activity will be re-evaluated only at the end of the rehabilitation programme (week-6). At the end of the rehabilitation programme, participants will be asked to evaluate the change in their condition since the first physiotherapy session, using a Global Rating of Change (GRC) question.

Figure 3.1. Schematic diagram of the study design. BPI, Brief Pain Inventory; DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; EMG, electromyography; IMU, inertial measurement unit; KT, kinesiotaping; RC, rotator cuff; WORC, Western Ontario Rotator Cuff Index.



3.1.4.2. Participants

Fifty-two (52) participants, aged between 18 and 65 years old, diagnosed with RCTe, will be recruited. To be eligible, participants will have to present one positive finding in each of the following categories: 1) painful arc of movement during flexion or abduction; 2) Neer (*sensitivity* 0.78, *specificity* 0.58) or Kennedy-Hawkins (*sensitivity* 0.74, *specificity* 0.57) impingement signs;[233] and 3) pain during resisted external rotation, abduction, or empty can test (*sensitivity* 0.69, *specificity* 0.62).[233] A combination of positive results to these clinical tests has values ≥0.74 for sensitivity and specificity for RCTe.[59] Participants will be excluded if they have: a) an open wound that compromises KT application; b) had a previous shoulder surgery; c) allergy or intolerance to KT; d) adhesive capsulitis, defined as loss of passive shoulder ROM greater than 50%;[266] e) history of glenohumeral luxation in the last 12 months or any fracture to the shoulder girdle; f) shoulder pain reproduced by cervical movements; g) clinical sign of full-thickness tears of any RC muscles identified by lag signs:[267] drop sign (*sensitivity* 0.73, *specificity* 0.77), external rotation sign (*sensitivity* 0.46, *specificity* 0.94), and internal rotation sign (*sensitivity* 1.00, *specificity* 0.84).[268]

3.1.4.3. Randomization, blinding and allocation concealment

An independent assessor, not involved in data collection, will generate the randomization list using a computer random-number generator, prior to the initiation of the study. A block randomization design (block size of 4, 6 or 8) will be applied to ensure an equal number of participants in each group. Given that it is unknown if gender influences the physiological response to KT, randomization will be stratified by sex. Allocation will be concealed in sealed and opaque envelopes that will be sequentially numbered. Each participant will receive an envelope that will be opened by the treating physiotherapist at the first therapy session. As it is impossible to blind participants and treating physiotherapist to KT application, a single-blind design was chosen.

The treating physiotherapist will be unaware of the data from the outcome measures, which will be assessed by an evaluator blinded to the group assignment. Patients will be blinded to the treatment provided to the other group. To assess blinding effectiveness, the assessor will answer a question related to their opinion on the allocation after each of the follow-up evaluations.

3.1.4.4. Rehabilitation programme (independent variable)

Each patient will attend 10 physiotherapy sessions over six weeks (two sessions during each of the first four weeks, then once a week). Both KT and No-KT groups will receive the same standardized

rehabilitation programme that will include sensorimotor training, manual therapy, stretching, resisted exercises for muscular strengthening, and patient education. Additionally, the participants will receive a list of four (4) exercises, based on their individual needs, to be performed at home without supervision. The rehabilitation programme will target deficits described in patients with RCTe and will take into consideration the specific needs of each patient. The same physiotherapist will conduct all rehabilitation programmes.

Sensorimotor training. Shoulder control exercises with progressive complexity in terms of movement plane, ROM, speed, and resistance will be the basis of this rehabilitation programme. These exercises will be implemented aiming at the re-education of movement control to correct kinematic alterations that lead to a superior migration of the humeral head and to scapular dyskinesis, or changes in the muscle activity of shoulder muscles.[6,7] The exercises will be performed in the frontal, sagittal and scapular planes, being graded according to resistance level (no resistance, passive, active assisted, and active with and without external resistance), and the use of feedback (with or without).[6] When the exercises will be executed properly, participants will perform them at home, in three sets of 10 repetitions a day. Once participants are able to elevate the injured arm without compensatory movements, suggesting adequate shoulder control, goal-directed reaching tasks will be performed to retrain movements requiring upper limb coordination. Work- or sport-specific re-education will also be performed according to the participant's own activities.

Manual therapy. Joint mobilisation techniques will be applied on the sternoclavicular, acromioclavicular, glenohumeral, and thoracic spine, wherever the ligamentous and capsular restraints are identified during the initial evaluation.[126,253,269-271] Once its necessity is confirmed, each technique will be performed three times for approximately 60-sec, with a between-set rest interval of 30-sec.[269] Details can be viewed in Appendix L, part B.

Stretching exercises. Stretches will be performed to enhance the flexibility of the glenohumeral capsule and underlying soft tissues, according to individual needs. Stretches will be oriented to be performed as home exercises throughout treatment, in three repetitions held for 30 seconds each.

Resisted exercises. Free weights, extremities weight, and resistance elastic tube will be used to strengthen RC muscles and scapular stabilizers.[6,7] Exercises will progress according to the following

phases: (a) phase 1, humerus in a neutral position to improve the depression function; (b) phase 2, ascending arm movements; (c) phase 3, higher-level exercises, including trunk strengthening.[126] The number of repetitions will vary from one to three sets of 10 to 30, progressing gradually. Patients will begin using a light resistance elastic band (yellow non-latex TheraBand Hygenic Corp., Akron, OH, USA),[272] in phase 1. Participants will progress to the next phase when exercises are performed with medium resistance band (red and green non-latex TheraBand). Patients should perform phase 2 without increasing symptoms for one week as requirements to advance to phase 3. Verbal and written instructions regarding the exercises to be performed at home will be given the participants.

Patient education. General guidance will be verbally provided to all patients to enhance understanding of shoulder overload, pain neuroscience, pain management, posture, rehabilitation stages, graded exposure to exercise, shoulder and body mechanics and movements that provoke impingement, besides verbal and written instructions regarding preferred shoulder positioning during sleep, work, and daily and sports activities.[273]

3.1.4.5. KT techniques

The skin will firstly be properly cleaned with isopropyl alcohol. Kinesio® Tex Classic will be applied using a combination of techniques designed for RCTe and underlying symptoms (Figure 3.2).[198] The first strip will be applied in Y-shape, light tension (15-25%), surrounding the three portion of the deltoid muscle as a group, from insertion to origin to provide inhibition and muscle relaxation.[173,198] A second strip (I-shape) will be applied for functional correction, recommended for multiaxial shoulder instability, with severe tension (50–75%), from 7–10 cm above the acromioclavicular joint to 7–10 cm below the deltoid tuberosity, passing over the supraspinatus, trapezius, glenohumeral joint, and middle deltoid.[198] The third strip will be applied in I-shape for mechanical correction at the glenohumeral joint, being placed with severe tension (50–75%) and inward pressure, from coracoid process to posterior deltoid, just slightly below the coracoacromial arch.[37, 75] The first strip will be applied in all patients of the KT-group, whereas second and third strips will be used according to the presence of corresponding deficits observed during individual weekly evaluations. All KT strips will be removed at the beginning of each session, and a new piece will be applied at the end. Participants will be requested to keep the KT until the next physiotherapy session or for a minimum of 72 hours, whichever comes first. All applications will follow the instructions and principles described by Kase *et al*,[198] and will be executed by the same physiotherapist, who is a practitioner certified by the Kinesio® Taping Association International. As a fundamental practice, a gradual

weaning will permit patients to readapt to the normal feedback condition.[274] Therefore, KT strips will be weaned gradually, according to individual improvement, as evaluated weekly by the treating physiotherapist.

Figure 3.2. Kinesiotaping application. First strip (1: Y-shape surrounding deltoid muscles), second strip (2: I-shape in functional correction for multiaxial shoulder instability over the glenohumeral joint, supraspinatus, trapezius and middle deltoid muscles) and third strip (3: I-shape in mechanical correction for glenohumeral joint).

To ensure that the length needed for the tension of each strip of kinesiotaping is standardized across participants, the *"skin area" (d)*, corresponding to the distance between the application points (origin and insertion) on the shoulder of each participant, will be measured. Then, this value will be inserted into the following formula:

$$l = ((d * 100) / (100 + k_1)) + (a_1 + a_2)$$

$$l = ((d * 100) / (100 + k_2)) + (a_1 + a_2)$$

where ***l*** is the kinesiotaping length, ***d*** is the skin area, ***k*** is the inferior and superior limit of the range of tension that should be applied to the strip, and ***a*** is the length of the anchors used in both strip extremities.

3.1.4.6. Data collection

3.1.4.6.1. Outcome measures (dependent variables)

The outcomes data will be collected by the same assessor, not involved in any other process of the study. The primary outcomes are the symptoms and functional limitations assessed using the *Disabilities of the Arm, Shoulder, and Hand (DASH)* questionnaire.[275] The secondary outcomes are the BPI, WORC index, and shoulder control, described as ROM, AHD and muscle activity. Global Rating of Change (GRC) will be also assessed.

3.1.4.6.2. Primary outcome

3.1.4.6.2.1. Symptoms and functional limitations

A previous systematic review[276] examined the quality of four self-reported questionnaires for the evaluation of functional limitations and symptoms in individuals with shoulder pain (Disabilities of the Arm, Shoulder, and Hand [DASH], Shoulder Pain and Disability Index [SPADI], American Shoulder and Elbow Surgeons [ASES] score, and Simple Shoulder Test [SST]). All these four questionnaires presented excellent reliability (ICC≥0.90). The DASH, ASES, and SPADI were reported to be acceptable for clinical use and no substantial evidence to recommend one questionnaire over the others was clearly identified in terms of psychometric properties. However, the DASH was the only one among these questionnaires that was valid for a French-Canadian population.[277] It has relative reliability superior to the SPADI for individuals with RCTe[278] and it is the questionnaire with the lowest absolute measurement error. According to Roy *et al*.,[276] the psychometric properties of the DASH are as good as, if not better, than those of the shoulder-specific scales reviewed. Based on these rationales, the DASH was the self-reported questionnaire chosen for assessing symptoms and functional limitations in our study.

The DASH is a 30-item self-report questionnaire, designed to measure physical disability and symptoms of upper limbs disorders,[275-277] through a scale ranging from 0 to 100 (the most severe disability).[276,277] Its items address the level of difficulty in performing, in the last week, several daily activities related to upper extremity (21 items); the severity of the pain symptoms, activity-related pain, tingling, weakness, and stiffness (five items); and their impact on social activities, sleep, work, self-image (four items).[277] The DASH has an excellent reliability (ICC=0.96), it is highly responsive following rehabilitation interventions for individuals with RCTe (effect size [ES]=1.06, standardized response mean [SRM]=1.08),[276] it has a minimal detectable change (MDC) of 11 points and a

clinically important difference (CID) of 10 points.[276,277] The validated Canadian-French version will be used (ICC=0.93; SRM=1.35; MDC=11.4 points; CID=10 points).[2,276,277]

3.1.4.6.3. Secondary outcomes

3.1.4.6.3.1. BPI and WORC index

As DASH has few questions related to pain, the BPI,[279,280] specific for assessing clinical pain, will also be filled out by the participants. It measures pain intensity on an 11-point numerical rating scale (0-10), according to its interference with general activity, mood, walking ability, normal work, relations with other people, sleep, and enjoyment of life, over the last 24 hours (ICC >0.80).[279,280] In addition, as the DASH is not specific for the shoulder or for RC disorders, the WORC index[281] will also be filled out. The WORC is a reliable and responsive (ICC=0.96; SRM=1.54; MDC=12 points; CID=13 points) questionnaire designed to measure health-related-quality-of-life in patients affected by RC injuries.[2,281]

3.1.4.6.3.2. Range of motion (ROM)

Limited and painful ROM is often observed in patients with RCTe.[110,226] In addition, KT has been shown to be effective in restoring pain-free ROM.[176,209] Therefore, active full and pain-free ROM in shoulder elevation in the frontal (abduction) and sagittal (flexion) planes will be measured using a manual goniometer. The goniometer is a reliable instrument for measuring shoulder ROM (ICC flexion = 0.95 [0.89-0.98]; ICC abduction = 0.97 [0.94-0.99]).[282] All measurements will be taken with patients standing. Participants will perform two repetitions for each movement. A 5-sec rest will be given between each trial and 1-min between conditions. The average of two trials will determine the mean ROM values for each condition.

3.1.4.6.3.3. Acromiohumeral distance (AHD) and muscle activity

Kinesiotaping has been shown to lead to an immediate increase in AHD in healthy individuals.[154,231] Therefore, AHD measurement was included as a secondary outcome of shoulder control as it gives an indication of the dynamic narrowing of the subacromial space using the tangential distance between humeral head bony landmarks and acromion inferior edge.[7,140]

First, two measures of AHD with shoulder at rest will be taken using an ultrasound scanner (Logic *e*9, GE Healthcare, Milwaukee, WI, USA) with a 6-15MHz linear array probe (model ML6-15-D).[7,140]

Thereafter, participants will perform two vertical abductions (frontal plane) at 60º. During this arm elevation, muscle activity of four shoulder muscles (upper trapezius, infraspinatus, middle and anterior deltoid) will be recorded using surface electromyography (Trigno™ Wireless EMG system, Delsys Inc., Boston, MA, USA). At the end-point of movement (60° of abduction), the ultrasonographic image of the AHD will be recorded. These measurements (muscle activity and ultrasound) will permit to determine the association between the presence of a dynamic narrowing of the AHD and the muscular activity of key shoulder muscles.

Ultrasonographic recordings. To record AHD images, the probe will be positioned on the anterior aspect of the lateral surface of acromion along the longitudinal axis of the humerus in a coronal plane and moved around 1 cm behind the acromion and humeral head. In this position, both acromion and humerus can be viewed. A strap will be used to restrain the abduction movement to 60º, which will be confirmed using an inclinometer. Participants will be instructed to maintain the strap slightly stretched during data collection, to maintain the angle of interest. All measurements will be performed with patients seated up straight against the backrest of the chair. The average over two AHD trials will be calculated for each angle examined.

EMG recordings. Before measurements, the skin over upper trapezius, infraspinatus, anterior and middle deltoid will be cleaned with isopropyl alcohol and hair will be removed, when necessary. Thereafter, a Trigno™ sensor (41 mm x 20 mm x 5 mm) will be placed on the muscle belly, parallel to the direction of the muscle fibers. The EMG-sensor placements will be defined in accordance with the Surface EMG for Noninvasive Assessment of Muscles (SENIAM) guidelines.[283] For the infraspinatus muscle, the EMG-sensor will be placed 3-4 cm below and parallel to the scapular spine, over the infrascapular fossa. For the upper trapezius, it will be placed at the midway between the spine on vertebra C7 and the acromion. Over the anterior deltoid, the EMG-sensor will be placed at one-finger width (1-2 cm) below the acromion and lateral clavicle, whereas at the middle deltoid, it will be placed at halfway between its insertion and the acromion.[90] No reference electrode will be used since this sensor already uses a 2-level single-differential method to minimize artifacts and baseline noise contamination through 4-parallel bars with their center 10 mm apart, and a signal bandwidth of 10-450 Hz. All EMG data will be recorded using Delsys EMGworks® Acquisition software. The EMG signals will be pre-amplified at the skin surface (300x gain, common mode rejection ratio 92dB at 60Hz) at a sampling rate of 1926 samples/s. All electrode placements, the wireless communication, and the signal quality will be verified by visual monitoring of signals at rest

and during isometric contractions.[8] Raw EMG data will be stored on a computer for offline analysis. Prior to analysis, recorded signals will be band-pass filtered (10-450 Hz, fourth-order zero-lag Butterworth digital filter), full-wave rectified and smoothed using a Root Mean Square (RMS) filter with a 0.25-sec time-window and 0.05 of window overlap. EMG amplitude data will then be normalized to a reference condition, where patients will raise their arm at 60º of scaption for 5-sec, with no load. Two trials will be performed for each arm, and the average of the RMS values will be used for normalization.

3.1.4.6.3.4. Global Rating of Change (GRC)

Participants will be asked to evaluate the change in their condition from the initial physiotherapy session using a GRC question. The GRC is a reliable 15-points scale (ICC = 0.90),[59,174,284] designed to report changes in clinical status over time as the perception of outcome after treatment.[59,174] Since patients generally feel satisfied with their improvements when reaching +4 GRC score,[284,285] we determined a priori that participants who will rate their perceived recovery at +4 *"moderately better or greater"* will be categorized as having a successful outcome.[7,126] Then, results from GRC will be dichotomized to GRC ≥ +4 (improvement) or GRC < +4 (non-improvement).

3.1.4.7. Sample size

Sample size calculation is based on changes evidenced by the DASH scores for individuals with RCTe. According to sample size calculation (G*Power 3.1.9.2; α=0.05, ES=0.79, power [1-β]=0.82, SD=14.17 DASH points,[213] CID=12.4 DASH points),[286] a minimum of 22 patients are needed in each group. When adding an expected loss to follow-up of 15%, a total of 26 patients per group is required. Therefore, 52 patients with RCTe will be recruited. This sample size is sufficient to detect the CID between the two groups.

3.1.4.8. Recruitment of patients

Fifty-two participants will be recruited. This number is feasible as a recent study from our research team successfully recruited 30 individuals with RCTe over six months. Taking into consideration the dropouts, we believe it is possible to recruit 26 participants over the same period. Therefore, considering a recruitment rate of five participants per month, on average, all participants should be enrolled in less than 11 months.

3.1.4.9. Withdrawal of individual participants

Principles underlying "intention-to-treat" analysis will be followed, meaning that every participant will be analysed according to the randomized treatment assignment. Therefore, noncompliance, protocol deviation, and withdrawal will all be ignored in the primary analyses. All dropouts and their underlying reasons will be reported.[287] Additionally, "per-protocol" analysis (i.e., the analysis will be restricted to participants who adhered to the intervention as stipulated in the protocol) will also be performed. We believe that the combination of these statistical strategies will increase confidence in the study results. To ensure appropriate insight of mechanisms underlying changes in symptoms and function, only participants who completed evaluation at week-6 will be considered for the secondary outcomes. Any harm or unintended effects during the programmes will be recorded.

3.1.4.10. Data integrity and analysis

All collected data will be accessible only to the research team. All data will be kept for five years after the end of the study, to ensure the completion of planned publications. After this period, all data will be destroyed.

3.1.4.11. Statistical analysis

Basic descriptive statistics (mean and standard deviation) will be reported for each participant's characteristic and outcome. All data will be tested to check the distributional assumptions for the inferential statistical analyses. Baseline demographic data will be compared using independent samples t-test and chi-square. If differences are seen in baseline characteristics, we will apply an ANCOVA model to adjust group comparisons for confounding variables.

The added effects of KT on the DASH, BPI, WORC and muscle activity will be examined using a mixed design analysis of variance (ANOVA) model (Groups [KT-group, No-KT group] × Evaluations [Baseline, week-3, week-6, week-12, 6-months), while a 3-way ANOVA for repeated measures (Group x Time x Angle [for AHD] or plane of movement [for ROM] will be performed for AHD and ROM. Bonferroni adjustments for multiple comparisons will be used, and the effect size will be reported ($\eta 2$). The GRC will be compared across groups using a Fischer's exact probability test. The level of significance will be set at $p<0.05$ for all statistical analyses.

3.1.5. Discussion

It is well reported that functional limitations associated with RCTe may remain for 12 months or more.[77] Personal, medical and socio-economic impacts of RCTe are well known,[248] and because RCTe results in a high rate of sick leave, assessment of the effectiveness of treatments is a priority.

Over the past few years, KT has been widely used in clinical practice; however, its effects on the rehabilitation of patients with RCTe need to be more evidenced. Despite the fact that some investigations examined the effects of KT on RCTe, no published study has, to our knowledge, addressed its mid- and long-term effects when added to a rehabilitation programme, as commonly used by clinicians. Furthermore, few studies have evaluated KT efficacy as an adjunct therapeutic resource, while applying identical physiotherapy treatment for both groups (experimental and placebo/control group). This makes it difficult to ascertain causation and may compromise the evidence of the real effects of KT. Therefore, investigations with a high level of standardisation are needed to determine the scientific validity of KT efficacy for the rehabilitation of individuals with RCTe.

3.1.5.1. Strength and limitations of this study

To our knowledge, this RCT will be the first to assess the mid- and long-term efficacy of KT added to a conventional rehabilitation programme for individuals with RCTe, addressing underlying variables that could help understanding the benefits alleged for this method. Because our standardized rehabilitation programme parallels those in current existence in a clinical setting, it will be possible to directly apply the results to clinical practice. Results will contribute to building robust evidence of the benefit of the addition of KT in physiotherapeutic intervention for RCTe, in addition to helping to establish the best clinical treatments for this population. Lastly, a series of measures such as a statistically justified sample size, methodological rigor, blinding, randomisation, and adequate concealment of group allocation, will be implemented in order to reduce the risk of bias.

On the other hand, we are aware of some limitations of this study. First, while patients will be blinded to the treatment provided to the other group, it is not feasible to blind the experimental group due to the nature of their own allocated treatment. Notwithstanding, a sham KT (placebo group) will not be included as previous literature has shown that establishing a sham taping protocol is problematic since KT applied over the skin could potentially produce some proprioceptive stimuli, which may act as confounding factor.[216,254,255]

3.2. Manuscript 3 (Immediate effects of kinesiotaping on acromiohumeral distance and shoulder proprioception in individuals with symptomatic rotator cuff tendinopathy)

3.2.1. Participants

Twenty-three individuals (14 men, 9 women) diagnosed with RCTe were recruited from a mailing list of employees and students at Laval University. To be eligible, participants had to present at least one positive finding in each of the following categories: a) painful arc of movement during shoulder flexion or abduction; b) Neer or Kennedy-Hawkins impingement sign;[233] and c) pain on resisted external rotation, abduction or empty can test.[233] Exclusion criteria were: a) open wound that compromised kinesiotaping application and ultrasound recording; b) previous shoulder surgery; c) allergy or intolerance to kinesiotaping; d) adhesive capsulitis;[266] e) history of glenohumeral luxation in the last 12 months or of fracture of the shoulder girdle; f) shoulder pain reproduced by cervical movements; g) clinical sign of RC full-thickness tears (lag signs).[267,268]

All participants signed a detailed informed consent. The sectorial rehabilitation and social integration research ethics committee of the CIUSSS de la Capitale Nationale approved this study, which complies with the ethical standards set out in the Declaration of Helsinki for human research.

3.2.2. Study design

All participants took part in a single evaluation session (cross-sectional design). After providing written informed consent, eligibility criteria were confirmed. Thereafter, participants filled out symptomatology and comorbidity questionnaires. Then, study outcomes were assessed. The active joint repositioning was evaluated first, followed by AHD.

Before collecting active joint repositioning data, two practice trials were performed in each tested position to familiarize the participants with the testing procedures. Thereafter, active joint repositioning of the painful shoulder was evaluated without kinesiotaping in the following order: 1) flexion, low-amplitude; 2) flexion, mid-amplitude; 3) abduction, low-amplitude; 4) abduction, mid-amplitude. Subsequently, measures of AHD with the arm at rest (0º) and 60º of shoulder abduction, without kinesiotaping, were taken consecutively. Finally, 3-strips of therapeutic kinesiotaping for RCTe was applied on the symptomatic shoulder (Figure 3.3) and, immediately after, the same measurements were retaken in the same order.

Figure 3.3. Kinesiotaping application.

3.2.3. Outcome measure

3.2.3.1. Active joint repositioning

The active joint repositioning was evaluated using a standardized procedure based on the methods described by Zanella *et al*[288] and Vafadar *et al*.[289] Previous studies using similar protocols have reported excellent test-retest reliability (intraclass correlation coefficients [ICC]=0.96–0.99)[288] of this method for evaluating active joint repositioning. Inertial measurement unit (IMU) sensors (Delsys Inc., Boston, MA, USA) were used to determine the accuracy in actively reproducing a shoulder angle. IMU sensors are reliable and valid for measuring shoulder angles.[290]

To record arm position, one sensor was placed at the acromioclavicular joint as a reference point. A second sensor was placed on the anterolateral face of the humerus, 5 cm above the lateral epicondyle, and a third on the posterior aspect of the forearm, 5 cm above from the styloid process of the ulna. Finally, to monitor the trunk position during arm elevation, an IMU sensor was placed over the spinous process of the C7 vertebra (Figure 3.4). All measurements were taken with participant standing.

For each arm position and specific range of movements, participants performed three trials. The first trial was performed eyes opened, where each participant auto-selected an arm position within the specific range (low-amplitude: 45º-65º, mid-amplitude: 80º-100º) delimited by marks on the panel.

The second and third trials were performed blindfolded. A laser dot, emitted by a laser pointer attached over the distal humerus with a customized bracelet, was used to identify, during the first trial, whether the angle achieved by the participant was within the predefined ranges (low- or mid-amplitude). Instructions to keep the elbow fully extended and forearm and wrist in a neutral position (thumbs up, without any upper limb rotation) during the whole movement, were provided to all participants between each trial. Additionally, participants were instructed to elevate their arms at a comfortable speed, to maintain this position for a few seconds (2 to 3 seconds) and bring the arms back to the starting position. Immediately after, participants were asked to actively reposition the shoulder at the same position previously selected, but without any auditory or visual feedback, and to stop the arm when they felt that the position, previously auto-selected, was reached again. At least, five seconds rest between trials and two minutes between movement ranges were given to all participants. During this task, participants did not receive any real-time feedback about their performance, except during open-eyes trials, where they could look at their hand, arm position and laser dot on the panel.

The angle reached during arm elevation was obtained from the IMU using Delsys EMGWorks® Analysis software (Delsys Inc., Boston, MA, USA). Absolute repositioning error, calculated from the difference between the average of the two blindfolded trials and the single opened eyes trial within each amplitude, was used for data analysis.

Figure 3.4. Placement of the IMU wireless sensor used in active joint repositioning task.

3.2.3.2. Ultrasound imaging

The AHD was measured using an ultrasound scanner (Logic *e*9, GE Healthcare, Milwaukee, WI, USA) with a 4-15MHz linear array probe. Ultrasound imaging has been shown to be a reliable method to assess AHD (ICC=0.98 [0.97-0.99], minimal detectable change [MDC]=0.70mm),[291] standard error of measurement [SEM]=0.9-1.6mm[151]. The validity of the ultrasound for measuring the AHD was reported through limits of agreement (LOA) as ranging from -0.44 to 0.72 mm.[292] Two trials were taken in two arm positions (at rest and at 60º of active shoulder abduction). The probe was positioned on the anterior aspect of the lateral surface of acromion along the longitudinal axis of the humerus in a coronal plane, where both the acromion and humerus can be viewed (Figure 3.5a and 3.5b). During recording at rest, participants were seated up with the arm in neutral position, forearm resting on a pillow on their lap, and elbow flexed at 90º. The same procedures were followed to record images at 60º shoulder abduction; however, a belt fixed to a custom-made chair and attached to the proximal forearm was used to restrain the abduction to 60º. Before each measurement, this angle (60º) was confirmed by an inclinometer, which is a valid and reliable tool for measuring shoulder angles (ICC flexion = 0.95 [0.90-0.98], ICC abduction = 0.97 [0.94-0.98], SEM=2º).[293] Participants were instructed to maintain the belt slightly stretched during data collection, to keep actively the angle of

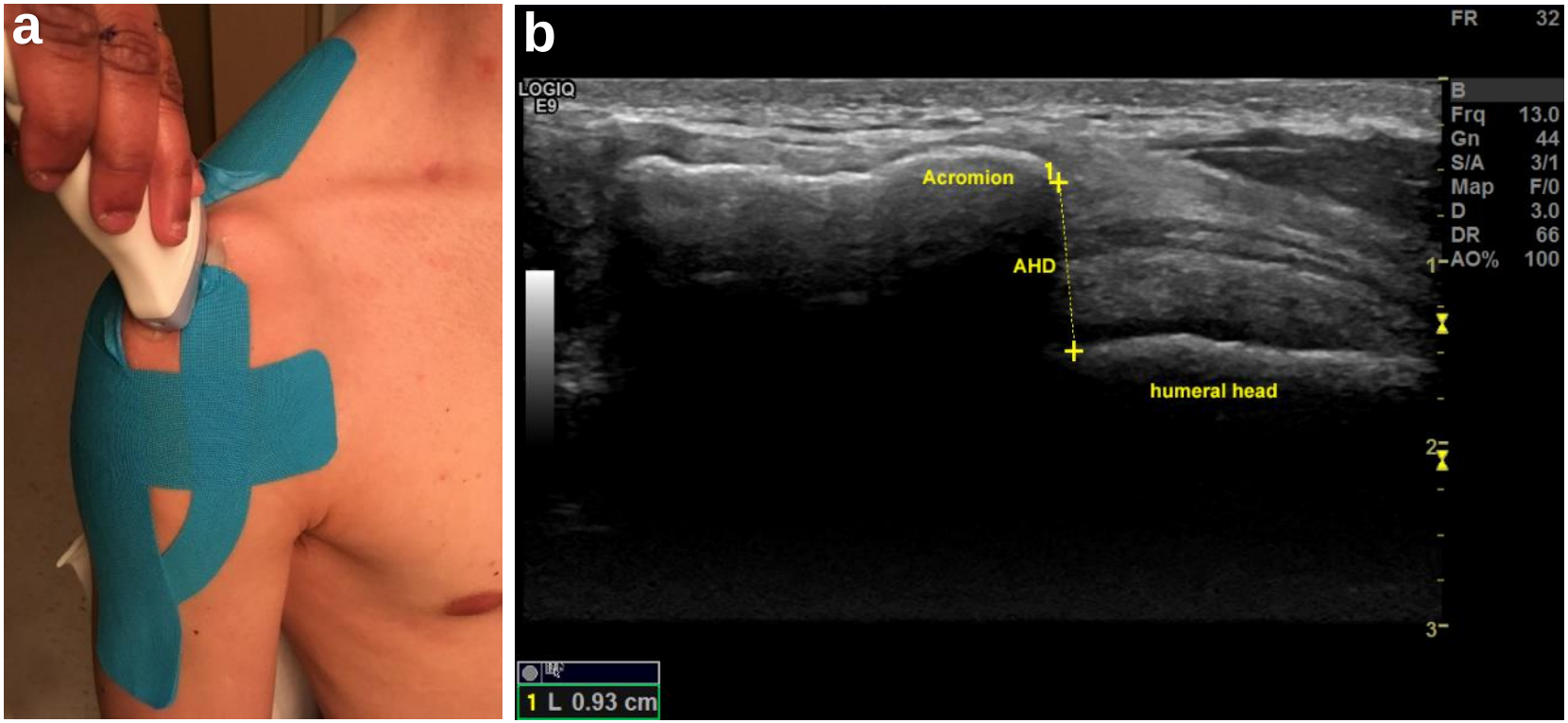
interest. To reduce the possibility of muscular fatigue, participants were instructed to bring their arm down between each trial or any time that fatigue was felt. An interval of, at least, 20-seconds were given between trials.

3.2.4. Kinesiotaping techniques

After a proper skin cleansing, the standard 5cm wide blue Kinesio® Tex Classic was applied on the symptomatic shoulder using a combination of techniques designed for RCTe and symptoms (Figure 3.3).[198] This technique involves the use of three tape strips, as follows: 1) Y-shape with light tension (15-25%), surrounding the deltoid muscles, from insertion to origin to provide inhibition and deltoid relaxation;[173,198,294] 2) I-shape with severe tension (50-75%), from 7-10 cm above the acromioclavicular joint to 7-10 cm below the deltoid tuberosity, passing over the supraspinatus, trapezius, glenohumeral joint, and middle deltoid,[198] aiming functional correction of multiaxial shoulder instability; 3) I-shape with severe tension (50-75%), placed with inward pressure, from the coracoid process to posterior deltoid, just slightly below the coracoacromial arch[197,198] for mechanical correction at the glenohumeral joint.

After application, adhesion of the kinesiotaping to the skin was stimulated by rubbing the surface of each strip vertically and horizontally. All kinesiotaping applications followed the principles described by Kase *et al*,[198] and were applied by the same physiotherapist, certified by Kinesio®Taping Association International. During AHD measurement with kinesiotaping, part of the second strip was cut to allow the placement of the probe between the acromion and humerus (Figure 3.5a).

Figure 3.5. Kinesiotaping technique for RCTe and ultrasonography illustrating the AHD measurements at rest (0º). The ultrasound transducer was placed and adjusted for viewing both the acromion and humeral head simultaneously.



3.2.5. Sample size

The sample size was determined based on expected change on the AHD at 60º abduction. Using similar AHD measurements, a previous study[231] that AHD at 60º abduction increased significantly (from 10.16 to 10.85mm, $p<.05$) in healthy subjects. Considering the following parameters (G*Power 3.1.9.2, t-tests, difference between two dependent means [matched pairs]; $\alpha=0.05$, power $[1-\beta]=0.95$, ES=0.817),[286] at least 22 individuals with RCTe would be sufficient to ensure the robustness of the results.

3.2.6. Statistical and data analysis

All data analyses were performed using SPSS Statistics 20 for *Windows* (IBM Corp., Armonk, USA). The level of statistical significance was set at 5%. Descriptive statistics are expressed as mean and standard deviation (SD).

For the AHD, the Shapiro-Wilk's test was used to detect the normal distribution of the AHD data. A 2-way analysis of variance (ANOVA) for repeated measures (general linear model; SPSS 20, proc GLM) was then used to evaluate the effects of the kinesiotaping application on AHD (2 angles [0º, 60º] x 2 conditions [no KT, with KT]). Intra-rater/intra-session reliability of AHD measurements was analysed by comparing the two measurements performed at each position using ICC (2-way mixed model and 95% confidence interval).

For active joint repositioning, a gamma distribution was detected. Therefore, a 3-way ANOVA for repeated measures using Generalized Estimating Equations (GEE; SPSS 20, proc GENLIN; corrtype=unstructured, distribution=Gamma, link=log) was used to compare the effects of kinesiotaping on the active joint repositioning with movement (flexion, abduction), range (low-amplitude, mid-amplitude) and condition (no KT, with KT) as factors. GEE's posthoc tests were conducted in attempting to detail interactions among factors.

CHAPTER 4. IMMEDIATE EFFECTS OF KINESIOTAPING ON ACROMIOHUMERAL DISTANCE AND SHOULDER PROPRIOCEPTION IN INDIVIDUALS WITH SYMPTOMATIC ROTATOR CUFF TENDINOPATHY

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Article published in the ***Clinical Biomechanics*** on November 10th, 2018.

4.1. Résumé

Contexte : Le kinesiotape est largement utilisé pour la réadaptation de la tendinopathie de la coiffe des rotateurs. Il a été suggéré qu'il puisse réduire les symptômes et de la fonction en améliorant le retour proprioceptif. De plus, il a été rapporté que le kinesiotape augmente l'espace sous-acromial chez les sujets sains. Cependant, ses effets sur la distance acromiohumérale et la proprioception à l'épaule des individus avec tendinopathie de la coiffe des rotateurs n'ont pas encore été déterminés. Cette étude a examiné les effets immédiats du kinesiotape sur la distance acromiohumérale et la proprioception à l'épaule chez des individus avec tendinopathie de la coiffe des rotateurs.

Méthodes : Vingt-deux personnes avec une tendinopathie chronique de la coiffe des rotateurs symptomatique ont été inclus. La distance acromiohumérale a été mesurée à l'aide d'une échographie au repos (0º) et à 60º d'abduction de l'épaule. La proprioception a été mesurée par repositionnement articulaire actif à faible (45º-65º) et moyenne (80º-100º) amplitudes de flexion et d'abduction de l'épaule. Un système de capteurs inertiels sans fils a été utilisé pour quantifier les angles à l'épaule. Premièrement, les mesures ont été prises sans kinesiotape. Ensuite, le kinesiotape a été appliqué sur l'épaule symptomatique et les mêmes mesures ont été reprises. Des ANOVA à mesures répétées ont été utilisées pour les analyses statistiques.

Résultats : Le kinesiotape a entraîné une augmentation significative de la distance acromiohumérale à 60° d'abduction (ΔDAH=0.94mm; IC 95%: 0.50 à 1.38, p<.001), dépassant le changement minimal détectable (0.70mm). Aucune différence significative n'a été observée pour la distance acromiohumérale au repos ni pour la proprioception lors du repositionnement articulaire actif à faible et moyenne amplitudes (p>.05).

Interprétation : Le kinesiotape a entraîné une augmentation immédiate de la distance acromiohumérale à 60º d'abduction qui, bien que ce changement semble mineur (↑10.5%), peut être significatif pour les patients symptomatiques, bien qu'il n'a eu aucun effet immédiat sur le repositionnement articulaire actif.

Mots-clés : bande élastique, abutement, bande kinésiologique, physiothérapie, douleur à l'épaule.

4.2. Abstract

Background: Kinesiotaping is widely used for the rehabilitation of rotator cuff tendinopathy. It has been argued to reduce symptoms and functional limitations through improvement of proprioceptive feedback. In addition, kinesiotaping has been reported to increase the subacromial space in healthy subjects. However, its effects on the acromiohumeral distance and shoulder proprioception of individuals with rotator cuff tendinopathy have not been ascertained. This study investigated the immediate effects of kinesiotaping on the acromiohumeral distance and shoulder proprioception in individuals with rotator cuff tendinopathy.

Methods: Twenty-two individuals with chronic rotator cuff tendinopathy were included. The acromiohumeral distance was measured using an ultrasound scanner at rest and 60º shoulder abduction. Proprioception was measured through active joint repositioning in low- (45º-65º) and mid-amplitude (80º-100º) of shoulder flexion and abduction. A wireless inertial measurement unit system was used to quantify shoulder angles. First, measurements were taken without kinesiotaping. Thereafter, kinesiotaping was applied on the symptomatic shoulder, and the same measurements were retaken. Repeated measures ANOVAs were used for statistical analyses.

Findings: Kinesiotaping induced a significant increase in acromiohumeral distance at 60° abduction (ΔAHD=0.94mm; 95%CI: 0.50–1.38, $p<.001$), exceeding the minimal detectable change (0.70mm). No significant difference was observed in acromiohumeral distance at rest or in proprioception during active joint repositioning in both low- and mid-amplitude ($p>.05$).

Interpretation*:* Kinesiotaping led to an immediate increase in acromiohumeral distance at 60º of abduction that, although it seems a minor change (↑10.5%), it may be significant for symptomatic patients, whereas it had no immediate effect on active joint repositioning.

Keywords: elastic tape, impingement, kinesiology tape, physiotherapy, shoulder pain.

(As published at the ***Clinical Biomechanics***)

4.3. Introduction

Rotator cuff tendinopathy (RCTe) is a very common musculoskeletal disorder that affects a large portion of the population.[66,295] Despite a multifactorial etiology,[140] narrowing of the subacromial space is considered a common characteristic of RCTe.[79] Shoulder neuromuscular control deficits, such as the altered performance of rotator cuff (RC) and scapular muscles, are likely involved in this mechanical alteration of the subacromial space.[42]

The subacromial space is estimated by measuring the acromiohumeral distance (AHD), which is defined as the tangential distance between the bony landmarks of the humeral head and inferior edge of the acromion.[140,151] The AHD ranges between 9 and 12mm in asymptomatic individuals[150,151] varying according to age, gender, pathology, shoulder position, and measurement technique.[230]

The AHD has been shown to be smaller in symptomatic individuals with RCTe in elevated arm positions when compared to healthy control.[151,230] As a normal subacromial space is essential for proper shoulder function, these studies suggest that alterations in shoulder neuromuscular control, leading to the narrowing of the subacromial space, could be an important generating factor of RCTe.

Proprioceptive feedback mechanisms also play an important role in proper joint control.[296,297] Proprioception can be divided into three components: joint position sense (interpretation of information concerning orientation in space), kinesthesia (interpretation of joint motions) and sensation of effort (interpretation of force generated within a joint).[48,297-299] Several tests have been developed to estimate the shoulder joint position sense using active joint repositioning (AJR) tasks. The AJR tasks measure the ability to actively reproduce a previously presented joint angle. Because integration between the central nervous system and peripheral receptors is believed to be a contributing factor for an adequate joint stability,[38,300] proprioception emerges as a crucial element of shoulder stability and control.[48,51,297]

Taping techniques could be an interesting option to improve shoulder neuromuscular control. Kinesiotaping is widely used in clinics,[294] and several types of application, such correction techniques are believed to improve shoulder neuromuscular control[197] by repositioning the humeral head in the glenoid fossa,[222] and thus favoring an increase of AHD. While patients with RCTe have been shown to have proprioceptive deficits,[301] kinesiotaping has been argued to stimulate muscle activity adaptation, via proprioceptive feedback, allowing to recognize the position of a limb in space and perceive a limb motion.[296] Therefore, kinesiotaping could improve both shoulder proprioception and AHD in this population.

Previous studies have reported that elastic taping may improve the AHD[154,231,232] and shoulder proprioception[228] in healthy individuals. Very few, however, have examined the effects of kinesiotaping on shoulder proprioception in individuals with RCTe, and none has investigated its effects on the AHD in this population. The current study, therefore, aims ***to investigate the immediate effects of kinesiotaping on AHD and active shoulder joint repositioning in individuals with RCTe.*** Based on the arguments presented above, we hypothesized that kinesiotaping would improve proprioception and increase AHD immediately after its application in individuals with RCTe.

4.4. Methods

The methodology used in this study is presented in section 3.2 *Manuscript 3 (Immediate effects of kinesiotaping on acromiohumeral distance and shoulder proprioception in individuals with symptomatic rotator cuff tendinopathy)*.

4.5. Results

Demographic characteristics are presented in Table 4.1. From the 23 participants included, one woman presented an AHD measure three times greater than the mean at baseline measurements. She was considered an outlier and was excluded from the statistical analyses. This resulted in 22 participants (63.6% men [n=14] and 36.4% women [n=8]) enrolled into the study.

Table 4.1. Demographic characteristics (n=22).

	Mean (SD)
Demographic characteristics	
Age (years)	29.1 (6.7)
Height (m)	1.77 (0.12)
Weight (kg)	74.4 (14.2)
Duration of symptoms (months)	16.9 (20.9)
Dominance	
Right handed	90.9%, n=20
Left handed	9.1%, n=2
Dominant shoulder affected (72.7%, 16/22)	
Right shoulder	93.7%, 15/16
Left shoulder	6.3%, 1/16

SD: standard deviation.

For AHD, a significant 2-way interaction between condition and angle was found (p=0.013). Post-hoc analysis showed a significant increase of AHD at 60º abduction with kinesiotaping compared to without kinesiotaping (ΔAHD=0.94 mm, p<0.001, observed power=0.987) (Table 4.2). There was no significant difference at rest (p=0.299). The intra-rater reliability of AHD measurements was excellent (at rest: ICC_{nokt}=0.93[0.83-0.97], ICC_{kt}=0.96[0.91-0.98]; at 60º of abduction, ICC_{kt}=0.97[0.93-0.99] and ICC_{nokt}=0.92[0.83-0.97].

For active joint repositioning, the ANOVA GEE model revealed no significant 3-way interaction (p=.773) among the factors (movement, range, intervention). In addition, there were no significant 2-way interactions. Details can be viewed in Table 4.3.

Table 4.2. Descriptive statistics of the acromiohumeral distance (AHD) in two conditions (with and without kinesiotaping) (n=22).

	AHD_{no-kt}	**AHD_{kt}**	**ΔAHD (95% CI)**	**p-value**
0º (at rest)	11.19 (1.47)	11.46 (1.85)	0.27 (-0.26 to 0.79)	0.299
60º abduction	8.94 (1.94)	9.88 (1.91)	0.94 (0.50 to 1.38)	<0.001*

Values expressed as mean (standard deviation). AHD is expressed as width in millimeters.
* Difference statistically significant (p<0.05).
AHD_{no-kt}: acromiohumeral distance without kinesiotaping. AHD_{kt}: acromiohumeral distance with kinesiotaping. ΔAHD: difference between conditions (AHD_{no-kt} and AHD_{kt}), while positive values mean increase and negative values mean reduction. CI: confidence interval.

Table 4.3. Mean absolute error scores during the joint repositioning task for testing proprioception in two conditions (without [No-KT] and with kinesiotaping [KT]) (n=22).

	No-KT	**KT**	**Mean difference (95% CI)**	**p-value**
Low-amplitude (45º – 65º)				
Flexion	3.48 (2.22)	3.01(2.61)	-0.46 (-1.61 to 0.68)	0.427
Abduction	2.69 (2.44)	3.15 (3.22)	0.47 (-0.88 to 1.82)	0.497
Mid-amplitude (80º - 100º)				
Flexion	2.90 (2.20)	3.33 (2.07)	0.42 (-0.68 to 1.54)	0.448
Abduction	1.95 (1.30)	2.75 (1.84)	0.80 (-0.26 to 1.86)	0.140

Values are expressed as mean (standard deviation). Proprioception is expressed as mean of absolute error in degrees (º).
No-KT: absolute error without kinesiotaping. KT: absolute error with kinesiotaping. Mean difference: difference between conditions (No-KT and KT), while positive values mean increase and negative values mean reduction in the absolute error. CI: confidence interval.

4.6. Discussion

This study demonstrated an immediate increase in the AHD at 60º shoulder abduction with kinesiotaping, whereas no significant changes in the absolute error (AE) were observed for the active joint repositioning in both low- and mid-amplitude movements.

Current evidence showed that kinesiotaping does not enhance proprioception in healthy subjects.[179,202] For example, Aarseth *et al*[202] investigated shoulder proprioception in healthy subjects with kinesiotaping at 50º, 90º and 110º in the scapular plane, whereas Zanca *et al*[179] examined shoulder proprioception with kinesiotaping at 50º, 70º and 90º in the scapular plane, but following a muscle fatigue protocol. Both studies did not find any significant effects in the joint position sense with kinesiotaping. Because healthy individuals are less likely to have proprioceptive deficits,[37] we hypothesized that individuals with symptomatic RCTe, in whom proprioceptive deficits are more common,[98] could benefit from the kinesiotaping for improving their proprioception. Notwithstanding, our results indicate that kinesiotaping did not improve active joint repositioning ability in individuals with RCTe, which does not support our *a priori* hypotheses.

Our findings corroborate Keenan *et al*.,[229] who did not find significant differences in shoulder threshold to detect passive motion when comparing individuals with RCTe (n=10) with (AE=2.17º) and without kinesiotaping (AE=2.85º). In our study, the mean absolute error measured without kinesiotaping were inferior to 3.5º, while the mean difference between conditions (without and with kinesiotaping) were less than 1º (Table 4.3). A possible explanation for the results of Keenan *et al*.,[229] and also ours, is the possibility that the performance during the active joint repositioning task was influenced by individual proprioceptive ability. It is likely that individuals with good proprioception or with baseline values near optimal ability may be good enough not to need any improvements in their level of proprioception, whereas individuals with poor proprioceptive ability may be more susceptible to the kinesiotaping effects. A previous study[302] has demonstrated that participants with poor proprioception (AE>5º) improved their abilities to detect passive motion with kinesiotaping. In our study, the number of participants presenting an AE≥5º was not large enough to provide robust results (n=5), but we observed that all of them improved, especially in mid-range movements, with mean improvements between 3 and 5º. Thus, the improvements in proprioceptive ability provided by kinesiotaping could be more significant in participants with initially poor proprioception. Therefore, further studies should focus on individuals identified with poor proprioceptive ability at baseline to determine whether the level of proprioceptive ability impacts the kinesiotaping effects.

Narrowing of the subacromial space is a common deficit associated with RCTe.[79] It is often associated with other deficits such as altered muscle activation and loss of force-couple among RC muscles, resulting in shoulder muscle imbalance.[30,42] Therefore, methods that could help to avoid excessive reduction in subacromial space during arm elevation may be important for individuals with RCTe. Previous studies have examined the effect of kinesiotaping on the AHD in healthy subjects.[154,231] Harput *et al*[231] investigated the immediate effects of kinesiotaping on AHD at 60º shoulder abduction in 41 asymptomatic volleyball players and found a significant increase in AHD with kinesiotaping (0.69mm, $p<.001$) that were, according to the authors, attributed to a mechanical correction provided by kinesiotaping.[231] Luque-Suarez *et al*[154] compared the effects of kinesiotaping to sham-kinesiotaping on AHD (n=49) at rest and 60º in the scapular plane. The authors found that kinesiotaping increased significantly the AHD (1.16mm) and argued that the increase was due to changes in the firing pattern of the RC muscles. Both studies addressed only asymptomatic participants.

To our knowledge, the current study is the first to examine the effects of kinesiotaping on AHD in individuals with symptomatic RCTe. Because previous studies have shown that kinesiotaping increased AHD in healthy subjects, we hypothesized that kinesiotaping might provide the same effect in individuals with RCTe. Our results showed that AHD increased significantly at 60º shoulder abduction with kinesiotaping (0.94mm), supporting our main hypothesis. Although it seems a minor change, the AHD increased, on average, by 10.5% with kinesiotaping compared to without, which may be significant for symptomatic patients. This result is in line with a recent study[152] that demonstrated a reduction of 7.4% (0.51mm) in the AHD of symptomatic shoulders at 60º in scapular plane compared to healthy contralateral shoulders. Given that a greater occupation ratio of the subacromial space in individuals with RCTe compared to healthy controls may be associated with this AHD reduction due to a thickness of supraspinatus tendon,[303] it is likely that the increase observed in our study might contribute to the reduction of compression of the subacromial structures during arm elevation. Therefore, the AHD increase observed in our study has potential to be important for pain relief. Notwithstanding, our results should be interpreted with caution, however, as the effects of kinesiotaping on symptoms and functional limitations were not investigated in this study. In addition, no significant correlation between the AHD and shoulder functional limitations in individuals with RCTe have been reported.[156] Therefore, our data do not allow us to state whether this increase is sufficient to provide clinically meaningful changes in symptoms and functional limitations caused by RCTe.

Our findings indicate that kinesiotaping may have contributed to restraining the humeral head superior translation during arm elevation, which could be interpreted as a mechanical correction in the glenohumeral joint; however, the physiological mechanism behind this effect is still unclear. Adjustments in the muscular activity emerge as a possible explanation for these results. A previous study[304] reported that H-reflex amplitude decreased with taping on lower trapezius in healthy subjects, contributing to inhibition of this muscle. Therefore, it is plausible that the activation of deltoid muscle has been inhibited with kinesiotaping, as intended by the first strip surrounding the three deltoid portions (Figure 3.3), favoring a reduction of the narrowing of the humeral head in the subacromial space during arm elevation, resulting in AHD increase. Nevertheless, as muscle activity was not investigated in our study, future work should verify whether kinesiotaping does reduce muscle activity.

4.6.1. Limitations

We recognize some limitations in this study. First, only the immediate effects of kinesiotaping were examined. Mid- and long-term examinations should be conducted to identify the prolonged effects of kinesiotaping. In addition, only one aspect of proprioception was explored in this study. Other aspects of proprioception such as kinesthesia and sensation of effort, could be more (or less) sensitive than the active joint repositioning sense to the changes in proprioception.

4.7. Conclusions

The application of kinesiotaping led to an immediate increase in AHD at 60º shoulder abduction, whereas it had no immediate effect on low- and mid-amplitude of active joint repositioning in individuals with RCTe. Future studies are needed to determine how much these effects are clinically meaningful, in the long-term, for symptomatic individuals with RCTe.

4.8. Footnotes

4.8.1. Funding

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). FCLO receives a doctoral scholarship from the Brazilian Government through the Science without Borders programme in association with the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES. JSR is supported by salary awards from the Fonds de Recherche Québec-Santé (FRQS) and the Canadian Institutes of Health Research (CIHR).

4.8.2. Competing interest

The authors have no relevant conflict of interests to declare.

4.8.3. Ethics approval

The sectorial rehabilitation and social integration research ethics committee of the Center Integrated University Health and Social Services from Capitale Nationale (CIUSSS-CN) approved this study, which complies with the ethical standards set out in the Declaration of Helsinki for human research.

CHAPTER 5. MID- AND LONG-TERM EFFECTS OF KINESIOTAPING ON SYMPTOMS AND FUNCTIONAL LIMITATIONS OF INDIVIDUALS WITH ROTATOR CUFF TENDINOPATHY: A SINGLE BLIND RANDOMISED CONTROLLED CLINICAL TRIAL

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Article submitted to ***Journal of Physiotherapy*** on October 15th, 2018.

5.1. Résumé

Question : Est-ce que le kinesiotape offre des bénéfices supplémentaires aux individus avec tendinopathie de la coiffe des rotateurs (TCR) à moyen et long terme lorsqu'inclus dans un programme de réadaptation ?

Devis : Groupes parallèles, essai randomisé contrôlé à simple insu, avec attribution masquée et analyse en intention de traiter.

Participants : 52 participants avec un diagnostic de TCR unilatérale.

Intervention : Les participants ont été assignés aléatoirement à l'un des deux groupes de traitement (kinesiotape [KT] ; et contrôle [No-KT]). Tous les participants ont reçu le même programme de réadaptation de six semaines, composé de 10 séances de physiothérapie. Le kinesiotape a été ajouté au programme de réadaptation du groupe KT.

Mesures : Les symptômes et les limitations fonctionnelles ont été évalués à l'aide du questionnaire Disabilities of the Arm, Shoulder, and Hand (DASH; variable principale), le Brief Pain Inventory (BPI) et le Western Ontario Rotator Cuff (WORC) à l'évaluation initiale, à la semaine 3, 6 et 12 et à 6 mois, tandis que des aspects sous-jacents tels que les amplitudes de mouvement (ADM) sans douleur et complètes et la distance acromiohumérale (DAH) ont été mesurées à l'évaluation initiale et à six semaines. Les effets du kinesiotape ont été évalués à l'aide d'ANOVA à mesures répétées à deux ou trois facteurs.

Résultats : Aucune interaction Groupe x Temps significative ($.386 \leq p \leq .638$) n'a été trouvée pour l'ensemble des variables. Une amélioration similaire et significative a été observée pour les deux groupes que ce soit pour le DASH, le BPI, et le WORC à la semaine 3, 6, 12 et à 6 mois, en comparaison à l'évaluation initiale (effet du temps : $p<.001$), et pour l'ADM sans douleur, l'ADM complète, et la DAH ($p<.05$).

Conclusion : Bien que les symptômes, les limitations fonctionnelles, les ADM, et la DAH se sont améliorés pour les deux groupes, il n'y a pas eu de différences inter-groupes à moyen et long terme. Par conséquent, le kinesiotape n'a pas apporté de bénéfices additionnels au programme de réadaptation de six semaines pour améliorer les symptômes et les limitations fonctionnelles chez les individus avec TCR.

Numéro d'enregistrement de l'essai : ClinicalTrials.gov (NCT02881021).

Mots-clés : bande élastique, bande kinésiologique, physiothérapie, coiffe des rotateurs, douleur à l'épaule, blessure des tendons.

5.2. Abstract

Question: Does the kinesiotaping provide additional benefits to individuals with rotator cuff tendinopathy (RCTe) at mid- and long-term when included within a rehabilitation program?

Design: Parallel-group, single-blinded, randomised controlled clinical trial with concealed allocation, and intention-to-treat analysis.

Participants: 52 participants with a diagnosis of unilateral RCTe.

Intervention: Participants were randomly assigned to one of two treatment groups (kinesiotaping [KT]; and no-kinesiotaping [No-KT]). All participants received the same 6-week rehabilitation program composed of 10 physiotherapy sessions. Kinesiotaping was added in the rehabilitation program of the KT-group.

Outcome measures: Symptoms and functional limitations were assessed with Disabilities of the Arm, Shoulder, and Hand (DASH; primary outcome) questionnaire, Brief Pain Inventory (BPI) and Western Ontario Rotator Cuff (WORC) index at baseline, week-3, week-6, week-12, and 6-months, while underlying aspects such as pain-free, full range of motion (ROM) and acromiohumeral distance (AHD) were measured at baseline and week-6. The effects of kinesiotaping were assessed using a two or three-way repeated-measures ANOVA.

Results: No significant Group x Time interactions ($.386 \leq p \leq .638$) were found for all outcomes. All measures showed significant similar improvements for both groups in DASH, BPI, and WORC at week-3, week-6, week-12, and 6-months compared to baseline (time effects: $p < .001$), and for pain-free ROM, full ROM, and AHD ($p < .05$).

Conclusion: Whereas symptoms, functional limitations, ROM, and AHD improved in both groups, there was no between-group difference in the mid- and long-term. Therefore, kinesiotaping did not provide additional benefits to a 6-week rehabilitation program for individuals with RCTe to improve symptoms and functional limitations.

Trial registration number: ClinicalTrials.gov (NCT02881021).

Keywords: elastic tape, kinesiology taping, physiotherapy, rotator cuff, shoulder pain, tendon injuries.

(As submitted to the ***Journal of Physiotherapy***)

What was already know on this topic?

Rotator cuff tendinopathy (RCTe) is the most frequent cause of shoulder pain. Kinesiotaping is a therapeutic resource widely used in clinics for rehabilitation of several musculoskeletal disorders, including rotator cuff tendinopathy. Previous studies have reported that kinesiotaping reduces symptoms and functional limitations of rotator cuff tendinopathy in short-term, besides to increase subacromial space in healthy subjects. While studies have examined the immediate effects of kinesiotaping on shoulder injuries, no published study had addressed the mid- and long-term effects of kinesiotaping when combined with a rehabilitation program (RP) for patients with RCTe (as used in clinics).

What does this study add?

The results from this study demonstrate that kinesiotaping does not provide additional benefits to the treatment of individuals with rotator cuff tendinopathy at mid- and long-term. Therefore, clinicians should not expect benefits provided by the kinesiotaping when an exercise-based conventional physiotherapy is simultaneously provided to this population. The findings contribute to clarify the clinical efficacy of the kinesiotaping as a therapeutic resource widely used by clinicians, clubs, and professional players.

Our RCT design included a rehabilitation programme that parallels those used in clinics for patients with rotator cuff tendinopathy, making our results suitable to be immediately transferred to the clinical practice.

How might it impact on clinical practice in the near future?

Both rehabilitation programmes (kinesiotaping and no-kinesiotaping) were effective in improving symptoms, functional limitations and underlying aspects of symptomatic individuals with rotator cuff tendinopathy. Similar improvements were observed for both groups in mid- and long-term. However, despite the effectiveness of a rehabilitation programme with kinesiotaping included, physiotherapists and clinicians must be aware that kinesiotaping will not provide additional mid- and long-term benefits for reducing pain, improving shoulder function and ROM, or increasing AHD to individuals with rotator cuff tendinopathy.

5.3. Introduction

Rotator cuff tendinopathy (RCTe) is a major cause of shoulder pain.[62,63] Dynamic narrowing of the subacromial space is a common characteristic of RCTe,[79] often triggered by lack of coordination among shoulder muscles,[42] compromising shoulder neuromuscular control.[18,19,79,129] Therefore, effective interventions to restore shoulder control and concomitantly reduce symptoms and functional limitations[7,126,276] should be prioritized.

Kinesiotaping is an adjunct resource commonly used for rehabilitating several musculoskeletal disorders. It is suggested to increase stimulation of cutaneous mechanoreceptors,[254] which, theoretically, may improve proprioceptive feedback[228,305] and enhance joint motor control. Accordingly, kinesiotaping is a potentially interesting option for improving shoulder control, and to reduce deficits and symptoms associated with RCTe. However, the precise functional mechanism of kinesiotaping is still hypothetical, and its clinical efficacy has not been thoroughly ascertained. Previous studies have demonstrated immediate and short-term positive effects of kinesiotaping in reducing pain and FL,[78,176,213] restoring range of motion (ROM),[209] and increasing AHD[306,307] in individuals with RCTe. To date, no published study examined the mid- and long-term effects of kinesiotaping when combined with a conventional rehabilitation programme for this population, as used in clinics. Currently, the evidence are insufficient to conclude on the efficacy of kinesiotaping for RCTe[183] and other musculoskeletal conditions.[261-265]

Given the lack of high-quality evidence guiding clinicians on the use of kinesiotaping for treating an RCTe, this randomised controlled trial (RCT) aimed to evaluate the mid- and long-term effects of kinesiotaping added to a 6-week rehabilitation programme focusing on sensorimotor training to reduce symptoms and functional limitations in individuals with RCTe. The effects of kinesiotaping on pain-free and full ROM and AHD were also assessed.

As both experimental and control groups received the same rehabilitation programme, we hypothesized that both groups would be effective in improving symptoms and functional limitations with the rehabilitation programme. However, based on previous findings on the effects of kinesiotaping in the targeted population, we hypothesized that participants assigned to the KT-group would experience greater and faster improvements in symptoms and FL.

5.4. Methods

5.4.1. Design

A single-blind (evaluator only) parallel-group RCT, including outcomes assessments at baseline, week-3, week-6, week-12, and 6-months, was conducted. During baseline evaluation, participants first provided written consent and eligibility criteria were confirmed. Thereafter, they completed questionnaires on sociodemographic, symptoms and FL. Pain-free and full shoulder ROM, and ultrasonographic AHD were recorded. Participants were then randomly assigned to either an experimental (KT: rehabilitation programme+kinesiotaping) or a control group (No-KT: rehabilitation programme alone) and attended 10 physiotherapy sessions over six weeks. Symptoms and functional limitations were evaluated at all five time-points, whereas pain-free and full ROM, and AHD were evaluated at baseline and week-6. Follow-up evaluations at week-12 and 6-months were performed via online questionnaires.

5.4.2. Participants

Individuals with RCTe were recruited from a mailing list of Laval University. To be included, participants had to: 1) be aged 18–65 years; 2) have one positive sign in each of the three following categories:[6] a) painful arc of movement (flexion, and/or abduction);[59] b) Neer or Kennedy-Hawkins impingement signs;[233] c) pain during resisted external rotation, abduction, or empty can test[233] (combined sensitivity and specificity >.74).[59] Potential participants were excluded if they had: a) an open wound compromising kinesiotaping application; b) previous shoulder surgery; c) allergy or intolerance to kinesiotaping; d) adhesive capsulitis (passive shoulder ROM <50%);[266] e) history of glenohumeral luxation (<12 months) or fracture to the shoulder girdle; f) shoulder pain reproduced by cervical movements or cervicobrachialgia; g) clinical sign of full-thickness RC tears (positive lag signs).[267,268] The sectorial rehabilitation and social integration research ethics committee of the CIUSSS-CN approved this study. The study protocol was previously registered on ClinicalTrials.gov (NCT02881021) and published.[294]

5.4.3. Sample size

An *a priori* sample size was calculated based on changes reported by the DASH scores for individuals with RCTe. According to sample size calculation (G*Power 3.1.9.2; α=0.05, ES=0.85, power [1-β]=0.80, SD=14.17 DASH-points,[213] CID=12.4 DASH-points),[286] 22 participants per group were required. Considering a possible loss to follow-up of 15%, 26 participants per group were recruited.

5.4.4. Randomisation, blinding and allocation concealment

An independent researcher conducted randomisation stratified by sex, using a block design (block size of 4–6–8). Allocation was concealed in sequentially numbered sealed opaque envelopes that were opened by the treating physiotherapist (blinded on outcome assessments and randomisation) at the first intervention. Participants were unaware of the treatment provided to other participants, neither that kinesiotaping was the central element of this research. Participants were instructed not to reveal or discuss treatment with the evaluator. To assess blinding effectiveness, the evaluator answered the following question at the week-6 evaluation: *"In your opinion, which intervention this participant received?"* The possible answers were: conventional (control group); intervention testing a new technique (experimental group); I have no idea.

5.4.5. Intervention

5.4.5.1. Rehabilitation programme

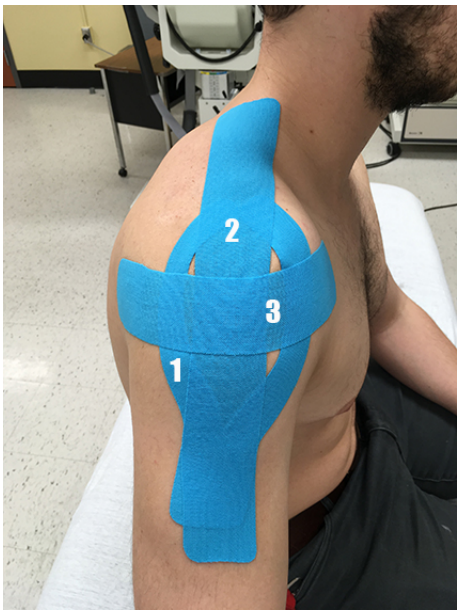
A standardized rehabilitation programme, consisting of 10 physiotherapy sessions of 30-45 minutes duration, was provided individually to all participants (twice-weekly during the first four weeks, then once-weekly). The intervention included patient education, manual therapy, stretching and resisted exercises. However, the focus relied on sensorimotor training using motor control exercises to reduce deficits caused by RCTe[6,7,126,273,294] and, hence, restore proper shoulder neuromuscular control. Exercises were chosen according to the individual needs of each participant. The only between-group difference in the intervention was the addition of kinesiotaping in the KT-group. Details on the rehabilitation programme can be found in Appendix L.

5.4.5.2. Kinesiotaping application

Prior to kinesiotaping application, the skin was cleaned, and hair was removed when necessary. All procedures for taping followed the principles of kinesiotaping method[197,198] and were performed by a certified physiotherapist. A specific application for RCTe and underlying deficits (Figure 5.1), composed of three strips of Kinesio® Tex Classic, was used on the injured shoulder according to the symptoms observed during clinical examination. While the strip-1 was applied to all participants, strip-2 and strip-3 were applied only when necessary (Figure 5.2). All strips were rubbed after application. Participants were advised to remove kinesiotaping immediately if adverse effects (chafe, rash, etc.) were felt. Otherwise, they were instructed to keep them for 72 hours or until the next intervention, whichever came first. Before starting the intervention, kinesiotaping was always

removed. A new kinesiotaping was applied at the end of each session. Before the first session, allergy testing to kinesiotaping was conducted for participants allocated to the KT-group.

Figure 5.1. Kinesiotaping technique for RCTe and underlying deficits. First strip (1: Y-shape surrounding deltoid muscles), second strip (2: I-shape in functional correction for multiaxial shoulder instability over the glenohumeral joint, supraspinatus, trapezius, and middle deltoid muscles), and third strip (3: I-shape in mechanical correction for glenohumeral joint).



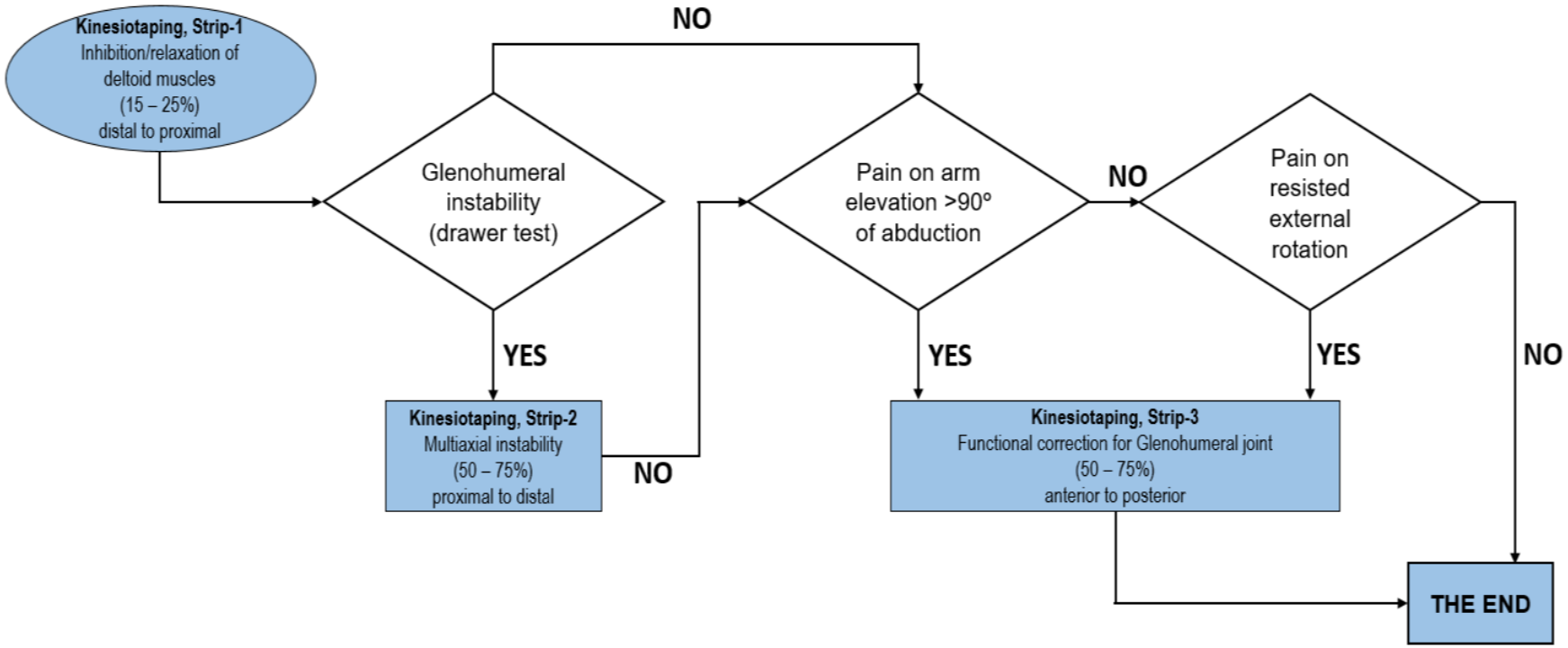
5.4.6. Outcome measures

Symptoms and FL, assessed using the DASH questionnaire, were the primary outcome. Pain, assessed with the Brief Pain Inventory (BPI), RC-specific symptoms and limitations, assessed with WORC index, shoulder ROM, and AHD, were the secondary outcomes.

5.4.6.1. *Symptoms and functional limitations (primary outcome)*

The validated French-Canadian version of the DASH (ICC=0.93[0.87-0.96]; SRM=1.35, MDC90%=11.4%, CID=8.4%, MCID=10.2 points)[2] was used to measure physical disability and symptoms of upper limbs disorders.[276,277] It consists of 30 items addressing the level of difficulty in performing daily activities and the severity of the symptoms.[277] A score of 100-points indicates the most severe disability.[276]

Figure 5.2. Flowchart for the kinesiotaping application. Strip-2 and 3 were used according to the presence of corresponding deficits observed during individual weekly evaluations.



The first strip was applied in Y-shape, light tension (15-25%), surrounding the three portion of the deltoid muscle as a group, from insertion to origin, to provide inhibition and muscle relaxation.[173,198] A second strip (I-shape) was applied for functional correction, recommended for multiaxial shoulder instability, with severe tension (50–75%), from 7–10 cm above the acromioclavicular joint to 7–10 cm below the deltoid tuberosity, passing over the supraspinatus, trapezius, glenohumeral joint, and middle deltoid.[198] The third strip was applied in I-shape for mechanical correction at the glenohumeral joint, being placed with severe tension (50–75%) and inward pressure, from coracoid process to posterior deltoid, just slightly below the coracoacromial arch.[197,198]

5.4.6.2. *Pain intensity and RC-specific symptoms*

As the DASH has only a few questions related to pain, the BPI (ICC>0.80)[279,280] was used to assess pain intensity. It is an 11-point numerical rating scale (0-10), which evaluates pain interference with general activity, mood, walking, normal work, personal relationships, sleep, and enjoyment of life, over the last 24 hours.[279,280]

The validated French-Canadian version of the WORC index (ICC=0.96[0.92-0.98], SRM=1.54, MDC90%=12.3%, CID=17.5%)[2] was used to evaluate symptoms and functional limitations specific to RC disorders. It uses 21 questions, with 100mm visual analogue scale responses on pain and physical symptoms, sports-recreation, work, social and emotional function.[2,281] The final score is reported as a percentage, where higher scores are associated with fewer symptoms.

5.4.6.3. *Range of motion*

Shoulder ROM was measured in two conditions (active pain-free and full ROM), using a universal goniometer (ICC=0.95-0.97).[282] In standing position, participants performed two trials of arm elevation, in frontal (abduction) and sagittal (flexion) planes, for each condition. To measure the pain-free ROM, participants were requested to: elevate their arms unilaterally (injured shoulder) and actively at a comfortable speed, until the first sensation of pain; hold the arm position for 2-3 seconds to allow measurements (goniometer was placed parallel to the humerus and the trunk to record the amplitude achieved); and bring their arm back to the starting position. Participants were instructed to maintain the elbow fully extended, and wrist and forearm at neutral position throughout trials. Mean values of the two trials were used for data analysis. The same procedures were followed for full ROM. Participants were instructed to reach their maximal amplitude, even if pain was present.

5.4.6.4. Acromiohumeral distance

The AHD measurements were taken in two arm positions: at rest (0º) and at 60º shoulder abduction. An ultrasound scanner (Logic *e*9, GE Healthcare, Milwaukee, USA) with a 4-15MHz linear-array probe was used to obtain images.[7,140] Images were recorded placing the probe on the anterior aspect of the lateral surface of the acromion, along with the longitudinal axis of the humerus in a frontal plane, where it is possible to visualise the acromion and humeral head simultaneously.[306] Measurements were first taken at rest, with participants seated up straight against the backrest of the chair, arm in neutral position, elbow flexed at 90º, and forearm resting on a pillow on their lap.[306] Thereafter, AHD at 60º abduction was quantified, where participants were requested to raise their

arm, with elbow flexed at 90º, until 60º of shoulder abduction. A strap, fixed to the chair and attached below the elbow joint, was used to restrain the movement to 60º. A digital inclinometer (Baseline®, New York, USA) confirmed the angle.[282] In both arm positions, participants performed two trials, and the average was used for statistical analysis. This method is reliable for estimating AHD (ICC=0.98, MDC=0.70mm[291]).

5.4.7. Data handling and statistical analyses

Baseline demographic data were compared between-group using independent *t*-test and chi-square. Intention-to-treat (using Last-Observation-carried-Forward method for handling missing data)[287] and per-protocol analyses were performed for all outcomes.

Except for the AHD, non-parametric repeated measures ANOVAs for longitudinal data (nparLD Package 2.1, R-software, v.3.3.3) were used since distributions were normal at baseline (as there was a wide range of clinical conditions) and gamma at week-6, week-12 and 6-months (as most participants improved close to optimal values).[308] The nparLD is the only ANOVA procedure that manages a change of distribution between groups and measurement times.[308] A two-way (2-Groups x 5-Time) nparLD ANOVA was used to compare the kinesiotaping effects on DASH, BPI, and WORC. Changes in the pain-free and full ROM were analysed using a three-way (2-Groups x 2-Times x 2-Plane of movements) nparLD ANOVA.

As far as assumptions were reached, the effects of kinesiotaping on AHD were analysed with a three-way (2-Groups x 2-Times x 2-Angles) repeated-measures ANOVA (SPSS v20, IBM Corporation, New York, USA). Effect size (Glass's Δ or η^2) were reported for all outcomes. The α criterion was always set at 5%.

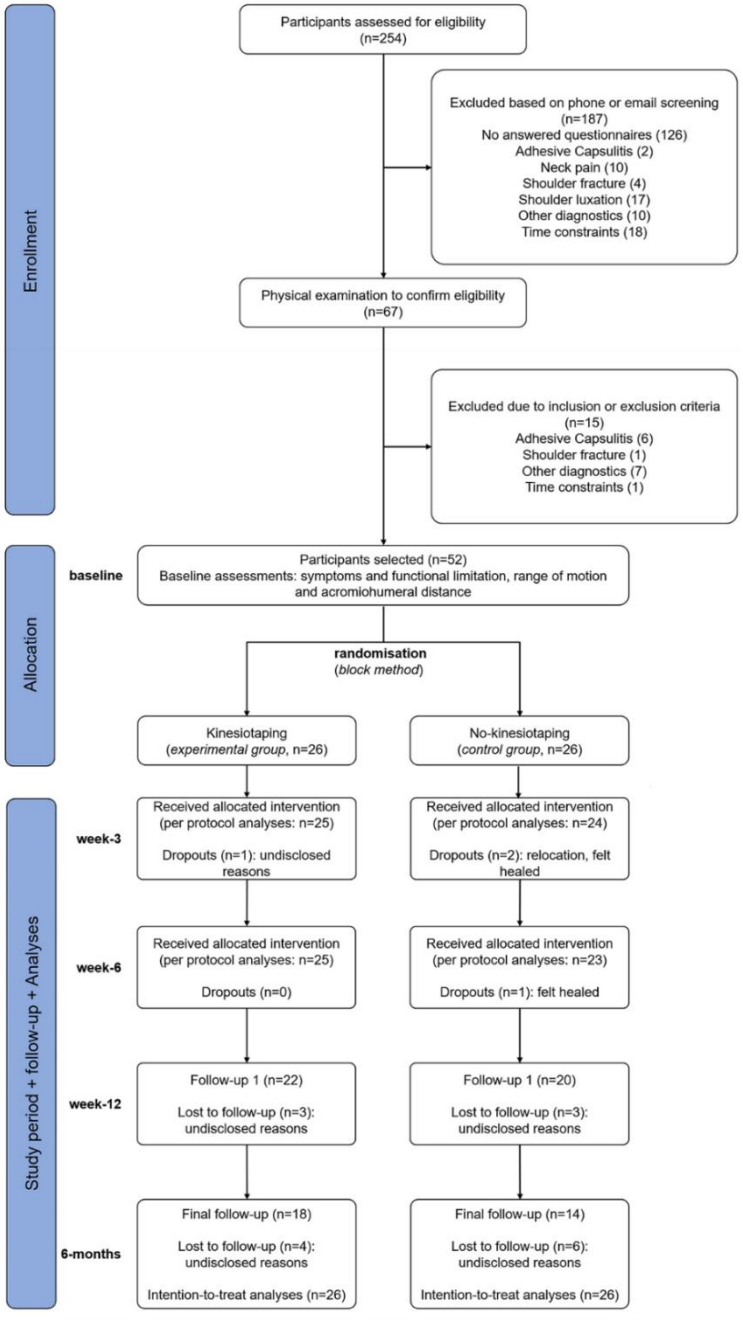
5.5. Results

5.5.1. Flow of participants through the study

Fifty-two participants were recruited between November/2016 and November/2017 and randomly assigned to one of the two groups (Figure 5.3). Four participants dropped out before the end of the 6-week treatment period (two declared to be healed and two for undisclosed reasons; participation proposition=92.3%). These participants missed a total of 27 physiotherapy sessions. Four additional participants missed three physiotherapy sessions each, totalling 39 interventions missed (attendance rate=92.5%). Seven and 10 participants (including the four dropouts) did not return their follow-up questionnaires at week-12 and 6-months, respectively (follow-up rate=86.5% and 80.8%). Home

exercises presented an adherence rate of 90.4%. No participants reported adverse effects to kinesiotaping nor to treatment provided. No between-group differences were found on baseline characteristics (Table 5.1). At week-6, the assessor declared to be unaware of the group allocation of any participants, confirming the efficiency of blinding.

Figure 5.3. Flow diagram of participants through the study.



5.5.2. Effects of kinesiotaping

Intention-to-treat and per-protocol analyses showed no Group effect (.184≤ p≤.621) nor Group x Time interaction (.386≤ p≤.638) for all outcomes analysed (Tables 5.2 and 5.3). However, time effects (p<.0001; except for AHD, p=.017) were detected for all measured outcomes. Groups never interacted with Time nor Plane of movement for pain-free ROM (.203≤ p≤.839) nor for full ROM (.456≤ p≤.933).

5.5.3. Description of the time effect for all outcomes

Mean DASH score improved (p<.0001) from baseline to week-3, and from week-3 to week-6, thereafter the scores were stable (Figure 5.4). Mean DASH change scores reached the CID (10.2 DASH-points)[276] at week-3 (Table 5.4). Similarly, mean WORC index and BPI score, improved (p<.0001) from baseline to week-3, from week-3 to week-6, and were stable thereafter (Figure 5.4). Mean WORC change index reached the CID (17.5%)[2] at week-3 and BPI (2mm)[309] at week-6.

For pain-free and full ROM, abduction (p<.0001) and flexion ROM increased (p≤.002) from baseline to week-6 (Table 5.4). Finally, for AHD, a significant time effect (p=.017) led to an increase of AHD at 60º abduction at week-6 (0.38±1.11mm) (Table 5.4).

Figure 5.4. Mean group scores to symptoms and functional limitations (DASH, BPI, and WORC). Error bars show standard deviation.

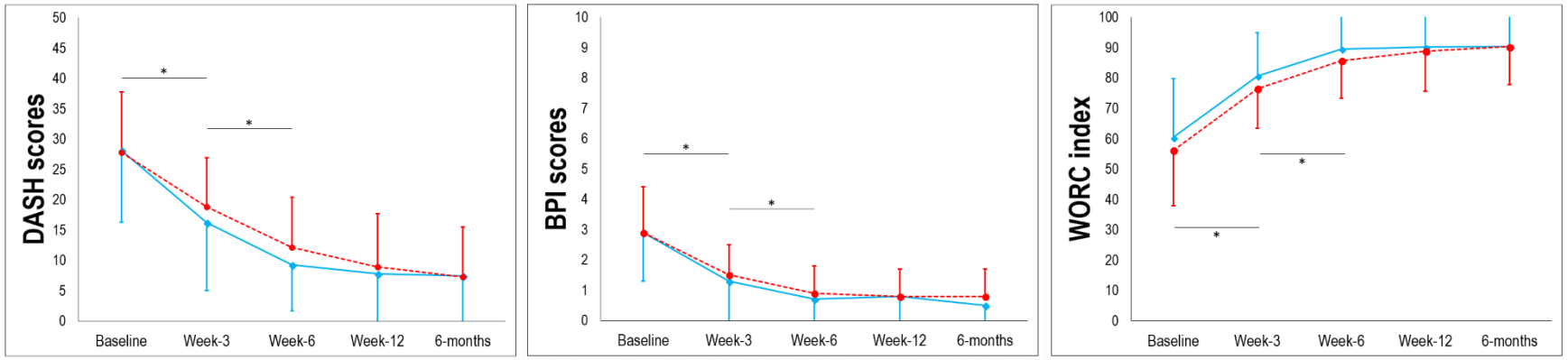


Table 5.1. Baseline characteristics of participants (n=52).

	Kinesiotaping (KT) (experimental group, n=26)	No-kinesiotaping (No-KT) (control group, n=26)	p-value
Demographic data			
Age (years)	30.9±9.0	29.4±7.5	.528
Sex (male), n (%)	15 (57.7)	15 (57.7)	1.000
Height (cm)	1.77±0.12	1.73±0.10	.226
Weight (kg)	75.5±15.0	72.2±12.7	.395
Dominance (right), n (%)	24 (92.3)	23 (88.5)	1.000
Dominant shoulder affected, n (%)	18 (69.2)	17 (65.4)	1.000
Overhead sports, n (%)	18 (69.2)	15 (57.7)	.565
Use of medication, n (%)	4 (15.4)*	4 (15.4)*	1.000
Hormonal alteration, n (%)	1 (3.8)	0 (0.0)	1.000
Educational level, n (%)[a]			.827
college	2 (7.7)	3 (11.5)	
bachelor	16 (61.5)	12 (46.2)	
master	4 (15.4)	5 (19.2)	
doctorate	4 (15.4)	5 (19.2)	
other	0 (0.0)	1 (3.8)	
Sick leave, n (%)	0 (0.0)	0 (0.0)	1.000
Daily workload, n (%)[a]			.211
part-time	12 (46.2)	15 (57.7)	
full-time	11 (42.3)	5 (19.2)	
unemployed	3 (11.5)	6 (23.1)	
Previous physiotherapy treatment for the current shoulder episode, n (%)	11 (42.3)	11 (42.3)	1.000
Symptoms of RCTe			
Duration of symptoms (months)	20.6±27.7	24.6±25.7	.748
Origin of symptoms, n (%)[a]			.775
sports	17 (65.4)	20 (76.9)	
accident/fall	4 (15.4)	3 (11.5)	
overuse	3 (11.5)	2 (7.7)	
I don't know	2 (7.7)	1 (3.8)	
Clinical examination, n (%)			
Presence of painful arc of movement (flexion)	21 (80.8)	21 (80.8)	1.000
Presence of painful arc of movement (abduction)	22 (84.6)	25 (96.2)	.350
Positive Neer impingement sign	18 (69.2)	19 (73.1)	1.000
Positive Hawkins-Kennedy test	24 (92.3)	25 (96.2)	1.000
Positive Jobe's test	15 (57.7)	18 (69.2)	.565
Pain on resisted external rotation	15 (57.7)	14 (53.8)	1.000
Pain on resisted abduction	19 (73.1)	18 (69.2)	1.000

Continuous variables: t-tests; categorical variables: Fischer's exact probability tests.
* Medication used included: antacid (1), anti-inflammatory (1), antipsychotic (1), hormonal regulator (1) (experimental group); antipsychotic (1), antidepressant (1), immunosuppressant (1) (control group).

Table 5.2. Group mean scores for all outcomes. Data expressed as mean ± standard deviation.

	Kinesiotaping (KT) (experimental group, n=26)	No kinesiotaping (No-KT) (control group, n=26)	Pooled group (n=52)
DASH scores (0-100)			
Baseline	28.1±11.8	27.8±10.0	27.9±10.8
Week-3	16.2±11.2	18.8±8.1	17.5±9.8
Week-6	9.3±7.6	12.1±8.3	10.7±8.0
Week-12	7.8±8.3	8.9±8.8	8.4±8.5
6-months	7.4±9.6	7.3±8.2	7.4±8.8
BPI scores (0–10)			
Baseline	2.9±1.6	2.9±1.5	2.9±1.5
Week-3	1.3±1.4	1.5±1.0	1.4±1.2
Week-6	0.7±0.9	0.9±0.9	0.8±0.9
Week-12	0.8±1.2	0.8±0.9	0.8±1.0
6-months	0.5±1.0	0.8±0.9	0.7±1.0
WORC index (0–100)			
Baseline	60.5±19.2	56.2±18.3	58.3±18.7
Week-3	80.7±14.2	76.5±13.1	78.6±13.7
Week-6	89.5±14.5	85.7±12.3	87.6±13.4
Week-12	90.1±15.1	88.8±13.2	89.4±14.1
6-months	90.3±15.7	90.3±12.5	90.3±14.0
Range of Motion (ROM)			
Pain-free – injured shoulder, flexion (º)			
Baseline	138.8±24.5	141.4±18.8	140.1±21.7
Week-6	158.1±9.9	156.8±10.3	157.7±10.0
Pain-free – injured shoulder, abduction (º)			
Baseline	125.2±29.1	120.5±25.2	122.8±27.1
Week-6	163.1±17.8	156.6±19.6	159.9±18.8
Full – injured shoulder, flexion (º)			
Baseline	160.7±11.2	160.4±9.3	160.6±10.2
Week-6	165.3±7.9	163.9±9.2	164.6±8.5
Full – injured shoulder, abduction (º)			
Baseline	160.9±17.5	158.3±19.0	159.6±18.1
Week-6	173.5±8.9	170.6±10.2	172.0±9.6
AHD at rest (0º) (mm)			
Baseline	10.98±2.17	11.77±2.12	11.38±2.16
Week-6	11.20±2.23	11.78±2.08	11.49±2.15
AHD at 60º abduction (mm)			
Baseline	8.18±2.33	8.57±2.15	8.37±2.23
Week-6	8.64±2.66	8.88±2.29	8.76±2.46

AHD, Acromiohumeral distance; BPI, Brief Pain Inventory; DASH, The Disabilities of the Arm, Shoulder, and Hand questionnaire; KT, kinesiotaping; No-KT, without kinesiotaping; ROM, range of motion; WORC, The Western Ontario Rotator Cuff index.

Table 5.3. Results (p-values) of ANOVAs statistical tests for the intention-to-treat analysis.

	Group effect	Time effect	Movement effect	Group x Time	Group x Movement	Movement x Time	Group x Time x Movement
nparLD							
DASH scores	.374	<.0001		.386			
BPI scores	.184	<.0001		.638			
WORC index	.214	<.0001		.533			
Range of motion (ROM)							
Pain-free	.282	<.0001	.052	.607	.203	<.0001	.839
Full	.504	<.0001	<.0001	.456	.611	<.0001	.933
GLM							
AHD at 60º abduction	.621	.017		.613			

AHD, acromiohumeral distance; ANOVA, Analysis of variance; BPI, Brief Pain Inventory; DASH, The Disabilities of the Arm, Shoulder, and Hand questionnaire; GLM, General linear model; nparLD, non-parametric longitudinal data; ROM, range of motion; WORC, The Western Ontario Rotator Cuff index.

Table 5.4. Outcomes changes over time (mean improvements) compared to baseline values throughout treatment (overall sample, n=52; intention-to-treat analysis).

	mean improvements mean±SD (95% CI)	***p*-value**	**Effect size (Glass's Δ)**
DASH scores (0-100)			
Week-3*	-10.4 (-7.5 to -13.3)‡§‖	<.0001	.961
Week-6	-17.2 (-13.9 to -20.5)†§‖	<.0001	1.593
Week-12	-19.6 (-16.3 to -22.9)†‡	<.0001	1.806
6-months	-20.6 (-17.2 to -23.9)†‡§	<.0001	1.899
BPI scores (0–10)			
Week-3	-1.5 (-1.1 to -1.9)‡§‖	<.0001	.950
Week-6*	-2.1 (-1.7 to -2.6)†	<.0001	1.364
Week-12	-2.1 (-1.7 to -2.6)†	<.0001	1.367
6-months	-2.2 (-1.8 to -2.7)†	<.0001	1.445
WORC index (0–100)			
Week-3*	20.2 (15.1 to 25.4)‡§‖	<.0001	1.083
Week-6	29.2 (23.4 to 35.1)†§‖	<.0001	1.565
Week-12	31.1 (25.3 to 36.9)†‡	<.0001	1.662
6-months	40.0 (26.2 to 37.7)†‡	<.0001	1.711
Pain-free ROM – injured shoulder (degrees)			
Week-6 (abduction)	37.0 (28.9 to 45.1)	<.0001	1.368
Week-6 (flexion)	17.4 (11.3 to 23.4)	<.0001	.801
Full ROM abduction – injured shoulder (degrees)			
Week-6 (abduction)	12.5 (7.8 to 17.2)	<.0001	.687
Week-6 (flexion)	4.0 (1.6 to 6.5)	.002	.397
AHD at 60º abduction (mm)			
Week-6	.38 (.07 to .69)	.017	.109

Data are expressed as mean ± standard deviation (95% CI). Intention-to-treat analyses (n=26 per group).
* Evaluation time-points in which the clinically important difference was reached.
† A statistically significant change in mean score compared with values at week-3 (p<0.05).
‡ A statistically significant change in mean score compared with values at week-6 (p<0.05).
§ A statistically significant change in mean score compared with values at week-12 (p<0.05).
‖ A statistically significant change in mean score compared with values at 6-months (p<0.05).

AHD, Acromiohumeral distance; BPI, Brief Pain Inventory; DASH, The Disabilities of the Arm, Shoulder, and Hand questionnaire; ROM, range of motion; SD, standard deviation; WORC, The Western Ontario Rotator Cuff index.

5.6. Discussion

This RCT assessed the effects of kinesiotaping added to a conventional rehabilitation programme for individuals with RCTe. Despite no Group x Time interaction, time effects observed indicated that both KT and No-KT groups improved significantly their symptoms and FL. Thus, our primary hypothesis concerning the improvements of shoulder condition in both groups was confirmed. Notwithstanding, our secondary hypothesis concerning the additional benefits of kinesiotaping, was not confirmed. Similar improvements in both KT and No-KT groups suggest that kinesiotaping did not provide additional benefits in short (week-3), mid- (week-6 and week-12) and long-term (6-months) to individuals with RCTe.

One of the possible explanations for the absence of kinesiotaping effects is that kinesiotaping technique used in this study may have acted over the same aetiologies or outcomes than the exercise-based rehabilitation programme. Indeed, therapeutic exercises have been evidenced to be effective in improving muscular recruitment and restoring shoulder motor control.[3,4,7,126,273,310] Therefore, if kinesiotaping has any effects, it is likely that the effects of the rehabilitation programme have surpassed the effects provided by the kinesiotaping. An alternative hypothesis is, however, that kinesiotaping may not produce any mid- or long-term effects.

One meta-analysis[183] and two systematic reviews[184,311] examined the clinical efficacy of kinesiotaping on RCTe and reported conflicting results. Desjardins-Charbonneau *et al.*[183] analysed 10 trials, including six RCTs,[173,175,176,209,212,260] and concluded that kinesiotaping may provide an immediate effect in increasing pain-free flexion and abduction ROM in short-term, but there was inconclusive evidence on its efficacy on overall pain reduction or improvement of function. McLaren *et al.*[311] reviewed five trials and found moderate evidence that kinesiotaping may improve pain and function in the short-term, whereas Saracoglu *et al.*[184] examined three kinesiotaping-related trials[78,173,176] that combined kinesiotaping plus interventions such as electrotherapy, manual therapy, and strengthening, and concluded that these combinations may be effective for improving pain, function, and ROM, in the short-term. Most studies included in these reviews, however, presented a high risk of bias, assessed only the immediate or short-term kinesiotaping effects, or tested kinesiotaping alone, instead of in conjunction with physiotherapy treatment as used in clinics.

Few studies have investigated the kinesiotaping as an adjunct resource for treating RCTe to allow parallel comparison to our data. Kaya *et al.*[175] compared the effects of kinesiotaping to manual therapy, both combined to exercises (stretching, strengthening and re-education for scapular stabilizers and RC muscles), and obtained comparable results as ours since similar improvements were observed in both groups, in terms of pain and functional limitations after six weeks. In contrast,

Şimşek *et al.*[176] compared RC and scapular strengthening exercises plus kinesiotaping to the same exercises plus sham-kinesiotaping and found that kinesiotaping was more effective than sham-kinesiotaping in improving pain, function, and pain-free abduction ROM in the short-term (five and 12 days). Another study also found improvements in pain-free ROM after using kinesiotaping in conjunction with physiotherapy intervention.[173] For their part, Djordjevic *et al.*[173] compared kinesiotaping plus mobilization with movements to exercises on active pain-free ROM and muscle strength and concluded that, in the short-term (five and 10 days), kinesiotaping plus mobilization with movements were superior to exercises in improving pain-free ROM. Different factors may explain the discrepancy between our results and the ones from studies that have concluded on the superiority of kinesiotaping. However, the main factor might be the rehabilitation programme, as our programme was centred on sensorimotor training for restoring a proper shoulder neuromuscular control, whereas other programmes focussed less on neuromuscular control and more on strengthening and mobilisation.

We also highlight other differences such as the length of follow-up and the kinesiotaping protocol. In most studies, only short-term follow-up was explored, whereas our study followed the participants in mid- and long-term. Before our study, there was no standard protocol for kinesiotaping application for RCTe, characterising a source of divergence between studies. Although all studies used a Y-shape kinesiotaping surrounding the deltoid muscles that, hypothetically, inhibits the deltoid activation,[197,198] as in our study, they also used additional strips over the acromioclavicular[175,176] and glenohumeral joint,[173,175,209,213,306] for scapular and glenohumeral mechanical correction, respectively, besides over supraspinatus[173,175,176,209,213] and lower trapezius, for improving hypothetically muscle activation,[213] that we did not. These differences may explain the contrasting results from our study to those above-mentioned.

5.6.1. Strength and limitations

As the strength of this study, we highlight the replication of clinical practice concerning the use of kinesiotaping combined with physiotherapy intervention. We also highlight the high adherence rate to the physiotherapy intervention and, finally, the isolation of kinesiotaping effects to determine its clinical efficacy. However, we are aware of some limitations to our study. An important lost to follow-up at mid- (week-12=13.5%) and long-term (6-months=19.2%) may have limited the continued effects of the treatment. Howbeit, as kinesiotaping was applied only until the week-6 evaluation, between-group differences were mostly expected for the rehabilitation programme period (week-3 and week-6), where the participants were assiduous. It is possible that some individuals with RCTe

benefited more from the kinesiotaping than others; subgroup analyses were not performed however, as the number of subjects was insufficient to keep statistical power. Lastly, RC electromyographic activity was recorded as described in the published protocol;[294] however, electromyographic activity pre- and post-treatment was not comparable due to a large increase in arm movement velocity after the treatment.

5.6.2. Clinical implications

Clinicians should not expect additional effects of kinesiotaping at mid-, or long-term if an exercise-based physiotherapy programme is also provided to individuals with RCTe.

5.7. Conclusion

Whereas symptoms, FL, ROM, and AHD improved in both groups, no between-group differences in the mid- and long-term were observed. Therefore, kinesiotaping did not provide additional benefits to a 6-week rehabilitation for individuals with RCTe to improve symptoms and FL.

5.8. Footnotes

5.8.1. Contributors

FCLO contributed to conception, design, and preparation of the procedures, data collection and conducted the recruitment, rehabilitation programme, interpretation, data analyses, and writing. BPF conducted the outcomes assessments and contributed to the analysis, and interpretation of the data. FD contributed to conception, study design and interpretation of the data. JSR and LJB contributed to conception, design, and preparation of the procedures. Both authors contributed to the analyses and interpretation of the data. JSR, LJB, FD, and BPF commented on the several versions of this study. All authors approved the final version of this manuscript.

5.8.2. Funding

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). FCLO receives a doctoral scholarship from the Brazilian Government through the Science without Borders programme in association with the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES. JSR and FD are supported by salary awards from the Fonds de Recherche Québec-Santé (FRQS) and the Canadian Institutes of Health Research (CIHR).

5.8.3. Competing interests

The authors have no relevant conflict of interests to declare.

5.8.4. Ethics approval

The sectorial rehabilitation and social integration research ethics committee of the Center Integrated University Health and Social Services (CIUSSS-CN).

5.8.5. Data sharing statement

Additional data from participants included in this study is not available, in accordance with the principles of confidentiality of the Institutional Review Board of Quebec Rehabilitation Institute (IRDPQ).

CHAPTER 6. DISCUSSION

In this thesis, the main interest was to determine the effectiveness of kinesiotaping in treating individuals with RCTe in the mid- and long-term. The effects of this therapeutic resource were tested in conjunction with a rehabilitation programme based on sensorimotor training. A well-structured rehabilitation programme including techniques aiming to improve shoulder control, global posture, range of motion, and the strength of the rotator cuff and scapulothoracic muscles, was implemented over six weeks, with an approach focused on the motor deficits caused by an RCTe. In addition, a set of investigations, using a cross-sectional design, including an assessment of the subacromial space width and shoulder proprioception was delineated and conducted prior to the implementation of the rehabilitation programme.

As the results from the studies included in this thesis have been already discussed in previous discussion subsection of the previous chapters (2, 4 and 5), this section approaches, briefly, the main results of this set of investigations, placing them in context with the current scientific literature. Lastly, a brief approach to the clinical implications of these results, are revisited.

6.1. Altered muscle activity in individuals with RCTe

The results from the systematic review allowed us to confirm that individuals with RCTe present alterations in the RC muscle activity that can be better observed during dynamic tasks.[42] To understand how these alterations in the RC muscles impact the shoulder functioning and contribute to the progression of an RCTe, it is important to revisit and take into consideration some aspects related to shoulder kinematics and glenohumeral joint stability.

Our results showed strong evidence that the muscular activity of the supraspinatus[131,243,244] and infraspinatus[131,236,243] are not affected by an RCTe during isometric contractions. However, in static positions, such as isometric contractions, where no upper limbs movements are required, alterations in the level of muscle activity are less likely to be observed. In contrast, our findings revealed an alteration in the level of activation for both supraspinatus[30,132,133] and infraspinatus[131-133] during arm elevation. However, the evidence on the impact of an RCTe on the activation of the infraspinatus and supraspinatus muscles during arm elevation, are still conflicting due to controversial results reported.[42]

The main explanation for these results is that the alterations of RC muscle activity occur in a precise range of angle during arm elevation, where the activation of specific muscles is required. For example, during arm elevation, more specifically when the arm approaches 90º of shoulder abduction, the infraspinatus and the teres minor are responsible for rotating the humerus externally to avoid

impingement of the supraspinatus tendon caused by the approach of greater tuberosity and the acromion.[30,31] Therefore, alterations in the level of activation of the infraspinatus may contribute to an RCTe caused by impingement. For the supraspinatus that raises the arm in the first 30º of shoulder abduction, the alteration in the level of activity is argued to be part of an inhibitory mechanism triggered to avoid pain caused by an excessive superior translation of the humeral head.[239] In fact, the limitation of this superior translation of the humeral head is assured by muscles from the inferior component of RC (infraspinatus, subscapularis, and teres minor).[30]

During more complex movements, such as sporting movements, all RC muscles have been reported to have their muscle activity affected by an RCTe, including subscapularis and teres minor. These muscles are not widely investigated, but our findings demonstrated moderate evidence of alteration in their muscle activation during unrestrained movements of individuals with RCTe.[42] A study from Myers *et al.*,[30] identified that the coactivation of the subscapularis with infraspinatus and supraspinatus is reduced, which compromise the system that rules the synchronous activation among RC muscles, labeled *force-couple*. Although the subscapularis and teres minor are not largely studied in individuals with RCTe, they have important participation in the two existing force-couples: coronal force-couple, which controls the upward translation of the humeral head and, hence, maintains the shoulder joint stability;[32] and transverse force-couple, which depress the humeral head into the glenoid fossa opposing the upward and outward forces from the deltoid and supraspinatus by providing a force in downward and inward[32] when the arm is at shoulder level or higher. Therefore, an alteration in the level of activity of one of these muscles hampers the synchronous system that controls the shoulder balance and maintain the shoulder joint stability,[30] requiring a reduction of activation for the supraspinatus, as previously mentioned. Therefore, RC muscle activity may play an important role in the shoulder kinematics,[19] so that any abnormality in the RC activation, in general, may compromise the scapular movements. A restriction in the scapular movements, such as posterior tilting, limits the opening of subacromial space created by the posterosuperior movement of the acromion.[12,14] Considering that a reduction of the AHD may result from this combination of alterations, we determined that the subacromial space width is an important outcome to be scrutinized in individuals with RCTe. For this reason, it was examined in the manuscript 2.

6.2. Acromiohumeral distance and shoulder proprioception immediately after kinesiotaping application

This cross-sectional study revealed that the kinesiotaping increased the AHD in individuals with RCTe, whereas their shoulder active joint repositioning was not modified immediately after a

kinesiotaping application. The AHD were estimated using ultrasonographic images of the subacromial space, whereas shoulder proprioception was measured using an active joint repositioning task. Both outcomes were measured in two conditions: without and with kinesiotaping.

Our results showed that, prior to testing, participants presented, on average, an AHD of 11.19 mm at rest. This value was within the range of values (9 to 12 mm) observed in asymptomatic individuals in the neutral position.[150,151] However, at 60º of shoulder abduction, the AHD was 8.94 mm. Interestingly, our results demonstrated that with kinesiotaping, individuals with RCTe increased significantly their AHD at 60º of shoulder abduction (0.94 mm, 95% CI: 0.50–1.38). Thus, with kinesiotaping, the mean AHD of individuals with RCTe returned immediately to the range considered as normal for asymptomatic individuals.[150,151] Although this increase seems small, it is important to point out that it represents an increase of 10.5% from the initial measurement. It is important to highlight that for individuals with RCTe, who often present a reduced subacromial space, it is likely that the increase observed in our study might be significant since it exceeded the MDC of 0.70 mm.[291] However, clinical effectiveness was not addressed in this study. Further studies should be conducted to confirm the clinical efficacy of the kinesiotaping in increasing the AHD in this population.

This is the first study to investigate the effects of kinesiotaping on AHD in symptomatic individuals with RCTe. Although previous studies have examined the effects of kinesiotaping on AHD in the short-term[154,231] and using several different kinesiotaping techniques, only healthy or asymptomatic people have been addressed. In these studies, Luque-Suarez *et al.*,[154] as well as Harput *et al.*,[231] found a significant increase of AHD with kinesiotaping in healthy subjects. While Luque-Suarez *et al.*[154] attributed these effects to changes in the firing patterns of RC motor units, Harput *et al.*[231] believed that kinesiotaping may have provided some mechanical correction in the scapular position resulting in contributions for increasing the AHD. Indeed, adjustments in the muscle activity contributing to correction of shoulder kinematics appears as a possible explanation for our results. This hypothesis seems plausible since AHD reduction has been correlated to abnormalities in shoulder kinematics[312] while the taping has been demonstrated to enhance the scapular kinematics.[225,260] However, these are just speculations since this study did not address the muscle activity and scapular kinematics.

Following a reasoning that possible adjustments in the muscle activity are provided by the kinesiotaping, one can be supposed that an increase of the proprioceptive stimulus on cutaneous mechanoreceptors should be also observed. However, our results revealed that any of the active joint repositioning abilities (2-ranges: low- and mid-amplitude x 2-plane of movement: flexion and abduction) tested did not change after the kinesiotaping application. Therefore, the kinesiotaping did not enhance the active joint repositioning ability of individuals with RCTe. This result is in line with

Keenan *et al.*,[229] who tested a different aspect of proprioception but also found no effects of kinesiotaping on the shoulder proprioception of individuals with RCTe.

One of the explanations for the absence of results in our study is related to the proprioceptive level of the participants. Although proprioceptive deficits are common in individuals with RCTe,[98] these impairments were not confirmed in our sample. According to Callaghan *et al.*,[302] an absolute error greater than 5º is a cue of poor proprioception. Theoretically, individuals in this condition are more susceptible to the effects of kinesiotaping than those who present an absolute error of less than 5º. In our study, the average of absolute error varied from 1.95º to 3.48º indicating a possibility of the participants does not have a real condition of proprioceptive deficits. Therefore, it is likely that the level of proprioceptive ability of the sample examined may not have been poor enough to be improved, which may have influenced the effects of kinesiotaping.

As the results revealed that the AHD of individuals with RCTe increased significantly immediately with the kinesiotaping, while shoulder active joint repositioning was not incremented, it is likely that the proprioceptive stimulus related to active joint repositioning may not be the main mechanisms explaining the effects of kinesiotaping, as previously theorized. However, other aspects of the proprioception, which could be more sensitive to the hypothetical proprioceptive stimulus provided by the kinesiotaping than the joint position sense, were not examined in this study.

6.3. Randomised controlled trial on the effects of kinesiotaping in the mid- and long-term

The fourth manuscript of this thesis is an RCT that investigated the effectiveness of the kinesiotaping used in conjunction to a rehabilitation programme for reducing symptoms, FL, and underlying deficits presented in individuals with RCTe, in the mid- and long-term.

The first hypothesis was that both groups would improve significantly their shoulder condition at the end of the treatment, especially in terms of symptoms and FL. This hypothesis was drawn since the same rehabilitation programme based on sensorimotor training exercises, which have been demonstrated as clinically effective in restoring the shoulder neuromuscular control,[100,313] would be provided to both groups. However, our main hypothesis was that individuals using kinesiotaping (allocated in the KT group) would present faster and more meaningful improvements than those who do not. This hypothesis was drawn based on previous studies reporting positive immediate and short-term effects of kinesiotaping on symptoms and FL,[78,176,213] AHD[306] and ROM[209] in individuals with RCTe.

Our results confirmed the first hypothesis drawn since both KT and No-KT groups improved significantly their symptoms and functional limitations in the mid (week-6 and week-12) and long-

term (6-months). In contrast, our secondary hypothesis was not confirmed, as the level of improvements was similar in both groups for all outcomes analyzed. Therefore, the improvements observed throughout the treatment cannot be attributed to the kinesiotaping. Thus, the main finding of this RCT demonstrated that the inclusion of kinesiotaping did not constitute additional benefits for the treatment of individuals with RCTe, in the mid- or long-term.

The goal of the kinesiotaping technique used in this study was, in general, the restoration of shoulder control. However, considering that exercises based on sensorimotor training, as those composing our rehabilitation programme, are effective for restoring shoulder neuromuscular control,[3,4,7,126,273,310] it is possible that both the kinesiotaping and the rehabilitation programme have acted over the same aetiologies. In this context, it is likely that the clinical effects of kinesiotaping have been similar or overcome by the effects of the rehabilitation programme. There is also a possibility of the kinesiotaping does not yield any effects at mid- or long-term.

Our RCT is the first study addressing the mid- and long-term effects of kinesiotaping on individuals with RCTe, which hampers comparison with the literature. However, our results are in line with a recent systematic review and meta-analysis[314] that investigated the effectiveness of kinesiotaping on non-specific low back pain. The authors concluded that, currently, there is no evidence supporting the use of kinesiotaping for treating this population in the short or mid-term.[314] Another RCT[315] examined the effectiveness of kinesiotaping in reducing pain and improving ROM and quality of life of individuals with neck pain. No evidence of additional benefits provided by the kinesiotaping was neither observed in this study.[315]

As between-group differences were not observed for all outcomes analyzed ($p>.05$) in our study, analyses were performed considering the sample as a pooled group. Our data indicated that all outcomes analyzed (pain, FL, AHD, ROM) improved significantly ($p\leq.017$) at the end of the treatment in comparison to baseline evaluation, which contributed to the high index of recovery perception of the participants after treatment. The self-perceived change in their shoulder condition from the initial physiotherapy session was evaluated using a GRC question, where 78.8% of the 52 participants reported to have perceived positive changes in their clinical status over time corresponding to a relevant improvement in their shoulder condition obtained with the treatment (≥ +4 GRC score: "*moderately better or greater*"). No participant reported a worsening in shoulder condition, whereas five participants did not answer the GRC question (the four who dropped out and one for undisclosed reasons).

We highlight that the symptoms and FL, assessed using the DASH questionnaire, exceeded the CID of 10.2 DASH-points[276] rapidly (week-3). At the end of the treatment (mid-term, week-6), the mean

DASH score was 10.7±8.0, corresponding to an improvement of 61.6% on the baseline DASH scores (27.9±10.8 DASH-points). In addition, the final mean DASH score was 7.4±8.8 DASH-points, representing an improvement of 74.5% (↓20.6 DASH-points).

The pain intensity and RC-specific symptoms, assessed with the BPI scores and the WORC index, respectively, also improved gradually. Continued significant improvements on the pain perceived and RC-specific symptoms were observed throughout the treatment. While the WORC index exceeded the CID of 17.5% at week-3, the BPI reached the CID of 2 mm[309] (which corresponds to 2 BPI-points) only at week-6. This late reach of CID, in comparison to DASH and WORC, may have occurred because participants of this study presented a chronic RCTe (≥20.6 months), where the level of pain intensity was not high at baseline (2.9±1.5 BPI-points).

Pain-free and full shoulder ROM, in both flexion and abduction, increased significantly ($p \leq .002$) at the end of the treatment, with no statistically significant difference between-groups. However, the use of kinesiotaping did not establish an advantage for increasing the ROM of individuals with RCTe. The effects of kinesiotaping were similar to the ones provided by the exercise-based rehabilitation.

Lastly, the AHD at 60º of shoulder abduction increased significantly after the treatment (0.38mm, 95% CI: 0.07–0.69) considering the pooled group. Although one of our study (manuscript 3) has shown that kinesiotaping provides an immediate increase of the AHD, our RCT revealed that the effect of kinesiotaping at mid- and long-term is not superior to the effects provided by a rehabilitation programme based on sensorimotor training.

CHAPTER 7. CONCLUSIONS

This doctoral project deals with important variables related to the kinesiotaping and the treatment of an RCTe, exploring concepts not yet investigated in clinical sciences to improve the clinical rehabilitation of individuals with RCTe. The findings reported in this doctoral dissertation contribute to building solid evidence that the kinesiotaping does not provide additional benefits to the mid- and long-term clinical rehabilitation of individuals with RCTe. The results of the studies included in this thesis are highly relevant to the development of more effective clinical approaches and treatments for this population, besides stimulating the continued development of new insights into current concepts in musculoskeletal rehabilitation using kinesiotaping.

7.1. Research avenues arising from this doctoral thesis and clinical recommendations

The set of investigations included in this doctoral thesis bring some results that can have a real impact on the rehabilitation of RC injuries and shoulder disorders, in general.

Through the findings from the first study, which had an exploratory character, it was possible to observe that alterations in the RC muscle activity can be evidenced during unrestrained dynamic movements. Given that, clinicians are encouraged to prefer dynamic tasks rather than static ones to evaluate muscle performance and shoulder motor control during the clinical assessment of patients with RCTe. Clinical evaluation of muscle performance and shoulder kinematics may help guide directions of a plan of rehabilitation, as described in the second manuscript. A relevant issue concerning the muscle performance of individuals with RCTe is whether the kinesiotaping may provide changes to normalize the muscle activation of RC or scapulothoracic muscles during arm elevation.

Considering that an altered performance of RC muscles affects the glenohumeral joint stability, contributing to the progression of shoulder dysfunction and compromising the subacromial space width, the third manuscript examined the use of kinesiotaping for improving the AHD and shoulder proprioception. Based on the results of this study, the use of a specific kinesiotaping technique for RCTe may provide an immediate increase of AHD. In contrast, no immediate effects of kinesiotaping on the shoulder active joint repositioning was demonstrated. These findings raised some questions related to the mechanism of functioning of the kinesiotaping. One of the most relevant issues raised is whether the kinesiotaping acts through mechanoreceptors stimulus for improving proprioceptive feedback. Considering that both outcomes, the AHD and active joint repositioning, can be associated with the increase of proprioceptive feedback, should the improvements in the shoulder active joint

repositioning be consistent with the immediate increase of the AHD? In other words, is the mechanism of functioning of the kinesiotaping is other than the proprioceptive stimulus?

Finally, the most important message for clinicians is brought by the fourth manuscript. Although kinesiotaping was not detrimental to the treatment, it did not constitute a crucial element in the rehabilitation of individuals with RCTe since no additional benefits were observed during the treatment of this population. Accordingly, clinicians and physiotherapist should not expect supplementary gain yielded by the kinesiotaping, whether a physiotherapy programme based on sensorimotor exercises, focusing on the shoulder neuromuscular control, is simultaneously provided to individuals with RCTe. Therefore, restoration of the shoulder neuromuscular control is the key to the success of a rehabilitation programme for this population.

A relevant question raised by these results is: why people using kinesiotaping in clinical practice, often report feeling better whether no effects on pain, functional limitations and other important outcomes coming from kinesiotaping have been demonstrated in mid- and long-term?

Further clinical RCTs are encouraged as they can be highly relevant to the development of more efficient approaches and treatments for individuals with RCTe. Howsoever, the quest for more effective rehabilitation of RCTe remains an exciting challenge.

ANNEXES

Annex A. Information sheets and consent forms

Centre intégré universitaire de santé et de services sociaux de la Capitale-Nationale
Québec

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Feuillet d'information

Numéro de projet : _____
(Réservé à l'administration)

I. Titre du projet :

Effets d'un programme de réadaptation sur les symptômes et les limitations fonctionnelles des personnes présentant une tendinopathie de la coiffe des rotateurs: Un essai clinique randomisé à simple insu.

II. Responsable et collaborateurs

(*avec affiliation professionnelle et identifier les cliniciens, coordonnateurs, étudiants, stagiaires, etc., s'il y a lieu*) :

(Référence)

Jean-Sébastien Roy, pht, Ph.D.; Chercheur, Centre interdisciplinaire de recherche en réadaptation et intégration sociale (CIRRIS); Professeur adjoint, Département de réadaptation, Université Laval.

Laurent J. Bouyer, Ph.D.; Chercheur, Centre interdisciplinaire de recherche en réadaptation et intégration sociale (CIRRIS); Professeur titulaire, Département de réadaptation, Université Laval.

Fábio Carlos Lucas de Oliveira, M.Sc.; Étudiant au doctorat en Médecine Expérimentale, Faculté de Médecine, Université Laval; Centre interdisciplinaire de recherche en réadaptation et intégration sociale (CIRRIS).

III. Organisme de subvention :

Gouvernement du Brésil - Science without Borders program.

IV. Introduction :

Nous sollicitons votre participation à un projet de recherche. Cependant, avant d'accepter de participer, veuillez prendre le temps de lire attentivement les renseignements qui suivent.

Ce feuillet d'information et de consentement vous explique le but de notre projet de recherche, les objectifs, les procédures, les avantages, les risques et les inconvénients, également, vous trouverez les cordonnées des personnes avec qui communiquer.

Le feuillet d'information et de consentement peut contenir des mots que vous ne comprenez pas. Par la suite, nous vous invitons à poser toutes les questions que vous jugerez utiles au chercheur responsable du projet, aux collaborateurs et autres membres du personnel affectés au projet de recherche et à leur demander de vous expliquer tout mot, terme technique ou renseignement qui n'est pas clair.

V. Nature et objectifs du projet :

Cette étude vise à évaluer l'efficacité d'un programme de réadaptation sur les symptômes que vous ressentez à votre épaule et sur la façon dont vous bougez votre épaule. En acceptant de participer à cette étude, vous devrez prendre part à quatre (4) séances d'évaluation, ainsi qu'à un programme de réadaptation supervisé par un physiothérapeute d'une durée de six (6) semaines, incluant 12 séances de

physiothérapie. Les séances d'évaluation et le programme de réadaptation seront réalisés dans les laboratoires du CIRRIS, à Québec.

Lors des séances d'évaluation, vous aurez à répondre à trois questionnaires afin d'évaluer vos symptômes. Nous évaluerons également les mouvements de votre épaule lors de mouvements d'élévation du bras. En mesurant la position des os de votre épaule (distance entre la tête humérale et l'acromion [partie de l'omoplate] aussi appelée distance acromiohumérale) à l'aide d'un système d'échographie, et la réponse de vos muscles à l'aide d'électrodes placées sur votre épaule (mesure de l'activation musculaire).

Notre souhaitons recruter 52 patients souffrant de douleur à l'épaule. Les résultats de cette étude nous aideront à mieux comprendre les mécanismes sous-jacents à la douleur à l'épaule et à mieux orienter les traitements.

VI. Déroulement du projet :

Toutes les rencontres se dérouleront au centre de recherche le CIRRIS. Voici un résumé des étapes du projet:

PARTIE 1 – Évaluation initiale : L'étude débutera par une rencontre au centre de recherche le CIRRIS avec le responsable du projet qui vous questionnera et effectuera des tests physiques (mouvements résistés et mouvements passifs à votre épaule) afin de vérifier votre admissibilité à l'étude. Si vous rencontrez les critères d'admissibilités, vous serez admis dans l'étude. Lors de cette même rencontre, si vous êtes admis à l'étude, nous procèderons à un examen physique de votre épaule (force et mobilité de votre épaule) et à l'évaluation du niveau de douleur et d'incapacité de vos épaules à l'aide des questionnaires auto administrés (DASH, Disabilities of the Arm, Shoulder & Hand; BPI, Brief Inventory Pain; WORC, Western Ontario Rotator Cuff Index). Par la suite, la mesure de la mobilité de votre épaule, ainsi que de la distance acromiohumérale et l'activité musculaire seront évaluées. La mobilité de votre épaule sera évaluée sous 2 conditions (amplitude maximale et amplitude sans douleur) à l'aide d'une caméra Microsoft Kinect™ (permet de mesurer les mouvements des articulations) et de marqueurs placés sur votre tronc et votre épaule. Pour chaque condition vous devrez effectuer 2 mouvements (flexion et abduction de l'épaule). La distance acromiohumérale sera mesurée en deux positions différentes du bras à l'aide d'un système d'échographie. L'échographie est une technique d'imagerie médicale qui permet l'observation des os, des muscles, des tendons et autres structures. L'activité musculaire de 3 muscles de l'épaule sera également évaluée à l'aide d'un système d'électromyographie (EMG). L'EMG est une technique que nous permet d'enregistrer l'activité électrique de vos muscles en utilisant des électrodes placées sur votre peau. Vous serez ensuite assigné aléatoirement à un des deux groupes d'intervention L'appartenance au groupe demeurera inconnue pour vous et l'évaluateur. Cette première rencontre aura une durée maximale de 90 minutes.

PARTIE 2 – Programme d'intervention en physiothérapie: Vous participerez au programme d'intervention de 6 semaines qui comprendra 12 séances en physiothérapie au centre de recherche le CIRRIS. Chaque séance en physiothérapie durera de 45 à 60 minutes, exceptée la première intervention (1ère). Ce programme d'intervention est basé sur les résultats des dernières études sur le sujet et ont pour but d'améliorer la qualité du mouvement de l'épaule et ainsi diminuer les symptômes reliés à la condition de votre épaule. Il comprend des exercices de contrôle du mouvement (exercices pour améliorer la qualité de votre mouvement), de renforcement et d'assoupissement, ainsi que des mobilisations passives. Vous aurez également à effectuer des exercices à domicile entre les séances supervisées (3 à 4 exercices à faire par jour [15-20 minutes par jour]; les exercices seront adaptés à votre condition).

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Feuillet d'information

Numéro de projet : _____
(Réservé à l'administration)

Lors de la 1ère évaluation de suivi, la distance acromiohumérale et votre capacité à repositionner votre bras après un mouvement passif (aussi appelée proprioception) seront mesurées. La proprioception est un paramètre essentiel pour la mobilité de votre épaule. Par la suite, vous commencerez le programme de réadaptation en recevant la première séance en physiothérapie (1ère intervention). Lors de cette première intervention, le physiothérapeute dressera une liste des déficits et un plan d'intervention. Il initiera l'intervention et vous donnera des conseils et des enseignements. La durée de cette 1ère séance sera d'environ 120 minutes alors que les interventions subséquentes seront uniquement composées du programme de réadaptation et seront d'une durée de 45-60 minutes.

PARTIE 3 – Évaluations de suivi :
À la 3e et à la 6e semaine, soit à la moitié et à la fin du programme d'intervention, des évaluations de suivi seront effectuées. Nous évaluerons le niveau de douleur et d'incapacités à l'aide des questionnaires autoadministrés. De plus, à la 6e semaine, nous effectuerons également la mesure de la mobilité de votre épaule, ainsi que de la distance acromiohumérale et l'activité musculaire. La durée de ces sessions sera d'environ 30 minutes pour l'évaluation à la 3e semaine et de 90 minutes pour celle de la 6e semaine.

PARTIE 4 – Évaluation finale :
L'évaluation finale aura lieu 12 semaines suivant l'évaluation initiale. Durant cette séance d'évaluation, le niveau de douleurs et d'incapacités sera réévalué. La durée de ces sessions sera d'environ 20 minutes.

PARTIE 1 **Évaluation initiale** **Laboratoires du CIRRIS**	**PARTIE 2** **Programme d'intervention en physiothérapie + Évaluation de suivi** **Laboratoires du CIRRIS**		**PARTIE 3** **Évaluations de suivi -** **Laboratoires du CIRRIS**	**PARTIE 4** **Évaluation finale** **Laboratoires du CIRRIS**
Semaine 0	**Semaine 1 à 6**		**Semaine 3 et 6**	**Semaine 7 à 12**
60 à 90 minutes	1ère séance 80 à 120 minutes	Interventions 2 à 12 Programme de réadaptation 30 à 60 minutes	3e : 30 minutes 6e : 90 minutes	15 à 20 minutes
Formulaire de consentement Évaluation des critères d'éligibilité Évaluation clinique (examen physique de l'épaule) Questionnaires de douleur et d'incapacités Évaluation de l'amplitude de mouvement Évaluation de la distance acromiohumérale (échographie) Évaluation de l'activité musculaire (EMG)	Évaluation de l'habilité à répéter les mouvements et à repositionner le bras (proprioception) Évaluation de la distance acromiohumérale (échographie) Programme de réadaptation (Intervention #1)	Programme de réadaptation: - Exercices de contrôle - Exercices de renforcement - Exercices d'étirement - Mobilisations passives -Exercices à domicile à effectuer entre les séances	Lors de la 3e et 6e sem. Questionnaires de douleur et d'incapacité Lors de la 6e semaine Évaluation de l'amplitude de mouvement Évaluation de la distance acromiohumérale (échographie) Évaluation de l'activité musculaire (EMG)	Exercices à domicile Questionnaires de douleur et d'incapacité (à la fin de la semaine 12)

Feuillet d'information

Numéro de projet : _____
(Réservé à l'administration)

VII. Risques potentiels et inconvénients personnels :

Risques potentiels: Les risques inhérents à cette étude correspondent aux risques normaux engendrés par une évaluation et une intervention en physiothérapie, c'est-à-dire une augmentation temporaire de douleur (24 à 48 heures). Des tests semblables à ceux effectués dans cette étude ont déjà été exécutés chez des personnes ayant la même atteinte que vous sans qu'il y ait eu détérioration de leur état. Si les évaluations et/ou les interventions augmentent vos symptômes, l'expérimentation pourra être réajustée ou arrêtée. Il vous sera possible en tout temps d'en aviser l'équipe de recherche.

Les examens électromyographiques et échographiques à l'épaule sont des techniques sécuritaires. Ainsi, en termes d'utilisation d'un tel équipement pour l'évaluation sur l'épaule, il n'y a aucun effet secondaire, complication ou contre-indication connu. Finalement, le Microsoft Kinect™ ne présente aucun risque connu pour les individus ne présentant pas de contre-indication médicale (notamment l'épilepsie). Toutefois, s'il y a une augmentation des symptômes causés par les techniques employées ou les tests d'évaluation, l'expérimentation pourra être réajustée ou même interrompue pour le patient en question.

Inconvénients: Vous aurez à vous déplacer quatre (4) fois aux laboratoires de centre de recherche le CIRRIS pour les évaluations de votre épaule (initiale [1], de suivi [2] et finale [1]). Vous recevrez toutefois une compensation (20$) pour couvrir vos frais de déplacement associés à ces évaluations.

Vous devrez également vous déplacer 12 fois au CIRRIS où un physiothérapeute vous offrira le programme de réadaptation (aucun frais). De plus, les coûts du stationnement sera couvert pour ces séances (un billet de stationnement vous sera remis à chaque intervention en physiothérapie).

VIII. Avantages possibles :

En acceptant de participer à cette étude, vous bénéficierez d'un programme d'intervention basé sur les résultats des dernières études sur le sujet. Le programme faisant partie de l'étude a démontré des bénéfices cliniques dans des études antérieures. Finalement, votre participation contribuera à faire avancer les recherches sur les interventions en réadaptation avec des personnes souffrant de douleurs à l'épaule.

IX. Participation volontaire et retrait de la participation :

Votre participation à ce projet de recherche est volontaire. Vous êtes donc libre de refuser d'y participer. Vous pouvez également vous retirer de ce projet à n'importe quel moment, sans avoir à donner de raisons, en faisant connaitre votre décision au chercheur responsable du projet ou à l'un des membres du personnel affectés au projet. Votre décision de ne pas participer à ce projet de recherche ou de vous retirer n'aura aucune conséquence sur la qualité des soins et des services auxquels vous avez droit ni sur votre relation avec le chercheur responsable du projet et les autres intervenants. Les responsables pourront également mettre fin à votre participation si vous ne répondez plus aux critères d'admissibilité. Si votre participation n'est plus requise pour l'étude, vous serez informé des raisons qui justifient cette décision.

X. Clause de responsabilité :

Feuillet d'information

Numéro de projet : _____
(Réservé à l'administration)

En acceptant de participer à cette étude, vous ne renoncez à aucun de vos droits ni ne libérez les chercheurs, le commanditaire ou les institutions impliquées de leurs obligations légales et professionnelles.

XI. Indemnité compensatoire :

Aucune rémunération n'est rattachée à votre participation. Une compensation de 20$ vous sera remise à chaque évaluation (4) pour couvrir vos frais de déplacement au centre de recherche le CIRRIS.

XII. Confidentialité, conservation et utilisation des résultats :

Les chercheurs et leur équipe respecteront la confidentialité dans les limites permises par la loi. Les résultats des tests et les informations recueillies demeureront confidentiels et ne seront accessibles qu'à l'équipe de chercheurs ou encore aux représentants du Comité d'éthique à la recherche à des fins de gestion ou de vérification du bon déroulement de la recherche. Votre nom sera remplacé par un code. La liste des numéros et des noms correspondants sera conservée dans un classeur verrouillé dans le bureau d'un des chercheurs. Ainsi, les données seront nominalisées et, de ce fait, toute publication scientifique découlant de cette étude respectera la confidentialité. Toutes les données seront conservées 5 ans après la fin du projet et détruites par la suite.

À des fins de surveillance et de contrôle, votre dossier de recherche pourrait être consulté par une personne mandatée par le Comité d'éthique de la recherche, ou par toute autre personne dument mandatée pour vérifier la gestion ou le bon déroulement de la recherche.

XIII. Questions sur le projet et personnes-ressources :

Vous pourrez joindre Jean-Sébastien Roy (418-529-9141, poste 6005 ou jean-sebastien.roy@rea.ulaval.ca) durant les heures ouvrables si vous avez des questions relatives à l'étude ou si votre condition se détériore à la suite des évaluations. Nous pourrons joindre votre médecin traitant si vous le désirez.

Si vous avez des questions d'ordre éthique, vous pouvez communiquer avec la coordonnatrice du comité d'éthique de la recherche de l'IRDPQ au 418 529-9141, poste 2888 ou coordonnatrice.cer@irdpq.qc.ca. Les frais d'interurbain seront remboursés sur présentation d'une pièce justificative, le cas échéant. Dans l'éventualité où vous désiriez formuler une plainte, vous pourrez vous adresser à la commissaire aux plaintes et à la qualité des services de l'IRDPQ à l'adresse courriel suivante : plaintes@irdpq.qc.ca ou par téléphone au 418 529-9141, poste 6247 (téléscripteur ATS : 418 649-3734).

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Formulaire de consentement

Numéro de projet : _____

Titre du projet : Effets d'un programme de réadaptation sur les symptômes et les limitations fonctionnelles des personnes présentant une tendinopathie de la coiffe des rotateurs: Un essai clinique randomisé à simple insu.

Chercheur responsable du projet : Jean-Sébastien Roy, pht, Ph.D.; Chercheur, Centre interdisciplinaire de recherche en réadaptation et intégration sociale (CIRRIS); Professeur adjoint, Département de réadaptation, Université Laval.

1) Le (la) responsable m'a informé(e) de la nature et des buts de ce projet de recherche ainsi que de son déroulement;
2) Le (la) responsable m'a informé(e) des risques et inconvénients associés à ma participation;
3) Ma participation à cette étude est volontaire et je peux me retirer en tout temps sans préjudice;
4) Les données de cette étude seront traitées en toute confidentialité et elles ne seront utilisées qu'aux fins scientifiques et par les partenaires identifiés au formulaire d'information;
5) J'ai pu poser toutes les questions voulues concernant ce projet et j'ai obtenu des réponses satisfaisantes;
6) Ma décision de participer à cette étude ne libère ni les chercheurs, ni l'établissement hôte de leurs obligations envers moi;
7) Je sais qu'aucune rémunération n'est rattachée à ma participation;
8) Le (la) responsable m'a remis un exemplaire du feuillet d'information et du formulaire de consentement;
9) J'ai lu le présent formulaire et je consens volontairement à participer à cette étude;
10) Je désire recevoir une copie des résultats de l'étude ❑ oui ❑ non

* Dans le cas de **personnes mineures**, il est de la responsabilité du parent qui signe le présent formulaire de consentement d'informer l'autre parent de la participation de l'enfant à la recherche et de fournir les coordonnées du chercheur.
* Pour les **personnes majeures inaptes**, remplacer la signature du participant par celle du mandataire.

Nom du participant	**Date de naissance**	**Numéro de téléphone**
Signature du participant *	Date	
Nom du chercheur	Date	Signature
Assentiment de la personne mineure (si possible)	Date	Signature

Réservé à l'administration Approbation du CÉR de l'IRDPQ _____ N° version : ____ Date : _____
2013-08

Annex B. Edinburgh Handedness Inventory

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

EDINBURGH HANDEDNESS INVENTORY[316]

Oldfield, RC. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, 9:97-113.

Indiquez votre préférence à utiliser la main gauche ou la main droite pour accomplir les activités suivantes en inscrivant une ou deux croix (+ ou ++) dans la colonne appropriée. Lorsque, pour une activité donnée, vous n'avez pas de préférence et que vous utilisez autant la main gauche que la main droite, placez une croix (+) dans chacune des colonnes. Par contre, si vous avez une préférence marquée pour une main et que vous n'utiliseriez jamais l'autre main à moins d'y être forcé. Inscrivez deux croix (++) dans la colonne appropriée.

Certaines de ces activités requièrent l'usage des deux mains. Dans ces cas, l'identification de la main concernée par la question est écrite entre parenthèses.

Efforcez-vous de répondre à toutes les questions; toutefois, si vous n'avez aucune expérience de l'objet ou de la tâche évoqués dans une question, vous pouvez vous abstenir d'y répondre.

	GAUCHE	DROITE
1. ÉCRIRE	_____	_____
2. DESSINER	_____	_____
3. LANCER	_____	_____
4. CISEAUX (MAIN QUI COUPE)	_____	_____
5. BROSSE À DENT	_____	_____
6. COUTEAU	_____	_____
7. CUILLÈRE	_____	_____
8. BALAI (MAIN SUPÉRIEURE)	_____	_____
9. FROTTER UNE ALLUMETTE	_____	_____
10. OUVRIR UNE BOÎTE (COUVERCLE)	_____	_____
TOTAL	_____	_____

Pour calculer le quotient de latéralité, appliquez la formule suivante:

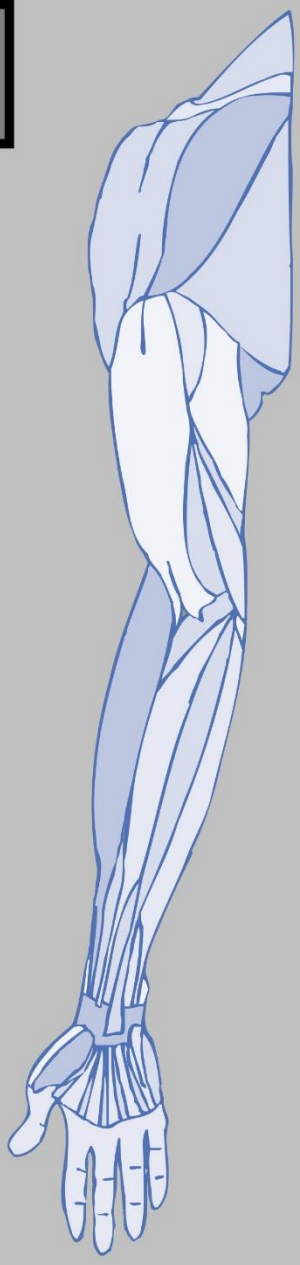
QL =Md – MgMd représente le nombre de croix de la colonne main droite
Md + MgMg représente le nombre de croix de la colonne main gauche

MERCI DE VOTRE COLLABORATION!

Évaluateur : _____ Date : _____/_____/_____

Annex C. Disabilities of the Arm, Shoulder and Hand (DASH) – French-Canadian version

Le DASH



INSTRUCTIONS

Ce questionnaire porte sur vos symptômes ainsi que sur votre capacité à réaliser certaines activités.

En vous basant sur votre condition de la dernière semaine, veuillez répondre à toutes les questions, en encerclant le numéro approprié.

Si vous n'avez pas eu l'occasion de réaliser une activité au cours de la dernière semaine, faites de votre mieux pour choisir la réponse qui serait la plus juste.

Répondez en vous basant sur votre capacité à réaliser la tâche sans vous soucier de comment vous l'effectuez ou de quelle main vous utilisez pour réaliser l'activité.

QUESTIONNAIRE DASH SUR LES INCAPACITÉS RELIÉES À UNE ATTEINTE AUX MEMBRES SUPÉRIEURS

Évaluez votre capacité à faire les activités suivantes au cours de la dernière semaine en encerclant le numéro dans la colonne appropriée. Répondez en vous basant sur votre capacité à réaliser la tâche sans vous soucier de comment vous l'effectuez ou de quelle main vous utilisez pour réaliser l'activité.

	Pas de difficulté	Difficulté légère	Difficulté moyenne	Difficulté sévère	Incapable
1. Ouvrir un pot neuf ou fermé serré.	1	2	3	4	5
2. Écrire.	1	2	3	4	5
3. Tourner une clé.	1	2	3	4	5
4. Préparer un repas.	1	2	3	4	5
5. Ouvrir une porte lourde en poussant.	1	2	3	4	5
6. Placer un objet sur une tablette située au-dessus de votre tête.	1	2	3	4	5
7. Faire de gros travaux ménagers (ex.: laver les murs, laver les planchers).	1	2	3	4	5
8. Jardiner ou faire l'entretien d'un terrain.	1	2	3	4	5
9. Faire un lit.	1	2	3	4	5
10. Transporter un sac d'épicerie ou un porte-document (valise).	1	2	3	4	5
11. Transporter un objet lourd (plus de 10 livres).	1	2	3	4	5
12. Changer une ampoule située au-dessus de votre tête.	1	2	3	4	5
13. Laver vos cheveux ou sécher vos cheveux à l'aide d'un séchoir	1	2	3	4	5
14. Laver votre dos.	1	2	3	4	5
15. Mettre un chandail.	1	2	3	4	5
16. Utiliser un couteau pour couper des aliments.	1	2	3	4	5
17. Activités de loisirs qui exigent peu d'effort (ex.: jouer aux cartes, etc.).	1	2	3	4	5
18. Activités de loisirs dans lesquelles votre bras, votre épaule ou votre main subit un impact (ex.: golf, utiliser un marteau, tennis, etc.).	1	2	3	4	5
19. Activités de loisirs durant lesquelles vous bougez votre bras librement (ex.: jouer au frisbee, au badminton, etc.).	1	2	3	4	5
20. Déplacements (transports).	1	2	3	4	5
21. Activités sexuelles.	1	2	3	4	5

QUESTIONNAIRE DASH SUR LES INCAPACITÉS RELIÉES À UNE ATTEINTE AUX MEMBRES SUPÉRIEURS

	Pas du tout	Un peu	Moyennement	Beaucoup	Extrêmement
22. Au cours de la dernière semaine, dans quelle mesure votre problème au bras, à l'épaule ou à la main a-t-il nui à vos activités sociales habituelles avec votre famille, amis, voisins ou groupes? (encerclez un chiffre)	1	2	3	4	5

	Pas limité du tout	Légèrement limité	Moyennement limité	Très limité	Incapable
23. Au cours de la dernière semaine, avez-vous été limité dans votre travail ou dans vos autres activités habituelles à cause de votre problème au bras, à l'épaule ou à la main? (encerclez un chiffre)	1	2	3	4	5

Évaluez la sévérité des symptômes suivants au cours de la dernière semaine. (encerclez un chiffre)

	Aucune	Légère	Modérée	Sévère	Extrême
24. Douleur au bras, à l'épaule ou à la main.	1	2	3	4	5
25. Douleur au bras, à l'épaule ou à la main lorsque vous réalisez toute activité spécifique.	1	2	3	4	5
26. Picotements (fourmillements) au bras, à l'épaule ou à la main.	1	2	3	4	5
27. Faiblesse au bras, à l'épaule ou à la main.	1	2	3	4	5
28. Raideurs (manque de souplesse) au bras, à l'épaule ou à la main.	1	2	3	4	5

	Pas de difficulté	Difficulté légère	Difficulté moyenne	Difficulté sévère	Tellement de difficulté que je ne peux pas dormir
29. Au cours de la dernière semaine, dans quelle mesure avez-vous eu de la difficulté à dormir à cause de votre douleur au bras, à l'épaule ou à la main? (encerclez un chiffre)	1	2	3	4	5

	Fortement en désaccord	En désaccord	Ni d'accord ni en désaccord	En accord	Fortement en accord
30. Dans quelle mesure êtes-vous d'accord avec la phrase suivante : « Je me sens moins capable, moins confiant ou moins utile à cause de mon problème au bras, à l'épaule ou à la main ».	1	2	3	4	5

COTATION DU DASH INCAPACITÉ/SYMPTÔME = $\left(\frac{\text{somme des valeurs choisies}}{\text{nombre de questions répondues}} - 1\right) \times 25$

Un score du DASH ne peut pas être calculé s'il y a plus que 3 réponses manquantes.

QUESTIONNAIRE DASH SUR LES INCAPACITÉS RELIÉES À UNE ATTEINTE AUX MEMBRES SUPÉRIEURS

MODULE TRAVAIL (OPTIONNEL)

Les questions suivantes portent sur l'impact de votre problème au bras, à l'épaule ou à la main sur votre capacité à travailler (incluant « tenir maison » si cela est votre principale occupation).

Indiquez quel est votre travail même si votre problème au bras, à l'épaule ou à la main vous empêche de le réaliser actuellement : _____

❑ Je n'ai pas de travail. (Ne répondez pas à cette section.)

Encerclez le numéro qui décrit le mieux votre capacité physique au cours de la dernière semaine. Si vous n'avez pas eu l'occasion de réaliser votre travail au cours de la dernière semaine, faites de votre mieux pour choisir la réponse qui serait la plus juste. Avez-vous eu de la difficulté à :

	Pas de difficulté	Difficulté légère	Difficulté moyenne	Difficulté sévère	Incapable
1. utiliser la même technique de travail que d'habitude?	1	2	3	4	5
2. faire votre travail habituel à cause de votre douleur au bras, à l'épaule ou à la main?	1	2	3	4	5
3. faire votre travail aussi bien que vous l'auriez voulu?	1	2	3	4	5
4. passer le même nombre d'heures que d'habitude à réaliser votre travail?	1	2	3	4	5

MODULE SPORTS/MUSIQUE (OPTIONNEL)

Les questions suivantes portent sur l'impact de votre problème au bras, à l'épaule ou à la main sur la pratique d'un instrument de musique, d'un sport ou des deux. Si vous pratiquez plus d'un sport ou d'un instrument (ou les deux), répondez en considérant l'activité qui est la plus importante pour vous.

Indiquez le sport ou l'instrument qui est le plus important pour vous peu importe si votre problème au bras, à l'épaule ou à la main vous empêche de le réaliser actuellement : _____

❑ Je ne pratique pas un sport ou un instrument. (Ne répondez pas à cette section.)

Encerclez le numéro qui décrit le mieux votre capacité physique au cours de la dernière semaine. Si vous n'avez pas eu l'occasion de réaliser cette activité au cours de la dernière semaine, faites de votre mieux pour choisir la réponse qui serait la plus juste. Avez-vous eu de la difficulté à :

	Pas de difficulté	Difficulté légère	Difficulté moyenne	Difficulté sévère	Incapable
1. utiliser la même technique que d'habitude pour pratiquer votre instrument ou sport?	1	2	3	4	5
2. pratiquer votre instrument ou sport habituel à cause de la douleur au bras, à l'épaule ou à la main?	1	2	3	4	5
3. pratiquer votre instrument ou sport habituel aussi bien que vous l'auriez voulu?	1	2	3	4	5
4. passer le même nombre d'heures que d'habitude à pratiquer votre instrument ou sport?	1	2	3	4	5

COTATION DES MODULES OPTIONNELS : Additionnez les valeurs encerclées;
divisez par 4 (nombre d'items); soustraire 1; multipliez par 25.
Un score au module optionnel ne peut pas être calculé si des items ne sont pas répondus.

Annex D. Brief Pain Inventory (BPI)

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

ÉVALUATION CLINIQUE INITIALE

(Adapté du Brief Pain Inventory[317] – Questions 3, 4, 5 et 6.)

Entourez d'un cercle le chiffre qui décrit le mieux la douleur										
1. « ...la plus intense que vous ayez ressentie pendant les dernières 24 heures. »										
0 Pas de douleur	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10** Douleur la plus horrible que vous puissiez imaginer
2. « ...la plus faible que vous ayez ressentie pendant les dernières 24 heures. »										
0 Pas de douleur	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10** Douleur la plus horrible que vous puissiez imaginer
3. « ... la douleur en général. »										
0 Pas de douleur	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10** Douleur la plus horrible que vous puissiez imaginer
4. « ... la douleur en ce moment. »										
0 Pas de douleur	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10** Douleur la plus horrible que vous puissiez imaginer

Évaluateur : _____ Date : _____/_____/_____

Annex E. Western Ontario Rotator Cuff (WORC) index

Western Ontario Rotator Cuff Index

Instructions

Dans le questionnaire suivant, vous aurez à répondre à des questions dans le format qui suit et vous devrez donner votre réponse en plaçant une barre oblique « / » sur la ligne horizontale.

NOTE :

1. Si vous placez une barre oblique « / » à l'extrême gauche de la ligne, comme dans l'exemple qui suit

vous indiquez alors que vous n'avez aucune douleur.

2. Si vous placez une barre oblique « / » à l'extrême droite de la ligne, comme dans l'exemple qui suit

vous indiquez alors que votre douleur est extrême.

3. Prenez note :
   a) Que plus vous placez votre barre oblique « / » à droite et **plus** vous présentez ce symptôme;
   b) Que plus vous placez votre barre oblique « / » à gauche et **moins** vous présentez ce symptôme;
   c) **Qu'il est important de ne pas placer votre barre oblique « / » en dehors de la ligne horizontale.**

Vous devez indiquer dans ce questionnaire l'intensité des symptômes ressentis dans la dernière semaine en relation avec votre problème d'épaule. Si vous n'êtes pas en mesure de déterminer quelle épaule est concernée ou si vous avez d'autres questions, veuillez demander des précisions avant de compléter ce questionnaire.

Si, pour une raison ou une autre, vous ne comprenez pas une question, s'il vous plaît, référez-vous aux explications qui se trouvent à la fin de ce questionnaire. Vous pourrez par la suite répondre en plaçant une barre oblique « / » sur la ligne horizontale à l'endroit approprié. **Si une question ne s'applique pas à votre situation, ou encore si elle concerne un symptôme qui ne s'est pas présenté au cours de la dernière semaine, veuillez imaginer la réponse qui correspondrait le mieux à votre situation.**

Version originale : The Development and Evaluation of a Disease-Specific Quality of Life Measurement Tool for Rotator Cuff Disease: The Western Ontario Rotator Cuff Index, American Academy of Orthopaedic Surgeon's Annual Meeting Book of Abstracts, 1998.

Section A : Symptômes physiques

Instructions

Les questions suivantes concernent les symptômes physiques que vous avez ressentis en relation avec votre problème à l'épaule. Dans tous les cas, veuillez indiquer l'intensité du symptôme ressenti dans la dernière semaine. Veuillez donner votre réponse en plaçant une barre oblique « / » à l'endroit approprié sur la ligne horizontale.

1. Dans quelle mesure éprouvez-vous de la douleur aiguë à votre épaule?

2. Dans quelle mesure éprouvez-vous de la douleur constante et lancinante à votre épaule?

3. Dans quelle mesure éprouvez-vous de la faiblesse à votre épaule?

4. Dans quelle mesure éprouvez-vous de la raideur ou un manque d'amplitude de mouvement à votre épaule?

5. Dans quelle mesure êtes-vous dérangé(e) parce que votre épaule claque, grince ou craque?

6. Dans quelle mesure éprouvez-vous de l'inconfort aux muscles de votre cou en raison de votre épaule

Section B : Sports / Loisirs

Instructions

La section suivante porte sur les conséquences que votre problème d'épaule a eues sur vos activités sportives ou vos loisirs au cours de la dernière semaine. Veuillez donner votre réponse en plaçant une barre oblique « / » à l'endroit approprié sur la ligne horizontale.

7. Dans quelle mesure votre épaule a-t-elle affecté votre condition physique?

8. Dans quelle mesure votre épaule a-t-elle affecté votre capacité à lancer fort ou loin?

9. Dans quelle mesure éprouvez-vous de la difficulté quand quelqu'un ou quelque chose va entrer en contact avec votre épaule atteinte?

10. Dans quelle mesure éprouvez-vous de la difficulté en raison de votre épaule lorsque vous faites des push-ups ou d'autres exercices exigeants pour l'épaule?

Section C : Travail

Instructions

La section suivante porte sur votre problème d'épaule et ses conséquences au cours de la dernière semaine sur vos tâches quotidiennes à l'intérieur et à l'extérieur de la maison. Veuillez donner votre réponse en plaçant une barre oblique « / » à l'endroit approprié sur la ligne horizontale.

11. Dans quelle mesure éprouvez-vous de la difficulté dans vos tâches quotidiennes à la maison ou dans la cour / le jardin?

Aucune difficulté — Difficulté extrême

12. Dans quelle mesure éprouvez-vous de la difficulté à travailler avec le bras au-dessus de l'épaule?

Aucune difficulté — Difficulté extrême

13. Dans quelle mesure utilisez-vous votre autre bras pour compenser pour votre bras atteint?

Pas du tout — Constamment

14. Dans quelle mesure éprouvez-vous de la difficulté quand vous soulevez des objets lourds à hauteur d'épaule ou en-dessous du niveau de l'épaule?

Aucune difficulté — Difficulté extrême

Section D : Style de vie

Instructions

La section suivante porte sur les conséquences que votre problème d'épaule a eues sur votre style de vie au cours de la dernière semaine. Encore une fois, veuillez donner votre réponse en plaçant une barre oblique « / » à l'endroit approprié sur la ligne horizontale.

15. Dans quelle mesure avez-vous de la difficulté à dormir en raison de votre épaule?

Aucune difficulté — Difficulté extrême

16. Dans quelle mesure avez-vous de la difficulté à vous coiffer les cheveux en raison de votre épaule?

Aucune difficulté — Difficulté extrême

17. Dans quelle mesure avez-vous de la difficulté à vous « chamailler », à vous « tirailler » ou à « jouer vivement » avec des membres de votre famille ou des amis?

Aucune difficulté — Difficulté extrême

18. Dans quelle mesure avez-vous de la difficulté à vous habiller ou vous déshabiller?

Aucune difficulté — Difficulté extrême

Section E : Émotions

Instructions

Les questions qui suivent font référence à la façon dont vous vous êtes senti(e) par rapport à votre problème d'épaule au cours de la dernière semaine. Veuillez donner votre réponse en plaçant une barre oblique « / » à l'endroit approprié sur la ligne horizontale.

19. Dans quelle mesure ressentez-vous de la frustration à cause de votre épaule?

20. Dans quelle mesure vous sentez-vous « au fond du baril » ou déprimé en raison de votre épaule?

21. Dans quelles mesures êtes-vous inquiet (inquiète) ou préoccupé(e) par les répercussions de votre problème d'épaule sur votre travail / vos occupations?

MERCI D'AVOIR COMPLÉTÉ LE QUESTIONNAIRE

Explications des questions du WORC

Section A : Symptômes physiques

Question 1.

Fait référence à la douleur à votre épaule qui est brève et soudaine ou que vous pourriez qualifier de momentanée.

Question 2.

Fait référence à une douleur sourde et diffuse qui semble être toujours là comparativement à la douleur aiguë dont il est question à la question 1.

Question 3.

Fait référence à un manque de force pour effectuer un mouvement.

Question 4.

Fait référence à la sensation que l'articulation ne veut pas bouger. Ceci est souvent ressenti le matin au lever, après des exercices ou après une période d'inactivité. Peut aussi faire référence à une diminution de mouvement de votre épaule dans une ou plusieurs directions.

Question 5.

Fait référence à tous ces bruits ou sensations que vous ressentez dans votre épaule peu importe le mouvement que vous exécutez.

Question 6.

Fait référence à l'importance de la tension, de la douleur ou des spasmes que vous ressentez au niveau des muscles de votre cou, qui semblent causés par votre problème d'épaule.

Section B : Sports/Loisirs

Question 7.

Fait référence à la forme physique que vous mainteniez avant le début de votre problème d'épaule (sont incluses une diminution de votre force et de votre tonus musculaire, ou la diminution de votre forme cardiovasculaire).

Question 8.

Fait référence à tout type d'activité avec le bras au-dessus de l'épaule qui demande une certaine force dans son exécution. Si vous ne lancez pas de balle, SVP, considérez toute autre activité comme un smash au volleyball, lancer un bâton à votre chien, nager au crawl, servir au tennis, etc.

Question 9.

Veuillez considérer toute situation où vous étiez sur vos gardes ou avez eu peur que quelqu'un ou quelque chose frappe ou touche votre épaule, comme par exemple, dans un endroit achalandé, dans un ascenseur, pendant la pratique d'un sport ou lorsque quelqu'un vous salue en vous

frappant sur l'épaule.

Question 10.

Fait référence à tout exercice qui vous demande de forcer avec votre épaule comme des « push-ups » ou du « Bench press », etc.

Section C : Travail

Question 11.

Fait référence à des activités comme ratisser les feuilles, pelleter, épousseter, passer l'aspirateur, enlever les mauvaises herbes ou laver le plancher ou des fenêtres, etc.

Question 12.

Fait référence à toute activité demandant que vous leviez vos bras au-dessus de la hauteur des épaules, c'est-à-dire placer des assiettes sur une tablette élevée, essayer d'atteindre un objet, peindre un plafond ou peindre avec le bras au dessus de la hauteur de l'épaule.

Question 13.

Fait référence au fait que vous utilisez votre autre bras pour toute activité ou pour votre travail, alors que normalement, vous auriez accompli cette activité ou ce travail avec votre bras atteint. Si votre autre épaule est aussi symptomatique à cause d'une pathologie de la coiffe des rotateurs ou à cause de toute autre maladie, veuillez, SVP, répondre à la question en faisant comme si votre autre épaule était normale.

Question 14.

Cette question ne fait pas référence au fait de lever des objets lourds au-dessus de la tête, mais bien sous la hauteur des épaules. Par exemple : soulever un sac d'épicerie, une caisse de boissons gazeuses, une valise, du matériel ou des outils au travail, des livres, etc.

Section D : Style de Vie

Question 15.

Fait référence à tout changement dans votre position de sommeil, au fait que vous vous réveillez durant la nuit, que vous avez de la difficulté à vous endormir ou que vous vous réveillez le matin sans vous sentir reposé(e).

Question 16.

Fait référence à tout ce que vous faites à vos cheveux et qui vous demande d'utiliser votre bras problématique. Par exemple : vous peigner, vous brosser ou vous laver les cheveux.

Question 17.

Fait référence à des jeux physiques vigoureux ou exigeants avec votre famille ou vos amis.

Question 18.

Fait référence au fait d'ouvrir ou de fermer une fermeture-éclair située dans votre dos, au fait de boutonner/déboutonner des boutons situés dansvotre dos, d'attacher ou détacher un soutien-

gorge, d'enlever ou de mettre un chandail, ou encore de rentrer une chemise ou un chandail à l'intérieur d'un pantalon.

Section E: Émotions

Question 19.

Fait référence à la frustration que vous ressentez face à votre incapacité, qui vous empêche de faire les choses que vous faites habituellement.

Question 20.

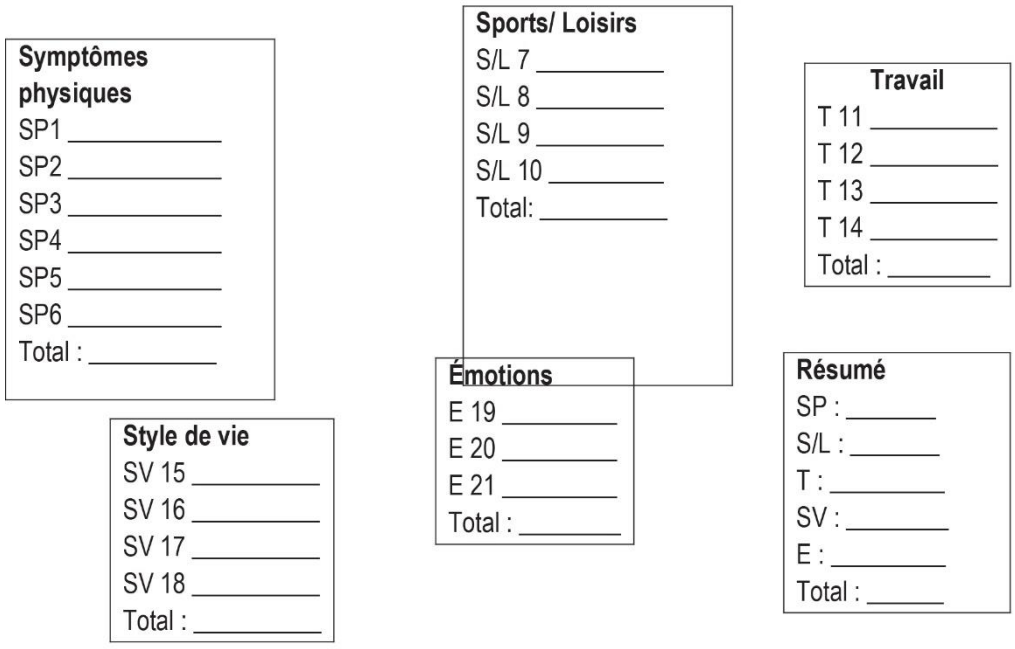
Se sentir au fond du baril : avoir le cafard, être déprimé, triste.

Question 21.

Fait référence à vos inquiétudes face à la condition de votre épaule qui risque de se détériorer plutôt que de s'améliorer, et face aux conséquences que cela pourrait avoir sur vos occupations ou votre travail (considérez aussi les activités quotidiennes à l'intérieur et à l'extérieur de la maison).

Cotation du questionnaire Western Ontario Rotator Cuff Index

1. Mesurez la distance à partir de la gauche de la ligne en millimètres (mm), au 0,5mm près. Inscrire chaque score à l'endroit approprié pour chacune des questions.
2. En additionnant le total des scores obtenus dans chaque domaine, vous obtiendrez un score sur 2100.
3. Pour convertir le score en pourcentage, le score obtenu doit être soustrait à 2100 et divisé par 21. Ex. Pour un score de 1625, le pourcentage sera (2100-1625)/21= 22,6%.



Annex F. Global Rating of Change (GRC)

Numéro d'identification: _____Date d'évaluation: _____/_____/_____
Semaine 3 ( )Semaine 6 ( )

ÉVALUATION DU CHANGEMENT GLOBAL (Global Rating of Change)[174]

Globalement, avez-vous noté un changement dans la condition de votre épaule depuis l'évaluation initiale?
Indiquez s'il y a eu un changement dans votre condition en choisissant parmi les trois options suivantes :

Changement noté	Cochez
Détérioré	
À peu près pareil; ni mieux, ni pire; stable	
Amélioré	

Si votre condition s'est améliorée ou détérioré depuis l'évaluation initiale, évaluez le niveau d'amélioration ou de détérioration en choisissant parmi ces sept options :

Amélioration			Détérioration
Un tantinet amélioré ☐			Un tantinet détérioré ☐
Un petit peu amélioré ☐			Un petit peu détérioré ☐
Quelque peu amélioré ☐			Quelque peu détérioré ☐
Modérément amélioré ☐	Ni mieux, ni pire ☐		Modérément détérioré ☐
Pas mal amélioré ☐			Pas mal détérioré ☐
Grandement amélioré ☐			Grandement détérioré ☐
Très grandement amélioré ☐			Très grandement détérioré ☐

From: *Jaeschke R, Singer J, Guyatt GH. Measurement of health status. Ascertaining the minimal clinically important difference. Control Clin Trials, 1989. 10(4):407-415.*

MERCI DE VOTRE COLLABORATION!

Évaluateur : _____ Date : _____/_____/_____

APPENDICES

Appendix A. Search strategy (manuscript 1)

TERMINOLOGY EMPLOYED FOR THE SEARCH STRATEGY

Concept 1: Outcomes *Electromyography* [MeSH]	Concept 2: Patients/Symptoms *Rotator cuff injuries* [MeSH]	Concept 3: Muscles *Rotator cuff muscles* [Mesh]
electromyograph*	tendinopath*	infraspinatus
EMG	impingement	supraspinatus
musc* activity	subacromial pain	teres minor
		subscapularis
		rotator cuff muscles

Terms used in the search strategy in the Pubmed database using a combination of keywords, as follows: 'OR' within each concept, and 'AND' between the concepts.

Appendix B. Checklist for assessing EMG (manuscript 1)

CHECKLIST FOR ASSESSING THE EMG REPORTS IN STUDIES

Criteria		Yes (2)	Partial (1)	No (0)	N/A
Electrodes					
1	Types of electrodes clearly described?				
2	General technical information on electrodes				
Amplification					
3	Description of the amplification procedure				
4	Relevant information on the amplification procedure adequately reported?				
Filtering					
5	Band pass filters and filter types clearly described and well applied?				
6	Frequency range according to the ISEK standards?				
Rectification					
7	Wave rectification well described?				
8	Method of EMG processing adequately reported?				
Sampling into the computer					
9	Nyquist theorem well applied?				
10	Information on A/D Board available?				
Normalization					
11	Preliminary subjects training to obtain the MVC?				
12	Muscle contraction analysed in sufficient details?				
EMG Crosstalk					
13	Information on EMG crosstalk				

SUMMARY SCORE (SS)

Total Sum (TS): *(number of "YES" * 2) + (number of "PARTIAL")*

Possible Sum (PS): *26 – (number of "N/A" * 2)*

Summary Score (SS): TS / PS

Definitions and Instructions for Assessment Scoring of EMG reports in randomized controlled studies

1. Types of electrodes clearly described?

(If the type of electrodes used to acquire the EMG data is described: *surface EMG, intramuscular wire, needle electrodes,* including basic characteristics of it as *material, geometry, size, single- or multi-strand, insulation material and etc.*)

Yes: The type of electrodes used in the data acquisition is easily identified in the section material and methods/methodology.

Partial: The type of electrodes is vaguely or incompletely reported or it is reported in other section.

No: The type of electrodes is not reported.

N/A: Should not be checked in this question.

2. General technical information on electrodes?

(If the study reports some of the most relevant technical information on the electrodes used, according to the type of EMG measurement.)

For Surface EMG: interelectrode distance, placement, orientation and cleansing the skin (skin preparation).

For Intramuscular wire: length of the exposed tip, method of insertion, depth of insertion, single or bipolar wire, location of insertion in the muscle, interelectrode distance, type and location of the ground.

For Needle electrodes: material, size of conductive contact points at the tip, depth of insertion and accurate location in the muscle.

Yes: Most relevant technical information of the electrodes is reported (taking into consideration the EMG type chosen).

Partial: The information/characteristics of the electrodes used are identified but most relevant technical information of the electrodes is missing.

No: Most relevant technical information of the electrodes is not reported.

N/A: Should not be checked in this question.

3. Description of the amplification procedure (gain range, single, differential, double differential, etc.).

Yes: The amplification procedure is clearly identified in the section material and methods/methodology.

Partial: The amplification procedure is vaguely or incompletely reported or they are reported in other section.

No: The amplification procedure is not described.

N/A: Should not be checked in this question.

4. Relevant information on noise processing.

(If the study reports the most relevant information on noise processing: *input impedance, Common Mode Rejection Ratio (CMRR) and signal-to-noise ratio.*)

Yes: Most of the relevant information on noise processing is approached in the section material and methods/methodology.

Partial: Most relevant information on noise processing is not clear, incomplete or, when reported, it is reported in other section.

No: There is no information on the noise processing available in the manuscript.

N/A: Should not be checked in this question.

5. Band pass filters and filter types clearly described and well applied?

Yes: The filtering of raw EMG data is adequately described, permitting the reader to relate the band pass filters (low or high pass filters) and the filter type (ex., Butterworth, Chebyshev, etc.) applied.

Partial: The filtering process is partially or incompletely described or the band pass filter or filter type is not clearly reported.

No: The band pass filters and filter type are not described.

N/A: Should not be checked in this question.

6. Frequency range according to the ISEK standards?

(If the frequency range is appropriately described and according to the ISEK recommendations.)

For Surface EMG: low cut-off equal/below 10Hz; high cut-off equal/above 350Hz).

For Intramuscular EMG: band pass filter of 10 – 450Hz).

For Needle recording: bandwidth of 10 – 1,500Hz.

Yes: The frequency range followed the ISEK recommendations, taking into consideration the EMG measurement chosen.

Partial: The parameters of the filter are not fully in line with the ISEK standards (one of the cut-offs is not in line with ISEK recommendations).

No: The frequency range did not follow the ISEK standards for reporting EMG data.

N/A: Should not be checked in this question.

7. Wave rectification well described?

Yes: The wave rectification carried out is adequate and it is well described in the section material and methods/methodology.

Partial: The wave rectification was carried out but the type (full or half wave) is not identified or it is not adequate.

No: The wave rectification is not described.

N/A: Should not be checked in this question.

8. Method of EMG processing adequately reported?

(If the study reports the processing EMG methods applied: smoothing, root mean square, integrals, power density spectra.)

Yes: The method of EMG processing is clearly and adequately described.

Smoothing: band pass filter reported in ms; linear envelope; mean absolute value.

Root Mean Square (RMS): time window.

Integrated EMG: threshold, time or voltage used to reset the integrator.

Power Density Spectra: time epoch used for calculation segment; algorithm like Fast Fourier Transform (FFT); type of windows prior FFT; number of zero padding applied; equation used to calculate the Median Frequency (MDF), Mean Frequency (MNF) and etc.; muscle length at the time of recording.

Other techniques fully scientifically described.

Partial: The method of EMG processing is mentioned but not adequately specified or described.

No: The method of EMG processing is not described.

N/A: Should not be checked in this question.

9. Nyquist theorem applied?

Yes: Sampling theorem well applied and clearly identified.

Partial: Sampling theorem applied but not mentioned by the authors.

No: The sampling theorem not applied.

N/A: Should not be checked in this question.

10. Information on A/D Board available?

(If the study provides information on A/D converter (number of bits, model, and manufacturer), offline analysis and/or storage in a computer.

Yes: Information on A/D board, offline analysis and/or storage in a computer is available in the manuscript.

Partial: Information on A/D board, offline analysis and/or storage in a computer is incomplete or hardly identified.

No: There is no information about the A/D board, offline analysis and/or storage in a computer.

N/A: Should not be checked in this question.

11. Preliminary subjects training to obtain the MVC?

(If the subjects were trained before to obtain the true maximal voluntary contraction (MVC) in force/torque analysis)

Yes: The authors report the subjects were trained.

Partial: There is some information about subjects training but not enough to replicate.

No: There is no information about subjects training or there is information the subjects were not trained before the MVC data acquisition.

N/A: The study did not analyze force/torque.

12. Muscle contraction analysed in sufficient details?

For isometric contraction: joint angle or muscle length, angles of adjoining joint, rate of rising force.

For non-isometric contraction: rate of rise of force, range of joints angle/muscle length, changes in the muscle length, velocity of shortening/elongation and load applied.

Yes: Most relevant items are clearly reported in the manuscript.

Partial: Some relevant information is missing.

No: There are no sufficient details related to the type of muscle contraction.

N/A: Should not be checked in this question.

13. Information on EMG crosstalk

(If the manuscript provides information on the EMG crosstalk from others muscles near the muscle of interest did not contaminate the recorded EMG signal.)

Yes: The authors made significant efforts to identify, determine and avoid the contamination by EMG crosstalk.

Partial: The authors identify EMG crosstalk or their efforts to avoid signals contamination, but there is not enough information to reproduce it.

No: Efforts to avoid or determine EMG crosstalk contamination is not reported.

N/A: There is no EMG crosstalk in the data acquisition.

Appendix C. Recruiting email

Courriel pour le recrutement (liste d'envoi de l'Univeristé Laval)

Avez-vous une douleur à l'épaule?
Si oui, participez à notre projet de recherche!

Dans le cadre d'une étude visant à **évaluer l'efficacité d'un programme de réadaptation sur les symptômes et incapacités liés aux douleurs à l'épaule**, nous sommes à la recherche de personnes souffrant de douleurs à l'épaule associées à une tendinopathie, et respectant les critères suivants:

- ✓ Être agé entre 18 et 65 ans;
- ✓ Présenter une douleur à l'épaule (tendinitis/tendinopathie);
- ✓ Pouvoir participer à:
  - ✓ 4 séances d'évaluation sur un période de 6 semaines.
  - ✓ un programme de réadaptation composé de 12 séances de physiothérapie sur une période de 6 semaines (séances de physiothérapie gratuites).

Toutes les activités seront effectuées au centre de recherche CIRRIS (525, boulevard Wilfrid-Hamel, Québec).

Vous n'aurez pas à defrayer le coût du traitment.

Durant les évaluations vous aurez à compléter des questionnaires, à réaliser des mouvements du bras, ainsi que des examens d'imagerie et des examens permettant d'évaluer l'activité musculaire de l'épaule.

Une compensation financière de 20$ vous sera remise à chacune des séances d'évaluation afin de couvrir vos frais de déplacement. Les coûts du stationnement seront couverts pour chaque intervention en physiothérapie.

Si vous êtes intéressés à participer ou si vous désirez obtenir des renseignements additionnels, contactez Fábio Oliveira par courriel fabio-carlos.lucas-de-oliveira.1@ulaval.ca.

Au plaisir de vous rencontrer !

Fábio Carlos Lucas de Oliveira, étudiant au doctorat en médecine expérimentale – réadaptation. Faculté de médecine, Université Laval.

Ce projet est sous la responsabilité de Jean-Sébastien Roy, Ph.D., chercheur au CIRRIS et professeur au département de réadaptation de l'Université Laval. Le projet a été approuvé par le comité d'éthique de la recherche du IRDPQ (projet #2016-496).

Appendix D. Recruiting poster

RECHERCHE DE PARTICIPANTS AVEC DOULEURS À L'ÉPAULE

Pour un projet intitulé: Effets d'un programme de réadaptation sur les symptômes et les limitations fonctionnelles des personnes présentant une tendinopathie de la coiffe des rotateurs.

CRITÈRES D'INCLUSION:

- ✓ Être agé entre 18 et 65 ans;
- ✓ Présenter une douleur à l'épaule (tendinitis/tendinopathie);
- ✓ Pouvoir participer à:
  - 4 séances d'évaluation sur un période de 6 semaines
  - ✓ un programme de réadaptation composé de 12 séances de physiothérapie.

CRITÈRES D'EXCLUSION:

- ➢ antécédent d'intervention chirurgicale à l'épaule;
- ➢ capsulite à l'épaule;
- ➢ antécédent de subluxation ou luxation glenohumérale;
- ➢ antécédent de fracture à l'épaule.

Pour tous renseignements, contactez : Fábio Oliveira, étudiant au doctorat en médecine expérimentale

Courriel: fabio-carlos.lucas-de-oliveira.1@ulaval.ca
Téléphone: 418-529-9141 poste 6043

Toutes les activités se dérouleront au CIRRIS (525, boulevard Wilfrid-Hamel, Québec).
Une compensation financière de 20$ vous sera remise à chacune des séances d'évaluation afin de couvrir vos frais de déplacement. Les coûts du stationnement seront couverts pour chaque intervention en physiothérapie.

Projet de recherche approuvé par le comité d'éthique de l'IRDPQ.

Ce projet est sous la responsabilité de Jean-Sébastien Roy, Ph.D., chercheur au CIRRIS et professeur au département de réadaptation de l'Université Laval. Le projet a été approuvé par le comité d'éthique de la recherche du IRDPQ (projet #2016-496).

Appendix E. Telephone interview – Primary screening

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

ENTRETIEN TÉLÉPHONIQUE – Dépistage primaire

Avant de prendre rendez-vous, pouvez-vous répondre aux questions suivantes:

1. Quel âge avez-vous?		
	Oui	Non
2. Avez-vous une plaie en cours de cicatrisation sur l'épaule douloureuse?		
3. Avez-vous subi une chirurgie à l'épaule ou à la colonne cervico-thoracique?		
4. Lorsque vous levez votre bras par l'avant et jusqu'à votre maximum, ressentez-vous de la douleur?		
5. Lorsque vous levez votre bras par le côté et jusqu'à votre maximum, ressentez-vous de la douleur?		
6. Avez-vous déjà subi une luxation (déboitement) de l'épaule?		
7. Avez-vous déjà subi une fracture à l'épaule?		
8. Ressentez-vous des douleurs au cou ou dans le haut du dos?		
9. Avez-vous reçu une infiltration (injection pour la douleur à l'épaule)?		
10. Si oui, combien et de quand date la dernière infiltration?		
11. 10. Avez-vous reçu un diagnostic de capsulite?		
12. 11. Prenez-vous des médicaments pour une autre condition que l'épaule?		
13. Si oui, quel type de médicament (anti-inflammatoires, antalgiques, …)?		
14. 12. Êtes-vous disponible pour participer à un programme de physiothérapie pendant 6 semaines (10 sessions de physiothérapie)?		
15. 13. Faites-vous du sport? Si oui, lequel?		

Appendix F. Eligibility criteria form and clinical tests

Effets d'un programme de réadaptation sur les symptômes et les limitations fonctionnelles des personnes présentant une tendinopathie de la coiffe des rotateurs: Un essai clinique randomisé à simple insu

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

CRITÈRES D'ELIGIBILITÉ

1. CRITÉRES D'INCLUSION			
1.1. Age entre 18 et 65 ans*		Oui ( )	Non ( )
1.2. Diagnostiqué avec tendinopathie de la coiffe des rotateurs		Oui ( ) Unilatéral ( ) Bilatéral ( )	Non ( )
1.3. Répondre positivement à au moins un des tests cliniques suivants:			
1.3.1. Arc de mouvement dolorous	a) *Flexion*	Positif ( )	Négatif ( )
	b) *Abduction*	Positif ( )	Négatif ( )
1.3.2. Tests cliniques positifs	a) *Neer*	Positif ( )	Négatif ( )
	b) *Kennedy-Hawkins*	Positif ( )	Négatif ( )
1.3.3. Douleur lors des mouvements isométriques résistés	a) *Rotation externe*	Positif ( )	Négatif ( )
	b) *Abduction*	Positif ( )	Négatif ( )
	c) Test de Jobe (empty can)	Positif ( )	Négatif ( )

2. CRITÉRES D'EXCLUSION		
2.1. Plaie ouverte qui compromettre l'application du kinesiotaping.*	Oui ( )	Non ( )
2.2. Antécédent de chirurgie à l'épaule ou à la colonne cervicothoracique*	Oui ( )	Non ( )
2.3. Allergie ou intolérance au kinesiotaping*	Oui ( )	Non ( )
2.4. Patron capsulaire glenohumeral (adhésive capsulite)*	Oui ( )	Non ( )
2.5. Antécédent de luxation de l'articulation glenohumeral*	Oui ( )	Non ( )
2.6. Antécédent de fracture à l'épaule*	Oui ( )	Non ( )
2.7. Douleur à l'épaule reproduite par symptômes liées à la colonne cervicale (cervicobrachialgie, myalgie du trapèze, thoracique haut)	Oui ( )	Non ( )
2.8. Signes cliniques d'une rupture complète de la coiffe des rotateurs (Lag signes)	Oui ( )	Non ( )

Avez-vous d'autres symptômes ou raison pour laquelle vous ne devriez pas participer à ce projet de recherche?Oui ( )Non ( )

Si OUI: _____

_____

MERCI DE VOTRE COLLABORATION!

Évaluateur : _____ Date : _____/_____/_____

* Questions déjà posées lors de l'entretien téléphonique.

Appendix G. Sociodemographic questionnaire

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

INFORMATIONS GÉNERALES

1. DONÉES SOCIODÉMOGRAPHIQUES ET ANTHROPOMÉTRIQUES		
Sexe	Masculin ( )	Féminin ( )
Date de naissance (jj/mm/aaaa)	Age: _____ ans |__|__|__|__|__|__|	
Taille (cm)	m |__|__|__|	in
Poids (Kg)	Kg |__|__|__|	lb
Dominance (Edinburgh Handedness Inventory)	Droite ( )	Gauche ( )
Côté atteint	Droit ( )	Gauche ( )
Niveau de scolarité	( ) Diplôme d'étude secondaire ( ) Diplôme d'étude collégial ( ) Autre, spécifier : _____	( ) Baccalauréat ( ) Maîtrise ( ) Doctorat
Occupation	( ) Travailleur à temps plein ( ) Travailleur à temps partiel ( ) Autre, spécifier : _____	( ) Sans emploi ( ) Retraité
Qu'est-ce que vous faites comme travail?	_____	

Type de votre occupation (fréquence/charge appliquée sur l'épaule) *Niveau d'activité*: I- sédentaire; II (1A, 1B, 2A)- léger; III (1C, 2B, 2C)- modéré; IV (3A, 3B, 3C)- élevé.	**Fréquence** **Charge (Kg)**	**A : rarement**	**B : < 3 fois semaine**	**C : continu**
	0	I	I	I
	1 : < 15	II	II	III
	2 : 15 - 25	II	III	III
	3 : > 25	IV	IV	IV

Êtes-vous en arrêt de travail?	Oui ( )	Non ( )
Si oui, avez-vous une compensation financière? Laquelle?	( ) SAAQ ( ) IVAC	( ) CSST ( ) Assurances personnelles

HISTOIRE ACTUELLE DE L'ÉPAULE ATTEINTE		
Depuis combien de temps avez-vous des problèmes/douleurs d'épaule?	_____ mois ou _____ années	
Qu'est-ce qui est à l'origine de ce problème/douleur à l'épaule?	( ) Je ne le sais pas *( ) Accident/chute, spécifier:*_____ *( ) Mouvements répétitifs* *( ) Aux sports* *( ) Début insidieux* ( ) Autre, spécifier : _____	
Avez-vous eu des traitements de physiothérapie pour votre problème/douleur à l'épaule?	Oui ( ) Combien : Quand? Début : Fin :	Non ( )
a) Si Oui, quel type de traitement de physiothérapie avez-vous reçu?		

2.2. Avez-vous eu d'autres traitements pour votre épaule?	Oui ( )	Non ( )
a) Si Oui, quel type de traitement de physiothérapie avez-vous reçu?	Chiropraxie ( ) Acupuncture ( ) Autre, spécifier: _____	
2.3. Actuellement, faites-vous un programme d'exercices ?	Oui ( )	Non ( )
2.4. Avez-vous déjà eu d'autre(s) épisode(s) de problème/douleur à votre épaule?	Oui ( )	Non ( )
a) Si Oui, combien d'épisode(s)?		
2.5. Avez-vous déjà eu une ou des infiltration(s) à votre épaule?	Oui ( )	Non ( )
a) Si Oui, combien et à quand remonte la dernière?		
2.6. Prenez-vous des médicaments pour réduire la douleur?	Oui ( )	Non ( )
a) Si Oui, lequel/lequels?		

3. CONDITION DE SANTÉ GÉNÉRALE		
3.1. Marquez les conditions que vous avez.		
a) Problème cardiaque	Oui ( )	Non ( )
b) Problème pulmonaire chronique d'asthme	Oui ( )	Non ( )
c) Hypertension artérielle	Oui ( )	Non ( )
d) Diabète	Oui ( )	Non ( )
e) Problème rénal	Oui ( )	Non ( )
f) Problème neurologique	Oui ( )	Non ( )
g) Cancer	Oui ( )	Non ( )
4. ANTÉCEDENTS CHIRURGICAUX		
4.1. Avez-vous déjà subi une chirurgie à une articulation (bras, jambes, cou, dos)?	Oui ( )	Non ( )
a) Si Oui, lequel/lequels?		
4.2. <u>Pour les femmes</u>: Avez-vous déjà subi une intervention chirurgicale dans l'abdomen (par exemple, de l'utérus, césarienne, etc.)?	Oui ( )	Non ( )
a) Si Oui, lequel/lequels?		
5. MÉDICATION		
5.1. Prenez-vous des médicaments <u>autres que</u> pour atténuer la douleur ?	Oui ( )	Non ( )
a) Si Oui, lequel/lequels?		
6. CONDITION À D'AUTRES ARTICULATIONS DES MEMBRES SUPÉRIEURES		
6.1. Avez-vous des douleurs/problèmes à d'autres articulations des membres supérieurs (au cou ou à la région dorsale)?	Oui ( )	Non ( )
a) Si Oui, lequel/lequels?		

Évaluateur : _____ Date : _____/_____/_____

Appendix H. Anamnese

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

ANAMNESE

HISTORY OF THE SHOULDER INJURY
Diagnosed injury:
Previous history of the injury:
Complementary exams:
What's is the patient's age?
What was the injury mechanism? (in case of an extrinsic factor)
Is the shoulder kept in a protected position?
How long has the patient been committed by this shoulder injury?
Are there signs of muscle spasms, deformity, atrophy, paresthesia?
Is there weakness and heavy upper-limb sensation after some activity?
Is there any sign of nerve injury?
What is the dominant hand?
How is the level of shoulder restriction?
Does the movement increase the level and intensity of pain?
Which activities increase the pain level?
What are the movements causing pain? What is the frequency of the pain?
When and where does the pain begin (during the movement)?
Is there any abnormality in the pattern of movement?
How about dyskinesis and scapular rhythm. Are they abnormal?

Appendix I. Outcome assessments forms – acromiohumeral distance (AHD), range of motion (ROM), and shoulder proprioception

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

Évaluation: ( ) initiale( ) finale( ) 1ére séance d'évaluation
Essais de test: ____ essai

DISTANCE ACROMIOHUMÉRALE
Acromiohumeral Distance

1. DISTANCE ACROMIOHUMÉRALE (cm)					
1.1. Épaule saine (assis)	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
1.1.1. At rest (0º d'abduction)					
1.1.2. 60º d'abduction verticale					
1.2. Épaule atteinte (assis)	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
1.2.1. At rest (0º d'abduction)					
1.2.2. 60º d'abduction verticale					

Évaluateur : _____ Date : _____/_____/_____

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

Évaluation: ( ) initiale( ) finale
Essais de test: ____ essais

AMPLITUDE DE MOUVEMENT ARTICULAIRE ACTIVES
(Active Range of Motion; digital inclinometer)

2. SANS DOULEUR (º)					
2.1. ABDUCTION	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
2.1.1. Épaule saine					
2.1.2. Épaule atteinte					
2.2. FLEXION	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
2.2.1. Épaule saine					
2.2.2. Épaule atteinte					

3. AMPLITUDE COMPLÈTE (º)					
3.1. ABDUCTION	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
~~3.1.1. Épaule saine~~			-	-	-
3.1.2. Épaule atteinte					
3.2. FLEXION	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
~~3.2.1. Épaule saine~~			-	-	-
3.2.2. Épaule atteinte					

Évaluateur : _____ Date : _____/_____/_____

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

Évaluation: ( ) initiale( ) finale( ) 1ére séance d'évaluation
Essais de test: ____ essai

DISTANCE ACROMIOHUMÉRALE (l'étude transversale)
Épaule atteinte

4. DISTANCE ACROMIOHUMÉRALE (mm)					
4.1. Sans KT (assis)	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
4.1.1. At rest (0º d'abduction)					
4.1.2. 60º d'abduction verticale					
4.2. Avec KT (assis)	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
4.2.1. At rest (0º d'abduction)					
4.2.2. 60º d'abduction verticale					

MERCI POUR VOTRE COLLABORATION!

Évaluateur : _____ Date : _____/_____/_____

Numéro d'identification: _____Date d'évaluation: _____/_____/_____

PROPRIOCEPTION (repositionnement articulaire)
Proprioception (joint repositioning)

SANS KINESIOTAPING

5. Épaule sains					
5.1. Forward flexion	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
5.1.1. Low range (45º – 65º)					
5.1.2. Middle range (80º – 100º)					
5.2. Vertical abduction	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
5.2.1. Low range (45º – 65º)					
5.2.2. Middle range (80º – 100º)					

6. Épaule atteinte					
6.1. Forward flexion	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
6.1.1. Low range (45º – 65º)					
6.1.2. Middle range (80º – 100º)					
6.2. Vertical abduction	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
6.2.1. Low range (45º – 65º)					
6.2.2. Middle range (80º – 100º)					

AVEC KINESIOTAPING

7. Épaule atteinte					
7.1. Forward flexion	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
7.1.1. Low range (45º – 65º)					
7.1.2. Middle range (80º – 100º)					
7.2. Vertical abduction	Droite ( )	Gauche ( )	Essai 1	Essai 2	Essai 3
7.2.1. Low range (45º – 65º)					
7.2.2. Middle range (80º – 100º)					

Évaluateur : _____ Date : _____/_____/_____

Appendix J. Assessor and participants blinding evaluation (manuscript 4)

Numéro d'identification: _____Date d'évaluation: _____/_____/_____
Semaine 3 ( )Semaine 6 ( )

ÉVALUATION DE SUIVI

ASSIGNATION AUX GROUPES – ÉVALUATION PAR L'ÉVALUATEUR

Au début de l'étude, le sujet a été assigné à l'un des deux programmes de réadaptation à l'étude. Selon vous, quelle intervention le sujet a-t-il reçue?

Intervention reçue	Cochez
1 – Intervention conventionnelle.	
2 – Intervention permettant de tester une nouvelle technique de traitement.	
3 – Aucune idée	

Si vous croyez connaitre l'intervention que le sujet a reçue, quels sont les éléments qui vous font croire qu'il a reçu cette intervention :

ÉVALUATEUR :

Numéro d'identification: _____Date d'évaluation: _____/_____/_____
Semaine 3 ( )Semaine 6 ( )

ÉVALUATION DE SUIVI
ASSIGNATION AUX GROUPES – ÉVALUATION PAR LE SUJET

Au début de l'étude, vous avez été assigné(e) à l'une des deux interventions à l'étude. Selon vous, quelle intervention avez-vous reçue?

Intervention reçue	Cochez
1 – Intervention conventionnelle.	
2 – Intervention permettant de tester une nouvelle technique de traitement.	
3 – Aucune idée	

Si vous croyez connaitre l'intervention que vous avez reçue, quels sont les éléments qui vous font croire que vous avez reçu cette intervention :

Appendix K. Home exercises adherence form

Numéro d'identification: _____Date d'évaluation: _____/_____/_____Session #____

BILAN DES ACTIVITÉS À DOMICILE

1. EXERCISES À DOMICILE		
1. Avez-vous fait les exercises d'entreînament du mouvement indiqué par le physiothérapeute?	Oui ( )	Non ( )
1.1 Si Oui, combien d'exercises et combien de jour par semaine?		
2. Avez-vous fait les exercises de renforcement musculaire indiqué par le physiothérapeute?	Oui ( )	Non ( )
2.1 Si Oui, combien d'exercises et combien de jour par semaine?		
3. Avez-vous fait les étirements indiqué par le physiothérapeute?	Oui ( )	Non ( )
3.1 Si Oui, combien d'exercises et combien de jour par semaine?		

2. AUTRES INTERVENTIONS		
2.1 Avez-vous pris un médicament prescrit pour votre épaule depuis la première évaluation?	Oui ( )	Non ( )
2.1.1. Si oui, lequel ou lesquels et à quelle fréquence?		
2.2 Avez-vous fait des activités sportives depuis la première évaluation?	Oui ( )	Non ( )
2.2.1 Si Oui, avez-vous ressenti une augmentation de douleur à l'épaule?	Oui ( )	Non ( )
2.3 Avez-vous fait des travaux manuels avec l'aide de votre bras (en dehors du travail habituel) depuis la première évaluation?	Oui ( )	Non ( )
2.3.1 Si Oui, avez-vous ressenti une augmentation de douleur à l'épaule?	Oui ( )	Non ( )
2.4 Avez-vous consulté d'autres professionnels depuis la première évaluation?	Oui ( )	Non ( )
2.4.1. Si Oui, quel(s) professionnel(s)?		

MERCI POUR VOTRE COLLABORATION!

Évaluateur : _____ Date : _____/_____/_____

Appendix L. Rehabilitation programme (manuscript 4)

Techniques included in the rehabilitation programme

All interventions were conducted at the laboratory of clinical evaluation of the CIRRIS (Center for Interdisciplinary Research in Rehabilitation and Social Integration) and were supervised by the same physiotherapist.

Part A. SENSORIMOTOR TRAINING

2 to 3 sets of 3 to 10 repetitions

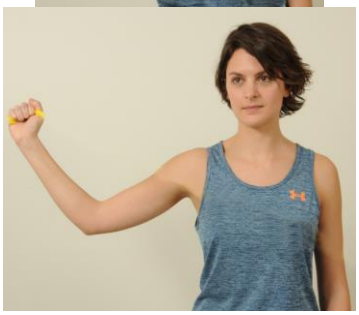
At least 75% of each session was devoted to sensorimotor training, which started with re-learning of shoulder control. Shoulder control exercises aiming the re-education of the participants for a proper shoulder movement control and correction of kinematic alterations,[6,7] with progressive complexity in terms of movement plane (frontal, sagittal, and scapular), range of motion, and speed.

Exercises were initially performed in 10 repetitions. When no fatigue or pain was felt during the first set, another set of 10 repetitions was added, up to a maximum of three sets. When proper shoulder control was achieved, without fatigue or pain, participants progressed to the next phase of exercises.

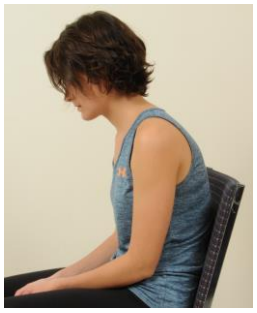
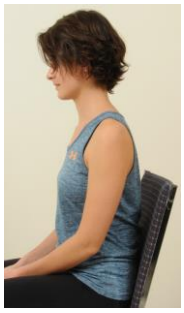
All techniques were performed pain-free and were ceased immediately in a presence of pain.[270,271] Participants were instructed to perform home exercises, without supervision and tailored to individual needs, throughout the treatment and follow-up period.

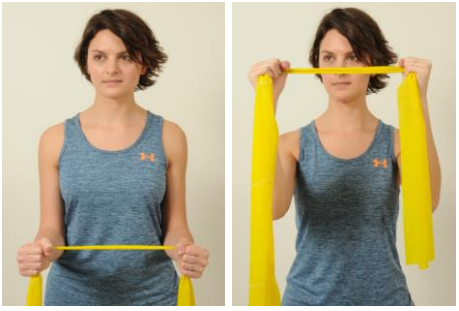
Work- or sport-specific movement training was also performed according to the participant's activities.

Exercises	Description	Illustrations
1. Arm elevation in the frontal plane	Keep the arm straight, thumbs up, and slowly raise the arm until 90º of vertical abduction or close to the painful point, without shrugging or elevating shoulder.	
2. Arm elevation in the sagittal plane	Keep the arm straight, thumbs up, and slowly raise the arm as far as until 90º of forward flexion or close to the painful point, without shrugging the shoulder.	
3. Arm elevation in the scapular plane (scaption)	Keep the arm straight, thumbs up, and slowly raise the arm as far as until 90º of scaption or close to the painful point, without shrugging the shoulder.	

4. Arm elevation in diagonal planes	With arm straight and hand at the contralateral waist level, raise the arm upward and away from your body. Follow the hand motion with your eyes.	 
5. Shoulder external rotation with the arm in abduction (45 – 90º)	Place the arm in abduction at or below shoulder level, elbow bent at 90º, and arm in internal rotation parallel to the ground with palms down toward the floor. Rotate the forearm backward, keeping elbow at 90º, without shrugging or elevating shoulder.	 

Phase 1: *active assisted movement, no resistance, with manual, verbal and visual feedback.*
Phase 2: *active movement, no resistance, with manual, verbal and visual feedback.*
Phase 3: *active movement, no resistance, with verbal and visual feedback.*
Phase 4: *active movement, no resistance, with verbal feedback.*
Phase 5: *faster active movement, external resistance, without feedback*

Exercises	**Description**	**Illustrations**
6. Scapular girdle posture control	Relax the body in flexion of trunk. Then, with arms alongside the body, correct your posture by bringing the chin in a tuck position, while placing the spine straight up and pulling shoulder blades down and back. Emphasis on keeping the motion horizontal, avoiding tilting the head back or looking at the ceiling, and avoiding shoulder elevation.	 

7. Cervical retroaction for postural re-education	Seated straight up, slowly move your head straight back and keep the chin in a tuck position while pulling shoulder blades down and back. Hold the position for 3-5 seconds. Emphasis on keeping the motion horizontal and avoiding tilting the head back or looking at the ceiling.	
8. Scapular position control during shoulder extension	Grasp the extremities of the band with both hands. With elbow straight and slightly apart of the body, rotate the arms externally and extend your arms backward, not shrugging the shoulder and not surpassing the level of buttocks.	
9. Scapular position control during external rotation in lateral decubitus	Lying sideways with one arm holding a dumbbell and the other hand under the ear so that you can rest your head on it. Keep the elbow of the arm holding the dumbbell at 90º flexion and the other arm parallel to your trunk. The upper arm will be parallel to the floor and stationary by your trunk. Thus, the hand holding the dumbbell will be in front of you. Then, rotate externally your forearm lifting the dumbbell without moving the trunk and shoulder. As you breathe, slowly return to your starting position.	 
10. Wall Push-Up	Facing a wall, standing a little farther than arm's length away, elbow in semi-flexion, and feet shoulder-width apart. Lean your body backward, by straightening the arms, and spreading both scapulae. Hold the position for 1-2 seconds. Breathe out and slowly reposition the scapula.	
11. Scapular control with hands on the wall	Standing, elbow flexed at 90º, holding a light resistance elastic band with both hands shoulder-width apart. Move both hands up to eyes level or at the painful point, without losing the elbow angle (90º) and without elevating shoulder. Hold the final position for 5 seconds, then, return to initial position slowly. 2 sets of 3 repetitions. Progression should increase the number of sets.	

Part B. MANUAL THERAPY

3 repetitions of 60 seconds duration each.

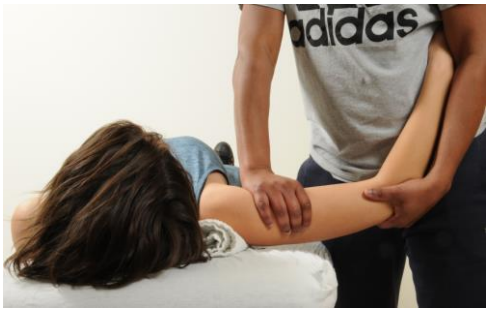
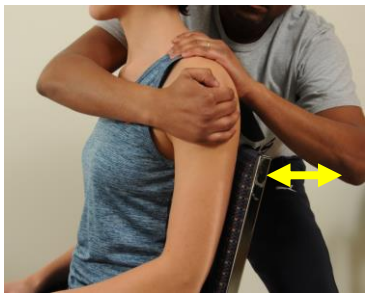
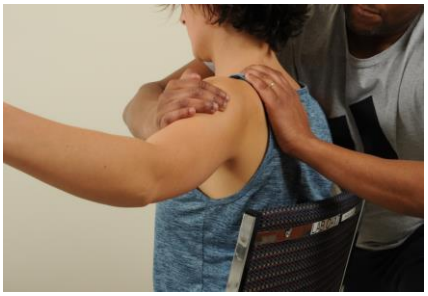
Non-thrust joint mobilisation techniques applied on sternoclavicular, acromioclavicular, glenohumeral, and thoracic spine[126] to provide breaking up adhesions when ligamentous and capsular restraints were identified in those regions during initial evaluation.[126,269-271]

Capsular restraints were clinically evaluated through a passive range of motion and mobility tests to identify the pattern of limitation. Based on the quality of movement at the very end of the available amplitude, an end feel perception of "leathery" indicated a capsular restraint.

Once its need was confirmed, at least one technique was performed for each targeted area, three times for approximately 60-sec, with a between-set rest interval of 30-sec.[269]

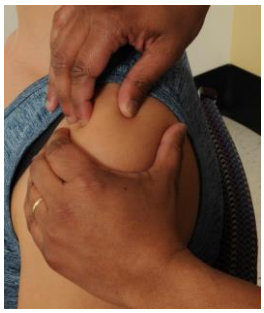
All techniques were pain-free and were ceased immediately in a presence of pain.[270,271]

Anterior and posterior shoulder techniques

Technique	Description	Illustrations
1. Glenohumeral glide (AP)	Patients lying supine, with arms in abduction (humeral position may vary). A towel is placed under scapula. Clinician stays between the arm and the patient's body, stabilizing the patient's elbow with his distal hand. The proximal hand is placed at the humeral head, where a glide in the posterior direction is applied.	
2. Glenohumeral mobilization (PA-AP)	Patients seated. While scapula is stabilized by one hand, the other wrap around the humeral head. Anterior and posterior glides are applied alternately.	
3. Mulligan's MWM (mobilization with movement)	Patients seated. While scapula is stabilized by one hand, the other wrap around the humeral head. A constant force in the posterior direction is applied as the patient actively elevates and lowers the arm.	

Inferior shoulder and clavicle techniques

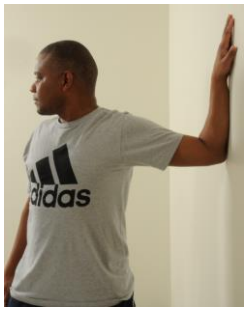
Technique	Description	Illustrations

4. Glenohumeral glide	Patients lying supine, with arm slightly over 90° of abduction. Clinician stabilizes the elbow of the arm abducted with one hand, while the other hand is placed on the humeral head, where inferior glide is applied.	
5. Clavicle glide (PA)	Patients seated, head in neutral position or turned away. Clinician stabilizes the shoulder by wrapping it laterally. With the other hand, pinches the distal clavicle with a thumb and index, and mobilise the acromion in anterior direction.	
6. Sternoclavicular glide	Patients lying supine, head in neutral position. Clinician, positioned behind the patient, stabilises clavicle with the thenar region of one hand, and place the thumb on clavicle's proximal end. Thumb over thumb, glide clavicle diagonally, in inferior-posterior direction.	

Part C. STRETCHING EXERCISES

2 x 30 seconds

Used as home exercises to enhance the flexibility of the pectoralis minor, glenohumeral joint capsule, and underlying soft tissues, according to individual needs.

Exercise	Description	Illustrations
1. Shoulder internal rotation towel stretch	Patients seated or standing while holding a towel with the affected arm behind the back, using the other arm to pull the affected arm up the back.	
2. Active and passive cross-body stretch	Patients seated or standing hold the affected elbow with the opposite hand in front of the body and slowly pull the elbow across the body until they felt a comfortable stretch. In the passive technique, the clinician uses the thenar eminence to stabilize the scapula medially.	 
3. Pectoral muscle stretch	Patients standing with forearm and palm also on the wall. Then, slowly turn the upper body away from the wall.	 
4. Shoulder flexion stretch	Patients hold a stick or cane with both hands while lying supine and use the unaffected arm to raise both arms overhead until they felt a comfortable stretch.	
5. Shoulder external rotation stretch	Patients lying supine and resting the affected arm on a pillow, 15.2 cm (6 in) from the side with the elbow bent. Then, holding a stick or cane with both hands, they apply downward pressure to the affected arm by rotating it back.	

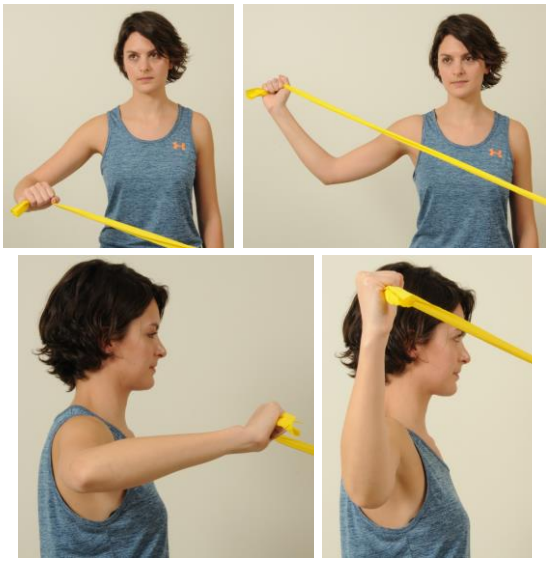
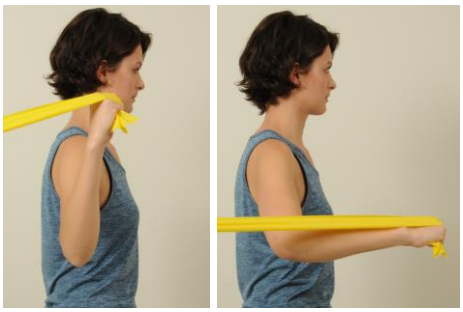
Part D. RESISTED EXERCISES

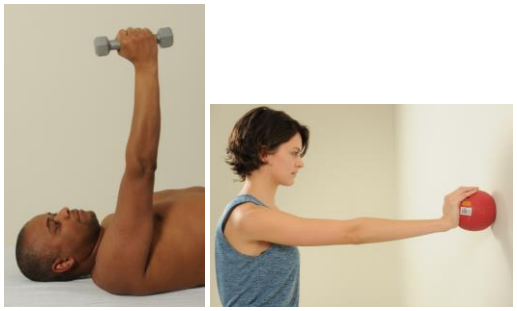
1 to 3 sets of 10 to 15 repetitions.

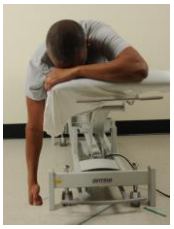
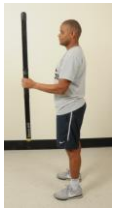
Free weight, extremities weight,[6,7] and resistance elastic tube[272] used to reinforce RC and scapular stabilizers muscles, especially internal and external rotators, lower trapezius and serratus anterior.

Exercises progressed from movements at humeral neutral position (below 45º of elevation) to ascending arm movements (above 45º) to higher-level exercises (endurance training using Bodyblade [Mad Dogg Athletics, Venice, CA, USA] at multiple levels of arm elevation, and trunk strengthening).[6,7,126,273]

Exercises varied according to the resistance level and feedback (verbal and visual, with or without).[34] Progression of the resistance elastic band exercises was based on Andersen *et al*.[272] Participants advanced to the next colour when the exercises were properly performed (without compensatory movements), indicating adequate shoulder control, and three sets of 10 repetitions were performed without substantial feeling of pain or fatigue.[126,129,273] Thereon, participants were requested to perform these exercises at home, without supervision, in 3 sets of 10 repetitions a day.

Exercise	Description	Illustrations
Phase 1 (light resistance: yellow and red elastic band)		
1. Resisted shoulder external rotation	Shoulder external rotation starting in approximately 45º of internal rotation, slightly crossing the body, with elbow flexed to 90º. Rotate the arm out so that it is lined up with the side of your body.	
2. Resisted shoulder internal rotation	Shoulder internal rotation starting in approximately 45º of external rotation, with the arm by the side and the elbow flexed to 90º. Rotate the arm in so that it crosses your body in approximately 45º of internal rotation.	

3. Resisted shoulder extension	Shoulder extension starting with the arm forward flexed approximately 45º.	
Phase 2 (medium resistance: green elastic band)		
4. Resisted scapular retraction	Scapular retraction starting with elbows flexed 90º, the shoulder in neutral rotation, and the arms by the side, pinching the scapulae.	
5. Resisted scapular protraction "Scapular punch"	Scapular protraction in the supine position, starting with elbow flexed to 90°. Then, punch arm up towards the ceiling, extending the arm, and lifting shoulder blade off the table. Alternatively, hold a medicine ball on the wall, keeping the shoulder down and back. With arms straight, push the heel of the hand forward to knead the ball, while protracting the shoulder. Hold the position and return slowly.	
6. "Scaption" (0º - 90°)	Lift band to shoulder level, staying in a plane of movement midway between front and side. The movement starts with the elbow extended, humerus in neutral rotation, thumb pointing up.	
7. Shoulder flexion (0°- 90°)	Lift band up to shoulder level at the sagittal plane (forward flexion). The movement starts with the elbow straight, humerus in neutral rotation, and thumb pointing up.	

8. Shoulder external rotation in 45º and 90° abduction	Standing facing doorway with the shoulder in 90° abduction, and elbow flexed at 90°. Movement pulling the band away from the door in external rotation (from 45° to 90°). Do not extend the elbow to complete the motion.	 
9. Shoulder internal rotation in 45º and 90° abduction	Standing facing away from the doorway with the shoulder in 90° of abduction, and elbow flexed at 90°. Movement pulling the band away from the door, in internal rotation (from 90° to maximum internal rotation as possible).	 
10. Shoulder horizontal abduction with scapular retraction, "T"	Lying prone, arms pendulum, and thumbs pointing up. Lift arm towards the ceiling in horizontal abduction, while squeezing shoulder blade towards the spine.	 
11. Shoulder elevation with scapular retraction, "Y"	Lying prone, arms pendulum, and thumbs pointing up. Lift arm diagonally above the shoulder towards the ceiling (arm elevation), squeezing shoulder blade towards the spine.	 
Phase 3 (medium/advanced resistance: blue elastic band)		
12. Bodyblade <60°	Hold Bodyblade below 60° of abduction. Exercises performed in both, horizontal and vertical planes.	 
13. Bodyblade >60°	Hold Bodyblade above 60° of abduction. Exercises performed in both, horizontal and vertical planes. *Only if exercise 12 is performed without discomfort or pain.	

14. Lawn mowner pull	Elastic tube anchored around a leg of the bed. Pull band diagonally overhead. Starting with feet at shoulder width apart, knees semi-flexed (isometric contraction), trunk flexed, and elbow extended at the level of the contralateral knee. Finish above 90° of abduction, in external rotation.	 
15. Hand and forearm plank	Place hands on the wall, bed, and floor, arms straight and slightly wider than shoulder-width apart, legs straight and toes grounded into the floor. Neck, spine, and shoulder should be aligned and motionless, and gluteus squeezed to stabilize the body. For the forearm plank, the forearm is placed on the bed instead of the hands. In both, position starts with shoulder blades protracted and hold the position.	 

Part E. PATIENT EDUCATION

General guidance provided verbally to enhance understanding of shoulder overload, pain neuroscience, pain management, posture, rehabilitation stages, graded exposure to exercise, body mechanics and movements that provoke impingement, besides verbal and written instructions regarding preferred shoulder positioning during sleep, work, and daily and sports activities.[126,273]

Exercises	Description
1. Sleeping	If you sleep well and wake up without pain, do not change anything. If you have trouble sleeping because of your shoulder, avoid resting your arm over your head and letting your arm resting across your body (may decrease blood flow). Try propping your arm on a pillow to keep the arm slightly away from your side.
Daily activities	Avoid working with arms near or above horizontal. Keep your elbows near your body for any prolonged work. Keep objects close to the body when lifting, especially repetitive activities. Use a stool when a high reach is required.
Strenuous work/sports	Incorporate the spine and hips for extreme and overhead movements. Be sure your fitness level matches the task you are doing, do not go beyond your capacity. Avoid excessive fatigue, take breaks when needed. Use assistive devices whenever possible (eg, carts, lift trucks).
Posture and movements promoting impingement	Avoid overuse or prolonged static postures. Avoid movements of forward flexion in combination with internal rotation of the humerus.

REFERENCES

1. Desmeules F, Braen C, Lamontagne M, Dionne CE, Roy JS. Determinants and predictors of absenteeism and return-to-work in workers with shoulder disorders. *Work.* 2016;55(1):101-113.
2. St-Pierre C, Dionne CE, Desmeules F, Roy JS. Reliability, validity, and responsiveness of a Canadian French adaptation of the Western Ontario Rotator Cuff (WORC) index. *Journal of Hand Therapy.* 2015;28(3):292-298; quiz 299.
3. Hanratty CE, McVeigh JG, Kerr DP, et al. The effectiveness of physiotherapy exercises in subacromial impingement syndrome: a systematic review and meta-analysis. *Seminars in Arthritis and Rheumatism.* 2012;42(3):297-316.
4. Littlewood C, Ashton J, Chance-Larsen K, May S, Sturrock B. Exercise for rotator cuff tendinopathy: a systematic review. *Physiotherapy.* 2012;98(2):101-109.
5. Steuri R, Sattelmayer M, Elsig S, et al. Effectiveness of conservative interventions including exercise, manual therapy and medical management in adults with shoulder impingement: a systematic review and meta-analysis of RCTs. *British Journal of Sports Medicine.* 2017;51(18):1340-1347.
6. Roy JS, Moffet H, Hebert LJ, Lirette R. Effect of motor control and strengthening exercises on shoulder function in persons with impingement syndrome: a single-subject study design. *Manual Therapy.* 2009;14(2):180-188.
7. Savoie A, Mercier C, Desmeules F, Fremont P, Roy JS. Effects of a movement training oriented rehabilitation program on symptoms, functional limitations and acromiohumeral distance in individuals with subacromial pain syndrome. *Manual Therapy.* 2015;20(5):703-708.
8. Roy JS, Moffet H, McFadyen BJ. Upper limb motor strategies in persons with and without shoulder impingement syndrome across different speeds of movement. *Clinical Biomechanics.* 2008;23(10):1227-1236.
9. Halder AM, Itoi E, An KN. Anatomy and biomechanics of the shoulder. *Orthopedic Clinics of North America.* 2000;31(2):159-176.
10. Terry GC, Chopp TM. Functional anatomy of the shoulder. *Journal of Athletic Training.* 2000;35(3):248-255.
11. Kapandji IA. *The Physiology of the Joints: Annotated Diagrams of the Mechanics of the Human Joints. Vol. 2, Lower Limb.* Churchill Livingstone; 1987.
12. Ludewig PM, Braman JP. Shoulder impingement: biomechanical considerations in rehabilitation. *Manual Therapy.* 2011;16(1):33-39.
13. Codman EA. *The shoulder; rupture of the suprasupinatus tendon and other lesions in or about the subacromial bursa.* Thomas Todd Company, printers; 1934.
14. MacConnail M, Basmajian J. *Muscles and Movements: a basis for human kinesiology.* Baltimore, MD: Williams & Wilkins Co.; 1969.
15. Laudner KG, Sipes RC, Wilson JT. The acute effects of sleeper stretches on shoulder range of motion. *Journal of Athletic Training.* 2008;43(4):359-363.
16. McClure P, Balaicuis J, Heiland D, Broersma ME, Thorndike CK, Wood A. A randomized controlled comparison of stretching procedures for posterior shoulder tightness. *Journal of Orthopaedic and Sports Physical Therapy.* 2007;37(3):108-114.
17. Burkhead WZ. *Rotator cuff disorders.* Michigan, USA: Lippincott Williams & Wilkins; 1996.
18. Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clinical Biomechanics.* 2003;18(5):369-379.
19. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Physical Therapy.* 2000;80(3):276-291.

20. Ludewig PM, Cook TM. Translations of the humerus in persons with shoulder impingement symptoms. *Journal of Orthopaedic and Sports Physical Therapy.* 2002;32(6):248-259.
21. Luime JJ, Verhagen AP, Miedema HS, et al. Does this patient have an instability of the shoulder or a labrum lesion? *JAMA.* 2004;292(16):1989-1999.
22. Myers JB, Wassinger CA, Lephart SM. Sensorimotor contribution to shoulder stability: effect of injury and rehabilitation. *Manual Therapy.* 2006;11(3):197-201.
23. Veeger HE, van der Helm FC. Shoulder function: the perfect compromise between mobility and stability. *Journal of Biomechanics.* 2007;40(10):2119-2129.
24. Santos MJ, Belangero WD, Almeida GL. The effect of joint instability on latency and recruitment order of the shoulder muscles. *Journal of Electromyography and Kinesiology.* 2007;17(2):167-175.
25. Struyf F, Cagnie B, Cools A, et al. Scapulothoracic muscle activity and recruitment timing in patients with shoulder impingement symptoms and glenohumeral instability. *Journal of Electromyography and Kinesiology.* 2014;24(2):277-284.
26. Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *Journal of Spinal Disorders.* 1992;5(4):383-389.
27. Mottram SL. Dynamic stability of the scapula. *Manual Therapy.* 1997;2(3):123-131.
28. Wallmann HW. Overview of shoulder injuries, pathologies, and disorders. *Home Health Care Management & Practice.* 2010;22(4):286-288.
29. Castelein B, Cools A, Bostyn E, Delemarre J, Lemahieu T, Cagnie B. Analysis of scapular muscle EMG activity in patients with idiopathic neck pain: a systematic review. *Journal of Electromyography and Kinesiology.* 2015;25(2):371-386.
30. Myers JB, Hwang JH, Pasquale MR, Blackburn JT, Lephart SM. Rotator cuff coactivation ratios in participants with subacromial impingement syndrome. *Journal of Science and Medicine in Sport.* 2009;12(6):603-608.
31. Borstad JD, Ludewig PM. Comparison of scapular kinematics between elevation and lowering of the arm in the scapular plane. *Clinical Biomechanics.* 2002;17(9-10):650-659.
32. Sharkey NA, Marder RA. The rotator cuff opposes superior translation of the humeral head. *American Journal of Sports Medicine.* 1995;23(3):270-275.
33. Prentice W, Arnheim D. *Principles of athletic training: A competency-based approach.* McGraw-Hill Higher Education; 2013.
34. Kibler WB, McMullen J. Scapular dyskinesis and its relation to shoulder pain. *Journal of the American Academy of Orthopaedic Surgeons.* 2003;11(2):142-151.
35. Schmidt R. *Motor Control and Learning: A Behavioral Emphasis.* 2nd ed. Champaign, IL: Human Kinetics; 1988.
36. Lephart SM, Pincivero DM, Giraldo JL, Fu FH. The role of proprioception in the management and rehabilitation of athletic injuries. *American Journal of Sports Medicine.* 1997;25(1):130-137.
37. Lephart SM, Warner JJ, Borsa PA, Fu FH. Proprioception of the shoulder joint in healthy, unstable, and surgically repaired shoulders. *Journal of Shoulder and Elbow Surgery.* 1994;3(6):371-380.
38. Roy JS, Bouyer LJ, Langevin P, Mercier C. Beyond the Joint: The Role of Central Nervous System Reorganizations in Chronic Musculoskeletal Disorders. *Journal of Orthopaedic and Sports Physical Therapy.* 2017;47(11):817-821.
39. Francis BA, Wonham WM. The internal model principle of control theory. *Automatica.* 1976;12(5):457-465.

40. Ito M. Control of mental activities by internal models in the cerebellum. *Nature Reviews Neuroscience.* 2008;9(4):304-313.
41. Sarlegna FR, Sainburg RL. The roles of vision and proprioception in the planning of reaching movements. *Advances in Experimental Medicine and Biology.* 2009;629:317-335.
42. de Oliveira FCL, Bouyer LJ, Ager AL, Roy JS. Electromyographic analysis of rotator cuff muscles in patients with rotator cuff tendinopathy: A systematic review. *Journal of Electromyography and Kinesiology.* 2017;35:100-114.
43. Leong HT, Ng GY, Chan SC, Fu SN. Rotator cuff tendinopathy alters the muscle activity onset and kinematics of scapula. *Journal of Electromyography and Kinesiology.* 2017;35:40-46.
44. Chester R, Smith TO, Hooper L, Dixon J. The impact of subacromial impingement syndrome on muscle activity patterns of the shoulder complex: A systematic review of electromyographic studies. *BMC Musculoskeletal Disorders.* 2010;11.
45. Cools AM, Witvrouw EE, Declercq GA, Vanderstraeten GG, Cambier DC. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *British Journal of Sports Medicine.* 2004;38(1):64-68.
46. Diederichsen LP, Norregaard J, Dyhre-Poulsen P, et al. The activity pattern of shoulder muscles in subjects with and without subacromial impingement. *Journal of Electromyography and Kinesiology.* 2009;19(5):789-799.
47. Moraes GFS, Faria CDCM, Teixeira-Salmela LF. Scapular muscle recruitment patterns and isokinetic strength ratios of the shoulder rotator muscles in individuals with and without impingement syndrome. *Journal of Shoulder and Elbow Surgery.* 2008;17(1 SUPPL.):S48-S53.
48. Myers JB, Lephart SM. The role of the sensorimotor system in the athletic shoulder. *Journal of Athletic Training.* 2000;35(3):351-363.
49. Machner A, Merk H, Becker R, Rohkohl K, Wissel H, Pap G. Kinesthetic sense of the shoulder in patients with impingement syndrome. *Acta Orthopedica Scandinavica.* 2003;74(1):85-88.
50. Safran MR, Borsa PA, Lephart SM, Fu FH, Warner JJ. Shoulder proprioception in baseball pitchers. *Journal of Shoulder and Elbow Surgery.* 2001;10(5):438-444.
51. Lubiatowski P, Ogrodowicz P, Wojtaszek M, et al. Measurement of active shoulder proprioception: dedicated system and device. *European Journal of Orthopaedic Surgery & Traumatology : Orthopedie Traumatologie.* 2013;23(2):177-183.
52. Grigg P. Peripheral neural mechanisms in proprioception. *Journal of Sport Rehabilitation.* 1994;3(1):2-17.
53. Kirkpatrick LJ, Allouh MZ, Nightingale CN, Devon HG, Yablonka-Reuveni Z, Rosser BW. Pax7 shows higher satellite cell frequencies and concentrations within intrafusal fibers of muscle spindles. *Journal of Histochemistry & Cytochemistry.* 2008;56(9):831-840.
54. Myers JB, Guskiewicz KM, Schneider RA, Prentice WE. Proprioception and neuromuscular control of the shoulder after muscle fatigue. *Journal of Athletic Training.* 1999;34(4):362-367.
55. Andres BM, Murrell GA. Treatment of tendinopathy: what works, what does not, and what is on the horizon. *Clinical Orthopaedics and Related Research.* 2008;466(7):1539-1554.
56. Desmeules F, Boudreault J, Roy JS, Dionne C, Fremont P, MacDermid JC. The efficacy of therapeutic ultrasound for rotator cuff tendinopathy: A systematic review and meta-analysis. *Physical Therapy in Sport.* 2015;16(3):276-284.
57. van der Heijden GJ. Shoulder disorders: a state-of-the-art review. *Bailliere's Best Practice & Research. Clinical Rheumatology.* 1999;13(2):287-309.
58. Alfredson H. The chronic painful Achilles and patellar tendon: research on basic biology and treatment. *Scandinavian Journal of Medicine & Science in Sports.* 2005;15(4):252-259.

59. Michener LA, Walsworth MK, Doukas WC, Murphy KP. Reliability and diagnostic accuracy of 5 physical examination tests and combination of tests for subacromial impingement. *Archives of Physical Medicine and Rehabilitation.* 2009;90(11):1898-1903.
60. Bigliani LU, Levine WN. Subacromial impingement syndrome. *Journal of Bone and Joint Surgery. American volume.* 1997;79(12):1854-1868.
61. Neer CS, 2nd. Impingement lesions. *Clinical Orthopaedics and Related Research.* 1983(173):70-77.
62. van der Windt DA, Koes BW, de Jong BA, Bouter LM. Shoulder disorders in general practice: incidence, patient characteristics, and management. *Annals of the Rheumatic Diseases.* 1995;54(12):959-964.
63. Chard MD, Hazleman R, Hazleman BL, King RH, Reiss BB. Shoulder disorders in the elderly: a community survey. *Arthritis and Rheumatism.* 1991;34(6):766-769.
64. Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC(3)-study. *Pain.* 2003;102(1-2):167-178.
65. Silverstein BA, Viikari-Juntura E, Fan ZJ, Bonauto DK, Bao S, Smith C. Natural course of nontraumatic rotator cuff tendinitis and shoulder symptoms in a working population. *Scandinavian Journal of Work, Environment and Health.* 2006;32(2):99-108.
66. Urwin M, Symmons D, Allison T, et al. Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. *Annals of the Rheumatic Diseases.* 1998;57(11):649-655.
67. Luime JJ, Koes BW, Hendriksen IJ, et al. Prevalence and incidence of shoulder pain in the general population; a systematic review. *Scandinavian Journal of Rheumatology.* 2004;33(2):73-81.
68. Peek AL, Miller C, Heneghan NR. Thoracic manual therapy in the management of non-specific shoulder pain: a systematic review. *Journal of Manual & Manipulative Therapy.* 2015;23(4):176-187.
69. Littlewood C, May S, Walters S. Epidemiology of rotator cuff tendinopathy: a systematic review. *Shoulder & Elbow.* 2013;5(4):256-265.
70. Redondo-Alonso L, Chamorro-Moriana G, Jimenez-Rejano JJ, Lopez-Tarrida P, Ridao-Fernandez C. Relationship between chronic pathologies of the supraspinatus tendon and the long head of the biceps tendon: systematic review. *BMC Musculoskeletal Disorders.* 2014;15:377.
71. Hill CL, Gill TK, Shanahan EM, Taylor AW. Prevalence and correlates of shoulder pain and stiffness in a population-based study: the North West Adelaide Health Study. *International Journal of Rheumatic Diseases.* 2010;13(3):215-222.
72. Cassou B, Derriennic F, Monfort C, Norton J, Touranchet A. Chronic neck and shoulder pain, age, and working conditions: longitudinal results from a large random sample in France. *Occupational and Environmental Medicine.* 2002;59(8):537-544.
73. Leijon O, Lindberg P, Josephson M, Wiktorin C. Different working and living conditions and their associations with persistent neck/shoulder and/or low back disorders. *Occupational and Environmental Medicine.* 2007;64(2):115-121.
74. Strom V, Roe C, Knardahl S. Work-induced pain, trapezius blood flux, and muscle activity in workers with chronic shoulder and neck pain. *Pain.* 2009;144(1-2):147-155.
75. Ge HY, Madeleine P, Arendt-Nielsen L. Gender differences in pain modulation evoked by repeated injections of glutamate into the human trapezius muscle. *Pain.* 2005;113(1-2):134-140.
76. Ge HY, Arendt-Nielsen L, Farina D, Madeleine P. Gender-specific differences in electromyographic changes and perceived pain induced by experimental muscle pain during sustained contractions of the upper trapezius muscle. *Muscle Nerve.* 2005;32(6):726-733.

77. van der Heijden GJ. Shoulder disorders: a state-of-the-art review. *Bailliere's Clinical Rheumatology.* 1999;13(2):287-309.
78. Kaya E, Zinnuroglu M, Tugcu I. Kinesio taping compared to physical therapy modalities for the treatment of shoulder impingement syndrome. *Clinical Rheumatology.* 2011;30(2):201-207.
79. Seitz AL, McClure PW, Finucane S, Boardman ND, 3rd, Michener LA. Mechanisms of rotator cuff tendinopathy: intrinsic, extrinsic, or both? *Clinical Biomechanics.* 2011;26(1):1-12.
80. Tashjian RZ, Farnham JM, Albright FS, Teerlink CC, Cannon-Albright LA. Evidence for an inherited predisposition contributing to the risk for rotator cuff disease. *Journal of Bone and Joint Surgery. American volume.* 2009;91(5):1136-1142.
81. Tempelhof S, Rupp S, Seil R. Age-related prevalence of rotator cuff tears in asymptomatic shoulders. *Journal of Shoulder and Elbow Surgery.* 1999;8(4):296-299.
82. Hegedus EJ, Cook C, Brennan M, Wyland D, Garrison JC, Driesner D. Vascularity and tendon pathology in the rotator cuff: a review of literature and implications for rehabilitation and surgery. *British Journal of Sports Medicine.* 2010;44(12):838-847.
83. Riley GP, Harrall RL, Constant CR, Chard MD, Cawston TE, Hazleman BL. Tendon degeneration and chronic shoulder pain: changes in the collagen composition of the human rotator cuff tendons in rotator cuff tendinitis. *Annals of the Rheumatic Diseases.* 1994;53(6):359-366.
84. Lewis J, McCreesh K, Roy JS, Ginn K. Rotator Cuff Tendinopathy: Navigating the Diagnosis-Management Conundrum. *Journal of Orthopaedic and Sports Physical Therapy.* 2015;45(11):923-937.
85. Meyer A. Chronic functional lesions of the shoulder. *Archives of Surgery.* 1937;35(4):646-674.
86. Rothman RH, Parke WW. The vascular anatomy of the rotator cuff. *Clinical Orthopaedics and Related Research.* 1965;41:176-186.
87. Macnab I. Rotator cuff tendinitis. *Annals of the Royal College of Surgeons of England.* 1973;53(5):271-287.
88. Lo YP, Hsu YC, Chan KM. Epidemiology of shoulder impingement in upper arm sports events. *British Journal of Sports Medicine.* 1990;24(3):173-177.
89. Moseley HF. The Vascular Supply of the Rotator Cuff. *Surgical Clinics of North America.* 1963;43:1521-1522.
90. Bigliani L, Morrison D, April E. The morphology of the acromion and its relationship to rotator cuff tears. *Orthopaedic Transactions.* 1986;10:216-228.
91. Bigliani LU, Ticker JB, Flatow EL, Soslowsky LJ, Mow VC. The relationship of acromial architecture to rotator cuff disease. *Clinics in Sports Medicine.* 1991;10(4):823-838.
92. Epstein RE, Schweitzer ME, Frieman BG, Fenlin JM, Jr., Mitchell DG. Hooked acromion: prevalence on MR images of painful shoulders. *Radiology.* 1993;187(2):479-481.
93. Gill TJ, McIrvin E, Kocher MS, Homa K, Mair SD, Hawkins RJ. The relative importance of acromial morphology and age with respect to rotator cuff pathology. *Journal of Shoulder and Elbow Surgery.* 2002;11(4):327-330.
94. Balke M, Schmidt C, Dedy N, Banerjee M, Bouillon B, Liem D. Correlation of acromial morphology with impingement syndrome and rotator cuff tears. *Acta Orthopaedica.* 2013;84(2):178-183.
95. Neer CS, 2nd. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. *Journal of Bone and Joint Surgery. American volume.* 1972;54(1):41-50.
96. de Witte PB, Nagels J, van Arkel ER, Visser CP, Nelissen RG, de Groot JH. Study protocol subacromial impingement syndrome: the identification of pathophysiologic mechanisms (SISTIM). *BMC Musculoskeletal Disorders.* 2011;12:282.

97. Lopes AD, Timmons MK, Grover M, Ciconelli RM, Michener LA. Visual scapular dyskinesis: kinematics and muscle activity alterations in patients with subacromial impingement syndrome. *Archives of Physical Medicine and Rehabilitation.* 2015;96(2):298-306.
98. Anderson VB, Wee E. Impaired joint proprioception at higher shoulder elevations in chronic rotator cuff pathology. *Archives of Physical Medicine and Rehabilitation.* 2011;92(7):1146-1151.
99. Berth A, Pap G, Neuman W, Awiszus F. Central neuromuscular dysfunction of the deltoid muscle in patients with chronic rotator cuff tears. *Journal of Orthopaedics and Traumatology.* 2009;10(3):135-141.
100. Ngomo S, Mercier C, Bouyer LJ, Savoie A, Roy JS. Alterations in central motor representation increase over time in individuals with rotator cuff tendinopathy. *Clinical Neurophysiology.* 2015;126(2):365-371.
101. Bank PJ, Peper CE, Marinus J, Beek PJ, van Hilten JJ. Motor consequences of experimentally induced limb pain: a systematic review. *European Journal of Pain.* 2013;17(2):145-157.
102. Hodges PW, Tucker K. Moving differently in pain: a new theory to explain the adaptation to pain. *Pain.* 2011;152(3 Suppl):S90-98.
103. Roy JS, Moffet H, McFadyen BJ, Lirette R. Impact of movement training on upper limb motor strategies in persons with shoulder impingement syndrome. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology.* 2009;1(1):8.
104. Woolf CJ. Central sensitization: implications for the diagnosis and treatment of pain. *Pain.* 2011;152(3 Suppl):S2-15.
105. Coutaux A, Adam F, Willer JC, Le Bars D. Hyperalgesia and allodynia: peripheral mechanisms. *Joint, Bone, Spine : revue du rhumatisme.* 2005;72(5):359-371.
106. Paul TM, Soo Hoo J, Chae J, Wilson RD. Central hypersensitivity in patients with subacromial impingement syndrome. *Archives of Physical Medicine and Rehabilitation.* 2012;93(12):2206-2209.
107. Borstad J, Woeste C. The role of sensitization in musculoskeletal shoulder pain. *Brazilian Journal of Physical Therapy.* 2015;19(4):251-257.
108. Nijs J, Goubert D, Ickmans K. Recognition and Treatment of Central Sensitization in Chronic Pain Patients: Not Limited to Specialized Care. *Journal of Orthopaedic and Sports Physical Therapy.* 2016;46(12):1024-1028.
109. Camargo PR, Avila MA, Alburquerque-Sendin F, Asso NA, Hashimoto LH, Salvini TF. Eccentric training for shoulder abductors improves pain, function and isokinetic performance in subjects with shoulder impingement syndrome - a case series. *Brazilian Journal of Physical Therapy.* 2012;16(1):74-83.
110. Dejaco B, Habets B, van Loon C, van Grinsven S, van Cingel R. Eccentric versus conventional exercise therapy in patients with rotator cuff tendinopathy: a randomized, single blinded, clinical trial. *Knee Surgery, Sports Traumatology, Arthroscopy.* 2017;25(7):2051-2059.
111. Dogan SK, Ay S, Evcik D. The effectiveness of low laser therapy in subacromial impingement syndrome: a randomized placebo controlled double-blind prospective study. *Clinics.* 2010;65(10):1019-1022.
112. Haik MN, Alburquerque-Sendin F, Camargo PR. Short-Term Effects of Thoracic Spine Manipulation on Shoulder Impingement Syndrome: A Randomized Controlled Trial. *Archives of Physical Medicine and Rehabilitation.* 2017;98(8):1594-1605.
113. Johansson K, Bergstrom A, Schroder K, Foldevi M. Subacromial corticosteroid injection or acupuncture with home exercises when treating patients with subacromial impingement in primary care--a randomized clinical trial. *Family Practice.* 2011;28(4):355-365.

114. Kachingwe AF, Phillips B, Sletten E, Plunkett SW. Comparison of manual therapy techniques with therapeutic exercise in the treatment of shoulder impingement: a randomized controlled pilot clinical trial. *Journal of Manual & Manipulative Therapy.* 2008;16(4):238-247.
115. Senbursa G, Baltaci G, Atay A. Comparison of conservative treatment with and without manual physical therapy for patients with shoulder impingement syndrome: a prospective, randomized clinical trial. *Knee Surgery, Sports Traumatology, Arthroscopy.* 2007;15(7):915-921.
116. Wang CH, McClure P, Pratt NE, Nobilini R. Stretching and strengthening exercises: their effect on three-dimensional scapular kinematics. *Archives of Physical Medicine and Rehabilitation.* 1999;80(8):923-929.
117. Worsley P, Warner M, Mottram S, et al. Motor control retraining exercises for shoulder impingement: effects on function, muscle activation, and biomechanics in young adults. *Journal of Shoulder and Elbow Surgery.* 2013;22(4):e11-19.
118. Cools AM, Witvrouw EE, Declercq GA, Danneels LA, Cambier DC. Scapular muscle recruitment patterns: Trapezius muscle latency with and without impingement symptoms. *American Journal of Sports Medicine.* 2003;31(4):542-549.
119. Hebert LJ, Moffet H, McFadyen BJ, Dionne CE. Scapular behavior in shoulder impingement syndrome. *Archives of Physical Medicine and Rehabilitation.* 2002;83(1):60-69.
120. Parsons IM, Apreleva M, Fu FH, Woo SL. The effect of rotator cuff tears on reaction forces at the glenohumeral joint. *Journal of Orthopaedic Research.* 2002;20(3):439-446.
121. Cools AM, Witvrouw EE, Declercq GA, Danneels LA, Cambier DC. Scapular muscle recruitment patterns: trapezius muscle latency with and without impingement symptoms. *American Journal of Sports Medicine.* 2003;31(4):542-549.
122. Wadsworth DJ, Bullock-Saxton JE. Recruitment patterns of the scapular rotator muscles in freestyle swimmers with subacromial impingement. *International Journal of Sports Medicine.* 1997;18(8):618-624.
123. Brox JI, Roe C, Saugen E, Vøllestad NK. Isometric abduction muscle activation in patients with rotator tendinosis of the shoulder. *Archives of Physical Medicine and Rehabilitation.* 1997;78(11):1260-1267.
124. Muth S, Barbe MF, Lauer R, McClure P. The effects of thoracic spine manipulation in subjects with signs of rotator cuff tendinopathy. *Journal of Orthopaedic and Sports Physical Therapy.* 2012;42(12):1005-1016.
125. Røe C, Brox JI, Bøhmer AS, Vøllestad NK. Muscle activation after supervised exercises in patients with rotator tendinosis. *Archives of Physical Medicine and Rehabilitation.* 2000;81(1):67-72.
126. Tate AR, McClure PW, Young IA, Salvatori R, Michener LA. Comprehensive impairment-based exercise and manual therapy intervention for patients with subacromial impingement syndrome: a case series. *Journal of Orthopaedic and Sports Physical Therapy.* 2010;40(8):474-493.
127. Endo K, Ikata T, Katoh S, Takeda Y. Radiographic assessment of scapular rotational tilt in chronic shoulder impingement syndrome. *Journal of Orthopaedic Science.* 2001;6(1):3-10.
128. Lukasiewicz AC, McClure P, Michener L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *Journal of Orthopaedic and Sports Physical Therapy.* 1999;29(10):574-583.
129. McClure PW, Michener LA, Karduna AR. Shoulder function and 3-dimensional scapular kinematics in people with and without shoulder impingement syndrome. *Physical Therapy.* 2006;86(8):1075-1090.

130. Reddy AS, Mohr KJ, Pink MM, Jobe FW. Electromyographic analysis of the deltoid and rotator cuff muscles in persons with subacromial impingement. *Journal of Shoulder and Elbow Surgery.* 2000;9(6):519-523.
131. Skolimowski J, Winiarski S, Anwajler J, Skolimowska B, Barczyk K, Dudek K. Bioelectric activity of selected muscle groups in people with impingement syndrome. *Acta of Bioengineering and Biomechanics.* 2009;11(1):37-45.
132. Pink M, Jobe FW, Perry J, Browne A, Scovazzo ML, Kerrigan J. The painful shoulder during the butterfly stroke: An electromyographic and cinematographic analysis of twelve muscles. *Clinical Orthopaedics and Related Research.* 1993(288):60-72.
133. Ruwe PA, Pink M, Jobe FW, Perry J, Scovazzo ML. The normal and the painful shoulders during the breaststroke. Electromyographic and cinematographic analysis of twelve muscles. *American Journal of Sports Medicine.* 1994;22(6):789-796.
134. Lin JJ, Hsieh SC, Cheng WC, Chen WC, Lai Y. Adaptive patterns of movement during arm elevation test in patients with shoulder impingement syndrome. *Journal of Orthopaedic Research.* 2011;29(5):653-657.
135. Cools AM, Declercq GA, Cambier DC, Mahieu NN, Witvrouw EE. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scandinavian Journal of Medicine & Science in Sports.* 2007;17(1):25-33.
136. Borstad JD. Resting position variables at the shoulder: evidence to support a posture-impairment association. *Physical Therapy.* 2006;86(4):549-557.
137. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *Journal of Orthopaedic and Sports Physical Therapy.* 2005;35(4):227-238.
138. Borich MR, Bright JM, Lorello DJ, Cieminski CJ, Buisman T, Ludewig PM. Scapular angular positioning at end range internal rotation in cases of glenohumeral internal rotation deficit. *Journal of Orthopaedic and Sports Physical Therapy.* 2006;36(12):926-934.
139. Gumina S, Di Giorgio G, Postacchini F, Postacchini R. Subacromial space in adult patients with thoracic hyperkyphosis and in healthy volunteers. *La Chirurgia degli Organi di Movimento.* 2008;91(2):93-96.
140. Desmeules F, Minville L, Riederer B, Cote CH, Fremont P. Acromio-humeral distance variation measured by ultrasonography and its association with the outcome of rehabilitation for shoulder impingement syndrome. *Clinical Journal of Sport Medicine.* 2004;14(4):197-205.
141. Graichen H, Bonel H, Stammberger T, Englmeier KH, Reiser M, Eckstein F. Subacromial space width changes during abduction and rotation--a 3-D MR imaging study. *Surgical and Radiologic Anatomy.* 1999;21(1):59-64.
142. Hebert LJ, Moffet H, Dufour M, Moisan C. Acromiohumeral distance in a seated position in persons with impingement syndrome. *Journal of Magnetic Resonance Imaging.* 2003;18(1):72-79.
143. Saupe N, Pfirrmann CW, Schmid MR, Jost B, Werner CM, Zanetti M. Association between rotator cuff abnormalities and reduced acromiohumeral distance. *American Journal of Roentgenology.* 2006;187(2):376-382.
144. Azzoni R, Cabitza P. Sonographic versus radiographic measurement of the subacromial space width. *La Chirurgia degli Organi di Movimento.* 2004;89(2):143-150.
145. Azzoni R, Cabitza P, Parrini M. Sonographic evaluation of subacromial space. *Ultrasonics.* 2004;42(1-9):683-687.
146. Cholewinski JJ, Kusz DJ, Wojciechowski P, Cielinski LS, Zoladz MP. Ultrasound measurement of rotator cuff thickness and acromio-humeral distance in the diagnosis of subacromial

impingement syndrome of the shoulder. *Knee Surgery, Sports Traumatology, Arthroscopy.* 2008;16(4):408-414.

147. Norwood LA, Barrack R, Jacobson KE. Clinical presentation of complete tears of the rotator cuff. *Journal of Bone and Joint Surgery. American volume.* 1989;71(4):499-505.
148. Nove-Josserand L, Edwards TB, O'Connor DP, Walch G. The acromiohumeral and coracohumeral intervals are abnormal in rotator cuff tears with muscular fatty degeneration. *Clinical Orthopaedics and Related Research.* 2005(433):90-96.
149. Petersson CJ, Redlund-Johnell I. The subacromial space in normal shoulder radiographs. *Acta Orthopedica Scandinavica.* 1984;55(1):57-58.
150. Pijls BG, Kok FP, Penning LI, Guldemond NA, Arens HJ. Reliability study of the sonographic measurement of the acromiohumeral distance in symptomatic patients. *Journal of Clinical Ultrasound.* 2010;38(3):128-134.
151. McCreesh KM, Crotty JM, Lewis JS. Acromiohumeral distance measurement in rotator cuff tendinopathy: is there a reliable, clinically applicable method? A systematic review. *British Journal of Sports Medicine.* 2015;49(5):298-305.
152. Navarro-Ledesma S, Luque-Suarez A. Comparison of acromiohumeral distance in symptomatic and asymptomatic patient shoulders and those of healthy controls. *Clinical Biomechanics.* 2018;53:101-106.
153. Harput G, Guney H, Toprak U, Colakoglu F, Baltaci G. Acute effects of scapular Kinesio Taping(R) on shoulder rotator strength, ROM and acromiohumeral distance in asymptomatic overhead athletes. *Journal of Sports Medicine and Physical Fitness.* 2017;57(11):1479-1485.
154. Luque-Suarez A, Navarro-Ledesma S, Petocz P, Hancock MJ, Hush J. Short term effects of kinesiotaping on acromiohumeral distance in asymptomatic subjects: a randomised controlled trial. *Manual Therapy.* 2013;18(6):573-577.
155. Seitz AL, McClure PW, Finucane S, et al. The scapular assistance test results in changes in scapular position and subacromial space but not rotator cuff strength in subacromial impingement. *Journal of Orthopaedic and Sports Physical Therapy.* 2012;42(5):400-412.
156. Navarro-Ledesma S, Struyf F, Labajos-Manzanares MT, Fernandez-Sanchez M, Morales-Asencio JM, Luque-Suarez A. Does the acromiohumeral distance matter in chronic rotator cuff related shoulder pain? *Musculoskelet Science & Practice.* 2017;29:38-42.
157. Myers JB, Laudner KG, Pasquale MR, Bradley JP, Lephart SM. Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *American Journal of Sports Medicine.* 2006;34(3):385-391.
158. Tyler TF, Nicholas SJ, Roy T, Gleim GW. Quantification of posterior capsule tightness and motion loss in patients with shoulder impingement. *American Journal of Sports Medicine.* 2000;28(5):668-673.
159. Harryman DT, 2nd, Sidles JA, Clark JM, McQuade KJ, Gibb TD, Matsen FA, 3rd. Translation of the humeral head on the glenoid with passive glenohumeral motion. *Journal of Bone and Joint Surgery. American volume.* 1990;72(9):1334-1343.
160. Grossman MG, Tibone JE, McGarry MH, Schneider DJ, Veneziani S, Lee TQ. A cadaveric model of the throwing shoulder: a possible etiology of superior labrum anterior-to-posterior lesions. *Journal of Bone and Joint Surgery. American volume.* 2005;87(4):824-831.
161. Dong W, Goost H, Lin XB, et al. Treatments for shoulder impingement syndrome: a PRISMA systematic review and network meta-analysis. *Medicine.* 2015;94(10):e510.
162. Tekeoglu I, Ediz L, Hiz O, Toprak M, Yazmalar L, Karaaslan G. The relationship between shoulder impingement syndrome and sleep quality. *European Review for Medical and Pharmacological Sciences.* 2013;17(3):370-374.

163. Kuijpers T, van der Windt DA, van der Heijden GJ, Bouter LM. Systematic review of prognostic cohort studies on shoulder disorders. *Pain.* 2004;109(3):420-431.
164. Lakke SE, Soer R, Takken T, Reneman MF. Risk and prognostic factors for non-specific musculoskeletal pain: a synthesis of evidence from systematic reviews classified into ICF dimensions. *Pain.* 2009;147(1-3):153-164.
165. Mallen CD, Peat G, Thomas E, Dunn KM, Croft PR. Prognostic factors for musculoskeletal pain in primary care: a systematic review. *British Journal of General Practice.* 2007;57(541):655-661.
166. Svendsen SW, Christiansen DH, Haahr JP, Andrea LC, Frost P. Shoulder function and work disability after decompression surgery for subacromial impingement syndrome: a randomised controlled trial of physiotherapy exercises and occupational medical assistance. *BMC Musculoskeletal Disorders.* 2014;15:215.
167. Brox JI, Gjengedal E, Uppheim G, et al. Arthroscopic surgery versus supervised exercises in patients with rotator cuff disease (stage II impingement syndrome): a prospective, randomized, controlled study in 125 patients with a 2 1/2-year follow-up. *Journal of Shoulder and Elbow Surgery.* 1999;8(2):102-111.
168. Brox JI, Staff PH, Ljunggren AE, Brevik JI. Arthroscopic surgery compared with supervised exercises in patients with rotator cuff disease (stage II impingement syndrome). *British Medical Journal.* 1993;307(6909):899-903.
169. Haahr JP, Andersen JH. Exercises may be as efficient as subacromial decompression in patients with subacromial stage II impingement: 4-8-years' follow-up in a prospective, randomized study. *Scandinavian Journal of Rheumatology.* 2006;35(3):224-228.
170. Haahr JP, Ostergaard S, Dalsgaard J, et al. Exercises versus arthroscopic decompression in patients with subacromial impingement: a randomised, controlled study in 90 cases with a one year follow up. *Annals of the Rheumatic Diseases.* 2005;64(5):760-764.
171. Ketola S, Lehtinen JT, Arnala I. Arthroscopic decompression not recommended in the treatment of rotator cuff tendinopathy: a final review of a randomised controlled trial at a minimum follow-up of ten years. *The Bone & Joint Journal.* 2017;99-B(6):799-805.
172. Lewis J. The End of an Era? *Journal of Orthopaedic and Sports Physical Therapy.* 2018;48(3):127-129.
173. Djordjevic OC, Vukicevic D, Katunac L, Jovic S. Mobilization with movement and kinesiotaping compared with a supervised exercise program for painful shoulder: results of a clinical trial. *Journal of Manipulative and Physiological Therapeutics.* 2012;35(6):454-463.
174. Jaeschke R, Singer J, Guyatt GH. Measurement of health status. Ascertaining the minimal clinically important difference. *Controlled Clinical Trials.* 1989;10(4):407-415.
175. Kaya DO, Baltaci G, Toprak U, Atay AO. The clinical and sonographic effects of kinesiotaping and exercise in comparison with manual therapy and exercise for patients with subacromial impingement syndrome: a preliminary trial. *Journal of Manipulative and Physiological Therapeutics.* 2014;37(6):422-432.
176. Şimşek HH, Balki S, Keklik SS, Ozturk H, Elden H. Does Kinesio taping in addition to exercise therapy improve the outcomes in subacromial impingement syndrome? A randomized, double-blind, controlled clinical trial. *Acta Orthopaedica et Traumatologica Turcica.* 2013;47(2):104-110.
177. Cools AM, Witvrouw EE, Declercq GA, Vanderstraeten GG, Cambier DC. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *British Journal of Sports Medicine.* 2004;38(1):64-68.

178. Michener LA, Walsworth MK, Burnet EN. Effectiveness of rehabilitation for patients with Subacromial impingement syndrome: a systematic review. *Journal of Hand Therapy.* 2004;17(2):152-164.
179. Zanca GG, Gruninger B, Mattiello SM. Effects of Kinesio taping on scapular kinematics of overhead athletes following muscle fatigue. *Journal of Electromyography and Kinesiology.* 2015.
180. Bennell K, Wee E, Coburn S, et al. Efficacy of standardised manual therapy and home exercise programme for chronic rotator cuff disease: randomised placebo controlled trial. *British Medical Journal.* 2010;340:c2756.
181. Bang MD, Deyle GD. Comparison of supervised exercise with and without manual physical therapy for patients with shoulder impingement syndrome. *Journal of Orthopaedic and Sports Physical Therapy.* 2000;30(3):126-137.
182. Abrisham SM, Kermani-Alghoraishi M, Ghahramani R, Jabbari L, Jomeh H, Zare M. Additive effects of low-level laser therapy with exercise on subacromial syndrome: a randomised, double-blind, controlled trial. *Clinical Rheumatology.* 2011;30(10):1341-1346.
183. Desjardins-Charbonneau A, Roy JS, Dionne CE, Desmeules F. The Efficacy of Taping for Rotator Cuff Tendinopathy: A Systematic Review and Meta-Analysis. *International Journal of Sports Physical Therapy.* 2015;10(4):420-433.
184. Saracoglu I, Emuk Y, Taspinar F. Does taping in addition to physiotherapy improve the outcomes in subacromial impingement syndrome? A systematic review. *Physiotherapy Theory and Practice.* 2018;34(4):251-263.
185. Haslerud S, Magnussen LH, Joensen J, Lopes-Martins RA, Bjordal JM. The efficacy of low-level laser therapy for shoulder tendinopathy: a systematic review and meta-analysis of randomized controlled trials. *Physiotherapy Research International.* 2015;20(2):108-125.
186. Desmeules F, Boudreault J, Roy JS, Dionne CE, Fremont P, MacDermid JC. Efficacy of transcutaneous electrical nerve stimulation for rotator cuff tendinopathy: a systematic review. *Physiotherapy.* 2016;102(1):41-49.
187. Ioppolo F, Tattoli M, Di Sante L, et al. Clinical improvement and resorption of calcifications in calcific tendinitis of the shoulder after shock wave therapy at 6 months' follow-up: a systematic review and meta-analysis. *Archives of Physical Medicine and Rehabilitation.* 2013;94(9):1699-1706.
188. Verstraelen FU, In den Kleef NJ, Jansen L, Morrenhof JW. High-energy versus low-energy extracorporeal shock wave therapy for calcifying tendinitis of the shoulder: which is superior? A meta-analysis. *Clinical Orthopaedics and Related Research.* 2014;472(9):2816-2825.
189. Bannuru RR, Flavin NE, Vaysbrot E, Harvey W, McAlindon T. High-energy extracorporeal shock-wave therapy for treating chronic calcific tendinitis of the shoulder: a systematic review. *Annals of Internal Medicine.* 2014;160(8):542-549.
190. Louwerens JK, Sierevelt IN, van Noort A, van den Bekerom MP. Evidence for minimally invasive therapies in the management of chronic calcific tendinopathy of the rotator cuff: a systematic review and meta-analysis. *Journal of Shoulder and Elbow Surgery.* 2014;23(8):1240-1249.
191. Balasubramaniam U, Dissanayake R, Annabell L. Efficacy of platelet-rich plasma injections in pain associated with chronic tendinopathy: A systematic review. *The Physician and Sportsmedicine.* 2015;43(3):253-261.
192. Miranda I, Sanchez-Alepuz E, Lucas FJ, Carratala V, Gonzalez-Jofre CA. Use of platelet-rich plasma in the treatment of rotator cuff pathology. What has been scientifically proven? *Revista Española de Cirurgia Ortopedica y Traumatología.* 2017;61(4):249-258.

193. Desmeules F, Boudreault J, Dionne CE, et al. Efficacy of exercise therapy in workers with rotator cuff tendinopathy: a systematic review. *Journal of Occupational Health.* 2016;58(5):389-403.
194. Toliopoulos P, Desmeules F, Boudreault J, et al. Efficacy of surgery for rotator cuff tendinopathy: a systematic review. *Clinical Rheumatology.* 2014;33(10):1373-1383.
195. Boudreault J, Desmeules F, Roy JS, Dionne C, Fremont P, Macdermid JC. The efficacy of oral non-steroidal anti-inflammatory drugs for rotator cuff tendinopathy: a systematic review and meta-analysis. *Journal of Rehabilitation Medicine.* 2014;46(4):294-306.
196. Mohamadi A, Chan JJ, Claessen FM, Ring D, Chen NC. Corticosteroid Injections Give Small and Transient Pain Relief in Rotator Cuff Tendinosis: A Meta-analysis. *Clinical Orthopaedics and Related Research.* 2017;475(1):232-243.
197. Kase K, Tatyusuki H, Tomoki O. *KinesioTM taping perfect manual.* 2nd ed. Tokyo; 1996.
198. Kase K, Wallis J, Kase T. *Clinical therapeutic applications of the Kinesio taping method.* 1st ed. Tokyo; 2003.
199. Lemos T, Kase K, Dias E. *Kinesio Taping®: Introdução ao método e aplicações musculares.* 3ª ed. São Paulo, SP: Andreoli; 2015.
200. Lemos TV, Junior JRS, Santos M, Rosa MMN, Silva L, Matheus JPC. Kinesio Taping effects with different directions and tensions on strength and range of movement of the knee: a randomized controlled trial. *Brazilian Journal of Physical Therapy.* 2018;22(4):283-290.
201. Cubala A, Sniegocki M, Hoffman J, et al. Use of the Kinesio Taping method in painful shoulder syndrome. *Medical and Biological Sciences.* 2012;26(4):71-76.
202. Aarseth LM, Suprak DN, Chalmers GR, Lyon L, Dahlquist DT. Kinesio Tape and Shoulder-Joint Position Sense. *Journal of Athletic Training.* 2015;50(8):785-791.
203. Aguilar-Ferrándiz ME, Castro-Sánchez AM, Matarán-Peñarrocha GA, Guisado-Barrilao R, García-Ríos MC, Moreno-Lorenzo C. A randomized controlled trial of a mixed Kinesio taping-compression technique on venous symptoms, pain, peripheral venous flow, clinical severity and overall health status in postmenopausal women with chronic venous insufficiency. *Clinical Rehabilitation.* 2014;28(1):69-81.
204. Artioli D, Bertolini G. Kinesio taping: application and results on pain: systematic review. *Fisioterapia e Pesquisa.* 2014;21(1):94-99.
205. Halseth T, McChesney JW, Debeliso M, Vaughn R, Lien J. The effects of kinesio taping on proprioception at the ankle. *Journal of Sports Science & Medicine.* 2004;3(1):1-7.
206. Murray H, Husk L. Effect of kinesiotaping on proprioception in the ankle. *Journal of Orthopaedic and Sports Physical Therapy.* 2001(31):A37.
207. Oliveira FC. Uma fita: Por quê e para que usam fitas coladas na pele? *Revista Tênis*. 112 ed. São Paulo; 2013.
208. Paoloni M, Bernetti A, Fratocchi G, et al. Kinesio Taping applied to lumbar muscles influences clinical and electromyographic characteristics in chronic low back pain patients. *European Journal of Physical and Rehabilitation Medicine.* 2011;47(2):237-244.
209. Thelen MD, Dauber JA, Stoneman PD. The clinical efficacy of kinesio tape for shoulder pain: a randomized, double-blinded, clinical trial. *Journal of Orthopaedic and Sports Physical Therapy.* 2008;38(7):389-395.
210. Melzack R, Wall PD. Pain mechanisms: a new theory. *Science.* 1965;150(3699):971-979.
211. Lee SH, Yoon C, Chung SG, et al. Measurement of Shoulder Range of Motion in Patients with Adhesive Capsulitis Using a Kinect. *PloS one.* 2015;10(6):e0129398.
212. Shakeri H, Keshavarz R, Arab AM, Ebrahimi I. Clinical effectiveness of kinesiological taping on pain and pain-free shoulder range of motion in patients with shoulder impingement syndrome:

a randomized, double blinded, placebo-controlled trial. *International Journal of Sports Physical Therapy.* 2013;8(6):800-810.

213. Shakeri H, Keshavarz R, Arab AM, Ebrahimi I. Therapeutic Effect of Kinesio-taping on Disability of Arm, Shoulder, and Hand in Patients with Subacromial Impingement Syndrome: A Randomized Clinical Trial. *Journal of Novel Physiotherapies.* 2013;3(4):1-5.
214. Castro-Sanchez AM, Lara-Palomo IC, Mataran-Penarrocha GA, Fernandez-Sanchez M, Sanchez-Labraca N, Arroyo-Morales M. Kinesio Taping reduces disability and pain slightly in chronic non-specific low back pain: a randomised trial. *Journal of Physiotherapy.* 2012;58(2):89-95.
215. Chang HY, Cheng SC, Lin CC, Chou KY, Gan SM, Wang CH. The effectiveness of kinesio taping for athletes with medial elbow epicondylar tendinopathy. *International Journal of Sports Medicine.* 2013;34(11):1003-1006.
216. Cho HY, Kim EH, Kim J, Yoon YW. Kinesio taping improves pain, range of motion, and proprioception in older patients with knee osteoarthritis: a randomized controlled trial. *American Journal of Physical Medicine & Rehabilitation.* 2015;94(3):192-200.
217. Garcia-Muro F, Rodriguez-Fernandez AL, Herrero-de-Lucas A. Treatment of myofascial pain in the shoulder with Kinesio taping. A case report. *Manual Therapy.* 2010;15(3):292-295.
218. Gonzalez-Iglesias J, Fernandez-de-Las-Penas C, Cleland JA, Huijbregts P, Del Rosario Gutierrez-Vega M. Short-term effects of cervical kinesio taping on pain and cervical range of motion in patients with acute whiplash injury: a randomized clinical trial. *Journal of Orthopaedic and Sports Physical Therapy.* 2009;39(7):515-521.
219. Lee JH, Yoo WG. Treatment of chronic Achilles tendon pain by Kinesio taping in an amateur badminton player. *Physical Therapy in Sport.* 2012;13(2):115-119.
220. Saavedra-Hernandez M, Castro-Sanchez AM, Arroyo-Morales M, Cleland JA, Lara-Palomo IC, Fernandez-de-Las-Penas C. Short-term effects of kinesio taping versus cervical thrust manipulation in patients with mechanical neck pain: a randomized clinical trial. *Journal of Orthopaedic and Sports Physical Therapy.* 2012;42(8):724-730.
221. Alam S, Malhotra D, Munjal J, Chachra A. Immediate effect of Kinesio taping on shoulder muscle strength and range of motion in healthy individuals: A randomised trial. *Hong Kong Physiotherapy Journal.* 2015.
222. Kim SY, Kang MH, Kim ER, Oh JS. Kinesio Taping improves shoulder internal rotation and the external/internal rotator strength ratio in patients with rotator cuff tendinitis. *Isokinetics and Exercise Science.* 2014;22:259-263.
223. Zanca GG, Mattiello SM, Karduna AR. Kinesio taping of the deltoid does not reduce fatigue induced deficits in shoulder joint position sense. *Clinical Biomechanics.* 2015;30(9):903-907.
224. Arab AM. A Randomized Clinical Trial of Kinesio-Taping on DASH in Patients with Subacromial Impingement Syndrome. *Journal of Novel Physiotherapies.* 2013;3(4).
225. Shaheen AF, Bull AM, Alexander CM. Rigid and Elastic taping changes scapular kinematics and pain in subjects with shoulder impingement syndrome; an experimental study. *Journal of Electromyography and Kinesiology.* 2015;25(1):84-92.
226. Kocyigit F, Acar M, Turkmen MB, Kose T, Guldane N, Kuyucu E. Kinesio taping or just taping in shoulder subacromial impingement syndrome? A randomized, double-blind, placebo-controlled trial. *Physiotherapy Theory and Practice.* 2016;32(7):501-508.
227. Oliveira VMAd, Batista LdSP, Pitangui ACR, Araújo RCd. Effectiveness of Kinesio Taping in pain and scapular dyskinesis in athletes with shoulder impingement syndrome. *Revista Dor.* 2013;14(1):27-30.
228. Burfeind SM, Chimera N. Randomized Control Trial Investigating the Effects of Kinesiology Tape on Shoulder Proprioception. *Journal of Sport Rehabilitation.* 2015;24(4):405-412.

229. Keenan KA, Akins JS, Varnell M, et al. Kinesiology taping does not alter shoulder strength, shoulder proprioception, or scapular kinematics in healthy, physically active subjects and subjects with Subacromial Impingement Syndrome. *Physical Therapy in Sport.* 2017;24:60-66.
230. Bey MJ, Brock SK, Beierwaltes WN, Zauel R, Kolowich PA, Lock TR. In vivo measurement of subacromial space width during shoulder elevation: technique and preliminary results in patients following unilateral rotator cuff repair. *Clinical Biomechanics.* 2007;22(7):767-773.
231. Harput G, Guney H, Toprak U, Colakoglu F, Baltaci G. Acute effects of scapular kinesiotaping on shoulder rotator strength, range of motion and acromiohumeral distance in asymptomatic overhead athletes. *Journal of Sports Medicine and Physical Fitness.* 2017;57(11):1479-1485.
232. Lyman KJ, Gange KN, Hanson TA, Mellinger CD. Effects of 3 Different Elastic Therapeutic Taping Methods on the Subacromial Joint Space. *Journal of Manipulative and Physiological Therapeutics.* 2017;40(7):494-500.
233. Alqunaee M, Galvin R, Fahey T. Diagnostic accuracy of clinical tests for subacromial impingement syndrome: a systematic review and meta-analysis. *Archives of Physical Medicine and Rehabilitation.* 2012;93(2):229-236.
234. Tekavec E, Joud A, Rittner R, et al. Population-based consultation patterns in patients with shoulder pain diagnoses. *BMC Musculoskeletal Disorders.* 2012;13:238.
235. Factor D, Dale B. Current concepts of rotator cuff tendinopathy. *International Journal of Sports Physical Therapy.* 2014;9(2):274-288.
236. Clisby EF, Bitter NL, Sandow MJ, Jones MA, Magarey ME, Jaberzadeh S. Relative contributions of the infraspinatus and deltoid during external rotation in patients with symptomatic subacromial impingement. *Journal of Shoulder and Elbow Surgery.* 2008;17(1 Suppl):87S-92S.
237. Hess SA, Richardson C, Darnell R, Friis P, Lisle D, Myers P. Timing of rotator cuff activation during shoulder external rotation in throwers with and without symptoms of pain. *Journal of Orthopaedic and Sports Physical Therapy.* 2005;35(12):812-820.
238. Wadsworth DJS, Bullock-Saxton JE. Recruitment patterns of the scapular rotator muscles in freestyle swimmers with subacromial impingement. *International Journal of Sports Medicine.* 1997;18(8):618-624.
239. Bertoft ES. Painful shoulder disorders from a physiotherapeutic view: a review of literature. *Critical Reviews in Physical and Rehabilitation Medicine.* 1999;11:229-277.
240. Kmet LM, Lee RC, Cook LS. Standard quality assessment criteria for evaluating primary research papers from a variety of fields. *Alberta Heritage Foundation for Medical Research.* 2004.
241. Barton CJ, Lack S, Malliaras P, Morrissey D. Gluteal muscle activity and patellofemoral pain syndrome: a systematic review. *British Journal of Sports Medicine.* 2013;47(4):207-214.
242. Van Tulder M, Furlan A, Bombardier C, Bouter L, Group EBotCCBR. Updated method guidelines for systematic reviews in the cochrane collaboration back review group. *Spine.* 2003;28(12):1290-1299.
243. Bandholm T, Rasmussen L, Aagaard P, Jensen BR, Diederichsen L. Force steadiness, muscle activity, and maximal muscle strength in subjects with subacromial impingement syndrome. *Muscle and Nerve.* 2006;34(5):631-639.
244. Michaud M, Arsenault AB, Gravel D. Muscular compensatory mechanism in the presence of a tendinitis of the supraspinatus. *American Journal of Physical Medicine.* 1987;66(3):109-120.
245. Johnson VL, Halaki M, Ginn KA. The use of surface electrodes to record infraspinatus activity is not valid at low infraspinatus activation levels. *Journal of Electromyography and Kinesiology.* 2011;21(1):112-118.

246. Waite DL, Brookham RL, Dickerson CR. On the suitability of using surface electrode placements to estimate muscle activity of the rotator cuff as recorded by intramuscular electrodes. *Journal of Electromyography and Kinesiology.* 2010;20(5):903-911.
247. Wickham J, Pizzari T, Stansfeld K, Burnside A, Watson L. Quantifying 'normal' shoulder muscle activity during abduction. *Journal of Electromyography and Kinesiology.* 2010;20(2):212-222.
248. Struyf F, Geraets J, Noten S, Meeus M, Nijs J. A Multivariable Prediction Model for the Chronification of Non-traumatic Shoulder Pain: A Systematic Review. *Pain Physician.* 2016;19(2):1-10.
249. van der Windt DA, Koes BW, Boeke AJ, Deville W, De Jong BA, Bouter LM. Shoulder disorders in general practice: prognostic indicators of outcome. *British Journal of General Practice.* 1996;46(410):519-523.
250. Frizziero A, Vittadini F, Gasparre G, Masiero S. Impact of oestrogen deficiency and aging on tendon: concise review. *Muscles, Ligaments and Tendons Journal.* 2014;4(3):324-328.
251. Oliva F, Piccirilli E, Berardi AC, Frizziero A, Tarantino U, Maffulli N. Hormones and tendinopathies: the current evidence. *British Medical Bulletin.* 2016;117(1):39-58.
252. Umer M, Qadir I, Azam M. Subacromial impingement syndrome. *Orthopedic Reviews.* 2012;4(2):e18.
253. Michener LA, Walsworth MK, Burnet EN. Effectiveness of rehabilitation for patients with subacromial impingement syndrome: a systematic review. *Journal of Hand Therapy.* 2004;17(2):152-164.
254. Drouin JL, McAlpine CT, Primak KA, Kissel J. The effects of kinesiotape on athletic-based performance outcomes in healthy, active individuals: a literature synthesis. *Journal of the Canadian Chiropractic Association.* 2013;57(4):356-365.
255. Lin JJ, Hung CJ, Yang PL. The effects of scapular taping on electromyographic muscle activity and proprioception feedback in healthy shoulders. *Journal of Orthopaedic Research.* 2011;29(1):53-57.
256. Coskun Benlidayi I, Salimov F, Kurkcu M, Guzel R. Kinesio Taping for temporomandibular disorders: Single-blind, randomized, controlled trial of effectiveness. *Journal of Back and Musculoskeletal Rehabilitation.* 2016;29(2):373-380.
257. El-Abd AM, Ibrahim AR, Hel-Hafez HM. Efficacy of kinesio taping versus postural correction exercises on pain intensity and axioscapular muscles activation in mechanical neck dysfunction: a randomized blinded clinical trial. *Journal of Sports Medicine and Physical Fitness.* 2017;57(10):1311-1317.
258. Kaplan S, Alpayci M, Karaman E, et al. Short-Term Effects of Kinesio Taping in Women with Pregnancy-Related Low Back Pain: A Randomized Controlled Clinical Trial. *Medical Science Monitor.* 2016;22:1297-1301.
259. Kelle B, Guzel R, Sakalli H. The effect of Kinesio taping application for acute non-specific low back pain: a randomized controlled clinical trial. *Clinical Rehabilitation.* 2016;30(10):997-1003.
260. Hsu YH, Chen WY, Lin HC, Wang WT, Shih YF. The effects of taping on scapular kinematics and muscle performance in baseball players with shoulder impingement syndrome. *Journal of Electromyography and Kinesiology.* 2009;19(6):1092-1099.
261. Montalvo AM, Cara EL, Myer GD. Effect of kinesiology taping on pain in individuals with musculoskeletal injuries: systematic review and meta-analysis. *The Physician and Sportsmedicine.* 2014;42(2):48-57.
262. Morris D, Jones D, Ryan H, Ryan CG. The clinical effects of Kinesio(R) Tex taping: A systematic review. *Physiotherapy Theory and Practice.* 2013;29(4):259-270.
263. Mostafavifar M, Wertz J, Borchers J. A systematic review of the effectiveness of kinesio taping for musculoskeletal injury. *The Physician and Sportsmedicine.* 2012;40(4):33-40.

264. Parreira Pdo C, Costa Lda C, Hespanhol LC, Jr., Lopes AD, Costa LO. Current evidence does not support the use of Kinesio Taping in clinical practice: a systematic review. *Journal of Physiotherapy.* 2014;60(1):31-39.
265. Williams S, Whatman C, Hume PA, Sheerin K. Kinesio taping in treatment and prevention of sports injuries: a meta-analysis of the evidence for its effectiveness. *Sports Medicine.* 2012;42(2):153-164.
266. Siegel LB, Cohen NJ, Gall EP. Adhesive capsulitis: a sticky issue. *American Family Physician.* 1999;59(7):1843-1852.
267. Hertel R, Ballmer FT, Lombert SM, Gerber C. Lag signs in the diagnosis of rotator cuff rupture. *Journal of Shoulder and Elbow Surgery.* 1996;5(4):307-313.
268. Miller CA, Forrester GA, Lewis JS. The validity of the lag signs in diagnosing full-thickness tears of the rotator cuff: a preliminary investigation. *Archives of Physical Medicine and Rehabilitation.* 2008;89(6):1162-1168.
269. Conroy DE, Hayes KW. The effect of joint mobilization as a component of comprehensive treatment for primary shoulder impingement syndrome. *Journal of Orthopaedic and Sports Physical Therapy.* 1998;28(1):3-14.
270. Mulligan B. *Manual Therapy: Nags, snags.* 4th Edition ed: Plane View Services; 1999.
271. Teys P, Bisset L, Vicenzino B. The initial effects of a Mulligan's mobilization with movement technique on range of movement and pressure pain threshold in pain-limited shoulders. *Manual Therapy.* 2008;13(1):37-42.
272. Andersen LL, Vinstrup J, Jakobsen MD, Sundstrup E. Validity and reliability of elastic resistance bands for measuring shoulder muscle strength. *Scandinavian Journal of Medicine & Science in Sports.* 2017;27(8):887-894.
273. McClure PW, Bialker J, Neff N, Williams G, Karduna A. Shoulder function and 3-dimensional kinematics in people with shoulder impingement syndrome before and after a 6-week exercise program. *Physical Therapy.* 2004;84(9):832-848.
274. Goldwasser RS, David CM. Weaning from mechanical ventilation: let's perform a strategy. *Revista Brasileira de Terapia Intensiva.* 2007;19(1):107-112.
275. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *American Journal of Industrial Medicine.* 1996;29(6):602-608.
276. Roy JS, MacDermid JC, Woodhouse LJ. Measuring shoulder function: a systematic review of four questionnaires. *Arthritis and Rheumatism.* 2009;61(5):623-632.
277. Durand MJ, Vachon B, Hong QN, Loisel P. The cross-cultural adaptation of the DASH questionnaire in Canadian French. *Journal of Hand Therapy.* 2005;18(1):34-39.
278. Schmitt JS, Di Fabio RP. Reliable change and minimum important difference (MID) proportions facilitated group responsiveness comparisons using individual threshold criteria. *Journal of Clinical Epidemiology.* 2004;57(10):1008-1018.
279. Tan G, Jensen MP, Thornby JI, Shanti BF. Validation of the Brief Pain Inventory for chronic nonmalignant pain. *Journal of Pain.* 2004;5(2):133-137.
280. Tatham B, Smith J, Cheifetz O, et al. The efficacy of exercise therapy in reducing shoulder pain related to breast cancer: a systematic review. *Physiotherapy Canada.* 2013;65(4):321-330.
281. Kirkley A, Alvarez C, Griffin S. The development and evaluation of a disease-specific quality-of-life questionnaire for disorders of the rotator cuff: The Western Ontario Rotator Cuff Index. *Clinical Journal of Sport Medicine.* 2003;13(2):84-92.

282. Kolber MJ, Hanney WJ. The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical report. *International Journal of Sports Physical Therapy.* 2012;7(3):306-313.
283. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of Electromyography and Kinesiology.* 2000;10(5):361-374.
284. Kamper SJ, Maher CG, Mackay G. Global rating of change scales: a review of strengths and weaknesses and considerations for design. *Journal of Manual & Manipulative Therapy.* 2009;17(3):163-170.
285. Hung CJ, Jan MH, Lin YF, Wang TQ, Lin JJ. Scapular kinematics and impairment features for classifying patients with subacromial impingement syndrome. *Manual Therapy.* 2010;15(6):547-551.
286. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods.* 2007;39(2):175-191.
287. Gupta SK. Intention-to-treat concept: A review. *Perspectives in Clinical Research.* 2011;2(3):109-112.
288. Zanella PW, Willey SM, Seibel SL, Hughes CJ. The effect of scapular taping on shoulder joint repositioning. *Journal of Sport Rehabilitation.* 2001;10(2):113-123.
289. Vafadar AK, Cote JN, Archambault PS. Interrater and Intrarater Reliability and Validity of 3 Measurement Methods for Shoulder-Position Sense. *Journal of Sport Rehabilitation.* 2016;Technical Report 19:2014-0309.
290. Cuesta-Vargas AI, Galan-Mercant A, Williams JM. The use of inertial sensors system for human motion analysis. *Physical Therapy Reviews.* 2010;15(6):462-473.
291. McCreesh KM, Anjum S, Crotty JM, Lewis JS. Ultrasound measures of supraspinatus tendon thickness and acromiohumeral distance in rotator cuff tendinopathy are reliable. *Journal of Clinical Ultrasound.* 2016;44(3):159-166.
292. McCreesh K, Adusumilli P, Evans T, Riley S, Davies A, Lewis J. Validation of ultrasound measurement of the subacromial space using a novel shoulder phantom model. *Ultrasound in Medicine & Biology.* 2014;40(7):1729-1733.
293. Kolber MJ, Fuller C, Marshall J, Wright A, Hanney WJ. The reliability and concurrent validity of scapular plane shoulder elevation measurements using a digital inclinometer and goniometer. *Physiotherapy Theory and Practice.* 2012;28(2):161-168.
294. de Oliveira FCL, de Fontenay BP, Bouyer LJ, Desmeules F, Roy JS. Effects of kinesiotaping added to a rehabilitation programme for patients with rotator cuff tendinopathy: protocol for a single-blind, randomised controlled trial addressing symptoms, functional limitations and underlying deficits. *British Medical Journal Open.* 2017;7(9):e017951.
295. Bjelle A. Epidemiology of shoulder problems. *Bailliere's Clinical Rheumatology.* 1989; 3(3):437-451.
296. Aydin T, Yildiz Y, Yanmis I, Yildiz C, Kalyon TA. Shoulder proprioception: a comparison between the shoulder joint in healthy and surgically repaired shoulders. *Archives of Orthopaedic and Trauma Surgery.* 2001;121(7):422-425.
297. Furmanek MP, Slomka K, Juras G. The effects of cryotherapy on proprioception system. *Biomedical Research International.* 2014;2014:696397.
298. Ager AL, Roy JS, Roos M, Belley AF, Cools A, Hebert LJ. Shoulder proprioception: How is it measured and is it reliable? A systematic review. *Journal of Hand Therapy.* 2017;30(2):221-231.

299. Proske U, Gandevia SC. The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. *Physiological Reviews.* 2012;92(4):1651-1697.
300. Suprak DN. Shoulder joint position sense is not enhanced at end range in an unconstrained task. *Human Movement Science.* 2011;30(3):424-435.
301. Sahin E, Dilek B, Baydar M, et al. Shoulder proprioception in patients with subacromial impingement syndrome. *Journal of Back Musculoskeletal Rehabilitation.* 2017;30(4):857-862.
302. Callaghan MJ, Selfe J, McHenry A, Oldham JA. Effects of patellar taping on knee joint proprioception in patients with patellofemoral pain syndrome. *Manual Therapy.* 2008;13(3):192-199.
303. Michener LA, Subasi Yesilyaprak SS, Seitz AL, Timmons MK, Walsworth MK. Supraspinatus tendon and subacromial space parameters measured on ultrasonographic imaging in subacromial impingement syndrome. *Knee Surgery, Sports Traumatology, Arthroscopy.* 2015;23(2):363-369.
304. Alexander CM, Stynes S, Thomas A, Lewis J, Harrison PJ. Does tape facilitate or inhibit the lower fibres of trapezius? *Manual Therapy.* 2003;8(1):37-41.
305. Seo HD, Kim MY, Choi JE, et al. Effects of Kinesio taping on joint position sense of the ankle. *Journal of Physical Therapy Science.* 2016;28(4):1158-1160.
306. de Oliveira FCL, de Fontenay BP, Bouyer LJ, Roy JS. Kinesiotaping increases the acromiohumeral distance in individuals with symptomatic rotator cuff tendinopathy. In: Combined Sections Meeting 2018, Orthopaedic Section Abstracts: Poster Presentations OPO1–OPO300. *Journal of Orthopaedic & Sports Physical Therapy.* 2018;48(1):A99.
307. de Oliveira FCL, Pairot de Fontenay B, Bouyer LJ, Roy JS. Immediate effects of kinesiotaping on acromiohumeral distance and shoulder proprioception in individuals with symptomatic rotator cuff tendinopathy. *Clinical Biomechanics.* 2018;61:16-21.
308. Noguchi K, Gel YR, Brunner E, Konietschke F. nparLD: an R software package for the nonparametric analysis of longitudinal data in factorial experiments. *Journal of Statistical Software.* 2012;50(12).
309. Farrar JT, Young JP, Jr., LaMoreaux L, Werth JL, Poole RM. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain.* 2001;94(2):149-158.
310. Kuhn JE. Exercise in the treatment of rotator cuff impingement: a systematic review and a synthesized evidence-based rehabilitation protocol. *Journal of Shoulder and Elbow Surgery.* 2009;18(1):138-160.
311. McLaren C, Colman Z, Rix A, Sullohern C. The effectiveness of scapular taping on pain and function in people with subacromial impingement syndrome: A systematic review. *International Musculoskeletal Medicine.* 2016;38(3-4):81-89.
312. Silva RT, Hartmann LG, Laurino CF, Bilo JP. Clinical and ultrasonographic correlation between scapular dyskinesia and subacromial space measurement among junior elite tennis players. *British Journal of Sports Medicine.* 2010;44(6):407-410.
313. Mansour C, Ouarezki Y, Jones J, et al. Trends in Scottish newborn screening programme for congenital hypothyroidism 1980-2014: strategies for reducing age at notification after initial and repeat sampling. *Archives of Disease in Childhood.* 2017;102(10):936-941.
314. Junior M, Almeida MO, Santos RS, Civile VT, Costa LOP. Effectiveness of Kinesio Taping(R) in Patients With Chronic Non-specific Low Back Pain: A Systematic Review With Meta-analysis. *Spine.* 2018.
315. Puerma-Castillo MC, Garcia-Rios MC, Perez-Gomez ME, Aguilar-Ferrandiz ME, Peralta-Ramirez MI. Effectiveness of kinesio taping in addition to conventional rehabilitation treatment on pain, cervical range of motion and quality of life in patients with neck pain: A randomized controlled trial. *Journal of Back and Musculoskeletal Rehabilitation.* 2018;31(3):453-464.

316. Oldfield RC. The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia.* 1971;9(1):97-113.
317. Cleeland CS, Ryan KM. Pain assessment: global use of the Brief Pain Inventory. *Annals of the Academy of Medicine Singapore.* 1994;23(2):129-138.