UNIVERSIDADE FEDERAL DE SÃO CARLOS

CENTRO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE

PROGRAMA DE PÓS-GRADUAÇÃO EM FISIOTERAPIA

**TESE DE DOUTORADO**

# Alterações biomecânicas e de sensibilidade à dor relacionadas ao encurtamento da cápsula posterior do ombro – Avaliação e tratamento

**Dayana Patricia Rosa**

**São Carlos**

**2018**

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Tese apresentada ao Programa de Pós-Graduação em Fisioterapia (PPGFT) da Universidade Federal de São Carlos (UFSCar), como parte dos requisitos para obtenção do título de Doutora em Fisioterapia.

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**São Carlos**

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Programa de Pós-Graduação em Fisioterapia

## Folha de Aprovação

Assinaturas dos membros da comissão examinadora que avaliou e aprovou a Defesa de Tese de Doutorado da candidata Dayana Patricia Rosa, realizada em 08/12/2017:

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“Você não escolhe as suas paixões. Suas paixões escolhem você”

(Jeff Bezos, fundador da Amazon)

“Escolha um trabalho que você ama e você nunca terá que trabalhar um dia sequer na vida”

(Confúcio, filósofo)

**Resumo**

Estudos têm mostrado que o encurtamento da cápsula posterior (ECP) pode estar envolvido com algumas disfunções e alterações de movimento do ombro. No entanto, não há um consenso sobre como avaliar o ECP isoladamente, considerando que alterações ósseas, como a retroversão umeral, podem influenciar as medidas sugeridas por estudos prévios. Há também escassez de estudos que avaliaram o efeito de tratamentos para o ECP, sendo que a falta de padronização das intervenções propostas dificulta as possibilidades de escolha na prática clínica. Com isso, os objetivos desta tese foram: 1) avaliar a cinemática escapular e umeral, a amplitude de movimento e a força dos rotadores laterais do ombro, o limiar de dor à pressão e a dor e a função do ombro em indivíduos com ECP, com e sem dor no ombro; 2) verificar os efeitos de um protocolo específico e outro não-específico para dor e ECP em indivíduos com encurtamento e dor no ombro para as mesmas variáveis do objetivo 1; e 3) determinar o quanto o ECP e a retroversão umeral interagem e influenciam os testes utilizados na prática clínica para avaliar a amplitude de movimento do complexo do ombro. O ECP foi quantificado pelo teste de *Low Flexion*. A retroversão umeral foi quantificada pelo ângulo bicipital do antebraço. A análise cinemática foi realizada por meio do sistema de rastreamento eletromagnético. Inclinômetro, dinamômetro e algômetro digitais foram utilizados para avaliar a amplitude de movimento, a força muscular e o limiar de dor, respectivamente. O questionário SPADI (*Shoulder Pain and Disabilities Index*) verificou a dor e função do ombro dos indivíduos. De um modo geral, os resultados mostraram que indivíduos com dor no ombro apresentaram alterações na cinemática da escápula e do úmero e na amplitude de movimento do ombro, que não foram intensificadas pela presença do ECP. No entanto, o ECP associado à dor no ombro contribuiu para um pior quadro de dor e função e uma diminuição do limiar de dor, que sugere um aumento da sensibilidade dolorosa nesses indivíduos. Após 4 semanas, apenas a intervenção específica melhorou o ECP, mas ambos os grupos diminuíram a translação do úmero, a dor no ombro e aumentaram a amplitude de movimento articular e o limiar de dor à pressão para os músculos avaliados. Quanto a interação do ECP e da retroversão umeral, os resultados mostraram que a torsão posterior do úmero e o ECP influenciaram os testes clínicos avaliados. No entanto, a combinação dessas alterações resultou em maiores limitações de amplitude de movimento do ombro. Com isso, percebe-se que indivíduos com a mesma disfunção musculoesquelética, como a dor no ombro, podem responder e se adaptar de maneira diferente em resposta à dor, e que as intervenções são essenciais para diminuir o quadro álgico. Além disso, apesar dos testes clínicos avaliados terem identificado as alterações de movimento adequadamente, são necessários novos estudos que verifiquem os resultados encontrados em indivíduos com disfunção no ombro.

**Palavras-Chave:** Alongamento, Dor, Escápula, Manguito Rotador, Mobilização, Retroversão.

**Abstract**

Some studies have shown that posterior capsule tightness may be related to shoulder dysfunctions and alterations in range of motion. However, there is no consensus in literature about how to specifically assess posterior capsule tightness, considering that bony adaptions, as humeral retroversion, may influence the clinical measurements suggested in previous studies. Furthermore, few studies have evaluated the effect of interventions on the posterior capsule tightness. In addition, the low quality of the studies limits the clinical decision-making. The aims of this thesis were: 1) to assess scapular and humeral kinematics, shoulder range of motion and external rotators strength, pressure pain threshold, pain and function in individuals with posterior capsule tightness with and without shoulder pain; 2) to compare the effects of a specific and a non-specific intervention to posterior capsule tightness and pain in individuals with capsule tightness and shoulder pain on the same outcomes presented in aim 1; 3) to determine how the posterior capsule tightness and humeral retroversion interact and influence measurements used to measure shoulder range of motion in the clinical practice. The posterior capsule tightness was quantified by the Low Flexion test. The humeral retroversion was quantified using the bicipital forearm angle. The electromagnetic system was used to measure kinematics. Digital inclinometer, dynamometer and goniometer were used to assess range of motion, muscle strength and pressure pain threshold, respectively. The Shoulder Pain and Disabilities Index (SPADI) assessed shoulder pain and function. In general, the results showed that individuals with shoulder pain presented changes in scapular and humeral kinematics and in shoulder range of motion, which were not intensified with posterior capsule tightness. However, the capsule tightness associated to shoulder pain contributed to worse pain and function of the shoulder, and decreased pressure pain threshold, which suggest increased pain sensitivity. After 4 weeks of intervention, only the specific one decreased the posterior capsule tightness. Both protocols decreased the humeral translations, shoulder pain and increased shoulder range of motion and pressure pain threshold. The posterior capsule tightness and humeral retroversion influenced the clinical measurements, but the two combined condition showed greater shoulder range of motion deficit. Thus, it is believed that individuals with the same musculoskeletal dysfunction, as shoulder pain, may respond differently to pain and develop individual adaptations to avoid pain and to preserve function. Further investigation of the clinical measurements used in the present study is needed in individuals with shoulder dysfunction.

**Key-Words:** Mobilization, Pain, Retroversion, Rotator Cuff, Scapula, Stretching.

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Esta tese de Doutorado dá continuidade à parceria estabelecida com o Prof. Dr. John Borstad, do *The College of St. Scholastica* nos Estados Unidos, durante o meu período de Mestrado (2012-2014), que também foi realizado sob orientação da Profa. Paula Camargo, e coorientação do Prof. John. Durante o Doutorado, seguimos a mesma linha dos estudos desenvolvidos no Mestrado que compreende analisar e propor intervenção às adaptações teciduais que possam estar relacionadas com a dor e às disfunções de movimento na articulação do ombro. Durante o Mestrado, meu objeto de estudo foi o encurtamento do músculo peitoral menor e três estudos foram desenvolvidos. No primeiro estudo, avaliamos a confiabilidade intra-avaliador, entre-avaliadores e entre-dias de um instrumento para mensurar o comprimento do músculo, considerando a distância entre suas origem e inserção, em indivíduos com e sem dor no ombro (Rosa et al., 2016). Concluímos que quantificar o comprimento do músculo peitoral menor considerando a distância entre suas origem e inserção é uma medida confiável. Posteriormente, verificamos os efeitos de uma técnica de alongamento para o músculo peitoral menor (Rosa et al., 2017) também em indivíduos com e sem dor no ombro. Neste estudo observamos que o alongamento no canto da parede (*corner stretch*) é efetivo para melhorar a dor e a função em indivíduos com dor no ombro, mas não altera o comprimento do músculo peitoral menor e a cinemática da escápula de forma significativa em indivíduos com e ser dor. Por fim, investigamos a correlação do comprimento do músculo peitoral menor com a amplitude de movimento de rotação lateral do braço paras as mesmas populações (Rosa et al., em revisão no periódico *Physiotherapy Theory and Practice*), e verificamos que não há correlação entre o comprimento do músculo e a amplitude de movimento de rotação lateral do braço para as mesmas populações.

A parceria estabelecida com o Prof. John permitiu sua visita ao nosso laboratório no Brasil por três vezes (2013-2015), assim como nossa ida, minha e da Profa. Paula, para os Estados Unidos numa visita à *Ohio State University,* onde o Prof. John coordenava um laboratório de análise de movimento em 2014. Em um desses encontros do nosso grupo de pesquisa, nasceu a ideia da presente tese. Em 2011, o Prof. John realizou um estudo em cadáveres para determinar um teste específico para quantificar o encurtamento da cápsula posterior do ombro. No entanto, poucos estudos haviam analisado os efeitos do encurtamento da cápsula na cinemática do ombro, assim como a investigação de intervenções efetivas para tal condição. Os poucos estudos encontrados, eram em sua maioria destinados à população de atletas arremessadores, sendo que nós acreditávamos fortemente que o encurtamento da cápsula poderia estar presente não só em arremessadores mas também na população em geral. Além disso, nenhum estudo havia utilizado o instrumento sugerido no estudo de 2011 (Borstad e Dashottar, 2011) para quantificar o encurtamento posterior da cápsula *in vivo.*

Nessa linha, foram realizados os estudos que deram origem aos dois primeiros manuscritos que compõem esta tese:

*Manuscrito I* - Avaliou a cinemática escapular e umeral, a amplitude de movimento de rotação medial e lateral, a força dos rotadores laterais do braço, o limiar de dor à pressão dos músculos trapézio superior, infraespinal, supraespinal, deltoide, elevador da escápula e tibial anterior, e a dor e a função do membro superior em indivíduos com encurtamento da cápsula posterior do ombro, com e sem dor no ombro. Os resultados deste estudo contribuem para um melhor entendimento de como pessoas com dor respondem e desenvolvem adaptações/mudanças em decorrência da presença da dor e de alterações teciduais como o encurtamento posterior da cápsula quando comparadas a indivíduos sem dor no ombro.

Pretende-se com esse estudo contribuir para abordagens mais direcionadas na prática clínica tanto para avaliação quanto para a intervenção nesses pacientes.

*Manuscrito II* – Comparou os efeitos de dois protocolos de intervenção, um específico para o encurtamento da cápsula posterior e dor e outro não específico, em indivíduos com encurtamento da cápsula e dor no ombro para as mesmas variáveis avaliadas no manuscrito I. Os resultados de melhora de dor e função por ambos os tratamentos propostos ressaltam a importância do alongamento e fortalecimento muscular em indivíduos com dor no ombro, sendo que técnicas específicas, como a mobilização articular, são necessárias para a diminuição do encurtamento da cápsula posterior. Tais resultados contribuem para o avanço na tomada de decisão clínica na área da fisioterapia, com intervenções mais direcionadas para pacientes com dor considerando a população em geral.

Durante o meu período de Doutorado, tive a oportunidade de fazer um estágio de pesquisa no exterior (bolsa BEPE FAPESP) pelo período de 1 ano sob supervisão do Prof. John. O estágio no exterior teve início na *Ohio State University* e se completou no *The College of St, Schollastica,* devido a nova posição assumida pelo Prof. John. Neste período, foram desenvolvidos mais dois estudos que complementaram a pesquisa desenvolvida no Brasil. Estes estudos avaliaram, principalmente, a influência do aumento da retroversão umeral no teste utilizado para quantificar o encurtamento da cápsula posterior. Também foi investigada a influência do encurtamento da cápsula e do aumento da retroversão em alguns testes clínicos utilizados para mensurar a amplitude de movimento do ombro. Como resultados desses estudos, foram redigidos os outros 2 manuscritos que completam esta tese:

*Manuscrito III* – Determinou a influência isolada e combinada do encurtamento da cápsula posterior e de um aumento na retroversão umeral em testes clínicos para amplitude de movimento em cadáveres. Os resultados deste estudo contribuem para a determinação de

testes de avaliação mais acurados, sendo que a realização de estudos *in vitro* aumenta a validade dos testes avaliados, uma vez que algumas alterações teciduais não podem ser provocadas *in vivo.*

*Manuscrito IV* - Identificou a influência do encurtamento da cápsula posterior e da retroversão umeral em testes clínicos de avaliação de amplitude de movimento em indivíduos com encurtamento da cápsula posterior com e sem aumento da retroversão umeral. Os resultados deste estudo complementam os achados do estudo III, nos quais a combinação de alterações teciduais e óssea, como o encurtamento da cápsula e a retroversão, provocou um maior déficit na amplitude de movimento identificada pelos testes propostos.

Ainda durante o meu período de Doutorado sanduíche, foi desenvolvido sob minha coorientação um outro estudo executado pela aluna de iniciação científica Júlia Ferreira, que também realizou um estágio no exterior (Bolsa BEPE FAPESP) no mesmo período em que estive na *Ohio State University*. Tal estudo investigou o movimento escapular durante a realização do teste utilizado para quantificar o encurtamento da cápsula e ainda se encontra em fase de análise de dados. A colaboração existente entre o nosso grupo de pesquisa no Brasil com o grupo de pesquisa da Profa. Dra. Paula Ludewig, na *University of Minnesota* nos Estados Unidos, me permitiu participar também do processo de análise de mais dois estudos que investigaram os efeitos da retroversão e translação umeral no espaço subacromial por meio de modelagem em ressonância magnética.

Durante o Doutorado, também tive a oportunidade de participar de importantes Congressos Internacionais relacionados a minha área de pesquisa, como: o *XXV Congress of International Society of Biomechanic*s (Glasgow/Escócia), *XXVI Congress of International Society of Biomechanic*s (Brisbane/Austrália), *11$^{th}$ Conference of the International Shoulder Group* (Winterthur/Suíça) e o *Combined Sections Meeting 2017* (San Antonio/Estados

Unidos), nos quais sempre apresentei resultados do trabalho desenvolvido ao longo desses 4 anos. Nesse período, também coorientei 4 alunos de iniciação científica e um destes estudos também encontra-se em análise de dados e resultará em mais um manuscrito. Em 2014, atuei como supervisora voluntária dos alunos do Estágio em Fisioterapia na Atenção Básica do curso de Fisioterapia da Universidade Federal de São Carlos e entre 2014-2016 participei do Projeto de Extensão para atendimento a Portadores de Dor no Ombro, realizados na Unidade Saúde Escola (USE) da Universidade Federal de São Carlos. Além disso, fui co-autora de um artigo do nosso grupo de pesquisa do Brasil que avaliou a diferença entre sexos para a cinemática da escápula (Habechian et al., 2016).

Diante do exposto, acredito que todo aprendizado que tive, principalmente no período da Pós-Graduação, me deu suporte e me preparou para que eu finalmente realize um dos meus maiores sonhos e atinja o meu principal objetivo, após vivenciar toda essa experiência tão desafiadora e que me encanta: a Docência! O que me motivou e me motiva é o sentimento de querer fazer a diferença através do Conhecimento, uma vez que o processo de Aprendizagem, mas do que um estímulo é algo que me emociona. A Pesquisa me ensinou a sempre querer buscar mais e hoje as novas ideias para estudos futuros são uma constante. Acredito que eu tenha aproveitado todas as oportunidades que me foram proporcionadas, e observei atentamente cada mestre que conviveu comigo, para que eu pudesse construir a Dayana que começa uma nova fase e a mais desafiadora delas!

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## CONTEXTUALIZAÇÃO

### *Dor no Ombro*

Em geral, a prevalência de dor no ombro na população varia de 7% a 26%.[92] Além da dor, estes indivíduos também apresentam limitações na amplitude de movimento do ombro, diminuição da capacidade laboral e das atividades de lazer, e dificuldade para dormir.[9] A maior parte dos casos de dor no ombro é diagnosticada como Síndrome do Impacto do Ombro,[15,159] que foi descrita por Neer em 1972.[114] De causa multifatorial, a Síndrome do Impacto tem sido associada a: déficits de força e amplitude movimento do ombro; mudanças na cinemática da escápula e do úmero; ativação de músculos do manguito rotador e escapulotorácicos alterada; realização de esportes ou atividades repetitivas com o braço acima da cabeça; morfologia óssea; e encurtamento de tecidos da região anterior e posterior da articulação glenoumeral.[4,16,125,152,168]

### *Encurtamento da Cápsula Posterior*

Acredita-se que o encurtamento da cápsula posterior esteja relacionado à algumas disfunções do ombro,[37,91,105] pois alterações cinemáticas,[8,74,85] de amplitude de movimento[75,99,150,151,157] e diminuição de força muscular,[84,99] identificadas em indivíduos com encurtamento da cápsula, foram semelhantes às descritas em indivíduos com dor no ombro.[86,89,93,83,164] Considerando que arremessadores e pessoas que realizam atividades acima da cabeça apresentam altas taxas de encurtamento da cápsula posterior,[167, 129] tal encurtamento é descrito como uma adaptação às altas cargas de estresse impostas à cápsula durante a fase de desaceleração do braço no movimento de arremesso.[16,122] Essas altas cargas repetitivas podem gerar microtraumas que podem estimular a fibrose da cápsula posterior e

restringir a amplitude de movimento normal do ombro.[18,122] No entanto, o encurtamento da cápsula posterior também foi encontrado em indivíduos que não realizavam atividade acima do nível da cabeça,[85,98,101,123] o que torna importante a realização de estudos que analisem os efeitos de tal adaptação associado à presença de dor no ombro.

A literatura sugere vários métodos de avaliação para o encurtamento da cápsula posterior.[10,158,163] Warner et al[163] propuseram avaliar o encurtamento quantificando a amplitude de adução horizontal à 90° de flexão do braço com o indivíduo em decúbito dorsal. Um outro estudo propôs avaliar a flexibilidade da cápsula posterior também através do teste de adução horizontal a 90° de elevação do braço, mas com o indivíduo em decúbito lateral,[158] uma vez que tal posicionamento permite que o terapeuta observe melhor o movimento da escápula. Ambos os testes apresentaram correlação entre o encurtamento posterior da cápsula, diminuição da rotação medial e aumento da rotação lateral da articulação glenoumeral em arremessadores.[17,80,113,157,158] Baseado nisso, medir a rotação medial com o braço a 90° de abdução é frequentemente utilizado para avaliar o encurtamento da cápsula posterior.[80,113,158] No entanto, foi realizado um estudo em cadáveres,[10] posteriormente validado *in vivo*,[11] que indicou maior tensão na cápsula posterior ocasionada pelos teste de flexão do ombro a 40° e 60° associados à rotação medial da glenoumeral, quando comparados a outros testes propostos para avaliar o encurtamento da cápsula posterior, incluindo a adução horizontal. No entanto, nenhum dos testes mencionados avaliou a influência da retroversão umeral em seus resultados, adaptação óssea que também pode levar a uma diminuição da rotação medial do braço.[31,75,104,120,127,130,151,153]

*Retroversão Umeral*

A retroversão umeral é parte inicial do desenvolvimento humano.[38,151] Crianças apresentam o ângulo de torção em torno de 70°, sendo que com o processo de desenvolvimento, esse ângulo corresponde à cerca de 30° em adultos.[38] Tal ângulo pode ser mensurado diretamente por meio de Raio-X[120,130,153] ou tomografia computadorizada.[22,31,62] No entanto, esse ângulo de torção tem sido amplamente mensurado por meio de ultrassom, um método de baixo-custo e não invasivo,[47,68,77,112,119,151,165] que resulta em uma medida alternativa e indireta da retroversão umeral conhecida como ângulo bicipital do antebraço.[70] Como a ulna é perpendicular ao eixo epicondilar do úmero, quando o cotovelo é posicionado à 90° de flexão, o ângulo formado entre a ulna e a vertical pode ser usado para quantificar a retroversão do úmero. No entanto, tal ângulo é inversamente proporcional ao ângulo de torção umeral.[173]

Um aumento desse ângulo tem sido descrito em atletas arremessadores.[95,104,111,127,145,151,153] Acredita-se que as repetidas forças rotacionais produzidas durante o movimento de arremesso possam limitar o movimento natural do úmero no sentido da anteversão e manter um posicionamento de retroversão.[38,79,151] Tal adaptação óssea tem sido relacionada a alterações de amplitude de movimento do ombro similares as apresentadas por indivíduos com encurtamento da cápsula posterior, como o déficit de rotação medial.[31,75,104,120,127,130,151,153] Considerando as alterações de amplitude de movimento similares entre ambas as condições, encurtamento da cápsula posterior e retroversão umeral, são importantes novas investigações que possam analisar a influência de cada uma das alterações isoladamente ou quando coexistem em um indivíduo.

*Cinemática da Escápula e do Úmero*

Dentre as alterações cinemáticas descritas em indivíduos com encurtamento da cápsula posterior têm-se o aumento da inclinação anterior e rotação interna da escápula e diminuição da rotação superior escapular em arremessadores e indivíduos com déficit de rotação medial do braço.[8,74] Estudos também demonstraram diminuição da translação posterior e aumento da translação superior do úmero durante a elevação do braço em indivíduos com encurtamento da cápsula posterior.[85,175] Da mesma forma, cadáveres em condição de encurtamento da cápsula foram identificados com aumento das translações superior e anterior do úmero durante o movimento passivo de flexão do braço.[56] Como mencionado anteriormente, tais alterações já foram previamente descritas em indivíduos com dor no ombro.[89, 93, 86,164] Uma translação anterior do úmero aumentada, durante o movimento de elevação do braço, em indivíduos com Síndrome do Impacto quando comparados a indivíduos assintomáticos;[83,90] e uma diminuição da rotação superior e da inclinação posterior, com aumento da rotação interna da escápula durante a elevação do braço[82,89,93,164] também já foram identificados em indivíduos com dor no ombro.

*Cápsula x Força de rotação do Ombro*

Déficit na força de rotação lateral do ombro também já foi previamente descrito em atletas com encurtamento da cápsula posterior e dor no ombro.[99] Marcondes et al[99] observaram que o ombro doloroso de tenistas com encurtamento da cápsula posterior apresentou diminuição da força dos rotadores laterais ao serem comparados à um grupo controle. Considerando o papel crítico que o manguito rotador desempenha na estabilização da glenoumeral em relação as translações excessivas durante a elevação do braço,[125] uma diminuição de força dessa musculatura pode contribuir para o aumento da translação do úmero em indivíduos com encurtamento da cápsula posterior e assim favorecer o

aparecimento de lesões nos tendões do manguito rotador, principalmente do músculo supraespinal.

*Sensibilidade à Dor*

Lesões no músculo supraespinal foram previamente relacionadas a alterações degenerativas relacionadas à idade, vascularização precária do tendão, movimentos repetitivos acima do nível da cabeça e impacto subacromial.[42,58] Acredita-se também que a interação de fatores como encurtamento da cápsula posterior, aumento da translação superior do úmero, alterações na cinemática escapular e déficit de força dos rotadores laterais, como descrito anteriormente, podem contribuir para a redução do espaço subacromial favorecendo a ocorrência de tais lesões. Esses danos ao tendão desencadeiam dor e inflamação, sendo que a persistência desses estímulos de micro-lesões podem iniciar um processo de sensibilização central ao longo do tempo.[26,161]

A sensibilização central corresponde ao aumento da excitabilidade neuronal resultando em dor crônica, hiperalgesia secundária (devido ao aumento do campo receptor dos nociceptores) e alodínia após lesões periféricas.[32,142] A hipersensibilidade central amplifica a entrada de impulsos nociceptivos decorrentes de tecidos danificados, ocasionando hipersensibilidade à dor também em áreas saudáveis, característica comum nas síndromes de dor crônica.[32,33,43,49,96,142,170] Processamento da dor aumentado a nível medular (neurônios do corno dorsal), causado por um contínuo bombardeamento de receptores periféricos,[161] já foi relacionado a alterações no sistema de modulação nociceptiva[26] em estudos com animais.

A hipersensibilidade à dor é frequentemente avaliada por meio do limiar de dor à pressão,[1,23,29,65,67] e já foi utilizada na investigação de hipersensibilidade dolorosa mecânica

em indivíduos com Síndrome do Impacto.[1,65,67] Hidalgo-Lozano et al[65] sugeriram presença de sensibilização central e periférica nessa população, enquanto Alburquerque-Sendín et al[1] não identificaram sensibilização central em indivíduos com Síndrome do Impacto. Uma revisão sistemática[141] concluiu que ainda não há evidências seguras sobre a sensibilização central em indivíduos com dor no ombro, sendo este um aspecto ainda controverso e que necessita mais estudos com alta qualidade metodológica. Além disso, não foram encontrados estudos que tenham verificado os limiares de dor em indivíduos com encurtamento da cápsula posterior para que os mecanismos neurofisiológicos resultantes desta condição possam ser melhor compreendidos.

*Intervenção Fisioterapêutica*

Entre os procedimentos de intervenção recomendados e frequentemente utilizados na fisioterapia para o tratamento de disfunções no ombro, destacam-se os exercícios terapêuticos e a terapia manual.[19,53,73,101,102,149] O alongamento e a mobilização da cápsula posterior são sugeridos como intervenção para aumentar a amplitude de rotação medial do ombro e diminuir o encurtamento da cápsula posterior em pessoas com e sem dor no ombro.[28,39,48,55,98,101,123,154,156] Apesar da efetividade dos protocolos, tais técnicas foram utilizadas em atletas,[28,39,48,55] indivíduos com síndrome do impacto[154,156] ou assintomáticos para dor no ombro[98,101,123] sem a presença de um grupo controle ou com descrição não detalhada dos protocolos, dificultando a reprodução das mesmas na prática clínica.

Algumas revisões sistemáticas foram conduzidas para investigar a efetividade de técnicas para redução do encurtamento da região posterior do ombro resultando em diminuição da rotação medial de tal articulação.[57,107,116] Quando apenas técnicas de alongamento foram empregadas na intervenção do encurtamento posterior do ombro,

moderada[107] e fraca evidência[116] foram demonstradas. No entanto, a associação das técnicas de mobilização e alongamento foram efetivas para reduzir a diminuição da rotação medial em indivíduos com encurtamento da cápsula posterior com e sem dor no ombro, apontando uma evidência moderada.[57] Para esta revisão foram incluídos 3 estudos que atenderam os critérios de inclusão.[28,98,156]

Um dos estudos encontrou uma diminuição do encurtamento da cápsula posterior, aumento da rotação medial e melhora da dor em indivíduos com impacto interno após um protocolo de alongamento (*sleeper* e *cross-body stretching*) e mobilização da cápsula posterior, e fortalecimento dos rotadores externos e estabilizadores da escápula.[156] No entanto, tal estudo não descreveu como realizou o protocolo de fortalecimento. Um outro estudo comparou os efeitos de duas intervenções para aumentar a amplitude de rotação medial da glenoumeral em indivíduos assintomáticos para dor no ombro.[98] Foi encontrado maior aumento da rotação medial, com manutenção do ganho após 4 semanas do término da intervenção, no grupo que realizou o alongamento *cross-body* e mobilização da cápsula posterior quando comparado ao grupo que realizou apenas o mesmo alongamento.[98] Cools et al.[28] compararam o efeito de duas intervenções (alongamentos *sleeper* e *cross-body stretching* com mobilizações da cápsula da cápsula posterior) em atletas com encurtamento da cápsula posterior com e sem dor no ombro. Ambas intervenções foram eficazes para aumentar a rotação medial da glenoumeral e diminuir a dor nos indivíduos sintomáticos, sendo que os ganhos foram mantidos após 3 semanas do término da intervenção. Além destes, um outro estudo foi realizado em indivíduos assintomáticos para dor no ombro com diminuição da rotação medial da glenoumeral e foi encontrado que o alongamento com adução através do corpo (*cross-body stretch*) foi mais efetivo que o alongamento em rotação medial e decúbito lateral (*sleeper stretch*) para aumentar a rotação medial do ombro.[101]

De acordo com o apresentado, percebe-se que ainda faltam estudos de análise de cinemática, amplitude de movimento, força, alterações de sensibilidade dolorosa, dor e função do ombro em indivíduos com encurtamento da cápsula posterior na população em geral, uma vez que a maioria dos estudos são em populações de atletas arremessadores. Torna-se importante identificar métodos adequados para quantificar o encurtamento da cápsula posterior, assim como determinar se existe uma relação entre o encurtamento, incapacidade do ombro, alterações biomecânicas e de sensibilidade dolorosa para uma melhor compreensão desta condição em indivíduos com e sem dor no ombro. Além disso, também é importante determinar a eficácia de programas de alongamento e/ou mobilização da cápsula posterior do ombro em condição de encurtamento desta estrutura, considerando que nenhum estudo avaliou a efetividade de protocolos de intervenção na força, cinemática do ombro e sensibilidade à dor em indivíduos com dor e encurtamento da cápsula posterior. Tais estudos permitem readequar as técnicas de tratamento que estão sendo utilizadas e fornecem embasamento científico a prática clínica para que sejam estabelecidos protocolos de intervenção mais eficazes e reprodutíveis para tal disfunção.

## OBJETIVOS DA TESE

Os objetivos desta tese foram:

1) avaliar a cinemática escapular e umeral, a amplitude de movimento de rotação e a força dos rotadores laterais do braço, o limiar de dor à pressão para os músculos da articulação do ombro, dor e a função do membro superior, em indivíduos com e sem encurtamento da cápsula posterior com e sem dor no ombro;

2) verificar os efeitos de dois protocolos de intervenção em indivíduos com encurtamento da cápsula posterior e dor no ombro para as mesmas variáveis acima descritas;

3) usar cadáveres para determinar a influência individual e combinada, do encurtamento da cápsula posterior e de um aumento na retroversão umeral em testes clínicos para amplitude de movimento;

4) identificar a influência do encurtamento da cápsula posterior e da retroversão umeral em testes clínicos de avaliação de amplitude de movimento em indivíduos sem dor no ombro, com e sem encurtamento da cápsula posterior com e sem aumento da retroversão umeral.

## HIPÓTESES

As hipóteses desta tese foram:

1) indivíduos com encurtamento da cápsula posterior com e sem dor no ombro apresentariam alterações em todas as variáveis descritas no objetivo 1, sendo que aqueles apenas com encurtamento da cápsula posterior apresentariam alterações semelhantes aos indivíduos com dor no ombro e indivíduos com encurtamento da cápsula posterior e dor apresentariam alterações ainda maiores para tais variáveis;

2) ambos os grupos apresentariam alterações nas variáveis avaliadas com diminuição da dor e melhora da função do membro superior afetado principalmente, mas que o grupo com intervenção específica para o encurtamento da cápsula posterior e dor apresentasse uma melhora maior após a realização da intervenção;

3) a combinação das condições de encurtamento da cápsula posterior e aumento da retroversão umeral resultaria em maior influência nos testes clínicos para amplitude de movimento avaliados.

**MANUSCRITO I**

# Interaction between posterior capsule tightness and shoulder pain on kinematics, range of motion, strength, pain and function

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**Manuscrito em revisão no periódico *Physical Therapy*** (Fator de Impacto 2,764)

**Abstract**

**Background:** Alterations related to posterior capsule tightness (PCT) are described in asymptomatic individuals. No studies have investigated the possible alterations present in individuals with PCT concomitant shoulder pain.

**Objectives:** To evaluate how PCT and shoulder pain interact to affect scapular and humeral kinematics, glenohumeral joint range of motion (ROM), strength of the glenohumeral external rotators (ER), pressure pain threshold (PPT) and shoulder pain and function.

**Design:** Cross-sectional study

**Methods:** Individuals were divided in 4 groups: no pain+no PCT group (n=28), no pain+PCT (n=27), pain+no PCT (n=25), and pain+PCT (n=25). PCT was determined by the low flexion (LF) test. Scapular kinematics and humeral translations were tracked during arm flexion. Shoulder internal (IR) and external rotation (ER) ROM, strength of the external rotators, PPT and Shoulder Pain and Disabilities Index (SPADI) were assessed in all individuals.

**Results:** The Pain+No PCT group showed increased scapular internal rotation ($P$<.001) and posterior tilt ($P$ =.01) and decreased humeral anterior translation ($P$ <.01). This group also showed higher LF test values when compared with both PCT groups ($P$ <.01). The No PCT groups showed more IR ROM ($P$ <.01). The Pain+PCT group showed decreased PPT for upper trapezius and levator scapulae muscles (P<.01) and presented the highest SPADI score ($P$<.01). The No pain+PCT group showed increased PPT for anterior tibialis muscle ($P$<.001).

**Limitation:** These results cannot be generalized to acute shoulder pain.

**Conclusion:** No interaction between pain and PCT to scapular and humeral kinematics was demonstrated, but limited ROM and worse pain condition was found in individuals with pain and PCT.

**Key Words:** contracture, glenohumeral joint, shoulder impingement syndrome.

## Introduction

Shoulder pain is a prevalent musculoskeletal complaint[10,14] that can impair participation in work and recreational activities, lead to difficulty in performing daily activities, and disrupt sleep.[9,78] Consequently, this condition has a negative effect on quality of life. Many potential causes of shoulder pain have been described, including degenerative changes in the supraspinatus tendon,[118] acromion morphology,[7] alteration in scapular and humeral head kinematic,[60,85,89,90,93] muscle length adaptations[13] or muscle activation changes, [12,89] repetitive overhead activity,[80,87,133] and posterior glenohumeral joint capsule tightness.[16,85]

Posterior capsule tightness (PCT) is a common soft tissue alteration in individuals who perform repetitive overhead sports or activities.[129,167] The tightness is described as an adaptation to repetitive high tensile loading on the posterior shoulder capsule during the deceleration phase of throwing.[16,122] When these stresses are frequent, as seen in throwing athletes, tissue microtrauma may stimulate posterior capsule fibrosis,[17,122] altering normal glenohumeral range of motion (ROM)[75,150,151,157] and shoulder kinematics.[8,56,74,85,174]

Alterations in scapular and humeral kinematics, similar to those described in individuals with shoulder pain,[83,90] have also been described in asymptomatic throwers and non-throwers with PCT and in cadavers with experimental PCT.[8,56,74] PCT has also been associated with decreased internal rotation (IR) and increased external rotation (ER) range of motion (ROM) in overhead athletes with and without shoulder pain and in individuals with shoulder pain.[75,99,150,151,157] Shoulder external rotator (ER) muscle deficit has also been reported in overhead athletes with PCT and shoulder pain,[84,99] which may decrease glenohumeral dynamic stabilization and contribute to shoulder pain.[99]

It is believed that all of the tissue and motion alterations described above can exacerbate and/or perpetuate shoulder symptoms and may lead to a chronic painful condition.[26,161] Previous studies have suggested that the chronicity of musculoskeletal dysfunction can initiate a sensitization process.[45,117,170] There is also evidence linking shoulder pain with peripheral (PS) and central sensitization (CS).[1,30,49,65,66,124] Because PCT is regularly present in throwing athletes with and without shoulder pain, it is important to also determine if this tissue alteration is present in non-throwers with and without shoulder pain, and to assess its potential effect on shoulder biomechanics.

The purpose of this study was to comprehensively evaluate how combinations of PCT and shoulder pain interact to affect scapular and humeral kinematics, IR and ER glenohumeral joint ROM, strength of the glenohumeral ER, pressure pain threshold (PPT) in the shoulder muscles, and upper-limb pain and function. Kinematics, ROM and strength were considered to be the primary outcomes. PPT, pain and function were secondary outcomes. It was hypothesized that asymptomatic individuals with PCT would present the similar outcomes as those individuals with shoulder pain, and that outcomes would be more affected in individuals having both shoulder pain and PCT.

## Methods

A total of 163 individuals were initially recruited and assessed for eligibility by a physical therapist with 5 years of experience. Sample size was determined using the G-Power software (version 3.1), and was based on a significance level of 0.05, power of 0.80 and an effect size of 0.25 to detect a clinically meaningful angular change of 5° in scapular kinematics.[13,51,136] Based on calculations, 25 individuals were required per group. One-hundred and five individuals completed the study (**FIGURE 1**) and were divided into four

groups based on the presence of PCT and shoulder pain: no pain + no PCT group (n=28), no pain + PCT (n=27), pain + no PCT (n=25), and pain + PCT (n=25). The descriptive data of the participants are presented in **TABLE 1**.

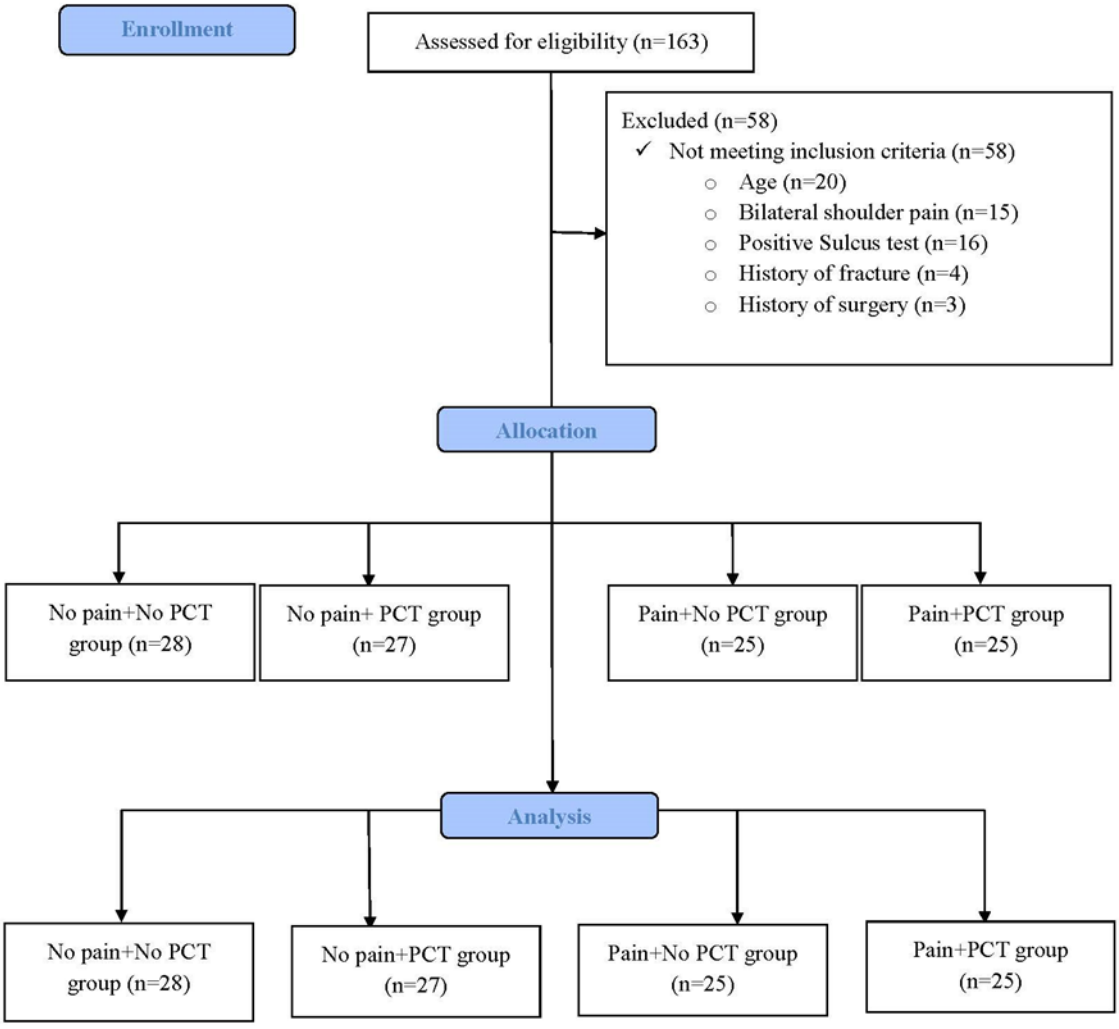


**FIGURE 1.** Flow diagram representing enrollment, allocation, and analysis of the groups.

**TABLE 1. Demographic characteristics of the participants of the study.**

| | No pain + no PCT (n=28) | No pain + PCT (n=27) | Pain + no PCT (n=25) | Pain + PCT (n=25) | p-value |
|---|---|---|---|---|---|
| **Female (%)** | 17 (63) | 12 (43) | 14 (56) | 14 (56) | - |
| **Age (years)** | 27.4 ± 6.6 | 29.0 ± 8.0 | 32.2 ± 12.3 | 33.5 ± 10.1 | 0.06 |
| **Height (m)** | 1.69 ± 0.08 | 1.70 ± 0.10 | 1.68 ± 0.12 | 1.68 ± 0.10 | 0.89 |
| **Weight (kg)** | 67.98 ± 11.73 | 70.04 ± 12.28 | 71.46 ± 15.61 | 69.88 ± 10.77 | 0.95 |
| **Overhead activity (%)** | 7 (25) | 5 (19) | 11 (44) | 11 (44) | 0.10 |
| **Dominant Shoulder Evaluated** | 23 | 23 | 14 | 24 | - |
| **Duration of pain (months)** | - | - | 35.52 ± 60.74 | 39.72 ± 44.88 | 0.48 |

Values are mean (standard ± deviation).

Abbreviation: PCT, Posterior Capsule Tightness

A group of individuals without shoulder pain, but with PCT, was included to determine the effect of PCT on the outcomes without any possible additional influence of pain. Similarly, a group of individuals without shoulder pain or PCT served as a control group. Pain and PCT had to be present as unilateral conditions. The groups were matched based on the individual's overhead activities because some individuals from the PCT groups were throwing athletes. Groups were also matched for demographic data to ensure baseline equivalence. All individuals were required to have active arm elevation of 150° as determined

by a digital inclinometer to ensure that an adequate range of scapula kinematic data would be captured with the electromagnetic system during arm elevation.

PCT was estimated with the Low Flexion Test (LFT, **FIGURE 2A**).[10] This test is performed with the humerus at 60° of sagittal plane arm elevation. In this position, the examiner supports the arm and allows glenohumeral IR to reach the end of passive motion. The digital inclinometer is positioned on the distal surface of the forearm to measure the angle between the forearm and the horizontal.[10] The validity and intra-rater reliability of the LFT have been reported as excellent when evaluated on the same day.[10,11] The posterior capsule was considered tight when a decrease of at least 7° in the LFT was identified in comparison to the contralateral side as previously determined in a pilot study.


**FIGURE 2.** Measurements of the Posterior Capsule Tightness by the Low Flexion test in the standing position (A); strength of the external rotators of the shoulder in the sitting position (B); and internal (C) and external (D) rotation range of motion of the arm in the supine position.

Individuals with shoulder pain had to report at least three months of symptoms consistent with shoulder impingement syndrome (SIS). Self-reported history and a clinical examination were used to diagnose SIS.[51,54,87,135] At least 3 of the following had to test positive:[51,54,87,135] Neer test,[114] Hawkins test,[59] Jobe test,[72] pain with passive or isometric resisted shoulder ER,[126,135] pain with active shoulder elevation,[69] and pain in the anterolateral shoulder region.[87,89,90,103,135]

Asymptomatic individuals were excluded if they had any of the positive signs and symptoms for SIS noted above. Individuals were also excluded from participating if they 1) were pregnant; 2) demonstrated glenohumeral joint ligamentous laxity based on a positive

sulcus,[115] apprehension[137] or anterior drawer test;[103] 3) reported a history of traumatic shoulder pathology, fracture or shoulder surgery; 4) had a history of adhesive capsulitis, scoliosis or systemic illnesses; 5) had bilateral symptoms; 6) had a body mass index > 28kg/m$^2$, because higher indexes may increase error through skin-motion artifact during kinematics data collection; 7) were allergic to transpore tape; 8) had received physical therapy treatment in the last 6 months[20] 9) had taken analgesics or muscle relaxants at 72 hours before the examination;[1] or 10) had a steroid injection in the last 6 weeks.[21]

The study was approved by the Ethics Committee of the University (protocol number 860.648). Data collection was performed at the Laboratory of Analysis and Intervention of the Shoulder Complex at Universidade Federal de São Carlos - Brazil. All individuals gave their written and informed consent to participate in this study, which was conducted according to the Helsinki Statement. All measurements were taken by the principal investigator who was not blinded to group assignment.

*3D Scapular Kinematics and Humeral Translations*

To measure scapular kinematics and humeral translations, the Flock of Birds® (miniBird®) hardware (Ascension Technology Corporation, Burlington, VT) integrated with the MotionMonitor™ software (Innovative Sports Training, Inc. Chicago, IL) was used for data capture and analysis.[13,54,90,136] The 3D position and orientation of three motion capture sensors were tracked simultaneously at a sampling rate of 100 Hz. Sensors were secured with double-sided adhesive tape and transpore tape to the sternum and acromion, and with a thermoplastic cuff to the distal humerus. The system transmitter was positioned directly posterior to the shoulder tested. Bony landmarks on the thorax, scapula and humerus were

palpated and digitized to transform the sensor data into local anatomically-based coordinate systems.

Local coordinate systems were established for the trunk, scapula and humerus as per the International Society of Biomechanics.[172] For all local coordinate systems the z-axis pointed laterally, the x-axis anteriorly and the y-axis superiorly. Scapular orientation relative to the trunk (internal/external rotation, upward/downward rotation and anterior/posterior tilt) were described using a YX'Z" Euler sequence.[172] Humeral orientation relative to the trunk (plane of elevation, elevation, and internal/external rotation) was described with a YX'Y" Euler sequence.

For humeral translations, the helical axis was determined and its anterior-posterior and superior-inferior vector components used to describe humeral head position.[90] Translations were reported as linear changes in the position of the estimated humeral head center relative to the glenoid at each angle of arm elevation.[2,83,89] The center of the humeral head was estimated by moving the arm passively through short arcs of motion (< 45°) to define the pivot point.[2] The helical axis is a single oblique axis about which the humerus is rotating for that specific phase of motion.[90] The superior-inferior translation of the humerus was described by the z-component of the helical translation vector, and the humeral anterior-posterior translation by the y-component.[90] Excellent helical axis within-day trial-to-trial reliability (ICC ~ 0.85; SEM ~ 1mm) was previously shown to measure the humeral translations.[90]

All kinematic data collection began with participants in a relaxed standing position. They elevated their arm from a dependent position through their full range of motion at a speed such that it took approximately 3 seconds to elevate and 3 seconds to lower their arm. Individuals maintained light fingertip contact with a flat planar surface and their thumb

pointed superiorly during these motions to maintain consistent positioning in the sagittal plane (**FIGURE 3**). Data were collected during three consecutive repetitions. This procedure has been shown to be reliable in individuals with and without shoulder pain.[51]

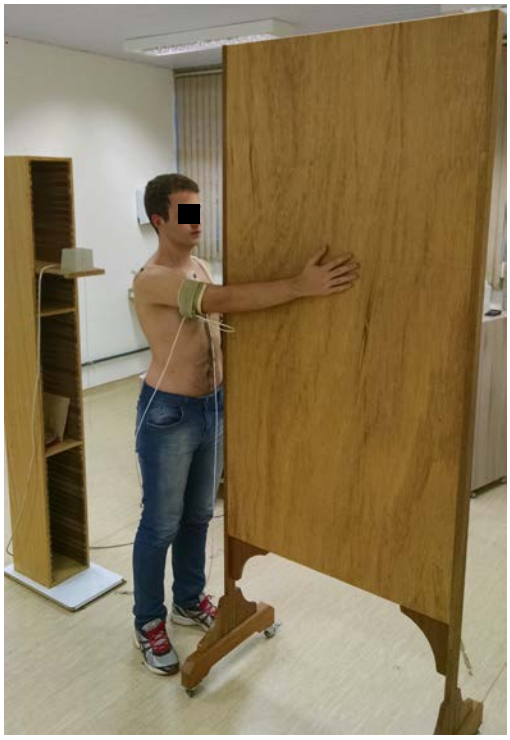

**FIGURE 3.** Set up for data collection for scapula and humeral kinematics.

*ROM assessment*

Glenohumeral IR and ER ROM were measured with a digital inclinometer (Acumar ™, Lafayette Intrument Company, Lafayette, IN). The inclinometer measures angles from a horizontal or vertical reference within 1° accuracy as reported by the manufacturer. The participant was positioned supine with the shoulder in 90° of abduction and the elbow flexed to 90°. The arm was then rotated into maximum IR and the inclinometer was placed on the ventral surface of the forearm (**FIGURE 2C**). For ER, the inclinometer was placed on the dorsal surface of the forearm at the maximum ER ROM (**FIGURE 2D**). These measurements

are commonly used in clinical practice and reported as reliable.[27] Each measure was taken twice and the mean value used for statistical analysis. The first evaluator was blinded during the measurements. A second evaluator recorded the results and stabilized the scapula during IR ROM assessment.

*Strength of the ER*

A handheld dynamometer (Lafayette Instrument Company, Lafayette, IN, USA) was used to measure strength of the ER of the shoulder. Individuals were positioned in sitting with the shoulder in neutral and the elbow flexed to 90°. The dynamometer was positioned between the wall and the dorsal surface of the wrist 2 cm proximal to the radial styloid process (**FIGURE 2B**). Participants were familiarized with the procedure by performing two submaximal trials with a 10-second rest interval. Afterwards, two 5-second maximal isometric contractions were performed against the wall with a rest interval of 30 seconds. The mean value of the 2 repetitions was used for data analysis. A standardized verbal encouragement to develop maximal strength in all contractions was given by the principal investigator to all participants during the testing procedure. A second examiner recorded the results to ensure that the first examiner was blinded during the test.

*Pressure Pain Threshold (PPT)*

PPT is defined as the minimal amount of pressure at which a sensation of pressure changes to pain.[40] A digital pressure algometer (model OE-220, ITO - Physiotherapy & Rehabilitation, Japan) was used for testing. The device consists of a $1cm^2$ rubber disk attached to a strain gauge, which displays values in kg force/$cm^2$. Pressure through the disk was applied at a rate of $1kgf/cm^2/s$ and participants pressed a hand-held switch when the

sensation first changed from pressure to pain.[160] Data were converted into kPa for further analysis. PPTs were evaluated unilaterally over the upper trapezius (halfway between neck and shoulder over the muscle fibers), infraspinatus (muscle belly bellow the middle point of the spine of the scapula), supraspinatus (middle point over the fossa of the scapula), middle deltoid (muscle belly close to inferolateral insertion), levator scapulae (2cm superior to the superior angle of the scapula) and tibialis anterior (halfway between the most superior attachment to the tibia and its tendon in the upper one third of the muscle belly) (**FIGURE 4**). Tibialis anterior was chosen because it has been used as a remote site in previous studies.[1,19]

The testing order of the muscles was randomized before the evaluation. PPTs were measured three times at each point by the first examiner and the mean value calculated for statistical analysis. A 20 second-rest period was allowed between each repetition. Reliability of pressure algometry has been found to be high (intra-class correlation coefficient, ICC: 0.91, 95%CI: 0.82-0.97) (Chesterton et al, 2007).[23]

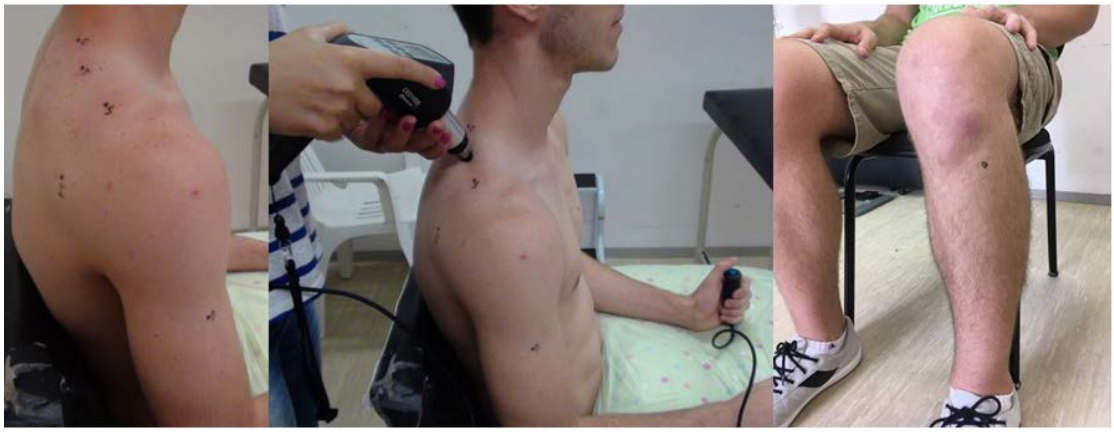

**FIGURE 4.** Pressure pain threshold measurement.

*Pain and function scores*

The Brazilian version of the Shoulder Pain and Disabilities Index (SPADI) Questionnaire was used to evaluate shoulder pain and dysfunction.[100] This version of the SPADI is valid and reliable for assessing pain and dysfunction in individuals with shoulder pain.[100] The SPADI is a self-assessment questionnaire that measures pain and functional activities. The pain dimension consists of five questions and functional activities are assessed with eight questions. The final score is calculated in percentage and a maximum score of 100 indicates the worst possible condition.[169] A numeric pain rating scale (NPRS) was used to evaluate pain immediately after each repetition during the data collection of kinematics. Scores on the NPRS range from 0 (no pain) to 10 (worst pain) and the scale is considered valid and reliable to assess individuals with shoulder pain.[108]

*Statistical Analysis*

Data were analyzed using the SPSS statistical 23.0 package (SPSS, Chicago, IL, USA). The Kolmogorov-Smirnov test was used to evaluate the distribution of data, and all variables were consistent with a normal distribution. A separate 1-factor analysis of variance (ANOVA) determined if differences existed between groups (independent variable) for the following dependent variables: demographic variables, LF test, PPT, ROM, ER strength, the SPADI and NPRS.

Scapular and humeral kinematic data at rest, 30°, 60°, 90° and 120° of humerothoracic elevation were selected for statistical analysis as dependent variables as well. Separate 2-factor ANOVA (group and angle as independent variables), with Tukey-Kramer post-hoc tests were used to test for interactions of group by arm elevation angle (rest, 30°, 60°, 90°,

120°) and for main effects of group for the three scapula rotations and two humeral translations. A *P* value of less than .05 was considered statistically significant for all analyses.

## Results

There were no statistically significant differences (*P*>.05) in the demographic characteristics between the four groups (**TABLE 1**).

*Scapular kinematics and humeral translations*

There were no 2-factor group by angle interactions (*P*>.05) for scapular kinematics or humeral translations (**FIGURE 5**).

There was a statistically significant main effect of group for scapular IR (*P*<.001; F=10.81) (**FIGURE 5A**), posterior tilt (PT) (*P*=.02; F=3.40) (**FIGURE 5C**), and anterior humeral translation (*P*<.001; F=11.23) (**FIGURE 5E**). The Pain+No PCT group showed increased IR of the scapula and decreased anterior translation of the humerus when compared to the other three groups, and increased PT of the scapula when compared with No pain+PCT group. There was no main effect of group for scapular upward rotation (UR) (*P*=.84; F=0.13) (**FIGURE 5B**) or humeral superior translation (*P*=.97; F=0.37) (**FIGURE 5D**).

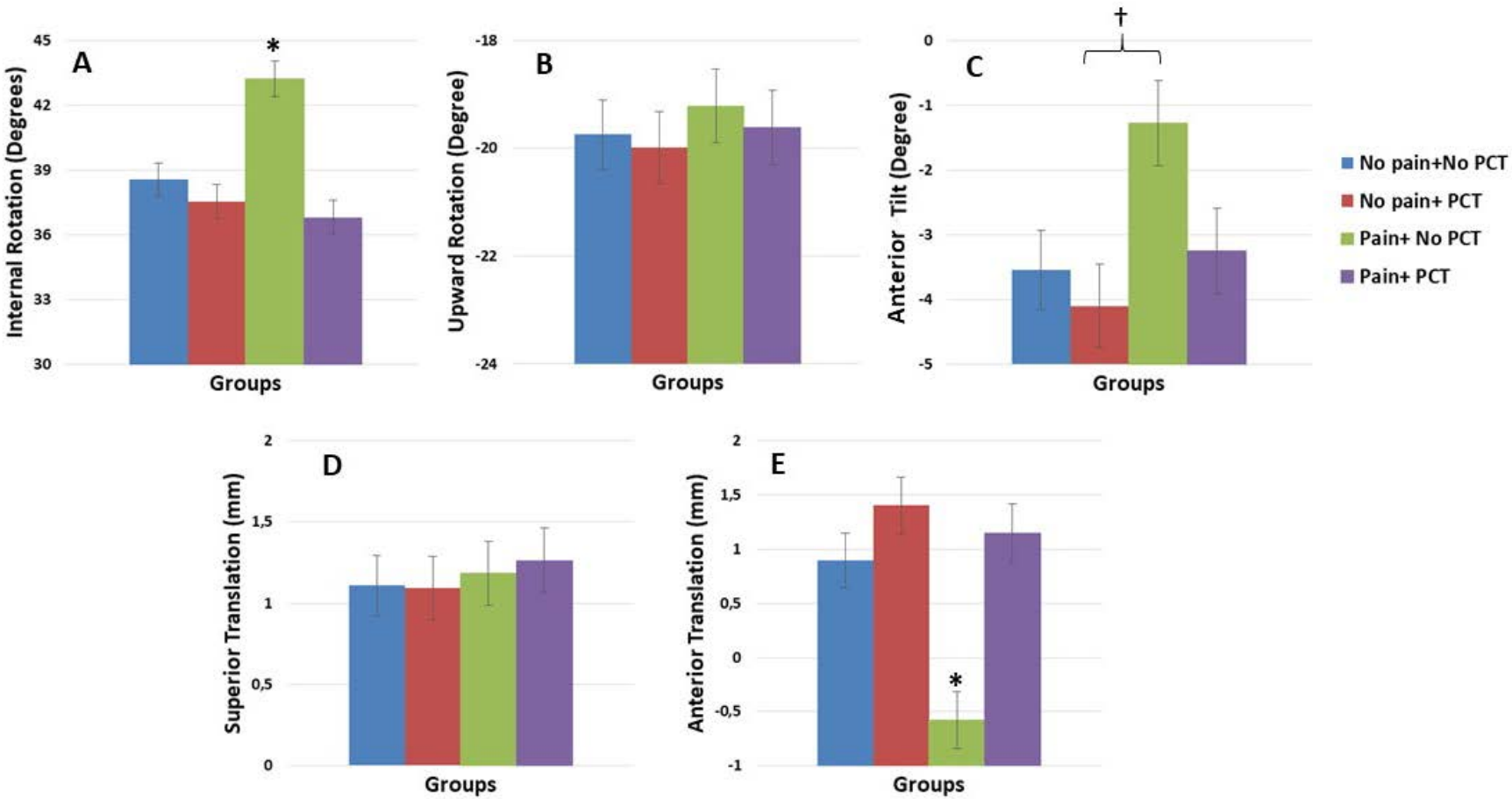


**FIGURE 5.** Main effect of group for internal (A) and upward (B) rotations and posterior tilt (C) of the scapula; and superior (D) and anterior (E) translations of the humerus during arm elevation for all groups. The error bars are standard error of mean. * $P<.001$, when compared to the other groups. † $P=.01$, when compared to the No pain+PCT group.

*Low Flexion Test*

The Pain+No PCT group showed higher LFT values (*P*=.001; F=5.62) when compared with No pain+PCT (*P*=.001) and Pain+PCT (*P*=.01) groups (**TABLE2**).

*ROM and ER strength*

The No pain+No PCT and Pain+PCT groups were different for IR ROM (*P*<.001; F=11.43) (**TABLE 2**). The No pain+No PCT group had more IR ROM than the Pain+PCT group (*P*<.001). The Pain+No PCT group also showed increased IR ROM when compared to both groups with PCT (*P*<.01) (**TABLE 2**). No differences between groups were found for ER ROM (*P*=.05; F=2.70) and strength of ER (*P*=.67; F=0.51) (**TABLE 2**).

**TABLE 2. Results of LFT, Internal and External Rotation ROM, External Rotator Strength,SPADI questionnaire and NPRS score for all groups.**

| | **No pain + no PCT (n=28)** | **No pain + PCT (n=27)** | **Pain + no PCT (n=25)** | **Pain + PCT (n=25)** |
|---|---|---|---|---|
| *LFT (°)* | 21.3 ± 6.3 (18.9-23.6) | 17.6 ± 6.9 (14.8 –20.3) | 25.4± 8.6 * (21.9 – 28.9) | 18.9 ± 7.6 (15.7 – 22.0) |
| *Internal Rotation (°)* | 71.4±14.7† (66.7 – 76.1) | 64.0 ± 12.8 (59.3 – 68.8) | 76.4±9.3 * (71.5 – 81.4) | 57.4 ±12.4 (52.4 – 62.3) |
| *External rotation (°)* | 102.6 ± 15.3 (96.9 – 108.2) | 99.7 ±13.2 (93.9 – 105.4) | 91.7±14.7 (85.7 – 97.6) | 95.4±16.4 (89.5 – 101.3) |
| *External Rotators Strength (N)* | 93.57±30.09 (81.90 – 105.24) | 95.18±26.90 (84.54 – 105.82) | 88.68±30.45 (76.11 – 105.25) | 85.64±37.33 (70.22 – 101.05) |
| *SPADI questionnaire* | 0.60 ± 1.54 (0.01 – 1.20) | 0.45 ± 1.35 (0.01 – 0.98) | 22.71±17.84 § (16.21 – 31.20) | 45.13±25.90‡ (34.44 – 55.82) |
| *NPRS score* | 0.01 ± 0.06 (-0.01 – 0.04) | 0.07 ± 0.34 (-0.07 – 0.22) | 1.63 ± 2.57 § (0.55 – 2.72) | 3.98 ± 2.50‡ (2.95 – 5.01) |

Results are mean ± standard deviation (95% Confidence Interval).

*$P$<.01, when compared to both groups with PCT.

†$P$<.001, when compared to Pain+ PCT group.

‡$P$<.001, when compared to all other groups.

§$P$<.05, when compared to both groups without pain.

Abbreviation: LFT, Low Flexion test; PCT, Posterior Capsule Tightness; N, Newton; NPRS, Numeric Pain Rating Scale.

*PPT*

Significant differences were observed among groups only for upper trapezius (*P*=.02; F=3.26), levator scapulae (*P*=.002; F=5.35) and anterior tibialis (*P*=.009; F=4.07) muscles. The Pain+PCT group showed decreased PPT for upper trapezius muscle when compared with No pain+PCT (*P*=.03) and Pain+No PCT (*P*=.04) groups. This group also presented decreased levator scapulae PPT, when compared with No pain+PCT (*P*=.003) and Pain+No PCT (*P*=.01) groups. On the other hand, the No pain+PCT group showed increased PPT for anterior tibialis muscle, compared to Pain+No PCT group (*P*=.006) (**FIGURE 6**).

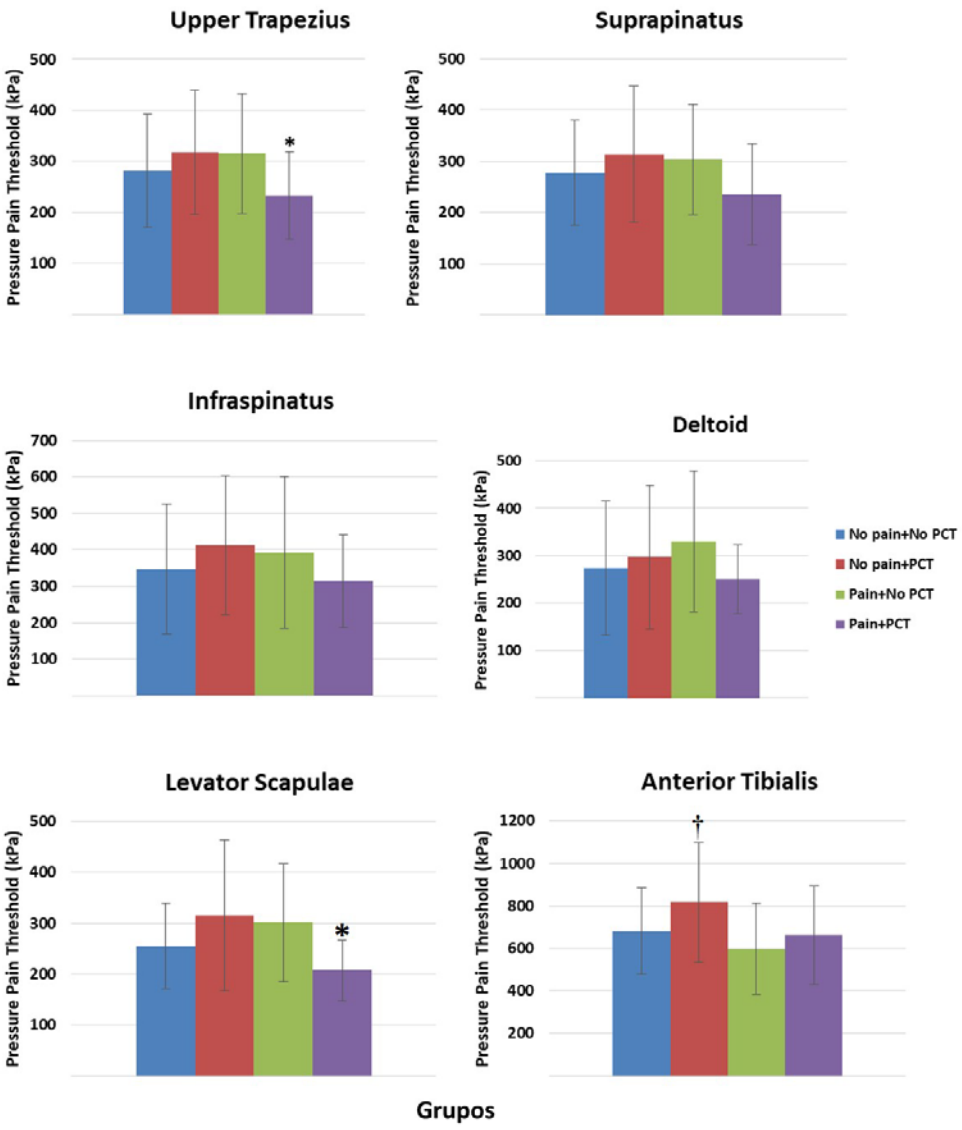


**FIGURE 6.** Pressure Pain Threshold (kPa) of each muscle evaluated for all groups. The error bars are standard deviation. *P<.05, when compared to No pain+PCT and Pain+NoPCT groups. † P=.006, when compared to Pain+No PCT.

*Pain and function scores*

The Pain+PCT group presented the highest SPADI score and NPRS during arm elevation when compared to the other groups (*P*<.001; F=49.97; *P*<.001; F=25.55,

respectively) (**TABLE 2**). The Pain+No PCT group also had higher SPADI scores and NPRS during arm elevation than both groups without pain ($P$<.001 and $P$<.02) (**TABLE 2**).

## Discussion

This study assessed the effects of PCT and shoulder pain on scapular and humeral kinematics, IR and ER ROM, ER strength, PPT and upper-limb function in asymptomatic and symptomatic individuals. In contrast to the hypothesis, only the group with pain but without PCT showed increased scapular IR and PT and decreased anterior translation of the humerus during arm elevation, when compared with other groups. This group also presented the largest LFT and IR ROM values among the groups, as well as decreased PPT for anterior tibialis muscle. On the other hand, individuals with pain and PCT showed the highest shoulder pain and dysfunction score, pain during arm elevation and decreased PPT for upper trapezius and levator scapulae muscles, partially supporting our hypotheses.

Increased scapular IR, demonstrated by the Pain+No PCT group in the present study, was previously reported in individuals with shoulder pain[12,60,89,140] and may contribute to internal impingement.[121] Many studies[12,44,60,80,89,93,103,140,147] have evaluated scapular kinematics in individuals with shoulder pain compared with controls, but a consistent IR pattern remains unclear. Some studies note increased IR[12,60,89,140] while others demonstrate no changes for scapular IR in individuals with shoulder pain.[44,80,93,103,147] The different methods used by these studies may explain the inconsistent results.

Decreased anterior tilt of the scapula when Pain+PCT group was compared with No pain+PCT group, partially supports our hypotheses. The increased anterior tilt demonstrated by the asymptomatic individuals with PCT was previously described in asymptomatic throwers[8,74] and was proposed as a factor that predisposes to shoulder pain because similar

alterations were described in individuals with SIS.[12,89,93] On the other hand, increased scapula PT was also noted in individuals with SIS[60,80,103,140] and might be an adaptation to avoid pain.

Few studies have evaluated the humeral head translations in individuals with shoulder pain.[83,85,90] The Pain+No PCT group results differ from previous studies regarding anterior translations. Ludewig and Cook[90] found increased anterior humeral translation in early phase of arm elevation in individuals with shoulder pain compared with asymptomatic individuals. Also, Lawrence et al[83] showed an increase of 1.4mm in anterior translation of the humerus in individuals with shoulder pain when compared to individuals without shoulder pain. The decreased anterior humeral head translation found in the present study was also reported in individuals with[85] and without shoulder pain and anterior capsule tightness.[174] Although anterior capsule tightness was not measured in the current study, this alteration may explain decreased anterior translation in Pain+No PCT group.

The lack of difference between groups for scapular UR and humeral superior translation suggests that pain and/or PCT may not have an important influence on scapula UR and humerus superior translation during arm elevation. However, based on scapular and humeral alterations in the Pain+No PCT group in the present study, we suggest that this group may make more motion adjustments than the other groups. These motions changes may be a strategy to avoid pain, as previously suggested in individuals with chronic pain.[94,143] However, a longitudinal study would be necessary to examine this hypothesis, comparing the scapular and humeral head behaviour in acute and chronic conditions.

The Pain+No PCT group also presented the highest LFT and IR ROM values among groups. As expected, the Pain+PCT group showed decreased LFT, IR ROM and the worst SPADI score, as well as the greatest amount of pain during arm elevation. This finding strengthens the hypothesis of shoulder motion adaptations to avoid pain in Pain+No PCT

group, whereas the less pain reported in this group can also contribute to the greater ROM and maintenance of function.

The lack of ER strength differences in this study did not support our hypothesis. Studies that demonstrated differences between sides for ER strength have used the supine position for evaluation[99] or have used manual resistance.[99,155] The different method used in the present investigation may explain the divergent results. We used the seated position because of its functional relevance to upper extremity activity[155] and the wall to standardize the test resistance. A position of 90° of shoulder and elbow flexion was more sensitive for detecting ER strength deficits than was scapular plane in individuals with SIS,[155] but is a potentially painful position and standardizing the resistance is difficult. Manual resistance during strength assessment is dependent on the evaluators' ability to hold the dynamometer, which can contribute to variability of the results.

Although the subjects in the present study had long duration of pain, the expected combination of ER weakness, impaired dynamic shoulder stabilization and pain sensitization was not supported. The Pain+PCT group demonstrated increased upper trapezius and levator scapulae PPT, suggesting a PS process. On the other hand, the Pain+No PCT group showed decreased tibialis anterior PPT, indicating a CS. A recent review[9] reported PS and CS in individuals with shoulder pain, but few studies[1,30,49,65,66,124] evaluated sensitization in those with SIS. A possible explanation for the different results in the pain groups in the current study is the multidimensionality of pain and variability in pain processing across individuals.[30] Based on this, the sensitization may manifest differently depending on the factors involved in the pain mechanism,[9] and peripheral and central processing cannot be related.[30] Thus, individuals with unilateral shoulder pain can present the same dysfunction, but dissimilar pain processing as found in the present study. Perhaps PS is not a requirement

for CS as previously believed, and vice versa.[30,117,170] However, more studies assessing pain sensitivity are necessary to clarify long duration pain processing patterns.

## Conclusion

The findings of this study showed no interaction between pain and PCT to scapular and humeral kinematics. On the other hand, the results suggest limited ROM and worse pain condition in individuals with pain and PCT. The results also suggests that individuals with the same musculoskeletal dysfunction, shoulder pain, respond differently to pain and develop individual adaptations to avoid pain and to preserve function.

**MANUSCRITO II**

# Comparison of specific and non-specific treatment approaches for individuals with posterior capsule tightness and shoulder pain: A Randomized Controlled Trial.

**Rosa DP, Borstad JD, Ferreira JK, Gava V, Santos RV, Camargo PR**

**Manuscrito em revisão no periódico *Physical Therapy*** (Fator de Impacto 2,764)

**Abstract**

**Background:** Posterior capsule tightness (PCT) has been associated to shoulder pain, changes in scapular and humeral kinematics, shoulder range of motion (ROM) and external rotators (ER) strength.

**Objectives:** To assess the effects of two interventions on scapular and humeral kinematics, pain, function, internal (IR) and external (ER) rotation ROM, shoulder ER strength, and pressure pain threshold (PPT) in individuals with PCT and shoulder pain.

**Design:** Randomized controlled trial prospectively registered.

**Methods:** Fifty-nine individuals with PCT and shoulder pain were randomized into: Experimental Intervention Group (EIG, n=31) or Control Intervention Group (CIG, n=28). PCT was established by the low flexion (LF) test. Scapular kinematics, humeral translations, pain, function, IR and ER ROM, ER strength and PPT were measured at pre- and post-treatment. EIG received specific intervention to pain and PCT and CIG received non-specific intervention during 4 weeks.

**Results:** EIG presented more scapular UR (mean difference=3.31°; 95% Confidence Interval (CI) = 1.29° to 4.98°) and increased LF (mean difference=4.66°; 95% CI= 0.71° to 8.61°) test than the CIG after treatment. Both groups presented less anterior (mean difference=-0.74mm; 95% CI= -1.28mm to -0.21mm) and superior (mean difference = -0.56mm; 95% CI= -0.88mm to -0.23mm) translation of the humerus, decreased pain and improved function (mean difference = -23.59; 95% CI=-28.73 to -18.45), increased IR ROM (mean difference = 4.65°; 95% CI = 1.84° to 7.47°) and increased PPTs for upper trapezius (mean difference = 60.10kPa; 95% CI = 29.31kPa to 90.89kPa), supraspinatus (mean difference = 63.74kPa; 95% CI= 29.60kPa to 97.89kPa) and deltoid (mean difference = 40.90kPa; 95% CI=12.35kPa to 69.45kPa) after treatment.

**Limitation:** These results cannot be generalized to others shoulder's dysfunctions.

**Conclusion:** The experimental intervention was more effective at improving PCT. Both interventions were effective in modifying humeral translations, decreasing pain and improving function, IR ROM and PPT. Alterations in scapular kinematics were not clinically relevant.

**Key Words:** Glenohumeral joint, Physical therapy, Rehabilitation, Mobilization.

## Introduction

Shoulder pain ranges from 7% to 26% in the general population.[92] Most cases are attributed to shoulder impingement syndrome (SIS).[15,159] SIS is multifactorial and has been associated with range of motion (ROM) and strength deficits, changes in scapular and humeral kinematics, altered rotator cuff and scapulothoracic muscle activation, repetitive overhead sports or activities, bony morphology, and tightness of the anterior and posterior shoulder.[4,152,167]

Posterior capsule tightness (PCT) is a frequent condition in individuals who perform repetitive overhead sports or activities.[129,167] Tightness is described as an adaptation to repetitive high tensile loading on the posterior shoulder capsule during the deceleration phase of throwing that can stimulate tissue hypertrophy and fibrosis.[16,122] Over time, the posterior capsule can become increasingly stiff and restrict the normal shoulder ROM. However, PCT was also reported in non-throwers.[85,156] In addition to these changes, PCT has been associated with decreased glenohumeral (GH) internal rotation (IR) ROM,[28,98,99,156] decreased rotator cuff strength,[84,99] and scapular kinematic alterations.[8,56,74,85,174] There are also relationships noted among scapular kinematic alterations, SIS, and central and peripheral sensitization.[1,19,30,124]

Studies have been conducted to evaluate the efficacy of different interventions on the shoulder impairments related to PCT,[28,98,156] and positive results were demonstrated for ROM, pain and function. On the other hand, two systematic reviews showed moderate[107] and weak evidence[116] when stretching was the only approach used to improve IR ROM deficit in asymptomatic individuals with posterior shoulder tightness or GH IR deficit. Another systematic review[57] reported that the combined effect of posterior shoulder mobilizations and stretching reduced the IR ROM deficit in individuals with and without shoulder pain.

However, no previous studies have assessed the effectiveness of physical therapy protocols on shoulder strength, scapular kinematics, humeral translations and pain sensitivity in individuals with pain and PCT.

This study compared the effects of combining specific mobilization, strengthening and stretching (experimental intervention) with sham ultrasound and non-specific strengthening and stretching (control intervention) on scapular and humeral kinematics, pain, function, ROM, shoulder external rotation (ER) strength, and pressure pain threshold (PPT) in individuals with PCT and shoulder pain. Kinematics, pain and function, ROM and strength were considered as the primary outcomes, and PPT was considered as secondary outcome. We hypothesized that the experimental group would demonstrate greater improvement than the control group after the intervention.

**Methods**

Twenty-five individuals per group were required to identify a clinically meaningful angular change of 5° in scapular kinematics and achieve a statistical significance level of 0.05 with power of 0.80.[13,51,128,136] Fliers posted in the local university setting, orthopedic clinics and surrounding community were strategies to recruit the sample. A total of 153 individuals with shoulder pain were initially evaluated for eligibility between March 2015 and March 2016, and 59 individuals with PCT were included in the study. The participants were randomly divided into two groups: Experimental Intervention Group (EIG, n=31) or Control Intervention Group (CIG, n=28), using the www.randomization.com (**FIGURE 1**). Voluntary enrollment was encouraged and no incentives were given to participate in this study.

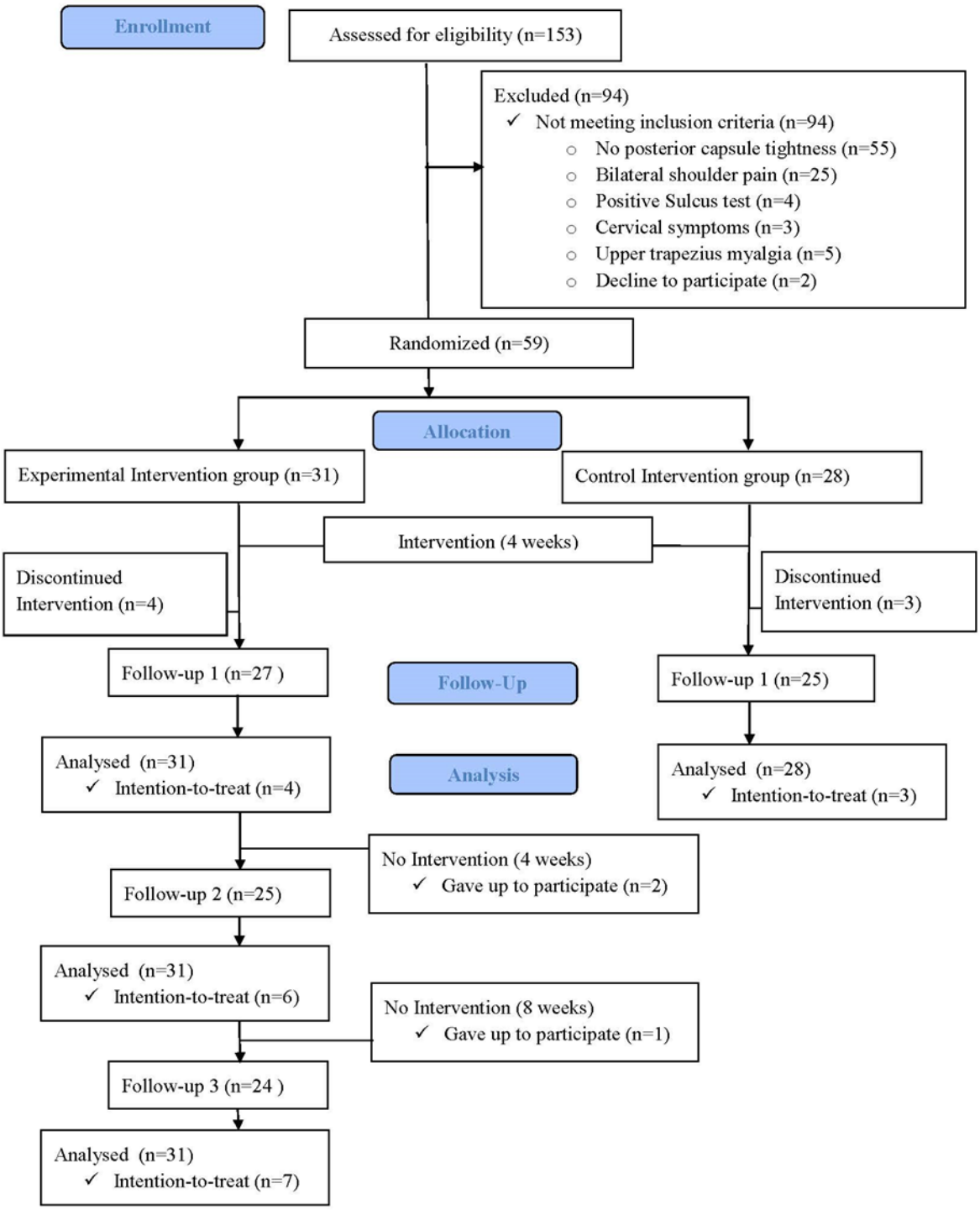


**FIGURE 1.** Flow diagram representing enrollment, allocation, procedures, and analysis for both groups.

Individuals had to have at least three months of symptoms consistent with SIS based on at least 3 of the following:[20,51,54,61,87,106,136,171] positive Neer test,[114] positive Hawkins test,[102] positive Jobe test,[72] pain with passive or isometric resisted shoulder ER,[136,149] and pain with active shoulder elevation,[69] Individuals also had to reach ~150° of arm elevation as determined by digital inclinometer to ensure a full data set of scapular kinematics and humeral translation captured with the electromagnetic system.

Individuals also needed to present with PCT measured by the Low Flexion (LF) Test.[10] This test is done by adding passive GH IR in a position of 60° of humerus elevation in the sagittal plane. A digital inclinometer is positioned on the distal surface of the forearm to quantify the angle between the forearm and horizontal.[10] Excellent intra-day reliability was previously described for this test.[11] If at least 7° of GH IR difference between sides was detected, the posterior capsule was considered tight as determined in a pilot study.

Exclusion criteria were as following: 1) pregnancy; 2) glenohumeral joint ligamentous laxity based on a positive Sulcus,[115] Apprehension[137] or Anterior Drawer test;[103] 3) history of traumatic shoulder pathology, fracture or shoulder surgery; 4) history of adhesive capsulitis, scoliosis or systemic illnesses; 5) bilateral symptoms; 6) body mass index>28kg/m$^2$ to minimize skin-motion artifact during kinematic data collection; 7) allergy to transpore tape; 8) physical therapy treatment in the last 6 months; 9) analgesics or muscle relaxants taken at 72 hours before the examination;[1] or 10) steroid injection in the last 6 weeks.[21]

The study was approved by the Ethics Committee of the University (protocol number 860.648) and registered at *ClinicalTrials.gov* (NCT02353442). Data collection was performed in the Laboratory of Analysis and Intervention of the Shoulder Complex at

Universidade Federal de São Carlos - Brazil. Participants signed an informed consent to participate.

*3D Scapular Kinematics and Humeral Translations*

For measurement of 3D scapular kinematics and humeral translations, data capture and analysis were completed using the Flock of Birds® (miniBird®) hardware (Ascension Technology Corporation, Burlington, VT) integrated with the MotionMonitor™ software (Innovative Sports Training, Inc. Chicago, IL). The 3D scapular and humeral translations tracking methodology used is described elsewhere.[19,54,89,90,134,136]

For all local coordinate systems the z-axis pointed laterally, the x-axis anteriorly and the y-axis superiorly. The YX'Z" Euler sequence[172] was used to describe scapular motions relative to the trunk in the sequence of IR/ER, upward (UR)/downward (DR) rotation and anterior (AT)/posterior (PT) tilt. Humeral orientation with reference to the trunk was determined using the YX'Y" Euler sequence, which defines the plane of elevation, elevation, and IR/ER.

For humeral translations, the helical axis was determined and its anterior-posterior and superior-inferior vector components used to describe humeral head position.[90] Detailed information on methodology can be found at Ludewig and Cook.[90] Excellent within-day trial-to-trial reliability (ICC ~ 0.85; SEM ~ 1mm) was previously shown to measure the humeral translations during arm elevation using helical axis.[90]

Individuals performed 3 repetitions of full elevation and lowering of the arm in the sagittal plane in a relaxed standing position. This procedure has been shown to be reliable in healthy individuals and individuals with SIS.[51]

*Shoulder Pain and Disabilities Index*

The SPADI was adopted to assess shoulder pain and function.[169] It is a reliable tool for assessing individuals with shoulder pain.[138] The final score is provided in percentage and a maximum score of 100 implies the worst possible condition.[169]

*GH IR and ER Range of Motion*

GH IR and ER ROM were quantified with a digital inclinometer (Acumar ™, Lafayette Instrument Company, Lafayette, IN). Measurements were taken in the supine position. The arm of the individuals was placed in 90° of abduction and elbow flexion as the initial position for both measurements. The inclinometer was positioned on the dorsal and palmar forearm surface for measurement of IR and ER ROM, respectively. Individuals were asked to actively rotate the arm into maximum ROM. The ROM was read and recorded at the end range by a second investigator to ensure blinding of the primary investigator. The second investigator also provided manual scapula stabilization during the assessment of IR ROM. These procedures were performed twice. Excellent reliability was reported for both measurements.[27]

*Strength of the shoulder ER*

The strength of the ER was measured by a handheld dynamometer (Lafayette Instrument Company, Lafayette, IN, USA) with individuals in the seated position and shoulder in the neutral position and elbow in 90° of flexion. The dynamometer was positioned between the dorsal wrist and wall, 2 cm proximal to the radial styloid process. Two submaximal repetitions of with 10-second rest interval were used for familiarization. For the measurement, individuals performed two 5-second maximal isometric contractions with a

resting time of 30 seconds between the repetitions. Verbal encouragements were used to stimulate the maximal strength. A second investigator recorded the measurements to ensure blinding of the primary investigator. Excellent reliability was showed for this measurement.[27]

*Pressure Pain Threshold*

A digital pressure algometer (model OE-220, ITO - Physiotherapy & Rehabilitation, Japan) was used to evaluate PPT. The device consists of a $1cm^2$ rubber disk attached to a strain gauge. All individuals had to press a hand-controlled switch when the pressure sensation changed to pain.[160] PPTs were evaluated unilaterally over the upper trapezius, infraspinatus, supraspinatus, middle deltoid, levator scapulae and tibialis anterior. The exact testing location for each muscle is described elsewhere.[1] Tibialis anterior was evaluated as a remote site as used in previous studies.[1,19] PPTs were randomly assessed three times for each point, with 20-second rest period between trials. High reliability of pressure algometry was previously described.[23]

*Procedure*

This was a randomized clinical trial with 1 blinded assessor. The primary investigator, who was blinded to the group assignment of the individuals, assessed LF test, IR and ER ROM, strength of the ER, scapular and humeral kinematics and PPT. Two additional investigators were responsible for randomization of the individuals to one of the 2 groups of treatment and to provide the treatments. Individuals were blinded to their group assignment.

*Intervention*

**Experimental Intervention group.** The EIG intervention consisted of 3 techniques: 1) anterior-posterior directed GH mobilization, 2) strengthening of the ER of the arm, and 3) stretching of the posterior capsule. The interventions were given only to the involved side. Initially, the therapist performed grade III and IV posterior mobilizations[38, 58] with the patients in the supine position with a towel under the scapula (**FIGURE 2A-C**).[28,98,149] The mobilization force was sustained for 30 seconds,[14] followed by a 30-second rest,[28] and repeated until the individuals received a total of 5 minutes of mobilization.[38, 56] Next, strengthening exercises for the ER of the arm were completed. Participants were in the sidelying position with neutral GH position and 90° of elbow flexion,[131,132] and performed maximum active ER holding a weight (**FIGURE 2D**). They first started with no weight in hands, and progressed to 0.5kg, 1.0kg, 1.5kg and 2kg based on the patients self-reported ability to perform the movement. Three sets of 10 repetitions were performed, with 30-second rest between sets.[20] Lastly, the sleeper-stretch was used to stretch the posterior capsule. Individuals were sidelying on their involved side with the shoulder and elbow in 90° of flexion, and performed passive glenohumeral IR using the opposite hand. They reported when a stretch was felt in the posterior region of the shoulder and held this position for 30 seconds (**FIGURE 2E**). The stretch was repeated 3 times with 30-second rest between repetitions.[20]

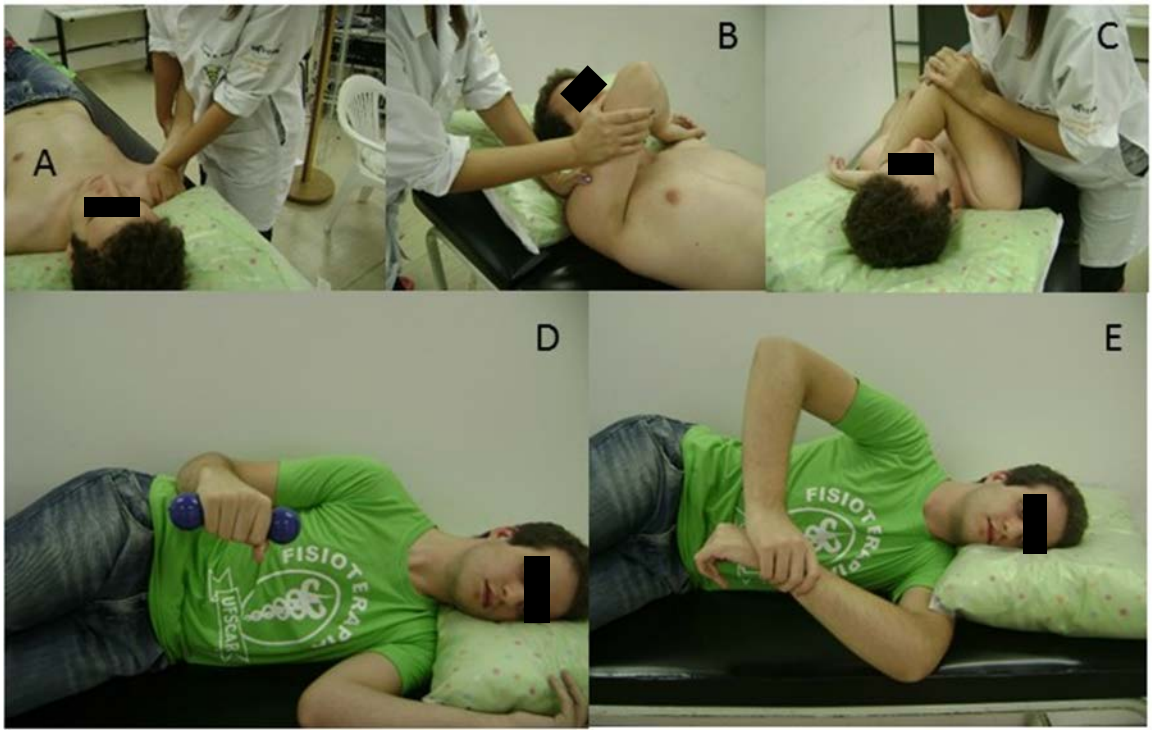


**FIGURE 2.** Experimentral group protocol: A, B, and C) Progression of posterior capsule mobilization, D) Strengthening of the external rotators, E) Posterior capsule stretching.

**Control Intervention group.** The CIG also received intervention only in the involved side that consisted of 3 techniques: 1) sham ultrasound, 2) scapular squeezing, and 3) stretching of the upper trapezius. The individuals received five minutes of sham ultrasound to the anterior shoulder in the supine position (**FIGURE 3A**). Following this procedure, they completed three sets of 10 repetitions of scapular retraction exercises without external resistance. Individuals were in the sitting position and were instructed to squeeze both scapulae (**FIGURE 3B**). Finally, the stretching for the upper trapezius was performed 3 times in the sitting position. The individuals had to flex to the opposite side and rotate the head to the same side that was going to be stretched[162] and hold this position for 30 seconds with 30-second rest between repetitions (**FIGURE 3C**).


**FIGURE 3.** Control group protocol: A) Sham ultrasound, B) Scapular squeezing exercise, C) Stretching of the upper trapezius.

Both groups received the treatment three times per week over a 4-week period. All sessions were supervised by a physical therapist. PCT and pain were assessed at the beginning and at the end of each session with the LF test and the Visual Analog Scale (VAS), respectively. If patients reported no pain in 2 consecutive sessions and the LF measurement on the involved side was no longer over 7° different from the contralateral side before the end of the 4-week period, treatment was stopped and they were assessed for follow up 1 by the primary evaluator. All individuals were assessed at pre- and post-intervention (follow-up 1) for all variables. The global rating scale of change (GROC) was only assessed at follow-up 1 to check the patient's self-perception of improvement. Follow-up assessments of 4

weeks (follow-up 2) and 8 weeks (follow-up 3) after treatment period were also performed only for the EIG. No intervention was performed between the follow-up assessments. The SPADI, LF test, IR and ER ROM were assessed in the follow-up assessments to evaluate the intervention effect over time.

*Statistical Analysis*

The data were analyzed using the SPSS statistical 17.0 package (SPSS, Chicago, IL, USA). For each variable, the mean value of the multiple repetitions was calculated and used for statistical analysis. The PPT data were converted into pressure SI units (kPa) before analysis. Data were normally distributed ($P>.05$) as verified by Kolmogorov–Smirnov test. For scapular IR, UR and PT and anterior and superior humeral translations, a mixed repeated measures 3-factor Analysis of Variance (ANOVA) was used to test group (EIG and CIG) x time (baseline and follow-up 1) x angle (rest, 30°, 60°, 90°, 120°) interactions. If no interactions (group x time x angle, group x time, angle x time) were observed, the main effect of time was analyzed. A 1-factor ANOVA was adopted to determine if differences existed between groups for the demographic variables. For SPADI, LF test, ROM, ER strength and PPT, a mixed repeated measures 2-factor ANOVA was used to test interactions of group (EIG and CIG) x time (baseline and follow-up 1). If no group x time interaction was observed, the main effect of time was analyzed. A repeated measure 1-factor ANOVA was used to test the time effect (baseline, follow-up 2, follow-up 3) for the SPADI, LF test and ROM in the EIG. The Bonferroni test was used for post-hoc analysis when necessary. A $P<.05$ was considered statistically significant.

An intention-to-treat analysis was performed using the expectation maximization method using SPSS, which estimates values to impute on missing data through an algorithm based on initial and observed values.[5]

Within and between-group effect sizes (ES) for all quantitative variables were calculated using Cohen's *d* coefficient[25] for both groups. An ES >0.8 was considered large, ~ 0.5 moderate, and <0.2 small.

## Results

**TABLE 1** shows the descriptive data for both groups. Seven individuals were lost to follow-up 1, and 3 individuals to follow-ups 2 and 3 (**FIGURE 1**). Thus, intention-to-treat analysis was performed in 10/59 individuals (**FIGURE 1**). The average number of sessions was 11.26 (standard deviation [SD]=1.37) and 11.32 (SD=1.07) for the EIG and CIG, respectively. Two individuals received less than 12 treatment sessions because they presented no pain and no difference between sides in the LF test in 2 subsequent sessions.

**TABLE 1. Descriptive data of the individuals.**

| | **Experimental Intervention group (n=31)** | **Control Intervention group (n=28)** |
|---|---|---|
| **Gender** | 9 women; 22 men | 11 women; 17 men |
| **Age (years)*** | 41.06 (12.87) | 40.07 (11.86) |
| **Height (m)*** | 1.71 ( 0.09 | 1.69 (0.08) |
| **Weight (kg)*** | 76.90 (13.72) | 76.09 (14.93) |
| **Evaluated shoulder** | 27 dominant; 4 non-dominant | 25 dominant; 3 non-dominant |
| **Duration of pain (months)** † | 41.90 (53.97) [3-180] | 40.21 (35.01) [2-120] |

*Values are mean (standard deviation).

†Values are mean (standard deviation) [range].

*3D Scapular Kinematics and Humeral Translations*

For scapular IR and PT, the triple interactions were not significant ($P$>.05), nor were the group x time and angle x time interactions ($P$>.05). The main effect of time was also not statistically significant for IR ($P$=.86) and PT ($P$=.69) of the scapula.

No significant triple interaction was determined for scapular UR ($P$=.68). There was significant group x time interaction effect ($P$=.03), where the EIG presented more UR of the scapula than the CIG at follow-up 1 (3.13°) (**FIGURE 4C** and **D)**. The EIG also presented increased scapular UR at follow-up 1 compared to baseline (2.76°) (**FIGURE 4C**). Angle x

time interaction was found ($P<.01$) where increased UR was shown at follow-up 1 compared to baseline at 90° (3.25°) and 120° (4.76°) of arm elevation (**FIGURE 4C** and **D)**.

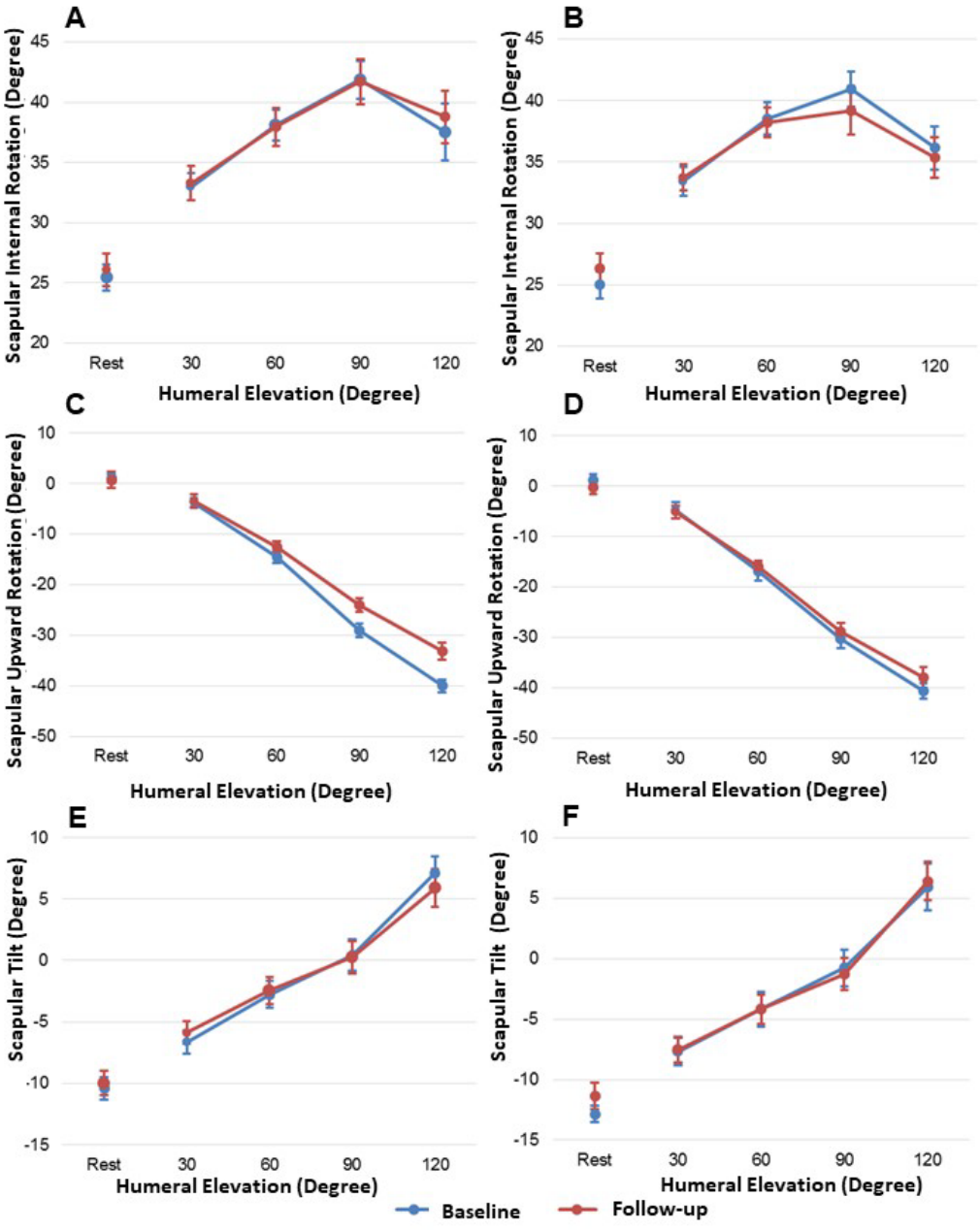


**FIGURE 4.** Baseline and follow-up 1 scapular internal rotation (A and B), upward rotation (C and D), and tilt (E and F) during elevation of the arm in the sagittal plane for the Experimental Intervention group (left) and the Control Intervention group (right). Values are mean (standard error).

For humeral anterior and superior translations, there was not a statistically significant triple interaction ($P>.05$) or significant group x time, and angle x time interactions ($P>.05$). However, a main effect of time was demonstrated for both humeral translations ($P<.01$). Less anterior and superior translation of the humerus (-0.74mm and -0.56mm, respectively) was found at follow-up 1 when compared to baseline (**Figure 5A, B, C and D)**.

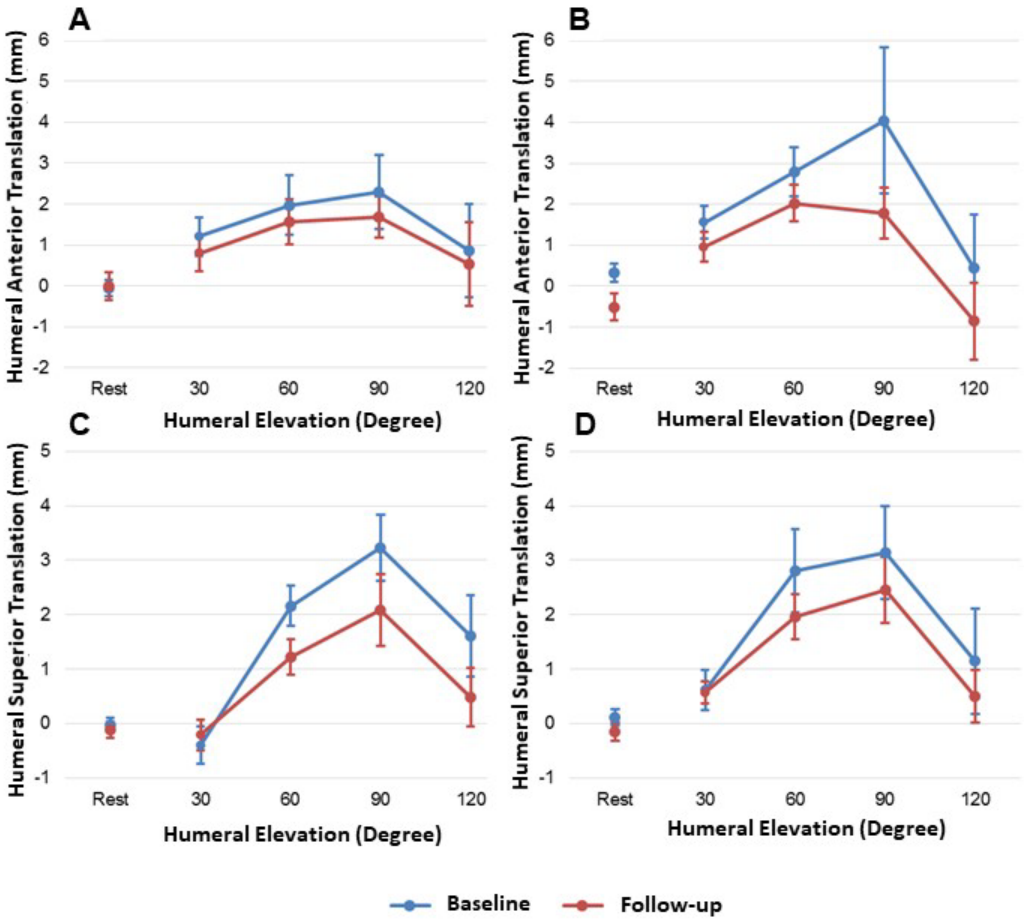


**FIGURE 5.** Baseline and follow-up 1 humeral anterior translation (A and B), and superior translation (C and D) during elevation of the arm in the sagittal plane for the Experimental Intervention group (left) and the Control Intervention group (right). Values are mean (standard error).

Cohen's *d* coefficient showed small within- and between-group ES of the interventions for scapular kinematics and humeral translations.

*Pain and Function*

**TABLE 2** reports results of the SPADI questionnaire. There was no significant group x time interaction ($P$=.07), but the main effect of time showed decreased pain and improved function for both groups at follow-up 1 ($P$<.01). Cohen's *d* coefficient showed a large within-group effect of intervention and a moderate between-group effect of intervention. A time effect was also found when baseline was compared with follow-ups 2 and 3 ($P$<.01*)* for the EIG (**TABLE 3**).

**TABLE 2. Results of SPADI questionnaire, LF Test, Internal and External ROM, ER strength, and GROC scale for both groups.**

| | **Baseline** | **Follow-Up 1** | **Within-Group Change** | **Within-group Effect size, Cohen d** | **Between-Group Differences in Change Scores** | **Between-group Effect size, Cohen d** |
|---|---|---|---|---|---|---|
| *SPADI* | | | | | -8.56 [-18.18, 1.06] | -0.46 [-0.98, 0.06] |
| Experimental | 46.22 (21.67) [37.95, 54.48] | 18.00 (13.85) [11.37, 24.63] | -28.21 [-35.30, -21.13] | -1.55 [-2.09, -0.96] | - | - |
| Control | 45.53 (24.34) [36.84, 54.23] | 26.56 (22.44 [19.59, 33.54] | -18.96 [-26.42, -11.51] | -0.81 [-1.39, -0.20] | - | - |
| Low Flexion test (°) | | | | | 4.66 [0.71-8.61] | 0.62 [0.08,1.13] |
| Experimental | 18.21 (6.67) [15.56, 20.87] | 22.59 (8.69) [19.87, 25.32] | 4.38 [1.08, 7.67] | 0.56 [0.05,1,06] | - | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| Control | 19.17 (8.07) [16.38, 21.96] | 17.93 (6.08) [15.07, 20.80] | -1.23 [-4.70, 2.23] | -0.17 [-0.70, 0.36] | - | - |
| Internal Rotation (°) | | | | | 2.35 [-4.14, 8.84] | 0.19 [-0.33, 0.70] |
| Experimental | 60.25 (13.13) [55.77, 64.14] | 62.81 (14.18) [58.34, 67.28] | 2.55 [-1.32, 6.44] | 0.18 [-0.31, 0.68] | - | - |
| Control | 53.71 (11.67) [48.99, 58.43] | 60.46 (10.14) [55.76, 65.17] | 6.75 [2.66, 10.83] | 0.61 [0.08, 1.13] | - | - |
| External Rotation (°) | | | | | -6.83 [-14.63, 0.96] | -0.47 [-0.97, 0.07] |
| Experimental | 87.70 (16.15) [81.32, 94.09] | 81.79 (14.59) [76.42, 87.16] | -5.91 [-13.72, 1.89] | -0.38 [-0.88, 0.12] | - | - |
| Control | 88.83 (19.35) [82.11, 95.54] | 88.62 (15.31) [82.97, 94.28] | -0.20 [-8.41, 8.01] | -0.01 [-0.54, 0.52] | - | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| External Rotation strength (N) | | | | | 11.87 [-3.95, 27.70] | 0.39 [-0.13, 0.90] |
| Experimental | 95.01 (32.18) [83.46, 116.56] | 101.61 (27.87) [90.71, 112.52] | 6.59 [-0.87, 14.07] | 0.21 [-0.28, 0.71] | - | - |
| Control | 89.67 (32.01) [77.53, 101.83] | 89.73 (32.82) [78.26, 101.21] | 0.06 [-7.80, 7.92] | 0.001 [-0.52, 0.53] | - | - |
| GROC | | | | | 0.51 [-0.63, 1.65] | 0.23 [-0.28, 0.74] |
| Experimental | - | 4.22 (2.15) [3.43, 5.01] | - | - | - | - |
| Control | - | 3.71 (2.24) [2.84, 4.58] | - | - | - | - |

Results are mean (standard deviation) [95% confidence interval].

*Low Flexion test*

There was a significant group x time interaction for PCT (*P*=.02). The EIG showed increased LF at follow-up 1 when compared to CIG (*P*=.02) and baseline (*P*=.01). Cohen's *d* coefficient showed moderate and small within-group effect of intervention for the EIG and CIG, respectively. The ES of intervention between groups was moderate. The increased LF remained for the EIG at follow-ups 2 and 3 compared with baseline (*P*<.01) (**TABLE 3**).

**TABLE 3. Within-group change and effect size at follow-ups 2 and 3 from baseline for SPADI, LF test and Internal and External ROM in the Experimental Intervention Group**

| | Change score at follow-up 2 from baseline | Effect size (follow-up 2 - baseline) | Change score at follow-up 3 from baseline | Effect size (follow-up 3 - baseline) |
|---|---|---|---|---|
| SPADI | -32.46 (-43.53, -21.40) | -1.85 (-2.42, -1.24) | -35.31 (-46.03, -24.58) | -2.01 (-2.59, -1.38) |
| Low Flexion Test (°) | 6.04 (2.21, 9.87) | 0.88 (0.36, 1.39) | 7.19 (2.61, 11.78) | 0.94 (0.40, 1.45) |
| Internal Rotation (°) | 5.82 (-1.77, 13.41) | 0.47 (-0.03, 1.40) | 10.49 (4.24, 16.74) | 0.94 (0.40, 1.45) |
| External Rotation (°) | -1.35 (-9.14, 6.44) | -0.08 (-0.57, 0.41) | 4.08 (-3.93, 12.09) | 0.25 (-0.24, 0.75) |

Values are mean of change or effect size (95% confidence interval).

*GH IR and ER Range of Motion*

No group x time interaction was observed for IR ROM ($P$=.14). However, the main effect of time demonstrated more IR at follow-up 1 ($P$<.01), independent of the intervention when compared to baseline. Cohen's *d* coefficient showed small and moderate within-group effect of intervention for the EIG and the CIG, respectively. The ES of intervention between groups was moderate. A time effect was demonstrated for EIG, when follow-up 3 was compared to baseline ($P$<.01).

No significant interactions (*P*=.32) or main effect of time (*P*=.28) were demonstrated for ER ROM. Cohen's *d* coefficient showed a small within-group effect of intervention and a moderate between-group effect of intervention. No time effect was demonstrated when baseline was compared to follow-ups 2 and 3 for the EIG (*P*=.06).

*Strength of the shoulder External Rotators*

The strength of ER did not show a significant group x time interaction (*P*=.23) or main effect of time (*P*=.22**)**. Cohen's *d* coefficient showed a small within-group effect of intervention and a moderate between-group effect of intervention.

*Pressure Pain Threshold*

No group x time interaction was demonstrated for PPT (*P*>.05). Statistically significant main effect of time was revealed for upper trapezius (*P*<.01), infraspinatus (*P*=.04), supraspinatus (*P*<.01) and deltoid (*P*<.01) at follow-up 1 when compared with baseline. Increased upper trapezius (60.10kPa), infraspinatus (47.30kPa), supraspinatus (63.74kPa) and deltoid (40.90kPa) PPTs were demonstrated after the intervention period independent of group assignment (**FIGURE 6**). Cohen's *d* coefficient showed a small within-group effect of intervention and a small to moderate between-group effect of intervention.

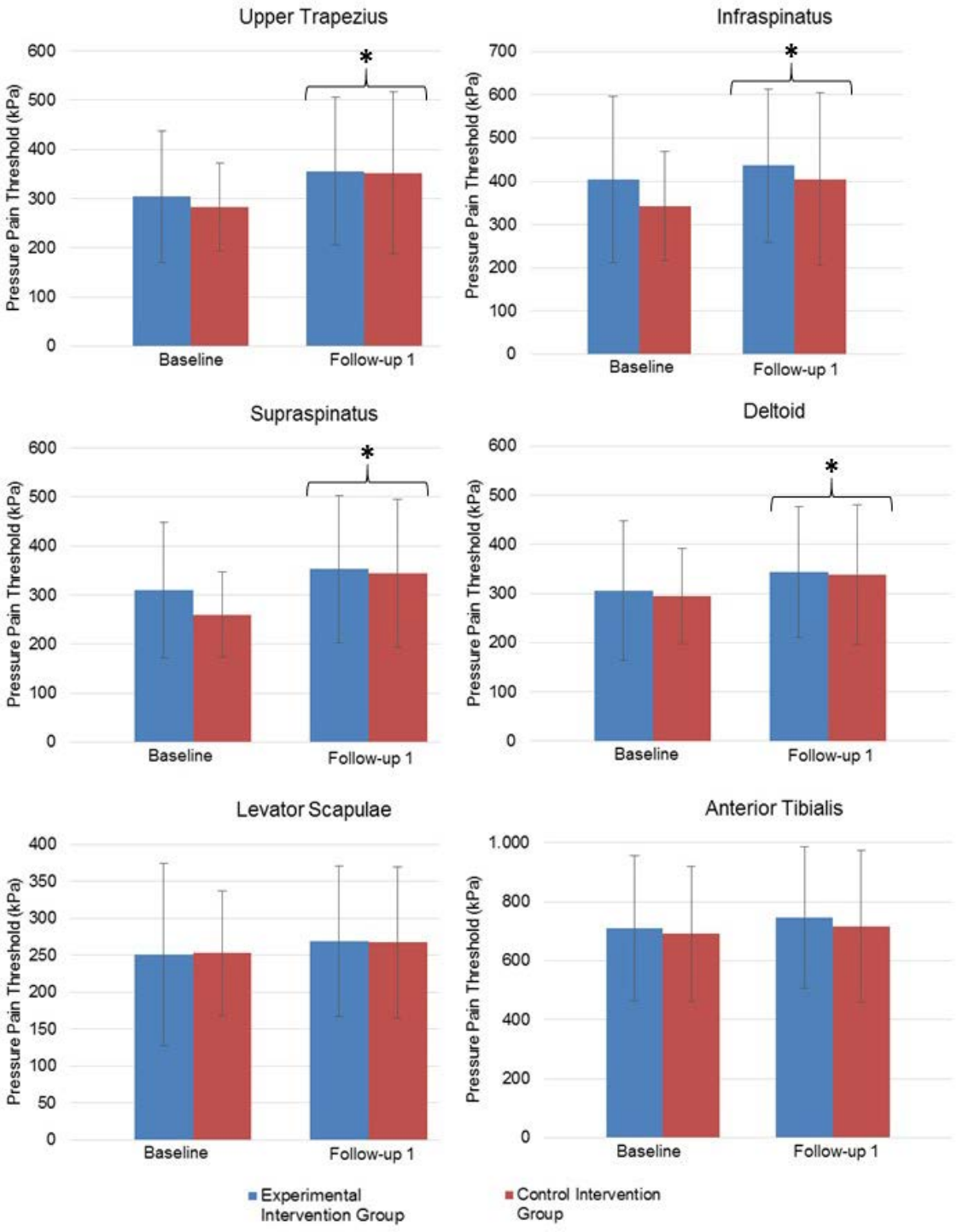


**FIGURE 6.** Pressure pain thresholds (kPa) of each muscle in both groups at Baseline and follow-up 1. *p<.05 when compared with baseline.

*Global Rating Scale of Change*

The GROC scale shows improved self-perception at follow-up 1 for the EIG (4.22 points) and CIG (3.71 points), but no differences between groups were found (*P*=.38) and a small ES of intervention was demonstrated.

## Discussion

This study compared the effects of two different interventions on scapular and humeral kinematics, pain, function, ROM, ER strength, and PPT in individuals with PCT and shoulder pain. Our results showed that a specific intervention, targeted to PCT and pain, was more effective at improving PCT than a non-specific intervention. Although some changes were also observed in scapular UR after the specific intervention, these were not clinically relevant. This study also demonstrated that the specific intervention did not further enhance improvements in humeral translations, pain, function, ROM, strength and PPT compared to a non-specific intervention in the same population.

For scapular kinematics, only the EIG showed increased UR after intervention (with small ES). However, the improvement was below the minimal clinically important difference (MCID) (5°) described in our methods. Other studies have evaluated the effects of different approaches on scapular kinematics in individuals with shoulder pain,[19,52,54,63,102,136,139,146,171] but the results are inconsistent. Some have demonstrated no differences for scapular UR[63,102,136,146] while others have showed increased UR of the scapula that was not clinically meaningful,[19,54,139,171] consistent with the results in the present study. The variability in scapular UR described in individuals with shoulder pain[82,88,103] may have contributed to the lack of clinically important change reported.

Anterior and superior translations of the humerus decreased in both groups after intervention (-0.74 mm and -0.56 mm, respectively). To our knowledge, no previous studies have assessed the effect of any intervention on humeral translations in individuals with shoulder pain or pain and PCT. Thus, no direct comparisons could be made between our results and previous studies. However, considering the limited dimensions of the subacromial space, small changes may have clinical relevance and might be related to the pain and function improvement in both groups. Future studies are warranted to determine the effectiveness of interventions on humeral translations.

The SPADI questionnaire showed a decrease in pain and improvement in function in both groups after intervention. A change in score of 8-13 points may be considered clinically significant.[138] Both interventions reduced a mean of 23.47 points in SPADI score overcoming the MCID previously reported.[138] Although no differences were demonstrated between groups, the EIG (-28.21) showed a reduction of 10 more points than CIG (-18.96) in the SPADI, which may suggest that a specific intervention might be better than a non-specific intervention to influence pain and function. Also, based on our SPADI follow-up results, the effects of specific protocol remained over time. This fact may help the clinician's decision-making.

The EIG increased 4.31° in the LF test with a large ES. This result may indicate a decrease in the PCT. The ICC and SEM values revealed in our reliability study for this measurement were 0.85 and 2.75°, respectively. Considering that the LF test increasing overcame the SEM adopted and it represented a large ES, we can suggest that the intervention might have contributed to the PCT improving. The positive results were maintained at follow-ups 2 and 3 for the EIG. As no differences were found for ER strength, we believe that the PCT improvement was result of the mobilization combined with the stretching.

Both groups had increased GH IR ROM at post-intervention with a small ES. This result did not support our hypothesis, and previous studies findings that demonstrated increased GH IR ROM after posterior shoulder mobilizations and stretching.[28,98,156] The different techniques used in the present study as compared to the previous investigations may explain the divergent results. Cools et al.[28] used passive stretching during 15 min to treat the patients, and also included cross-body stretching to the protocol. This protocol[28] may have applied more stress on the capsule and posterior shoulder muscles and possibly explains the increased IR ROM. The intervention was supervised in the current study, but we cannot ensure that the capsule was adequately targeted during the sleeper-stretch. Another study[156] included a home care approach in addition to physical therapy sessions to increase IR ROM in individuals with internal impingement and PCT. In this case, the number of sessions (3 times per week with therapist + daily home exercises) may explain the IR ROM increase found in their study.

Both interventions also improved the upper trapezius, infraspinatus, supraspinatus and deltoid PPT. Although the MCID for PPT improvements in individuals with shoulder dysfunctions are unknown, we cannot exclude that the pain sensitivity was altered because of interventions. The sensitization process has been indicated to contribute to modest treatment results,[3,9,41] and it may result in a chronic pain condition.[3,45,46,117,170] The long duration of pain (~40months) presented by the individuals in the present study does not seem to have compromised their recovery after treatment and it also does not seem to be related to the development of with pain sensitization.

The natural recovery process, the placebo effect and the real effect of the intervention should be considered as potential reasons for the improvement observed in the CIG. Future studies should evaluate the time effect only, including a group to check the time recovery

effect. Although the control group received a non-specific intervention, they performed active strengthening and stretching, which could support the importance of motion to decrease the shoulder dysfunction. The placebo effect could also have contributed to the CIG improvement, considering the patient's expectations receiving treatment and the therapist beliefs proving treatment.[6]

## Conclusion

This study showed that the experimental protocol was more effective for improving PCT in individuals with shoulder pain and PCT. Increased scapular UR was also observed in the experimental group following treatment, but the changes were not considered clinically meaningful. Both interventions were effective in changing humeral translations and in improving pain, function, IR ROM, and local pain sensitivity in individuals with shoulder pain and PCT.

**MANUSCRITO III**

# The effect of Posterior Capsule Tightness and Humeral Retroversion on 5 Glenohumeral Joint Range of Motion clinical measurement – A cadaver study

**Rosa DP, Camargo PR, Borstad JD**

**Manuscrito em revisão no periódico *Journal of Orthopaedic & Sports Physical Therapy*** (Fator de Impacto 2,825)

**Abstract**

**Study Design:** Controlled laboratory cadaveric study using repeated-measures analysis.

**Background:** Glenohumeral (GH) range of motion (ROM) alterations may be caused by increased humeral retroversion (HR) or posterior capsule tightness (PCT) or both. PCT may alter HR measurements and vice-versa, investigating how these tissue adaptions interact to impact clinical measurements may improve the assessment process.

**Objectives:** To evaluate the effect of experimental tissue alterations on clinical measures, using cadavers.

**Methods:** Five clinical measurements were quantified in 8 fresh-frozen cadavers, submitted to four experimentally created conditions: Baseline (only dissected); HR condition (20° increase of HR); PCT condition (20% of PCT); and combined PCT+HR. Bicipital forearm angle (BFA), low flexion (LF) test, GH internal (IR) and external (ER) rotation, and horizontal adduction (HAD) were assessed. All measurements were taken by the same blinded tester. A one-factor repeated measures ANOVA were used to identify the condition's impact in each clinical measurement in separate.

**Results:** There was a significant main effect of condition for BFA ($P$=.02; F=4.03); LF ($P$=.02; F=3.86), IR ($P$=.03; F=3.65), and ER ($P$<.01; F=15.15), but not for HAD ($P$=.29; F=1.33). HR condition showed decreased BFA of 16.1° and 15.8° when compared with PCT and PCT+HR conditions, respectively. PCT+HR condition decreased the LF test by 13.5°, and HR condition decreased IR ROM by 14.2° when compared to Baseline. All conditions increased ER when compared with Baseline.

**Conclusion:** Greater ROM changes were found in both HR conditions, which suggests that bony alterations influence motion more than soft tissue adaptions do.

**Key words:** Capsular contracture; Retrotorsion; Shoulder; Tissue.

## Introduction

Alterations in shoulder range of motion (ROM) are common in individuals who perform repetitive overhead activities, especially the dominant arm of throwing athletes.[31,75,104,120,127,130,151,153] These individuals have been widely investigated and studies consistently demonstrate decreased glenohumeral joint (GHJ) internal rotation (IR) and increased external rotation (ER) ROM.[31,75,104,120,127,130,151,153] It is suggested that bony and soft tissue adaptations such as increased humeral retroversion (HR), posterior capsule tightness (PCT), and/or posterior muscles tightness explain these changes in ROM.[31,111,120,127,130,156,157]

Posterior capsule tightness is a prevalent soft tissue alteration in subjects who perform overhead sports or activities.[129,167] Capsule tightness is described as an adaptation to repetitive high tensile loading on the posterior shoulder capsule during arm deceleration,[16,122] which over time increases tissue stiffness and restricts glenohumeral IR ROM. Clinical measurements for PCT include quantifying horizontal adduction (HAD) ROM in the supine[163] or side lying positions.[158] However, in a cadaver study that evaluated posterior capsule strain across several measurements, Borstad and Dashottar[10] found that the low flexion test (LF), a measure of IR ROM at 60° of arm flexion, caused higher strain on the posterior capsule than did HAD.[10]

Increased HR is another common tissue alteration noted on the dominant arm of overhead athletes.[95,104,111,127,145,151,153] Humeral retroversion is part of initial human development,[38,151] but repetitive rotational forces produced during the overhead throw can limit full anteversion during skeletal maturation and result in increased retroversion.[38,79,151] Increased HR will shift the total arc of humeral rotation, resulting in apparent decreased IR and increased ER ROM.[31,76,120,130] The HR angle can be directly measured with

radiographs[120,130,153] or computed tomography,[22,31,62] while ultrasound[112,165] and a digital inclinometer[35,50] are low-cost and non-invasive alternative measurements. These alternative measures result in an indirect measure of HR called the bicipital forearm angle (BFA),[70] which corresponds to the angle between the ulna and vertical and is inversely related to HR.[173]

Although many studies have evaluated these ROM alterations in overhead athletes,[31,75,104,120,127,130,153] only Thomas et al.[151] assessed HR, PCT and IR deficit ROM in the same group of throwers. Thomas et al.[151] correlated HR and PCT from a single measurement session, but the interaction between HR and PCT on the clinical measurements has not been evaluated. A recent cadaver study also evaluated the influence of PCT on the LF test, HAD and IR ROM measurements, however the HR effect was not assessed.[34] Considering that PCT may alter HR measurements and increased HR almost certainly alters PCT measurements, the accurate interpretation of the clinical measurements for tissue and ROM alterations at the shoulder is a concern. Because accurate measurements are necessary to clinical practice, using cadavers to clarify the interaction among tissue adaptations may advance the clinical interpretation of these measurements. Therefore, the purpose of this study was to use cadaver specimens to determine the individual and combined effects of HR and PCT on five clinical measurements for shoulder ROM. Our hypothesis was that HR and PCT, when combined, would alter the clinical measurements to a greater extent than either adaptation alone.

## Methods

### *Specimens*

Eight fresh-frozen cadaver specimens (4 male, 4 female; mean ± SD age, 78.0 ± 9.91 years) consisting of a scapula and full upper extremity were used for this study. The specimens were stored at temperatures between –28°C and –30°C and were thawed for 24 hours prior to testing. All specimens were prepared for testing by removing the skin over the posterior shoulder and upper arm and reflecting the deltoid, infraspinatus, and teres minor muscles to expose the posterior capsule.[34] The scapula was rigidly attached to a custom-made testing frame that could be positioned to simulate the upright and supine positions. The testing frame positioned the scapula in anatomic neutral position, with the medial border vertical and the plane of the scapula oriented 30° anterior to the frontal plane (**FIGURE 1**).[10,34] Before initiating the tests, a physical therapist with over 17 years of clinical experience preconditioned each cadaver specimen by passively rotating the glenohumeral joint to the end of the available range. Studies using materials from deceased individuals is determined by the Ohio State University Human Research Protection Program as not meeting the federal definition of human subject research requiring review.

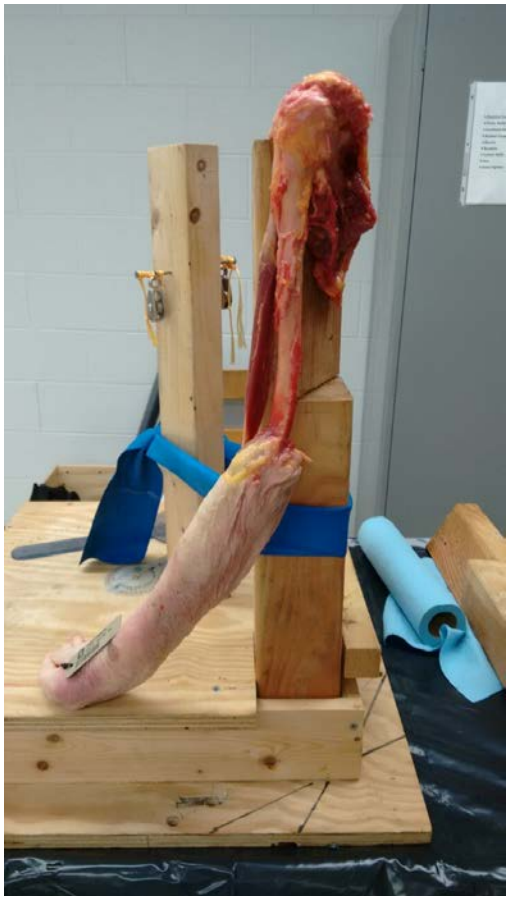

**FIGURE 1.** Specimen setup for data collection (Baseline Condition).

*Design and Procedures*

A within-subject repeated-measures design was used to compare five simulated clinical measurements of ROM across four GHJ conditions. Because scapular motion was constrained during the measurements the GHJ elevation angles were adjusted. For example, when simulating in vivo humeral elevation of 90°, an elevation angle of 60° was used to account for the lack of 30° of scapular upward rotation.[10,34,109] The humeral elevation angles in the starting position of each measurement were quantified by a goniometer to standardize the measurements. Each prepared cadaver specimen was tested across four conditions: Baseline (no tissue alterations); HR (increased HR alone); PCT (PCT alone); and HR+PCT

(PCT plus increased HR). The sample size estimates were calculated with PASS software using 10° +/-15° mean differences between conditions, power of 0.80 and an alpha of 0.05.

To create HR, the humerus was cut into distal and proximal segments, the lower segment was externally rotated 20°, and the two segments re-aligned and secured at the cut using hardware that was purchased for this purpose (**FIGURE 2**). Prior to cutting, a reference line was made longitudinally on the bone. The cut bisected this reference line, a goniometer was used to quantify a 20° rotation relative to the reference line, and a second mark on the proximal segment representing HR was made. HR was simulated by aligning the reference line on the distal segment with the HR mark on the proximal segment. Baseline alignment was achieved by re-aligning the marks for the reference line. Alignment during the experiment was checked prior to every measurement and malalignment was not detected at any point during the study.

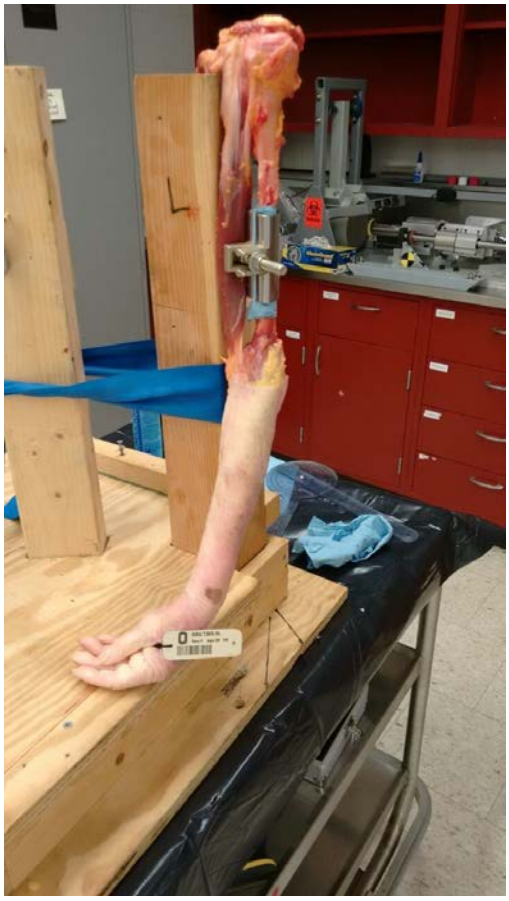

**FIGURE 2**. Humeral retroversion experimentally created.

To create PCT, thermal energy (VAPR 3; Mitek, Inc) was applied to the posterior capsule. Landmarks at the glenoid and humerus were used to quantify the original posterior capsule length and to track decreases caused by the application of energy. Length decreases of 20% were used for this study because this change has been shown to increase capsule stiffness and has been used successfully to study the effect of PCT on motion[10,34] and to develop the LF measurement.[10]

Under each of the four conditions, the clinical measurements were taken in random order. Out of necessity, the sequence of the conditions was always: Baseline; HR; PCT+HR; and PCT. Of the two tissue alterations, only HR could be reverted back to baseline alignment,

which allowed the alterations to be tested individually and in combination but not to be randomized. The clinical measurements were BFA, LF, GHJ IR and ER and HAD ROM. The first investigator moved the cadaver joint to the measurement position, while a second investigator quantified the measurements using a digital inclinometer (Baseline Evaluation Instruments; Enterprises Incorporated, White Plains, NY, USA), except for HAD measurement.

The BFA was determined using previously published methods that established the procedures, validity and reliability.[35,50,70,151,173] Briefly, this measurement captures the angle of the forearm relative to vertical when the bicipital tuberosities are oriented in the horizontal plane. With the cadaver supine, the elbow was positioned in 90° of flexion. The investigator rotated the arm into IR and ER while palpating the bicipital tuberosities until they were oriented horizontally. The digital inclinometer was then placed on the distal forearm surface and the angle relative to vertical was recorded.

The LF test is performed at 60° of humerus flexion in the sagittal plane, followed by passive IR of the arm.[10] The digital inclinometer was positioned on the distal surface of the forearm to measure the angle between the forearm and horizontal.[10] The validity and intra-reliability of the LF measurement have been reported as excellent.[10,11]

To measure IR and ER ROM, the arm of the upright cadaver was placed in 60° of abduction and the elbow flexed at 90°. The arm was then passively rotated into IR and the inclinometer was placed on the dorsal surface of the forearm. For ER, the arm was passively rotated into ER and the inclinometer was placed on the palmar surface of the forearm. IR and ER were quantified as the amount of rotation relative to horizontal. This measurement is regularly used clinically and noted to be reliable.[27]

HAD was measured with the humerus at 60° of arm flexion and neutral IR/ER, and the elbow positioned at 90º of flexion. From this position the humerus was adducted in the transverse plane until the end of passive range.[10,34,80,122,164] The goniometer was positioned over the estimated center of the GHJ with one arm of the device parallel to the testing frame and the other arm aligned with the specimens' humerus. The HAD ROM was determined as the angle between the both arms of the goniometer.

For all measurements, two repetitions were quantified and the mean of those two measures used for analysis. The same investigator positioned the shoulder for each measurement on for all cadavers.

*Statistical Analysis*

The data were analyzed using the NCSS 2007 statistical software (NCSS, LLC, Kaysville, UT). Normality was evaluated by Kolmogorov–Smirnov test, and all variables showed $p > .05$. A series of one-factor (Condition) repeated measures ANOVA with measurement ROM the dependent variable were used to identify the condition's impact on each clinical measurement. The Tukey-Kramer test was used for post-hoc analysis. A p value of less than .05 was considered statistically significant.

**Results**

**FIGURE 3** shows the clinical measurements for each condition. For BFA, the HR condition was decreased (*P*=.02; F=4.03) by 16.1° and 15.8° compared with PCT and PCT+HR conditions, respectively. IR ROM was decreased in the HR condition by 14.2° (*P*=.03; F=3.65) compared with Baseline. The LF test was decreased by 13.5° (*P*=.02; F=3.86) in the PCT+HR compared with the Baseline condition. ER ROM was increased in

all conditions (*P*<.01; F=15.15) when compared with Baseline, while HAD ROM (*P*=.29; F=1.33) was not significantly different across any of the four conditions. (**TABLES 1** and **2**)

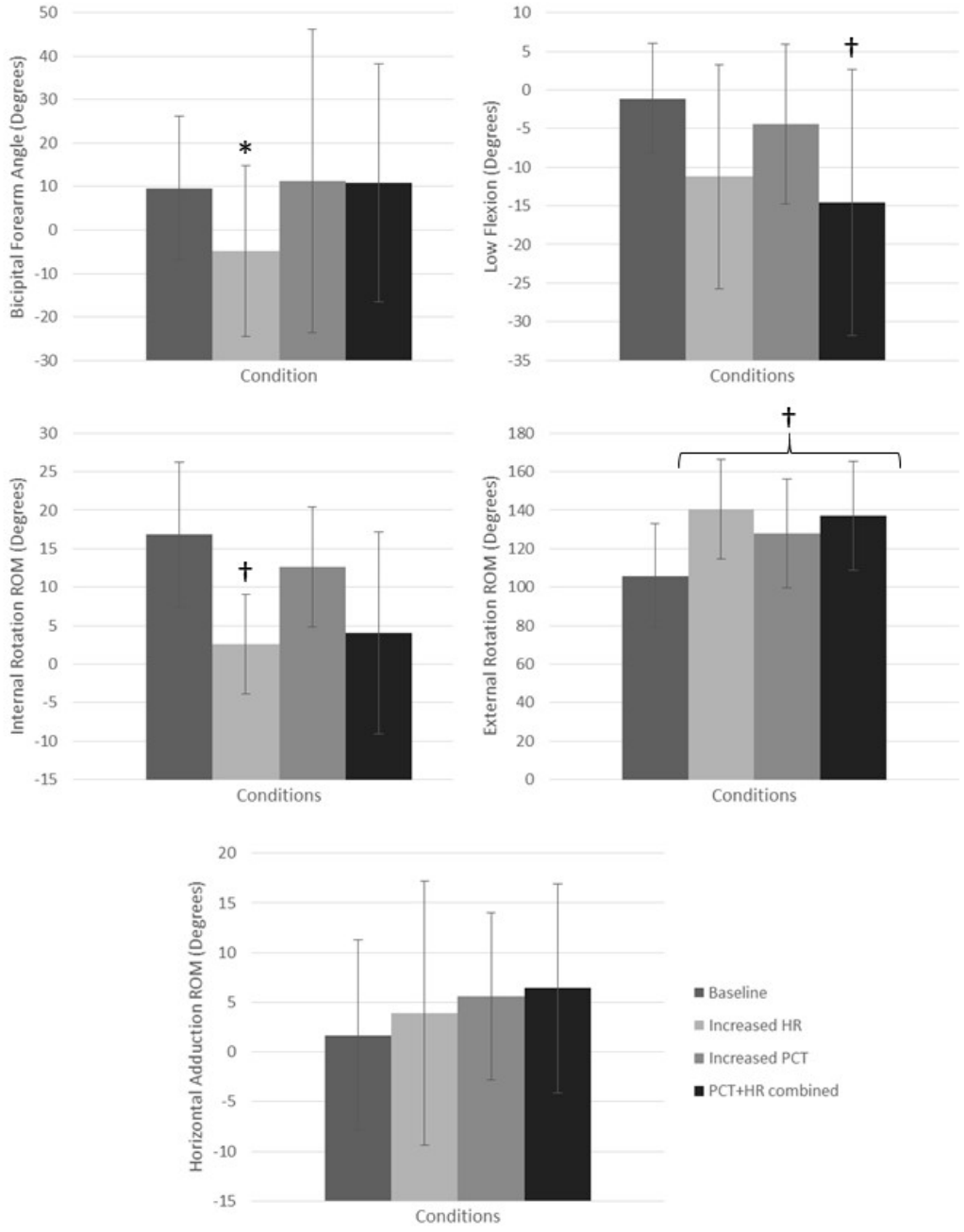


**FIGURE 3.** Mean ± standard deviation of each simulated clinical measurement. *p<0.05, when compared to PCT and PCT+HR conditions. †p<0.05, when compared to Baseline condition. Abbreviations: HR, humeral retroversion; PCT, posterior capsule tightness; ROM, range of motion.

**TABLE 1. Result of One-Factor repeated measures Analysis of Variance**

| Clinical Measurement | df | F value | P value |
|---|---|---|---|
| *BFA* | 3 | 4.03 | 0.02* |
| *LF test* | 3 | 3.86 | 0.02* |
| *IR ROM* | 3 | 3.65 | 0.03* |
| *ER ROM* | 3 | 15.15 | <.001* |
| *HAD ROM* | 3 | 1.33 | 0.29 |

Abbreviations: HR, humeral retroversion; PCT, posterior capsule tightness; BFA, bicipital forearm angle; LF, low flexion; IR, internal rotation; ROM, range of motion; ER, external rotation; HAD, horizontal adduction.

* Significant clinical measurement effect.

**TABLE 2. Mean difference for the significant Clinical Measurement Effect**

| Clinical Measurement | Conditions | Mean difference ± SE |
|---|---|---|
| ***BFA*** | | |
| | PCT x HR | 16.1 ± 6.6 |
| | PCT+HR x HR | 15.8 ± 5.1 |
| ***LF test*** | | |
| | Baseline x PCT+HR | 13.5 ± 6.3 |
| ***IR ROM*** | | |
| | Baseline x HR | 14.2 ± 4.4 |
| ***ER ROM*** | | |
| | HR x Baseline | 34.6 ± 5.3 |
| | PCT x Baseline | 22.1 ± 7.1 |
| | PCT+HR x Baseline | 31.2 ± 7.7 |

Abbreviations: SE, standard error; HR, humeral retroversion; PCT, posterior capsule tightness; BFA, bicipital forearm angle; LF, low flexion; IR, internal rotation; ROM, range of motion; ER, external rotation; HAD, horizontal adduction.

## Discussion

In the present study, we analyzed the effects of HR and PCT on 5 simulated clinical measurements using cadavers. It was hypothesized that the HR and PCT would change the clinical measurements and that these changes would be magnified in the combined condition. However, our findings indicated that the HR and PCT+HR conditions resulted in the largest

ROM alterations for most of the assessed measurements, suggesting that bony adaptions may contribute more to motion alterations than soft tissue adaptions at the shoulder.

The BFA was decreased in the HR condition compared to PCT and Baseline conditions. Considering that this clinical measure is inversely related to HR,[173] this result confirms the increased HR created in this condition. It was expected that PCT+HR condition would also decrease the BFA, but our data show no differences on BFA for the PCT+HR, Baseline and PCT conditions. We speculate that the PCT condition somehow offsets the influence of HR, leading to similar Baseline and PCT+HR values for BFA test. This study was the first to use cadavers to investigate the effects of experimentally increased HR on clinical measurements and further investigation of humeral torsion is needed in human subjects and patients before results of this study can be extrapolated to clinical practice.

Contrary to prior studies, the LF test was significantly decreased only in PCT+HR condition and not in the PCT alone condition. Previous studies have demonstrated high strain on posterior shoulder capsule when shoulder flexion is combined with IR.[10,34,71] However, these investigations did not include the HR effect on motion, which may have influenced their findings. Our results indicate that HR influenced the LF test more than the PCT alone condition, suggesting that LF may not isolate ROM limitations due to PCT. It is possible that because the PCT condition was always tested last, an order effect influenced our results. We were constrained to our testing condition order because of a limited number of cadaver specimens available. Future studies that can randomize test conditions may be able to clarify these results.

PCT, HR and posterior muscle tightness have all been described as potential influences on IR ROM deficits at the GHJ.[31,111,120,127,130,156,157] In the present study, only the HR condition significantly decreased IR ROM when compared to Baseline. Some *in vivo*

studies have evaluated the effect of PCT or HR on ROM changes in throwing athletes.[47,64,148] Baseball players demonstrate IR ROM deficit associated more strongly with increased HR than with PCT,[47,64] which our results appear to support. On the other hand, in a study that evaluated both PCT and HR in baseball players, there was greater decrease in IR ROM when these conditions were both present and when ROM changes were corrected by HR differences as compared to when PCT alone was present.[148] The current literature regarding IR ROM deficit remains controversial and more studies are necessary to determine the tissue alteration(s) responsible for IR ROM deficits, including studies that evaluate the contribution of posterior shoulder muscle alterations.

The increase in ER ROM typically seen in throwing athletes is reported as an adaption that is complementary to the IR ROM deficit.[31,75,104,120,127,130,151,153] Our study showed increased ER for all conditions compared to Baseline, despite the finding that no IR ROM changes were found in the PCT alone or PCT+HR conditions. As no previous studies have compared the effect of PCT and HR separately or in combination, more investigation of the clinical applicability of this ER ROM adaption is warranted. However, based on our outcomes, it appears that glenohumeral ER motion was more influenced by the experimentally created conditions than was glenohumeral IR.

On the other hand, none of the conditions significantly changed the HAD ROM. Previous cadaver studies did not demonstrate increased posterior shoulder capsule strain with the HAD test.[10,71] Another recent exploratory cadaver study demonstrated that HAD ROM may not be the best test to assess the PCT because no motion alterations were observed after experimental posterior capsule contracture.[34] Our results support these previous findings that HAD may not capture the ROM changes caused by PCT or HR.

## Conclusion

The results of this study indicate that HR alone and when combined with PCT has a significant influence on BFA, LF, and, IR and ER ROM measurements. All four experimental conditions increased ER ROM, while none of them influenced the HAD measurement. Thus, from this study, it appears that the bony alteration of HR has the greatest influence on shoulder ROM, while PCT alone did not significantly affect clinical measurements. Further investigation is needed to identify how these conditions may influence the clinical measurements evaluated in asymptomatic individuals and individuals with shoulder pain before the results of the present study can be translated to clinical practice.

**MANUSCRITO IV**

# The influence of posterior glenohumeral joint capsule tightness and humeral retroversion on clinical measurements

**Rosa DP, Camargo PR, Borstad JD**

**Manuscrito submetido ao periódico *Journal of Orthopaedic & Sports Physical Therapy*** (Fator de Impacto 2,825)

**Abstract**

**Study Design:** Cross-Sectional

**Background:** Individuals who perform overhead throwing activities often demonstrate decreased glenohumeral internal rotation (IR) and increased external rotation (ER) range of motion (ROM). Evidence for osseous and soft tissue adaptations such as increased humeral retroversion (HR) and/or posterior capsule tightness (PCT) may help explain these ROM changes. However, because these tissue adaptations have been studied only in isolation, the combined effects of osseous and soft tissue changes on ROM are not understood.

**Objectives:** To assess the influence of PCT and HR on six ROM clinical measurements in asymptomatic individuals with PCT and/or HR.

**Methods:** 75 asymptomatic individuals were assigned to one of 4 groups: Control group without PCT and symmetrical HR (n=28); PCT only group (n=17); HR only group (n=15); and a PCT and HR combined group (n=15). Six clinical measurements were quantified using a digital inclinometer: Bicipital forearm angle (BFA), low flexion (LF) test, GH internal (IR) and external (ER) rotation, and horizontal adduction (HAD).

**Results:** HR and PCT+HR groups showed decreased BFA compared with the Control and PCT groups ($P<.001$). PCT and PCT+HR group demonstrated decreased LF ($P<.01$) compared to the other groups. PCT+HR group also presented decreased IR ROM compared to the Control ($P<.001$) and to HR ($P<.001$) groups and increased ER ROM compared to the Control ($P<.001$) and PCT ($P<.001$) groups. No differences between groups were found for HAD ($P=.58$) and EIR ROM ($P=.57$).

**Conclusion:** A combination of tissue adaptions seems to contribute more to shoulder ROM alterations than does the same adaptions when conditions are presented alone.

**Level of Evidence:** Individual Cohort study, level 2b

**Key words:** Posterior shoulder; Range of motion; Retrotorsion; Shoulder.

## Introduction

Individuals who perform repetitive overhead activities or sports frequently demonstrate shoulder range of motion (ROM) alterations.[31,75,104,120,127,130,151,153] Studies have consistently demonstrated decreased glenohumeral internal rotation (IR) and increased external rotation (ER) ROM in the dominant arm of throwing athletes.[24,31,75,97,104,120,127,130,151,153] Bony and soft tissues adaptations such as increased humeral retroversion (HR), posterior capsule tightness (PCT), and/or posterior muscles tightness may explain these ROM changes.[31,111,120,127,130,156,157]

Humeral retroversion represents the degree of humeral torsion along its longitudinal axis[86] and increased HR is commonly present on the dominant arm of overhead throwing athletes.[95,104,111,127,145,151,153] Repetitive ER forces produced during the overhead throw are proposed to contribute to increased amounts of retroversion.[38,79,97,151] Posterior capsule tightness (PCT) is also a prevalent tissue alteration in individuals who perform overhead sports or activities.[129,167] This alteration is described as an adaptation to repetitive high tensile loading on the posterior shoulder capsule during the deceleration phase of throwing.[16,122] The capsule may become increasingly stiff over time, restricting normal glenohumeral motion.

The bicipital forearm angle (BFA)[70] is a valid and reliable indirect measure of HR that has been used in many studies.[50,112,144,151,165,173] BFA is inversely related to HR[173] and corresponds to the angle between the ulna and vertical when the elbow is positioned in 90° of flexion for the supine patient. Clinical measurements for PCT are typically accomplished by quantifying horizontal adduction (HAD) in the supine[163] or side lying positions.[158] However, in a cadaver study of posterior capsule strain, Borstad and Dashottar[10] found that the low flexion test (LF), a measure of IR ROM at 60° of arm flexion, caused higher strain on the posterior capsule than HAD.[10] While HAD may best reflect posterior shoulder muscle

adaptations,[81] other studies demonstrate higher strain on posterior shoulder muscles with shoulder extension and IR (EIR) compared to HAD.[36,110]

A key problem for measuring posterior shoulder adaptations is that the interaction effects among the potential tissue alterations on the various clinical measurements is unknown. One way to approach solving this problem is to evaluate how HR and PCT, separately and in combination, influence the measurements used in clinical practice. Thomas et al.[151] correlated HR, PCT and IR ROM deficits from a single measurement session in those suspected of having posterior shoulder tightness but the interaction effects were not evaluated. Therefore, the purpose of this study was to identify the influence of PCT and HR on six clinical measurements used to evaluate shoulder motion in asymptomatic individuals with PCT and/or HR. Our hypothesis was that PCT and HR in combination would have a greater influence on posterior shoulder motion measurements than when PCT or HR were present alone.

**Methods**

Eighty-one individuals between 18 and 40 years of age with no current shoulder pain were recruited for this study (**FIGURE 1**). Using G-Power software (version 3.1), with the power set at 0.8 and α at 0.05, the sample size was calculated to be 15 individuals per group considering a difference of 10° of HR between groups. The HR difference was used for calculating sample size estimates because it was expected that HR would be less common than PCT in the general population. From among those recruited, seventy-five individuals enrolled in this study (**FIGURE 1**). Enrolled individuals were assigned to one of four groups based on their clinical measurements: a control group without PCT and symmetrical HR (Control, n=28); a PCT only group with LF side-to-side differences of >7° (PCT, n=17); a

HR only group with BFA side-to-side differences of >10° (HR, n=15); and a PCT and HR combined group with ipsilateral LF >7° and HR >10° (PCT+HR, n=15). The groups were also matched based on the individual's overhead activities and demographic data. The descriptive data of the individuals are presented in **TABLE 1**.

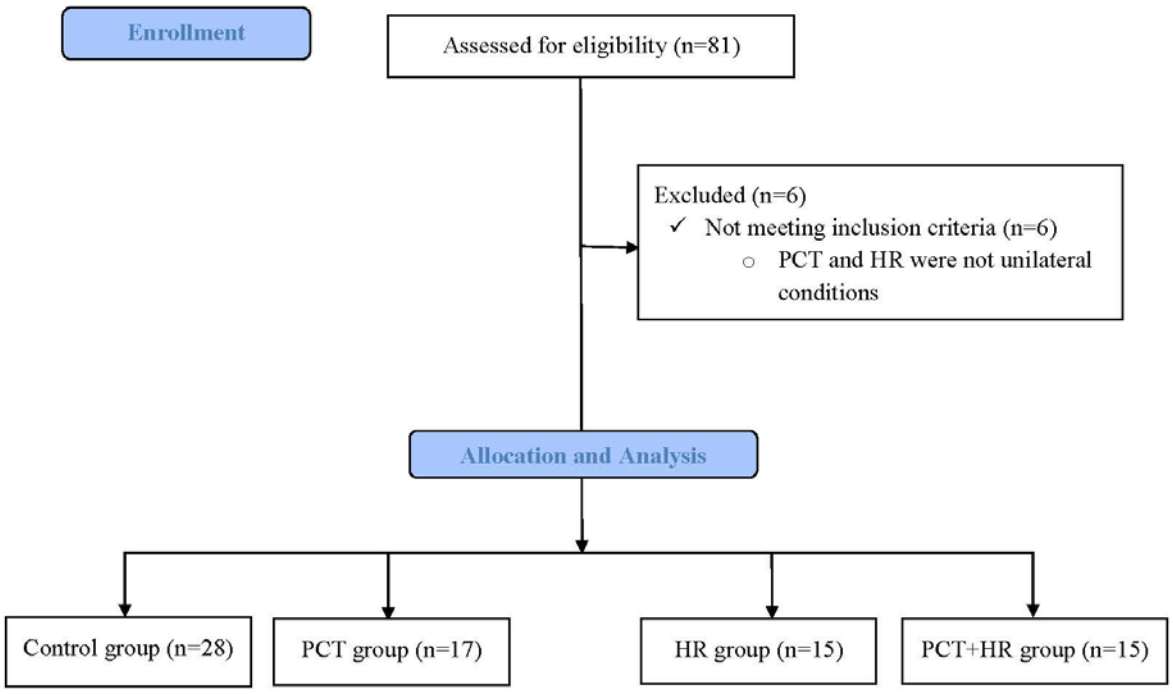


**FIGURE1**. Flow diagram representing enrollment, allocation, and analysis of the groups.

The LF Test (**FIGURE 2A**) was used to quantify PCT.[10] This test is performed with the humerus at 60° of sagittal plane arm elevation. In this position, the examiner supports the arm and allows glenohumeral IR to reach the end of passive motion. A digital inclinometer is then placed on the distal surface of the forearm to measure the angle between the forearm and the horizontal.[10] The validity and intra-rater reliability of the LF test have been reported as excellent.[10,11] Based on prior data,[11] we considered the posterior capsule to be tight with a 7° or greater decrease in the LF test in comparison to the contralateral side.

HR was measured indirectly by the BFA, as described in previous studies.[35,50,70,151,173] The BFA is determined by the angle of the forearm relative to vertical when the bicipital tuberosities are oriented in the horizontal plane. Individuals are measured in supine with the elbow in 90° of flexion. The investigator rotates the arm into IR and ER while palpating the bicipital tuberosities until their apex's are oriented horizontally. The digital inclinometer is then positioned on the distal forearm surface and the angle relative to vertical recorded.

Individuals were excluded if they had: ligamentous laxity or glenohumeral joint instability based on positive Sulcus,[115] Apprehension[137] or anterior drawer tests;[103] impingement syndrome; a history of clavicle, scapula or humerus fracture; a history of shoulder surgery or traumatic injury; adhesive capsulitis or scoliosis; a systemic musculoskeletal pathology.

This study was approved by the Institutional Review Board at the Ohio State University. The participants gave their written and informed consent to participate in this study, which was conducted according to the Helsinki Statement. All measurements were taken by the principal investigator who was not blinded to group assignment.

*ROM measurements*

Glenohumeral IR, ER, HAD and EIR ROM were measured using a digital inclinometer (Baseline Evaluation Instruments; Enterprises Incorporated, White Plains, NY, USA). The inclinometer measures angles from a horizontal or vertical reference within 1° accuracy as described by the manufacturer. IR, ER and HAD ROM were measured with the individual in supine. IR and ER are quantified at 90° of shoulder abduction and elbow flexion. After rotating the GHJ into maximum IR and ER, the inclinometer is placed on the ventral

or dorsal surface of the forearm, respectively (**FIGURE 2C** and **D**). These measurements are commonly used in clinical practice and reported as reliable.[27]

To measure HAD the arm is positioned at 90° of flexion and neutral IR/ER. From this position, the arm is adducted in the frontal plane with scapula motion monitored by the evaluator until the end of passive GHJ range with no scapula motion are noted. The inclinometer is placed on the arm and the angle relative to the vertical quantified. This measurement has demonstrated excellent reliability.[36,81,113] The EIR ROM was measured in the seated position with the arm positioned at 60° of extension and supported by the evaluator, with the elbow at 90° of flexion. Maximum passive IR ROM is measured with the inclinometer on the ventral surface of the forearm (**FIGURE 2F**). This measurement was also reported as reliable.[36]

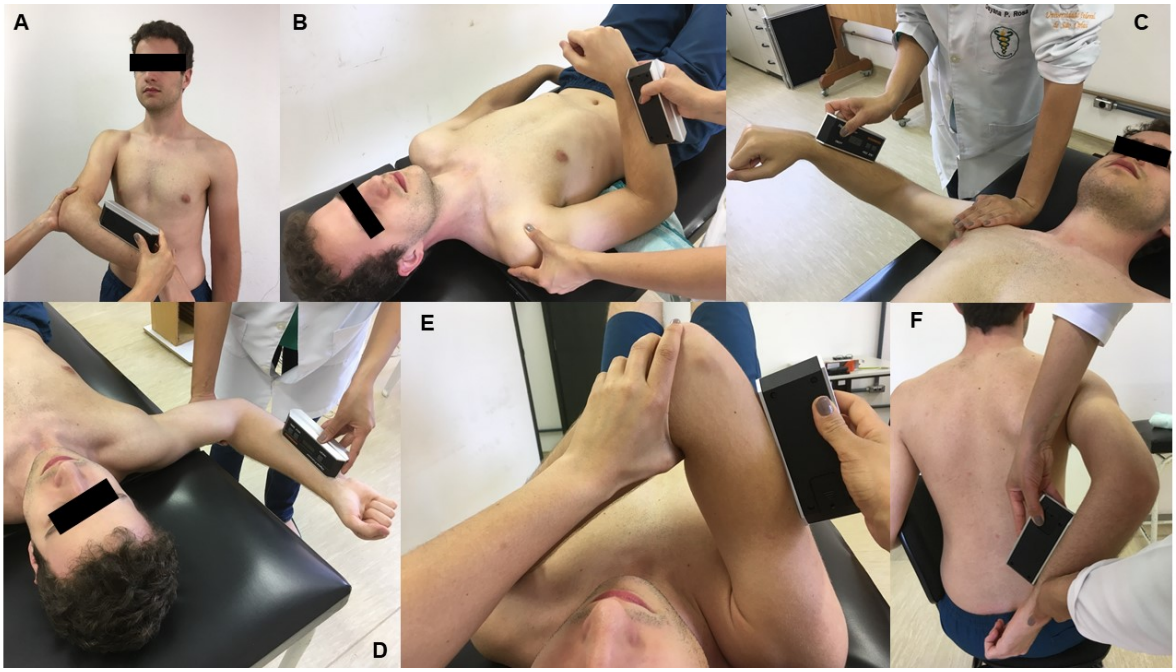


**FIGURE 2.** Clinical measurements: Low Flexion Test (A); Bicipital Forearm Angle (B);; Internal Rotation (C); External Rotation (D); Horizontal Adduction (E); and Extension with Internal Rotation (F).

*Procedures*

Enrolled individuals provided demographic information (sex, age, height, weight, arm dominance) and reported their present and past history of physical activity. Prior to the clinical measurements, each individual had a clinical examination that included active movement assessment and application of special tests to assess for instability or rotator cuff pathology. The clinical examination was done by a licensed physical therapist with 5 years experience.

Following the examination, all individuals were evaluated bilaterally for the clinical measurements described above (**FIGURE 2**). Two measurements, BFA and LF, were used to assign participants to groups, and were also included in the statistical analysis. The mean of two measurements was used for analysis and group assignment. All measurements were taken prior to group assignment by the first author who was blinded to the values.

*Statistical Analysis*

Data were analyzed using the SPSS 17.0 statistical software (SPSS, Chicago, IL). Normality was evaluated using the Kolmogorov–Smirnov test, and all variables showed were consistent with a normal distribution. A series of one-factor (group) repeated measures ANOVA was adopted to determine if measurement values were different based on the unique combinations of suspected tissue alteration. The side-to-side difference (With the Condition side – Contralateral Side) for each clinical measurement was considered as the dependent variable. A post-hoc analysis was conducted with Tukey-Kramer post-hoc tests. Because BFA and LF were used for group assignment it was expected that they would be different between groups, so the main focus of analysis were glenohumeral IR, ER, HAD and EIR ROM. A *P* value of less than .05 was considered statistically significant.

## Results

**TABLE 1** shows the descriptive data for the groups of the study.

**TABLE 1. Descriptive data of the groups.**

| | Control (n=28) | PCT (n=17) | HR (n=15) | PCT+HR (n=15) | *P*-value |
|---|---|---|---|---|---|
| **Sex** | 19 women; 9 men | 13 women; 4 men | 10 women; 5 men | 3 women; 12 men | 0.90 |
| **Age (years)** | 25.14 ± 4.29 | 23.73 ± 5.13 | 26.67 ± 6.13 | 22.14 ± 2.65 | 0.13 |
| **BMI ($kg/m^2$)** | 25.88 ± 3.72 | 24.50 ± 4.52 | 24.62 ± 2.97 | 25.73 ± 2.74 | 0.78 |
| **Evaluated Shoulder** | 26 dominants; 2 non-dominants | 17 dominants | 14 dominants; 1 non-dominant | 14 dominants; 1 non-dominant | 0.74 |
| **Overhead Activity** | 8* | 9 | 13 | 13 | <0.001 |

Results are mean ± standard deviation.

*$P$ <.001, when compared to all other groups.

Abbreviations: PCT, posterior capsule tightness; HR, humeral retroversion; BMI, body mass index.

**TABLE 2** shows the clinical measurement data for each group for both sides. The HR only and PCT+HR groups demonstrated less BFA, indicating increased retroversion, compared with the Control and PCT groups ($P$ <.001) (**FIGURE 3, TABLE 4**). Decreased LF test was found in PCT only group compared to the Control ($P$ <.001) and HR ($P$ <.001)

groups (**FIGURE 3, TABLE 4**). The PCT+HR group also showed decreased LF test values compared to all other groups (*P* <.01) (**FIGURE 3, TABLE 4**). The same group had lower IR ROM compared to the Control (*P* <.001) and HR only (*P* <.001) groups, but it presented the higher ER ROM compared to the Control (p<.001) and PCT only (*P* <.001) groups (**FIGURE 3, TABLE 4**). On the other hand, no differences between groups were found for HAD (p=.58) and EIR (p=.57) (**FIGURE 3, TABLE 3**).

**TABLE 2. Mean ± standard deviation (95% Confidence Interval) of each clinical measurement for all groups.**

| **Clinical Measurement** | **Control *(n=28)*** | | **PCT *(n=17)*** | | **HR *(n=15)*** | | **PCT+HR *(n=15)*** | |
|---|---|---|---|---|---|---|---|---|
| | *With the condition side* | *Contralateral side* | *With the condition side* | *Contralateral side* | *With the condition side* | *Contralateral side* | *With the condition side* | *Contralateral side* |
| **BFA (°)** | 33.8±7.1 (31.1, 36.6) | 34.5±7.4 (31.7, 37.4) | 36.1±6.7 (32.5, 39.5) | 36.1±5.3 (33.3, 38.8) | 24.3±9.2 (19.1, 29.4) | 36.4±8.2 (31.8, 41.1) | 22.8±4.7 (20.2, 25.4) | 39.1±5.2 (36.2, 41.9) |
| **LF (°)** | 20.8±6.2 (18.4, 23.2) | 22.4±5.8 (20.1, 24.6) | 19.3±7.7 (15.3, 23.2) | 29.9±7.8 (25.9, 33.9) | 19.7±5.4 (16.7, 22.7) | 21.4±4.9 (18.6, 24.2) | 13.1±8.2 (8.5, 17.6) | 27.7±7.5 (23.6, 31.8) |
| **IR ROM (°)** | 58.9±8.5 (55.5, 62.2) | 63.0±6.9 (60.3, 65.7) | 58.9±9.6 (53.9, 63.8) | 68.3±10.2 (63.1, 73.5) | 56.1±11.1 (49.9, 62.3) | 62.4±9.3 (57.2, 67.6) | 48.1±9.5 (42.8, 53.4) | 63.4±9.0 (58.3, 68.3) |
| **ER ROM (°)** | 95.5±15.1 (89.6, 101.3) | 97.6±13.8 (92.3, 103.0) | 86.9±13.6 (79.9, 93.9) | 90.7±12.9 (84.1, 97.3) | 98.6±10.7 (92.6, 104.6) | 95.6±12.1 (88.8, 102.3) | 105.6±11.3 (99.3, 111.8) | 94.7±11.1 (88.6, 100.8) |
| **HAD ROM (°)** | 23.6±3.4 (22.2, 24.9) | 25.1±3.9 (23.6, 26.6) | 22.6±4.3 (20.4, 24.8) | 23.9±3.9 (21.9, 26.0) | 20.4±4.4 (17.9, 22.8) | 20.3±5.8 (17.1, 23.5) | 17.12±3.3 (15.3, 18.9) | 17.2±4.7 (14.5, 19.8) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **EIR ROM (°)** | 49.2±13.3 | 40.6±14.1 | 50.7±13.4 | 44.8±15.6 | 39.7±16.9 | 35.7±12.4 | 39.1±10.9 | 34.0±6.8 |
| | (44.0, 54.3) | (35.1, 46.1) | (43.8, 57.5) | (36.8, 52.9) | (30.4, 49.1) | (28.8, 42.6) | (33.1, 45.2) | (30.2, 37.8) |

Abbreviations: PCT, posterior capsule tightness; HR, humeral retroversion; BFA, bicipital forearm angle; LF, low flexion; IR, internal rotation; ROM, range of motion; ER, external rotation; HAD, horizontal adduction; EIR, extension with internal rotation.

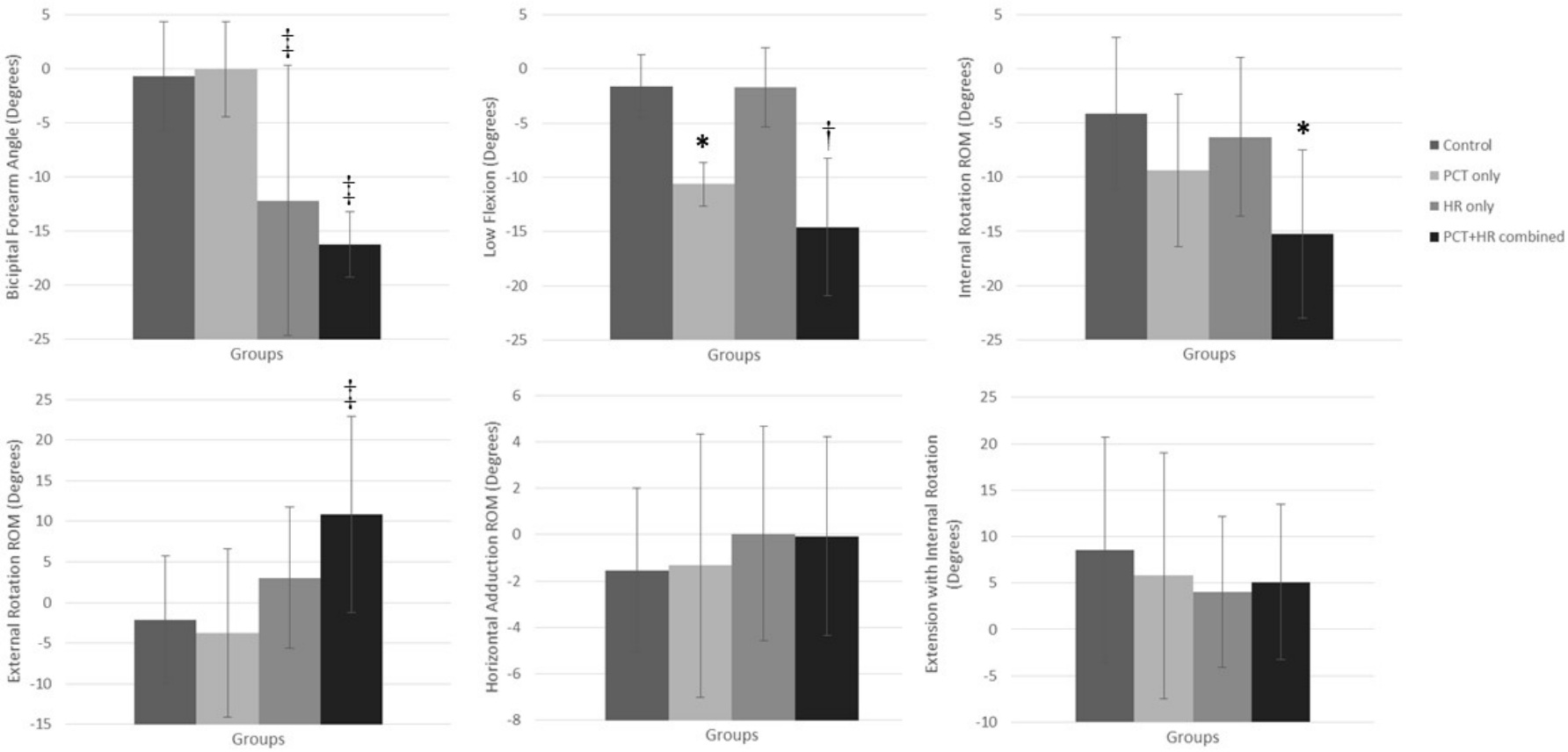


**FIGURE 3.** Between side-to-side difference ± standard deviation of each clinical measurement evaluated. **P*<.001, when compared to Control and HR groups. † *P* <.01, when compared to the other groups. ‡ *P* <.01, when compared to the Control and PCT groups. ROM, range of motion; PCT, posterior capsule tightness; HR, humeral retroversion.

**TABLE 3. Result of One-Factor repeated measures Analysis of Variance**

| Clinical Measurement | df | F value | P value |
|---|---|---|---|
| *BFA* | 3 | 25.37 | <.001* |
| *LF test* | 3 | 52.59 | <.001* |
| *IR ROM* | 3 | 8.19 | <.001* |
| *ER ROM* | 3 | 7.96 | <.001* |
| *HAD ROM* | 3 | 0.64 | .58 |
| *EIR ROM* | 3 | 0.67 | .57 |

Abbreviations: HR, humeral retroversion; PCT, posterior capsule tightness; BFA, bicipital forearm angle; LF, low flexion; IR, internal rotation; ROM, range of motion; ER, external rotation; HAD, horizontal adduction; EIR, extension with internal rotation.

* Significant group effect.

**TABLE 4. Mean difference (95% CI), in degrees, for the significant Group Effect.**

| Clinical Measurement | Group Comparison | Mean difference (95% CI) | P Value |
|---|---|---|---|
| ***BFA*** | | | |
| | Control x HR | 11.5 (5.7, 17.2) | <.001 |
| | Control x PCT+HR | 15.5 (9.8, 21.8) | <.001 |
| | PCT x HR | 12.1 (5.8, 18.5) | <.001 |
| | PCT x PCT+HR | 16.2 (9.8, 22.5) | <.001 |
| ***LF test*** | | | |
| | Control x PCT | 9.1 (5.9, 12.1) | <.001 |
| | Control x PCT+HR | 13.0 (9.8, 16.2) | <.001 |
| | HR x PCT | 8.9 (5.3, 12.4) | <.001 |
| | PCT x PCT+HR | 3.9 (0.4, 7.5) | .02 |
| | HR x PCT+HR | 12.9 (9.2, 16.5) | <.001 |
| ***IR ROM*** | | | |
| | Control x PCT+HR | 11.1 (5.0, 17.2) | <.001 |
| | HR X PCT+HR | 8.9 (2.0, 15.9) | =.006 |
| ***ER ROM*** | | | |
| | Control x PCT+HR | 13.0 (4.96, 21.0) | <.001 |
| | PCT+HR x PCT | 14.6 (5.7, 23.5) | <.001 |

Abbreviations: 95% CI, 95% Confidence Interval; BFA, bicipital forearm angle; LF, low flexion; IR, internal rotation; ROM, range of motion; ER, external rotation; PCT, posterior capsule tightness; HR, humeral retroversion.

**Discussion**

This study was the first to attempt to determine the separate and combined effects of PCT and HR on shoulder ROM measurements. Our purpose was to determine how PCT and HR interact to influence the clinical measurements that are being used to evaluate motion loss in clinical practice. We hypothesized that both alterations would influence the clinical measurements and that these changes would be greater in individuals suspected of having both PCT and HR. As expected, the largest ROM alterations were demonstrated by the PCT+HR group. The PCT only and HR only groups also influenced the clinical measurements evaluated. In this way, our findings indicate that combined tissue adaptions seems to contribute more to motion loss in individuals without shoulder pain than does soft tissue or osseous adaptions when exhibited alone.

The BFA, an indirect measurement of HR, was decreased in the groups with retroversion, revealing increased HR as expected and reported previously.[50,64,77,151] The PCT condition did not significantly affect the BFA measurement, showing that this test might be helpful to assess and classify individuals with HR only. Also, the LF test suggested to quantify the PCT[10] was significantly decreased in PCT+HR and PCT groups. This result corroborated to previous studies' findings, which demonstrated that LF test resulted in less ROM after experimental posterior capsule contracture in cadavers.[10,34] The fact that Dashottar and Borstad[34] assessed cadavers and did not aim to evaluate the HR in their sample, could limit the use of this measurement to quantify the PCT. As the HR adaption did not influence the LF test results in the present study, we can also suggest that the LF test might be used to assess the PCT in individuals that present this soft tissue adaption.

IR ROM deficit is frequently related to PCT, HR and posterior muscle tightness.[31,111,120,127,130,156,157] Our results demonstrated significantly decreased IR for the

PCT+HR group only when compared to the Control and HR only groups, suggesting that the PCT alone does not seem to influence this clinical measure. Hibberd et al.[64] also evaluated PCT and HR alterations in high school baseball players and did not report combined alterations (PCT+HR) in their sample. However, they reported that IR ROM was not associated with posterior capsule thickness or muscle stiffness, but instead was associated with increased HR. Another study evaluated the relationship between posterior capsule thickness/stiffness and decreased IR ROM in college baseball players.[148] This study demonstrated decreased IR when PCT and HR were combined and when side-to-side HR differences were corrected for to evaluate the PCT influence alone.[148] Our results partially agree with these findings, considering that PCT and HR were associated with decreased IR ROM only when the two conditions were combined. Thus, more studies are needed to evaluate the origin of IR ROM deficits. Further studies should also determine the contribution of posterior shoulder muscles to motion alterations.

Increased ER ROM is reported as an adaption to IR ROM deficit to maintain the total ROM arc.[24,31,68,75,97,104,120,127,130,151,153] Our results noted increased ER ROM in the PCT+HR group compared to Control and PCT only groups, a finding that is expected based on the IR ROM deficit noted in the same group. Increased HR in throwing athletes is a common alteration[120,130] that results in this type of shift in the arc of ER and IR ROM. This shift in ROM noted in the PCT+HR group is likely to be from an increase in HR because most individuals in this group reported a history of repetitive overhead activity. A prospective study[166] followed overhead athletes for approximately seven years and observed that individuals with ER ROM deficit had increased risk of shoulder injury and surgery than did individuals who presented IR deficit. Although Wilk et al.[166] did not evaluate PCT or HR in their sample, our findings may indicate that the increased ER ROM found might represent an

adaption to avoid shoulder dysfunction overtime. However, more prospective studies are needed to confirm this hypothesis.

Previous studies[10,34] have demonstrated that HAD ROM may not be the best clinical measurement to assess PCT, considering that no significant motion changes were observed after experimental posterior capsule contracture in cadavers. However, these studies did not evaluate the HR influence on the HAD measurement. Our results agree with these previous findings and also demonstrated that HR adaption did not influence HAD ROM. It is proposed that this measurement might be more sensitive to posterior muscles tightness,[81] but we did not assess the muscle stiffness in the present study. The infraspinatus muscle tightness could be estimated by EIR ROM. [36] This measurement was not influenced by the PCT or HR conditions as well, suggesting that these tissue alterations do not influence the posterior muscles tension. However, posterior shoulder muscle tightness was not evaluated in the present study and should be assessed in future research exploring the influence of tissue alterations on shoulder ROM and clinical measurements.

**Conclusion**

The results of this study indicate that the PCT and HR alone influence the shoulder ROM, but PCT combined with HR seems to restrict more the glenohumeral motion. This suggests that a combination of tissue adaptions may contribute more to shoulder ROM alterations than does the same adaptions when conditions are presented alone. The findings also indicate that the LF and BFA tests seems to be specific to quantify the PCT and HR, respectively. Further exploration that includes assessment of posterior shoulder muscle tightness and individuals with shoulder dysfunction are needed before clinical application of the findings of this study can be realized.

## CONSIDERAÇÕES FINAIS

Diante dos resultados dos estudos apresentados pode-se concluir que:

- O encurtamento da cápsula posterior e a dor no ombro não resultaram em alterações consideráveis na cinemática da escápula e do úmero, mas acarretaram em pior condição de dor, disfunção, restrição de amplitude de movimento e hipersensibilidade dolorosa em indivíduos com dor e encurtamento da cápsula.

- As adaptações desenvolvidas em resposta à dor ou alterações teciduais, como o encurtamento da cápsula posterior, podem se dar de maneira diferente em cada indivíduo com o intuito de preservar a função, mesmo que esses indivíduos apresentem a mesma disfunção musculoesquelética: dor no ombro.

- Uma intervenção específica para o encurtamento posterior da cápsula e dor no ombro foi mais efetiva para melhorar o encurtamento da cápsula, mas não foi mais efetiva para melhorar a cinemática escapular e umeral, dor e a função, amplitude de movimento, força e hipersensibilidade a dor. Tais achados, ressaltam a importância de intervenções que preconizem o alongamento e a movimentação ativa em indivíduos com dor crônica na articulação do ombro, medidas de baixo-custo e de fácil execução que podem viabilizar o sucesso da prática clínica.

- Os estudos em cadáveres e *in vivo* que avaliaram a interação do encurtamento da cápsula e da retroversão do úmero apresentaram resultados similares sobre a influência do encurtamento da cápsula posterior e do aumento da retroversão umeral nos testes clínicos de amplitude de movimento avaliados. Embora o estudo em cadáveres tenha indicado que as adaptações ósseas, como a retroversão umeral, parecem contribuir mais para as alterações de movimento do que as alterações teciduais como o encurtamento, o estudo *in vivo* mostrou que ambas, encurtamento posterior da cápsula e retroversão, influenciam os testes clínicos,

resultando em maiores limitações de movimento quando são combinadas. No entanto, o estudo *in vivo* mostrou que os testes utilizados para quantificar o encurtamento da cápsula e a retroversão umeral são capazes de identificar tais alterações. O teste de adução horizontal não sofreu alterações para nenhuma das condições testadas, mostrando mais uma vez que não deve ser utilizado para avaliar o encurtamento posterior da cápsula. Desta forma, os terapeutas devem considerar a avaliação por meio dos testes indicados para o encurtamento da cápsula posterior e da retroversão do úmero em indivíduos com alterações de amplitude de movimento, principalmente para as rotações medial e lateral do braço, sendo que novos estudos devem ser realizados incluindo populações com dor para que os resultados do presente estudo possam ser extrapolados para a prática clínica.

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# ANEXO

UNIVERSIDADE FEDERAL DE SÃO CARLOS/UFSCAR

## PARECER CONSUBSTANCIADO DO CEP

**DADOS DO PROJETO DE PESQUISA**

**Título da Pesquisa:** Alterações biomecânicas e neurofisiológicas em indivíduos com encurtamento da cápsula posterior do ombro- Avaliação e tratamento

**Pesquisador:** Dayana Patricia Rosa

**Área Temática:**

**Versão:** 2

**CAAE:** 35480714.4.0000.5504

**Instituição Proponente:** Programa de Pós-Graduação em Fisioterapia - PPGFt

**Patrocinador Principal:** Financiamento Próprio

**DADOS DO PARECER**

**Número do Parecer:** 860.648

**Data da Relatoria:** 27/10/2014

**Apresentação do Projeto:**

Estudo clínico, experimental e de intervenção,sendo constituído por dois estudos. O estudo 1 avaliará a cinemática escapular e umeral, a força dos rotadores laterais e o limiar de dor em portadores de encurtamento de CP com e sem dor no ombro de cem indivíduos. O estudo 2 verificará os efeitos de dois protocolos de intervenção em número de 50 sujeitos com encurtamento de CP e dor no ombro para as mesmas variáveis do estudo 1.

**Objetivo da Pesquisa:**

A pesquisadora informa que o objetivo do primeiro estudo consistirá em avaliar a dor e função do membro superior, amplitude de movimento (ADM) de rotação do braço, a força dos rotadores laterais do braço, o limiar de dor e a cinemática escapular e umeral em sujeitos com encurtamento de cápsula posterior com e sem dor no ombro. O segundo estudo verificará os efeitos de dois protocolos de intervenção em sujeitos com encurtamento de cápsula posterior e dor no ombro

**Endereço:** WASHINGTON LUIZ KM 235
**Bairro:** JARDIM GUANABARA **CEP:** 13.565-905
**UF:** SP **Município:** SAO CARLOS
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UNIVERSIDADE FEDERAL DE SÃO CARLOS/UFSCAR



nas variáveis acima descritas.

**Avaliação dos Riscos e Benefícios:**

No primeiro parecer, este Comitê solicitou à pesquisadora padronizar os riscos informados na Plataforma Brasil e no TCLE, bem como os procedimentos para minimizá-los, o que foi acatado. A pesquisadora cita como riscos: "aumento dos sintomas após os dias de avaliação e atendimentos nos sujeitos com dor no ombro; melhora não-significativa no quadro doloroso, posto que cada sujeito evolui de maneira diferente; pequena irritação da pele após a remoção da fita dupla face nos dias de avaliação; regiões doloridas após as avaliações do limiar de dor à pressão; e cansaço ou tontura devido a permanência do sujeito em pé durante a avaliação cinemática".Como benefícios diretos no

"melhora dos sintomas, após a realização da intervenção" e indiretos "ajudar o profissional clínico em uma melhor conduta terapêutica em portadores de dores no ombro".

**Comentários e Considerações sobre a Pesquisa:**

Projeto de relevância científica e social para a temática.No primeiro parecer este Comitê solicitou à pesquisadora esclarecimentos sobre o local da pesquisa e método de recrutamento dos sujeitos,considerando a necessidade de autorização prévia da instituição onde o estudo será realizado. A pesquisadora aponta que os sujeitos serão recrutados "pessoalmente pela pesquisadora responsável e por meio de cartazes que serão

distribuídos dentro da Universidade e na comunidade" e a pesquisa será realizada no Laboratório de Análise e Intervenção do Complexo do Ombro, localizado no Departamento de Fisioterapia da UFSCar.A pesquisadora providenciou o Termo de Autorização Prévia da Instituição onde ocorrerá o estudo.

**Considerações sobre os Termos de apresentação obrigatória:**

As pesquisadoras seguiram todas as recomendações do CEP, apresentando os documentos que estavam faltando e realizando as alterações pertinentes.

**Recomendações:**

Nada a acrescentar

**Conclusões ou Pendências e Lista de Inadequações:**

Sem pendências

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**Situação do Parecer:**

Aprovado

**Necessita Apreciação da CONEP:**

Não

**Considerações Finais a critério do CEP:**

SAO CARLOS, 06 de Novembro de 2014

**Assinado por:**
**Ricardo Carneiro Borra**
**(Coordenador)**

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## APÊNDICE I

### TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

1. Você está sendo convidado para participar da pesquisa "Alterações biomecânicas e neurofisiológicas em indivíduos com encurtamento da cápsula posterior do ombro – Avaliação e tratamento".
2. Você foi selecionado por meio de testes clínicos, por apresentar ou não dor no ombro e/ou encurtamento da cápsula posterior do ombro, mas sua participação não é obrigatória.
3. O objetivo deste estudo será avaliar a dor e função do membro superior, amplitude de movimento de rotação do braço, a força dos rotadores laterais do braço, o limiar de dor e a cinemática escapular e umeral em sujeitos com encurtamento de cápsula posterior com e sem dor no ombro e verificar os efeitos de dois protocolos de intervenção em sujeitos com encurtamento de cápsula posterior e dor no ombro nas variáveis acima descritas.
4. Sua participação nesta pesquisa consistirá em: (1) entrevista com o pesquisador para avaliar se você preenche os requisitos previstos nos critérios de inclusão do estudo; (2) fornecer informações tais como: idade, peso, altura, histórico da dor no ombro, ocupação; (3) duas avaliações compostas por: a) avaliação do encurtamento da cápsula posterior e amplitude de movimento do ombro com o inclinômetro digital; b) avaliação da força de rotação lateral do ombro com um dinamômetro manual; c) ter 2 sensores (1,8x0,8x0,8 cm cada) fixados à pele na escápula e manúbrio do esterno com fita dupla face, e um manguito que será fixado no braço, logo acima do cotovelo, com velcro, para avaliação da cinemática da escápula; c) elevar o braço de modo ativo em uma amplitude confortável para registro das variáveis estudadas. Os sensores serão retirados no final da coleta dos dados; d) e avaliação do limiar de dor à pressão com um algômetro digital. A sessão para coleta dos dados pode ter duração de até 1hora e meia. Após a 1ª avaliação você receberá tratamento por até 4 semanas e retornará para a última avaliação. O procedimento não tem caráter invasivo.
5. Sua participação nesta pesquisa pode apresentar alguns riscos como: uma pequena irritação (vermelhidão) da pele após a remoção da fita dupla face para retirada dos sensores. Esse desconforto será similar a quando se retira um bandage da pele. Você também poderá sentir algumas regiões doloridas após a avaliação do limiar de dor à pressão, que desaparecerá entre 24h-48h após o teste. Durante a maior parte da avaliação você ficará em pé, o que poderá causar cansaço ou uma sensação de tontura. No entanto, se necessário, você terá permissão para se sentar para evitar esses riscos. A sua dor poderá aumentar após os dias de avaliação e atendimentos, que espera-se serem reduzidos com a intervenção. Após a intervenção você ainda poderá relatar dor no ombro e por isso nova avaliação será realizada ao término da intervenção e outras técnicas serão utilizadas se houver necessidade. Com este estudo espera-se identificar alterações biomecânicas e neurofisiológicas que possam estar alteradas em pessoas com dor no ombro ou encurtamento da cápsula posterior e com isso ajudar o profissional clínico em uma melhor conduta terapêutica em pessoas com dor no ombro; além da melhora dos sintomas, após a realização da intervenção nos sujeitos com dor.
6. Todos os procedimentos serão realizados pelo pesquisador abaixo identificado.
7. Quaisquer dúvidas a respeito dos procedimentos e da sua participação na pesquisa serão esclarecidas antes e durante o curso de pesquisa pelo pesquisador responsável.

8. A qualquer momento você pode desistir de participar e retirar seu consentimento, sendo que isso não trará nenhuma penalização ou prejuízo em sua relação com o pesquisador ou com a instituição.
9. As informações obtidas através dessa pesquisa serão confidenciais e asseguramos o sigilo sobre sua participação.
10. Os dados não serão divulgados de forma a possibilitar sua identificação, sendo que os arquivos gerados no processo de avaliação serão identificados a partir de uma numeração.
11. Você receberá uma cópia deste termo onde consta o telefone e o endereço do pesquisador principal, podendo tirar suas dúvidas sobre o projeto e sua participação, agora ou a qualquer momento.

_____

Dayana Patricia Rosa

Washington Luiz, Km. 235, São Carlos – SP. Fone: (16) 981259012

**Declaro que entendi os objetivos, riscos e benefícios de minha participação na pesquisa e concordo em participar. O pesquisador me informou que o projeto foi aprovado pelo Comitê de Ética em Pesquisa em Seres Humanos da UFSCar que funciona na Pró-Reitoria de Pós-Graduação e Pesquisa da Universidade Federal de São Carlos, localizada na Rodovia Washington Luiz, Km. 235 - Caixa Postal 676 - CEP 13.565-905 - São Carlos - SP – Brasil. Fone (16) 3351-8110. Endereço eletrônico:** cephumanos@power.ufscar.br

São Carlos, _____ de_____de_____

_____

Sujeito da pesquisa

# APÊNDICE II

ÍNDICE DE DOR E INCAPACIDADE NO OMBRO (SPADI-BRASIL)

Nome:_____ Braço avaliado:____ Data:___/___/____

## Escala de Incapacidade

Os números ao lado de cada item representam o grau de dificuldade que você teve ao fazer aquela atividade. O número zero representa "Sem dificuldade" e o número dez representa "Não conseguiu fazer". Por favor, indique o número que melhor descreve quanta dificuldade você teve para fazer cada uma das atividades durante a semana passada.
Se você não teve a oportunidade de fazer uma das atividades na semana passada, por favor, tente estimar qual número você daria para sua dificuldade.

| Durante a semana passada, qual o grau de dificuldade que você teve para: | | |
|---|---|---|
| 1. Lavar seu cabelo com o braço afetado? | ( )NA | Sem dificuldade 0 1 2 3 4 5 6 7 8 9 10 Não conseguiu fazer |
| 2. Lavar suas costas com o braço afetado? | ( )NA | Sem dificuldade 0 1 2 3 4 5 6 7 8 9 10 Não conseguiu fazer |
| 3. Vestir uma camiseta ou blusa pela cabeça? | ( )NA | Sem dificuldade 0 1 2 3 4 5 6 7 8 9 10 Não conseguiu fazer |
| 4. Vestir uma camisa que abotoa na frente? | ( )NA | Sem dificuldade 0 1 2 3 4 5 6 7 8 9 10 Não conseguiu fazer |
| 5. Vestir suas calças? | ( )NA | Sem dificuldade 0 1 2 3 4 5 6 7 8 9 10 Não conseguiu fazer |
| 6. Colocar algo em uma prateleira alta com o braço afetado? | ( )NA | Sem dificuldade 0 1 2 3 4 5 6 7 8 9 10 Não conseguiu fazer |
| 7. Carregar um objeto pesado de 5kg (saco grande de arroz) com o braço afetado? | ( )NA | Sem dificuldade 0 1 2 3 4 5 6 7 8 9 10 Não conseguiu fazer |
| 8. Retirar algo de seu bolso de trás com o braço afetado? | ( )NA | Sem dificuldade 0 1 2 3 4 5 6 7 8 9 10 Não conseguiu fazer |

**Total_____/possível_____ x 100 =_____**

## Escala de Dor

Os números ao lado de cada item representam quanta dor você sente em cada situação. O número zero representa "Sem dor" e o número dez representa "A pior dor". Por favor, indique o número que melhor descreve quanta dor você sentiu durante a semana passada em cada uma das seguintes situações.
Se você não teve a oportunidade de fazer uma das atividades na semana passada, por favor, tente estimar qual número você daria para sua dor.

| | | |
|---|---|---|
| 1. Qual a intensidade da sua dor quando foi a pior na semana passada? | | Sem dor 0 1 2 3 4 5 6 7 8 9 10 Pior dor |
| Durante a semana passada, qual a gravidade da sua dor: | | |
| 2. Quando se deitou em cima do braço afetado? | ( )NA | Sem dor 0 1 2 3 4 5 6 7 8 9 10 Pior dor |
| 3. Quando tentou pegar algo em uma prateleira alta com o braço afetado? | ( )NA | Sem dor 0 1 2 3 4 5 6 7 8 9 10 Pior dor |
| 4. Quando tentou tocar a parte de trás do pescoço com o braço afetado? | ( )NA | Sem dor 0 1 2 3 4 5 6 7 8 9 10 Pior dor |
| 5. Quando tentou empurrar algo com o braço afetado? | ( )NA | Sem dor 0 1 2 3 4 5 6 7 8 9 10 Pior dor |

**Total_____/possível_____ x 100 =_____**

**PONTUAÇÃO TOTAL DO QUESTIONÁRIO: _____**

## APÊNDICE III

### The Ohio State University or College of St. Scholastica Consent to Participate in Research

**Study Title: The Interaction between Posterior Capsule Tightness and Humeral Retroversion**

**Principal Investigator: John D. Borstad, PT, PhD**

- **This is a consent form for research participation.** It contains important information about this study and what to expect if you decide to participate. Please consider the information carefully. Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to participate.
- **Your participation is voluntary.** You may refuse to participate in this study. If you decide to take part in the study, you may leave the study at any time. No matter what decision you make, there will be no penalty to you and you will not lose any of your usual benefits. Your decision will not affect your future relationship with The College of St Scholastica. If you are a student or employee at the College, your decision will not affect your grades or employment status.
- **You may or may not benefit as a result of participating in this study.** Also, as explained below, your participation may result in unintended or harmful effects for you that may be minor or may be serious depending on the nature of the research.
- **You will be provided with any new information that develops during the study that may affect your decision whether or not to continue to participate.** If you decide to participate, you will be asked to sign this form and will receive a copy of the form. You are being asked to consider participating in this study for the reasons explained below.

**1. Why is this study being done?**

It is not currently clear how to accurately interpret asymmetrical shoulder range of motion. We are interested in determining how soft tissue tightness (posterior capsule tightness) and/or bony alterations (humeral retroversion) influence clinical measurements of shoulder motion. We aim to improve the interpretation of shoulder motion measurements so that clinicians can make better decisions about how to treat shoulder motion asymmetry. Our goal is to learn more about how posterior capsule tightness and humeral retroversion interact to influence the clinical measurements that are being used to evaluate motion loss.

**2. How many people will take part in this study?**

We anticipate screening up to 120 subjects to end up with a total of 60 subjects in the group analysis.

**3. What will happen if I take part in this study?**
You will provide demographic information (gender, age, height, mass, arm dominance) and present or past history of overhead activity. You will have a brief clinical examination that includes an active shoulder movement assessment and special tests to rule out musculoskeletal shoulder pathology. If you qualify for the study, you will have five range of motion measurements and three muscle tone measurements taken on both shoulders. The range of motion measurements bring your shoulder to the end of its normal passive range. The muscle tone measurements push a small blunt instrument into the skin over three shoulder muscles.

**4. How long will I be in the study?**
You will be enrolled for only one testing session that is estimated to last no longer than 30 minutes.

**5. Can I stop being in the study?**
You may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The College of St Scholastica.

**6. What risks, side effects or discomforts can I expect from being in the study?**
You may have minor discomfort in your shoulders during or after the range of motion and stiffness measurements. Low forces are used to position your shoulder joint for measurements and when pressing into the muscles.

**7. What benefits can I expect from being in the study?**
There are no obvious direct benefits to you from participating. The purpose of this study is to define the interaction between posterior capsule tightness, humeral retroversion, and muscle tone on clinical measurements for shoulder motion loss. The direct benefit will be to clinicians who evaluate and treat shoulder pathology.

**8. What other choices do I have if I do not take part in the study?**
You may choose not to participate without penalty or loss of benefits to which you are otherwise entitled.

**9. Will my study-related information be kept confidential?**
Efforts will be made to keep your study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law.
Also, your records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The The College of St Scholastica Institutional Review Board or Office of Responsible Research Practices;

**10. What are the costs of taking part in this study?**
There are no direct costs to you for participating.

**11. Will I be paid for taking part in this study?**
You will not be compensated for participating in this study.

**12. What happens if I am injured because I took part in this study?**
If you suffer an injury from participating in this study, you should notify the researcher or study doctor immediately, who will determine if you should obtain medical treatment.

The cost for this treatment will be billed to you or your medical or hospital insurance. The College of St Scholastica has no funds set aside for the payment of health care expenses for this study.

**13. What are my rights if I take part in this study?**
If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights you may have as a participant in this study.

You will be provided with any new information that develops during the course of the research that may affect your decision whether or not to continue participation in the study.

You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled.

An Institutional Review Board responsible for human subjects research at The College of St Scholastica reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and College policies designed to protect the rights and welfare of participants in research.

**14. Who can answer my questions about the study?**
For questions, concerns, or complaints about the study you may contact **John Borstad at 614-688-8131**.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact **John Borstad at 614-688-8131**.

**Signing the consent form**

I have read (or someone has read to me) this form and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form**.**

| **Printed name of subject** | **Signature of subject** |
|---|---|

**AM/PM**

**Date and time**

| **Printed name of person authorized to consent for subject (when applicable)** | **Signature of person authorized to consent for subject (when applicable)** |
|---|---|
| **Relationship to the subject** | **AM/PM**<br>**Date and time** |

**Investigator/Research Staff**

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

| **Printed name of person obtaining consent** | **Signature of person obtaining consent** |
|---|---|
| | **AM/PM**<br>**Date and time** |

**Witness(es)** - *May be left blank if not required by the IRB*

| **Printed name of witness** | **Signature of witness** |
|---|---|
| | **AM/PM**<br>**Date and time** |
| **Printed name of witness** | **Signature of witness** |
| | **AM/PM**<br>**Date and time** |

**APÊNDICE IV**

**Data Collection Form**

**Demographic Information**

| | |
|---|---|
| **Age** | **Work** |
| **Sex M F** | **Recreation** |
| **Ethnicity** | **Weight** |
| **Current Pain? Y N** | **Repetitive overhead tasks? Y N** |
| **Pain in last 6 months? Y N** | **Dominant Shoulder R L** |

**Shoulder assessment:**

| **Teste** | **Right** | **Left** |
|---|---|---|
| **Neer** | + - | + - |
| **Jobe** | + - | + - |
| **Hawkins** | + - | + - |
| **Sulcus** | + - | + - |
| **Instability** | + - | + - |

| **Low Flexion** | Right | Left | Difference |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| ***Mean*** | | | |

**Group Assignment:** PCT S

PCT>7° difference

**Test Shoulder:** R L

| **Humeral Retroversion** | Right | Left | Difference |
|---|---|---|---|
| 1 | | | |
| 2 | | | |

**Group Assignment:** HR S

HR>15° difference

**Test Shoulder:** R L

| | | | |
|---|---|---|---|
| ***Mean*** | | | |

| **Internal Rotation** | Right | Left | Difference |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| ***Mean*** | | | |

| **Cross-body adduction** | Right | Left | **Extension with IR** | Right | Left |
|---|---|---|---|---|---|
| 1 | | | 1 | | |
| 2 | | | 2 | | |
| ***Mean*** | | | ***Mean*** | | |