UNIVERSIDADE FEDERAL DE SÃO CARLOS
CENTRO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE
PROGRAMA DE PÓS-GRADUAÇÃO EM FISIOTERAPIA

EFEITOS DA BANDAGEM ELÁSTICA NA PROPRIOCEPÇÃO DO OMBRO E DESEMPENHO SENSÓRIO-MOTOR DURANTE ATIVIDADE DE BEBER EM INDIVÍDUOS HEMIPARÉTICOS CRÔNICOS

GABRIELA LOPES DOS SANTOS

São Carlos
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Tese apresentada ao Programa de Pós-Graduação em Fisioterapia do Centro de Ciências Biológicas e da Saúde da Universidade Federal de São Carlos como parte dos requisitos para obtenção do título de Doutor em Fisioterapia. Área de concentração: Processos de Avaliação e Intervenção em Fisioterapia.

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Centro de Ciências Biológicas e da Saúde
Programa de Pós-Graduação em Fisioterapia

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“Feliz aquele que transfere o que sabe e aprende o que ensina”.

(Cora Coralina)

“O que vale na vida não é o ponto de partida e sim a caminhada. Caminhando e semeando, no fim terás o que colher".

(Cora Coralina)

RESUMO

Cerca de 50 a 70% dos indivíduos pós-Acidente Vascular Cerebral (AVC) apresentam perda de função do membro superior (MS) mesmo em fase crônica. Diante disso, diversas estratégias de intervenções têm sido propostas. Uma técnica coadjuvante amplamente utilizada na neurorreabilitação é a aplicação da bandagem elástica (*taping*). Contudo, sua eficácia no tratamento de indivíduos pós-AVC ainda é controversa e pouco investigada. **Objetivos:** Verificar os efeitos imediatos do *taping*, aplicado no ombro parético, sobre a propriocepção (senso de posição articular) e desempenho sensório-motor do MS durante uma atividade funcional (beber). **Métodos:** Treze indivíduos com hemiparesia crônica foram alocados aleatoriamente em dois grupos: (1) aqueles que foram submetidos a fita placebo primeiro e após um mês ao *taping* (P) e (2) aqueles que foram submetidos ao *taping* primeiro e após um mês à fita placebo (BE). O senso de posição articular foi avaliado usando um dinamômetro e quantificado pelo erro absoluto do ombro a 30° e 60° de abdução e flexão. O desempenho sensório-motor durante a atividade de beber foi avaliado usando um sistema de análise tridimensional e quantificado por parâmetros espaço-temporais e cinemáticos escalares (ângulos iniciais, amplitude de movimento e ângulos finais) bem como pelo estudo das curvas cinemáticas tempo-normalizadas dos ângulos do tronco, escápula, ombro e cotovelo por meio da análise *Statistical Parametric Mapping*. As fitas foram aplicado no músculo deltóide (porções anterior, média e posterior). *O taping* foi aplicado sem tensão no sentido de facilitação muscular. Todas as avaliações foram realizadas antes e após 10 minutos da aplicação das fitas. **Resultados:** Não foram observadas diferenças entre os grupos na linha de base para todas as variáveis. Na condição com *taping*, ambos os grupos diminuíram o erro absoluto para todos os movimentos e ângulos (efeito moderado), melhorou a posição do ombro (mais linha média), reduziu a protração da escápula e a flexão do tronco no início, durante e no final da tarefa de beber sem alterar os parâmetros espaço-temporais. Além disso, o *taping* proporcionou uma melhora da elevação do ombro, rotação da escápula e extensão do cotovelo em momentos específicos da tarefa (efeito pequeno a médio). Não foram observados efeitos da fita placebo para ambos os grupos. **Conclusão:** O *taping* promove melhora no senso de posição articular e movimentos articulares do MS durante uma atividade funcional, apontando para seu papel como terapia coadjuvante.

Palavras-chaves: Atividades cotidianas, reabilitação, extremidade superior, paresia.

ABSTRACT

Around 50 to 70% of subjects post-stroke presented reduction of upper limb (UL) function even during chronic phase. Therefore, several therapeutic strategies have been proposed. An adjuvant technique widely used in neurorehabilitation is the application of elastic tape (taping). However, its efficacy in the treatment of post-stroke subjects still require further investigation. **Objectives:** To verify the immediate effects of taping applied on paretic shoulder on proprioception (joint position sense - JPS) and sensorimotor performance of UL during functional task (drinking). **Methods:** Thirteen subjects with chronic hemiparesis were randomly allocated into two groups: 1) those who received Sham Tape (ST) first and after one month they received Elastic Tape (ET); 2) those who received Elastic Tape (ET) first and after one month they received Sham Tape (ST). JPS was assessed using a dynamometer and quantified by absolute error of shoulder at 30° e 60° of abduction and flexion. Sensorimotor performance during drinking task was assessed using tridimensional analysis and quantified by spatiotemporal and scalar kinematic parameters (starting angles, range of motion, and angles at the end) as well as by study of time-normalized kinematic waveforms of trunk, scapula, shoulder and elbow through Statistical Parametric Mapping analysis. Tapes were applied on deltoid muscle (anterior, middle, and posterior) without tension following the muscle facilitation direction. All assessments were performed before and 10 minutes after tapes application. **Results:** No differences were observed between groups at baseline for all variables. In the taping condition, both groups decreased absolute error for all movements and angles (moderate effect), improved shoulder position (more to midline), reduced scapula protraction and trunk flexion with no changes in spatiotemporal parameters. In addition, taping provided an improvement in shoulder elevation, scapula lateral rotation and elbow extension (small to medium effects). No effects of sham tape were observed for both groups in any variable. **Conclusion:** Taping provided an improvement in the shoulder JPS and UL joint motions during functional activity, pointing to its role as adjuvant therapy.

Keywords: Activities of daily living, rehabilitation, upper extremity, paresis.

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LISTA DE ABREVIATURAS E SIGLAS

LaFiN	Laboratório de Pesquisa em Fisioterapia Neurológica
AVC	Acidente Vascular Cerebral
MS	Membro Superior
AVDs	Atividades de vida diária
ADM	Amplitude de movimento
SPM	*Statistical Parametric Mapping*
BE	Bandagem elástica
P	Placebo
UL	*Upper limb*
JPS	*Joint position sense*
ET	*Elastic tape group*
ST	*Sham tape group*
MAS	*Modified Ashworth Scale*
FMA	*Fugl-Meyer Assessment*
ISB	*International Society of Biomechanics*
CO	*Confidence Interval*
SEM	*Standard Error of Measurement*
ES	*Effect size*
BMI	*Body mass index*
ROM	*Range of motion*
ADL	*Activities of daily living*
3DMA	*Three-dimensional Motion Analysis*
ULEMA	*Upper Limb Evaluation in Motion Analysis Software*
PD	*Phase duration*
%PD	*Relative phase duration*
PV	*Peak velocity*
%TPV	*Time to peak velocity*
TD	*Trajectory deviation*
PTA	*Point of task achievement*
SPM{t})	*SPM scalar output*
Tcritical	*Critical threshold*

SUMÁRIO

APRESENTAÇÃO

Esta tese está estruturada de acordo com as normas do Programa de Pós-Graduação em Fisioterapia da UFSCar e faz parte de uma linha de pesquisa implementada no Laboratório de Pesquisa em Fisioterapia Neurológica (LaFiN) durante o período do mestrado. Os estudos realizados no mestrado observaram que indivíduos hemiparéticos crônicos após Acidente Vascular Cerebral (AVC) apresentam alterações bilaterais na propriocepção (senso de posição articular – ANEXO 1), no controle sensório-motor do ombro durante movimentos submáximos sustentados (*steadiness*-ANEXO 2) e durante a atividade de beber (ANEXO 3), a qual foi caracterizada por um maior número de alterações nas articulações proximais do MS, principalmente nas posições estáticas e durante a fase alcance.

Além disso diante das análises necessárias para avaliação do desempenho do MS, foi estabelecida, durante o mestrado, uma parceria internacional com o grupo da Prof^{a}. Dr^{a}. Kaat Desloovere da Universidade de Leuven (KU Leuven, Bélgica), o que permitiu a condução dos estudos do doutorado, uma vez que este grupo desenvolveu um software em ambiente Matlab para análise tridimensional dos movimento do MS, o qual foi utilizado nas análises dos dados do mestrado e doutorado. Assim, baseado neste resultados, questionou-se como seria possível intervir nestes aspectos utilizando um recurso de baixo custo e amplamente utilizado na prática clínica. Neste âmbito destacou-se a bandagem elástica, a qual tem sido atribuídos diversos efeitos, como um aumento da *input sensorial* capaz de melhorar a ativação muscular. Nesse sentido, o projeto de doutorado visou compreender como este recurso poderia influenciar a propriocepção e desempenho sensório-motor durante atividades funcionais.

Desta forma, para esclarecer esse questionamento, inicialmente será apresentada uma breve contextualização do problema a ser abordado e os objetivos do projeto seguido pelo estudo I publicado na PLoS ONE (Qualis A1, fator de impacto 2.806) e pelo estudo II submetido a Journal of Physiotherapy (Qualis A1, fator de impacto 4.083). Por fim, serão apresentadas as considerações finais da tese, bem como as atividades desenvolvidas no período do doutorado.

CONTEXTUALIZAÇÃO

O Acidente Vascular Cerebral (AVC) é a principal causa de incapacidades na população adulta mundial (Langhorne *et al.*, 2011; Murray *et al.*, 2012; Feigin *et al.*, 2014). Aproximadamente 50 a 70% dos pacientes pós-AVC apresentam incapacidades envolvendo o membro superior (MS) contralateral à lesão, as quais estão relacionados com a perda de função e desuso mesmo após dois a quatro anos do AVC (Hunter e Crome, 2002; Alt Murphy *et al.*, 2011). Esses déficits podem contribuir para a redução na independência funcional envolvendo as atividades de vida diária (AVDs), que por sua vez pode prejudicar a participação social e a qualidade de vida (Jorgensen *et al.*, 1999; Desrosiers *et al.*, 2003; Faria-Fortini *et al.*, 2011; Hatem *et al.*, 2016).

As principais AVDs prejudicadas nos indivíduos pós-AVC são aquelas relacionadas ao autocuidado e alimentação (Schaechter *et al.*, 2002; Van Vliet e Sheridan, 2007; Freitas *et al.*, 2011). De acordo com a literatura, durante atividades de alcance-preensão e beber, estes pacientes realizam movimentos mais lentos, menos retilíneos e direcionados ao alvo com um maior número de ajustes ao longo da trajetória e erro ao alcançar o alvo (Van Vliet e Sheridan, 2007; Wagner *et al.*, 2007; Alt Murphy *et al.*, 2011; Aprile *et al.*, 2014; Stewart *et al.*, 2014; Santos, Russo, *et al.*, 2017). Além disso, estes pacientes apresentaram alterações angulares que variam de acordo com a tarefa avaliada e a fase da tarefa (Alt Murphy *et al.*, 2011; Robertson *et al.*, 2012; Aprile *et al.*, 2014; Kim *et al.*, 2014; Santos, Russo, *et al.*, 2017). Por exemplo, durante a fase de transporte do copo a boca (incluindo o ato de beber), hemiparéticos pós-AVC apresentam maior flexão do cotovelo, protração da escápula e flexão anterior do tronco no momento em que o copo está próximo a boca (Santos, Russo, *et al.*, 2017), bem como um maior amplitude de movimento (ADM) de abdução/adução do ombro e menor amplitude de flexão/extensão do ombro (Kim *et al.*, 2014).

Além dessas alterações, uma abordagem alternativa de análise mais ampla dos dados biomecânicos contínuos, denominada como *Statistical Parametric Mapping* (SPM) (Pataky, 2010; Pataky *et al.*, 2013; Nieuwenhuys *et al.*, 2016; Nieuwenhuys *et al.*, 2017; Simon-Martinez *et al.*, 2017), identificou que indivíduos hemiparéticos crônicos com comprometimento moderado do MS, quando comparado a indivíduos saudáveis pareados por idade e gênero, apresentaram um maior número de alterações angulares durante a fase de alcance da atividade de beber, a qual foi caracterizada por maior rotação externa de ombro e flexão tronco durante toda a fase; maior inclinação anterior da escápula até metade da fase; um movimento do ombro mais no plano frontal, maior flexão homolateral de tronco, protração e rotação medial da escápula no início da fase, os quais foram observados novamente por volta da metade da fase, exceto pelo movimento do ombro (Santos, Russo, *et al.*, 2017).

De acordo com a literatura, essas alterações de desempenho durante as AVDs em indivíduos hemiparéticos pós-AVC podem ser atribuídas a alterações somatossensoriais, como por exemplo, as alterações proprioceptivas (Myers e Lephart, 2000; Roijezon *et al.*, 2015; Santos, Russo, *et al.*, 2017) que podem prejudicar o controle de *feedback* e *feedforward*, influenciando negativamente a estabilidade, precisão e coordenação dos movimentos, como àqueles necessários ao adequado posicionamento da mão para preensão do copo durante a atividade de beber (Myers e Lephart, 2000; Riemann e Lephart, 2002; Dukelow *et al.*, 2012; Roijezon *et al.*, 2015). Cerca de 50% dos indivíduos hemiparéticos pós-AVC apresentam alterações na propriocepção (Dukelow *et al.*, 2010). De acordo com estudos prévios, estes pacientes apresentam déficits proprioceptivos no membro parético durante os movimentos de rotação interna e externa (Niessen *et al.*, 2008) e abdução e flexão do ombro (Dos Santos *et al.*, 2015).

Assim, diante destas alterações presentes em indivíduos hemiparéticos, diversas intervenções são aplicadas na prática clínica com o intuito de minimizar os déficits de propriocepção e desempenho sensório-motor, fim de possibilitar um ganho e/ou melhora na função motora do MS. Uma das técnicas coadjuvantes de baixo custo e amplamente utilizada na prática clínica que visa otimizar a função é a bandagem elástica (BE), a qual consiste na aplicação de uma fita adesiva elástica sobre a pele com diferentes graus de tensão (Oh, 2013; Van Herzeele *et al.*, 2013). A esta estratégia de intervenção são atribuídos inúmeros efeitos decorrentes dos estímulos contínuos sobre os receptores através do alongamento e compressão da pele durante o movimento articular (Callaghan *et al.*, 2008; Pamuk e Yucesoy, 2015; Santos, Souza, *et al.*, 2017).

De acordo com estudos prévios em indivíduos saudáveis, a BE aumentou o senso de posição articular do ombro (Lin *et al.*, 2011) e facilitou a inclinação posterior e rotação para cima da escápula durante elevação do ombro no plano escapular e frontal (Van Herzeele *et al.*, 2013). Além destes efeitos mecânicos, estudo de Callanghan e colaboradores (2008) observaram que na condição com BE foi observada uma maior ativação bilateral do córtex sensório-motor primário e córtex sensorial primário bem como uma diminuição bilateral da ativação do cerebelo e área motora cingulada, as quais são regiões relacionadas com a tomada de decisão, planejamento de complexidade e os aspectos inconscientes da percepção (Callaghan *et al.*, 2012). Desta forma, os resultados destes estudos sugerem que a BE pode ser um estratégia de intervenção eficaz devido aos mecanismos sutis que influenciam a atividade cerebral e ao suporte mecânico oferecido.

Assim, baseado nestes achados prévios e na neurociência, esses efeitos podem ser explicados através da íntima relação entre as funções somatossensoriais e motoras no córtex (Kandel *et al.*, 2000). Em outras palavras, o estímulo tátil proporcionado pela bandagem elástica estimula os mecanorreceptores presentes na pele, aumentado o *input* sensorial para o córtex somatossensorial contralateral via tálamo (Kandel *et al.*, 2000; Clark *et al.*, 2015; Roijezon *et al.*, 2015). O córtex somestésico primário apresenta conexão com áreas de associação multimodais, as quais integram as informações de diversas modalidades sensoriais, como a visual e proprioceptiva. Essas áreas estão vinculadas a áreas de associação motora multimodal, como a área de associação parietal posterior, límbica e anterior (córtex pré-frontal) que transformam a informação sensória em movimento planejado e calculam os programas necessários para esses movimentos. Além disso, essas áreas de associação motora multimodal apresentam conexão com o córtex motor primário e áreas pré-motoras, os quais enviam a informação eferente para a medula e músculos, podendo estimular a atividade muscular (Kandel *et al.*, 2000).

No entanto, de acordo com revisão, a evidência dos efeitos da bandagem elástica em pacientes neurológicos ainda é pequena e inconclusiva (Grampurohit *et al.*, 2015). Estudos demonstraram que a fita elástica não altera a dor no ombro (Pandian *et al.*, 2013; Kalichman *et al.*, 2016), subluxação (Huang *et al.*, 2016), ADM (Pandian *et al.*, 2013; Kalichman *et al.*, 2016) e função motora avaliada através do Índice de incapacidade e dor no ombro (Pandian *et al.*, 2013) em indivíduos pós-AVC (Pandian *et al.*, 2013; Kalichman *et al.*, 2016); outros estudos observaram que efeitos contrários, tais como redução da dor, melhora na ADM (Huang *et al.*, 2016; Pillastrini *et al.*, 2016) e função motora avaliado por meio da Escala Fugl-Meyer e Escala de avaliação motora modificada (Kim e Kim, 2015; Huang *et al.*, 2016). Além da falta de consenso, vale destacar que os efeitos da BE foram comparados à grupos submetidos somente a terapia convencional (Kim e Kim, 2015; Pillastrini *et al.*, 2016), a condição sem BE

(Kalichman *et al.*, 2016) e a fita placebo que consistiu na aplicação da BE sem corrigir o posicionamento da cabeça do úmero na fossa glenóide (Pandian *et al.*, 2013) ou sem tensão (Huang *et al.*, 2016), os quais podem gerar viés na sua interpretação, uma vez que não foi comparado por intervenção similar ou foi comparada a ela mesma.

Desta forma, estudos aleatorizados placebo-controlados são necessários para o embasamento científico do uso da BE dentro de um programa de reabilitação de indivíduos hemiparéticos crônicos, uma vez que este recurso de baixo custo vem sendo amplamente utilizado na prática clínica. Assim, de acordo com os efeitos do BE na ativação muscular, cinemática articular e propriocepção de indivíduos saudáveis e sua influência na atividade cerebral, a presente tese de doutorado apresenta a hipótese de que a BE, aplicado sobre o ombro parético, será capaz de melhorar a propriocepção (senso de posição articular) e o desempenho sensório-motor durante a atividade de beber em indivíduos hemiparéticos crônicos.

OBJETIVOS

Avaliar os efeitos da Bandagem Elástica (BE), aplicada no ombro parético (deltóide posterior, anterior e médio), sobre o senso de posição articular do ombro (flexão e abdução) e o desempenho sensório-motor durante a atividade de beber em indivíduos hemiparéticos crônicos comparado a fita não elástica (placebo, P).

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ESTUDO I

Elastic Tape Improved Shoulder Joint Position Sense in Chronic Hemiparetic Subjects: A Randomized Sham-Controlled Crossover Study

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Abstract

Background: Elastic tape has been widely used in clinical practice in order to improve upper limb (UL) sensibility. However, there is little evidence that supports this type of intervention in stroke patients. **Objective:** To verify the effect of elastic tape, applied to the paretic shoulder, on joint position sense (JPS) during abduction and flexion in subjects with chronic hemiparesis compared to sham tape (non-elastic tape). Furthermore, to verify if this potential effect is correlated to shoulder subluxation measurements and sensorimotor impairment. **Methods:** A crossover and sham-controlled study was conducted with post-stroke patients who were randomly allocated into two groups: 1) those who received Sham Tape (ST) first and after one month they received Elastic Tape (ET); 2) those who received Elastic Tape (ET) first and after one month they received Sham Tape (ST). The JPS was evaluated using a dynamometer. The absolute error for shoulder abduction and flexion at 30° and 60° was calculated. Sensorimotor impairment was determined by Fugl-Meyer, and shoulder subluxation was measured using a caliper. **Results:** Thirteen hemiparetic subjects (average time since stroke 75.23 months) participated in the study. At baseline (before interventions), the groups were not different for abduction at 30° ($p=0.805$; $p=0.951$), and 60° ($p=0.509$; $p=0.799$), or flexion at 30° ($p=0.872$; $p=0.897$) and 60° ($p=0.853$; $p=0.970$). For the ET group, differences between pre and post-elastic tape for abduction at 30° ($p<0.010$) and 60° ($p<0.010$), and flexion at 30° $p<0.010$) and 60° ($p<0.010$) were observed. For the ST group, differences were also observed between pre and post-elastic tape for abduction at 30° ($p<0.010$) and 60° ($p<0.010$), and flexion at 30° ($p<0.010$,) and 60° ($p<0.010$). Potential effects were only correlated with shoulder subluxation during abduction at 30° ($p=0.001$, $r=-0.92$) and 60° ($p=0.020$, $r=-0.75$). **Conclusion:** Elastic tape improved shoulder JPS of subjects with chronic hemiparesis regardless of the level of UL sensorimotor impairment. However, this improvement was influenced by the subluxation degree at abduction.

Keywords: rehabilitation; upper extremity; somatosensory disorders; evidence-based practice

Introduction

Stroke is one of the leading causes of death and disability in adults (Murray *et al.*, 2012; Feigin *et al.*, 2014). Approximately 70% of post-stroke patients have sensorimotor deficits in the upper limb (UL), which result in contralateral hemiparesis injury. These sensorimotor deficits can include somatosensory alterations, which impair movement control and joint stability (Myers e Lephart, 2000; Roijezon *et al.*, 2015). An important subsystem of the somatosensory system involves proprioception (Hillier *et al.*, 2015), which consists of afferent information originating from mechanoreceptors (Riemann e Lephart, 2002b; Proske e Gandevia, 2012; Hillier *et al.*, 2015). Proprioception can be divided into three submodalities, i.e. kinesthesia, sense of tension or force and joint position sense (JPS) (Myers e Lephart, 2000; Riemann e Lephart, 2002a; Proske e Gandevia, 2012; Hillier *et al.*, 2015; Roijezon *et al.*, 2015). Proprioceptive deficits impair feedback and feedforward control, which negatively influence joint stability, acuity and coordination movements (Hillier *et al.*, 2015; Roijezon *et al.*, 2015), mainly small or precise movements (Dukelow *et al.*, 2012), as well as motor skill acquisition (Dukelow *et al.*, 2012; Proske e Gandevia, 2012).

Fifty percent of post-stroke subjects present proprioceptive deficits in the UL (Dukelow *et al.*, 2010). According to previous studies, subjects with chronic hemiparesis presented bilateral deficits of kinesthesia during internal and external shoulder rotation (Niessen, Janssen, *et al.*, 2008; Niessen *et al.*, 2009), as well as bilateral deficits of JPS during movement abduction and flexion of the shoulder. These deficits are related to the degree of shoulder subluxation (Santos *et al.*, 2015). Moreover, these proprioceptive deficits are also associated with UL motor recovery and function (Meyer *et al.*, 2014), which impair the performance of activities of daily living (Dukelow *et al.*, 2012), and possibly restrict participation and quality of life. Therefore, treating proprioceptive impairments is one of the main objectives in rehabilitation programs for stroke patients (Doyle *et al.*, 2014; Colombo *et al.*, 2016).

Given these clinical findings, some strategies to improve proprioception have been used in clinical practice, such as augmentation of somatosensory information via passive techniques that involves manual therapy, soft tissue techniques and taping or brace applications (Clark *et al.*, 2015; Roijezon *et al.*, 2015). Taping consists of an adjunct technique, which uses an elastic adhesive tape over the skin in order to stimulate mechanoreceptors via continuous skin stretching and compression during joint motion

(Clark *et al.*, 2015; Roijezon *et al.*, 2015). Based on accepted principles in neuroscience, it can be hypothesized that these afferent stimuli are transmitted to the contralateral area of the somatosensory cortex, which integrates information from different sensory and motor modalities (Kandel *et al.*, 2000). One taping technique widely used in clinical practice is the Kinesio Taping method (Kase *et al.*, 2003).

According to previous studies, taping increased electromyographic activity and improved the shoulder joint position sense of healthy individuals (Lin *et al.*, 2011; Burfeind e Chimera, 2015). Moreover, taping helped to perform simple and proprioceptive activities during knee extension in healthy subjects, which were associated with more bilateral activation in the primary sensorimotor cortex and primary sensory cortex, and less bilateral activation in the cingulate motor area and cerebellum (Callaghan *et al.*, 2012). Thus, these results demonstrated that taping can influence neural activation, as well as provide biomechanical support, i.e., improving shoulder girdle stability (Callaghan *et al.*, 2012; Burfeind e Chimera, 2015). Regarding stroke patients, a systematic review (Grampurohit *et al.*, 2015) highlighted that the effects of taping on pain intensity, muscle tone, range of motion and strength were inconclusive, and that there was insufficient evidence related to activity and participation. Hence, the authors concluded that there is a need for more in-depth research that can verify the taping effects on this population.

Although systematic review (Grampurohit *et al.*, 2015) and studies have shown that elastic tape does not reduce shoulder pain (Pandian *et al.*, 2013; Kalichman *et al.*, 2016) and subluxation (Huang *et al.*, 2016), nor does it increase the range of motion (Pandian *et al.*, 2013; Kalichman *et al.*, 2016), motor function and functionality in post-stroke subjects (Pandian *et al.*, 2013; Kalichman *et al.*, 2016), other studies observed opposite effects of the UL from the same population, such as reduced pain, improvements in range of motion (Huang *et al.*, 2016; Pillastrini *et al.*, 2016), motor function and functionality (Lee *et al.*, 2015; Huang *et al.*, 2016) after intervening with elastic tape. Thus, the literature supported the lack of consensus of the effects of elastic tape used in the UL of post-stroke subjects, requiring more studies. Furthermore, to the best of our knowledge, there is no evidence regarding the effect of taping on proprioception (joint position sense) in this population. Our study will test if taping is able to provide any improvement of the sensorial feedback in the shoulders of chronic post-stroke subjects.

The main purpose of this study was to verify the effect of the elastic tape, used on the paretic shoulder (anterior, middle, and posterior deltoid), on the JPS of the paretic side during abduction and flexion in chronic hemiparetic subjects, compared to rigid tape (sham). Secondly, another aim was to verify if the possible improvement of shoulder girdle stability provided by the elastic tape on the paretic side could influence the JPS of the non-paretic side. Thirdly, another objective was to verify if this potential effect (difference between pre and post intervention after elastic tape) on the paretic shoulder was correlated to the baseline shoulder subluxation measurements and sensorimotor impairment. Therefore, it can be observed whether there is a relationship between the amount of deficits and response to the treatment. The following hypotheses were tested: (1) elastic tape improves JPS on the paretic side, (2) elastic tape improves JPS on the non-paretic side by increasing the proximal stability and (3) this change is negatively correlated to the baseline subluxation grade and sensorimotor impairment.

Material and Methods

Experimental design

This study presents a randomized sham-controlled crossover study, which was conducted with chronic hemiparetic subjects at a center (UFSCar, Brazil). Patients were recruited from lists acquired from the rehabilitation center and the University Hospital of São Carlos, São Paulo, Brazil. Patients were not involved in any rehabilitation program. The research activities of this study received ethical approval by the Ethics Committee in Brazil (Number: 966636) and was registered in the Clinical Trials (URL: http://www.clinicaltrials.gov. Unique identifier: NCT02390115). Written informed consent was obtained from each patient prior to taking part in the study. All data regarding the trial for this intervention were registered. However, the registration date was retrospective to the participants´ enrollment due to insufficient information for registration, for example, little information regarding the tape application protocol. The CONSORT checklist, study protocol and individual data are available as supporting information.

Assessments were divided into three days and all evaluations were carried out at the Federal University of São Carlos (UFSCar), Brazil. On the first day, screening to select the sample and clinical assessment was done. In the first and second sessions, the JPS was assessed, followed by a wash-out period of one month between sessions. In both sessions, the JPS test was run without and with intervention (elastic or sham tape). Patients were randomly assigned to one of two groups using sealed opaque envelopes to receive the Sham Tape (ST) first or the Elastic Tape (ET) first. An independent staff member prepared the envelopes. However, the assessor and patient were not blinded when the intervention took place due to the color of the tape and not being able to cover the limb, which could generate more sensory input and impair the test. Thus, before the test, the assessor read a standard text to the patient: "I will put the tape on your shoulder and you will do a test, which I will explain later". A schematic representation of the experimental design is shown in Fig 1.

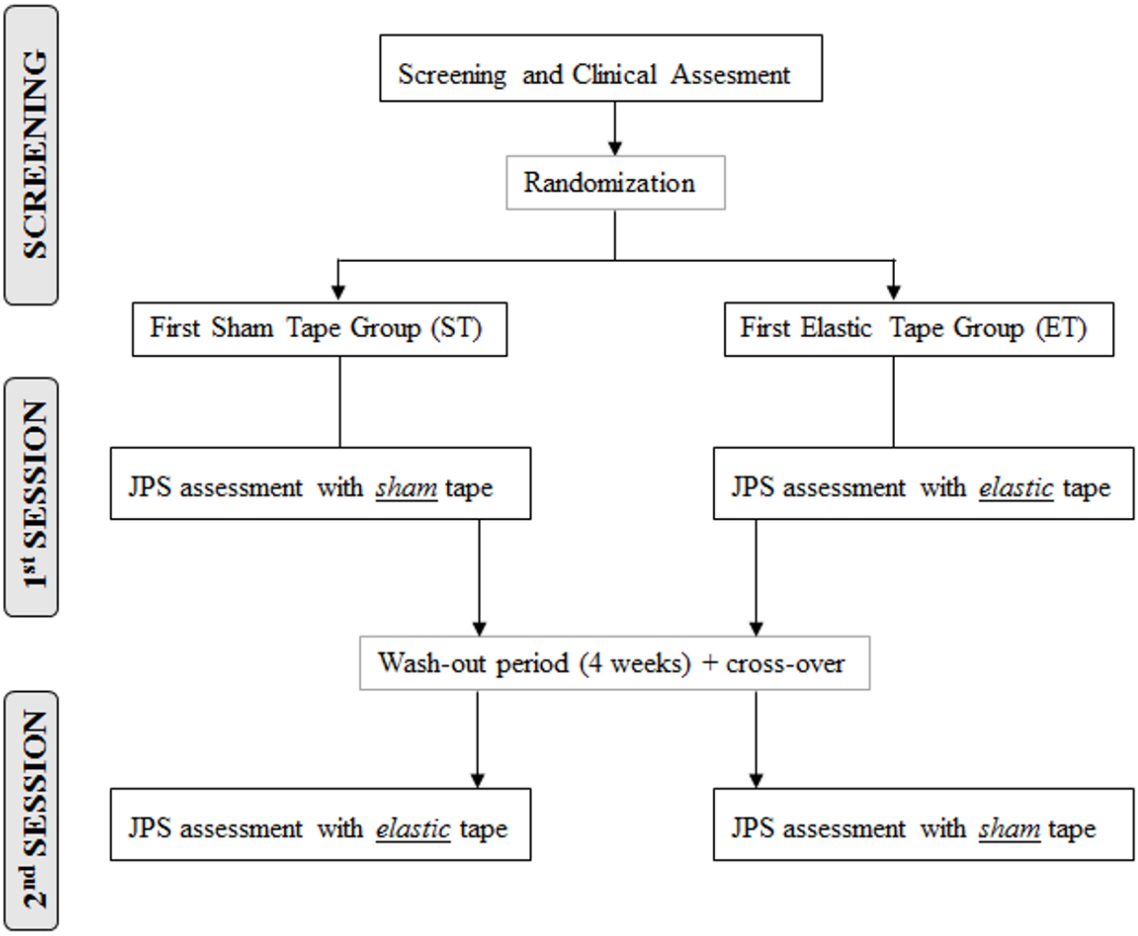

Figure 1. Schematic representation of the experimental design. JPS: Joint Position Sense.

Participants

Considering the hemiparetic subjects, the following inclusion criteria were used: (1) unilateral ischemic stroke of either hemisphere with lesions restricted to the anterior vascular territory (anterior and medium cerebral arteries) observed in the medical report of the MRI; (2) at least 6 months post stroke; (3) spasticity for shoulder abductor and flexor muscle level of less than 3 on the Modified Ashworth Scale (MAS); (4) mild or moderate UL sensorimotor impairment (score of ≥ 30 on the Fugl-Meyer UL motor part) (De Baets *et al.*, 2014); (5) proper trunk control, defined as the ability to remain in a seated position without support for the trunk and/or of the arms for one minute, and a minimum score on the Mini-Mental State Examination, according to the subject's educational level (Folstein *et al.*, 1975). Individuals who had more than one stroke could be included if the vascular accident involved the same hemisphere.

The following exclusion criteria were applied: diabetes mellitus, ulcers or skin lesions; elastic tape adverse reactions (redness and itching); serious cardiovascular or peripheral vascular disease (heart failure, arrhythmias, angina pectoris or myocardial infarction); other orthopedic or neurological diseases that affected the data collection were; cognitive or communication impairments; shoulder pain during the test; history of muscle or joint injuries at the shoulder complex or cervical joints (fractures or surgery); abnormal sensitivity, understanding of aphasia, apraxia, hemineglect and/ or plegia. In addition, individuals with other neurologic diseases, hemorrhagic stroke or any injury to the occipital lobe, brainstem or cerebellum were also excluded. Furthermore, individuals with a passive range of motion of the shoulder lower than 90° flexion, 30° extension and adduction were excluded. These ranges of motion were necessary to standardize the application of elastic tape.

Clinical Assessment

One evaluator performed the clinical assessment. Participants were submitted to an interview that included collecting personal data, a physical examination (anthropometric data), and investigating the upper extremity sensorimotor impairment adopting the Fugl-Meyer Assessment (FMA) (Maki *et al.*, 2006). Furthermore, the scores for motor function, sensitivity and coordination/velocity of the FMA were calculated. The presence of shoulder subluxation was quantified using a caliper. Based on the distance between the lateral edge of the acromion and the upper edge of the humeral head, the subluxation was graded as 0, 1+, 2+ or 3+ for distances of <0.5 cm, 0.5 to 1 cm, 1 to 2 cm, or >2 cm, respectively (Paci *et al.*, 2005; Santos *et al.*, 2015). The same assessor took this measurement on two different days in exactly the same way (clinical and first proprioception assessment) in order to perform the intra-rater reliability measurement. The reliability for the subluxation measurement using a caliper was the Intraclass Correlation Coefficient, ICC (2, 1) = 0.97; 95% Confidence Interval [0.50 – 0.99]; Standard Error of Measurement (SEM) = 0.10 cm. The side of the lesion was verified in the MRI medical report (Youdas *et al.*, 1991; Weir, 2005). Manual preference was assessed by the Edinburgh Handedness Inventory (Oldfield, 1971), considering the preference before the stroke.

Joint Position Sense (JPS) Assessment

The JPS assessment was carried out using a dynamometer (Biodex Multi-joint System 3, Biodex Medical System Inc., New York). Before each test, the dynamometer was calibrated according to the manufacturer´s guidelines. The subjects were positioned in the dynamometer seat with 90° of hip flexion, and the pelvis and trunk were stabilized using straps. The attachment was fixed at the distal part of the arm (Santos *et al.*, 2015).

The following instructions were given to the patient: (1) the dynamometer will move your arm to a specific position, (2) you will remain in this position for ten seconds, observe where your arm is positioned, (3) the dynamometer will return your arm to the starting position, (4) the dynamometer will move your arm again, and (5) press the button to stop the machine when you notice that your arm has reached the previous position (Santos *et al.*, 2015). The stop button was held in the non-paretic hand. Initially, one familiarization trial was conducted. During the test, participants were blindfolded to rule out visual cues and no communication was allowed (Niessen, Veeger, Koppe, Konijnenbelt, Van Dieën, *et al.*, 2008; Yalcin *et al.*, 2012). The dynamometer moved each subject's upper extremity passively at a fixed rate of 2.0° per second from the starting position (0° of abduction or flexion) to the reference positions (30° and 60° of abduction and then 30° and 60° of flexion). The absolute error (in degrees) was calculated as the difference between the indicated and reference positions (Niessen, Veeger, Koppe, Konijnenbelt, Van Dieen, *et al.*, 2008).

The test was carried out three times for each limb (paretic or non-paretic), movement (abduction or flexion) and angle (30° or 60°), and then after, as well as before elastic or sham tape intervention. Twenty-four movements were performed for each limb, and the absolute error was the average of three attempts. The order of movements and angles was randomized to prevent possible learning effects, however the assessments always started with the paretic limb.

Intervention

A physiotherapist who was certified in Kinesio Taping placed the tapes (sham and elastic) on the paretic shoulder. Blue Kinesio® Tex Gold Finger Print tape (5 cm wide) was used for the elastic tape intervention and Cremer tape strips (5 cm wide) (Cremer S/A, São Paulo, Brazil) were used for the sham intervention. After putting on the tapes, and before re-evaluating the JPS, the patients remained seated for 10 minutes. Then, the JPS test was performed again with the intervention (sham or elastic tape). A previous study showed a short-time effect after 10 minutes using the elastic tape (Gomez-Soriano *et al.*, 2014).

To attach the elastic tape, the acromioclavicular joint was considered as the initial anchor and one point immediately below the insertion of the deltoid muscle as the final anchor. The first tape was placed on the anterior portion of the deltoid with the shoulder at 30° passive extension. The second tape was placed on the middle portion of the deltoid with the shoulder at 30° passive horizontal adduction. To place the third tape on the posterior deltoid, the limb was positioned at 90° of passive flexion of the shoulder (Fig. 2). The elastic tape tension was described as “paper tension” and was equivalent to 10-15% of the total elastic tape tension, i.e., no tension was applied to the tape by the therapist (Jaraczewska e Long, 2006). According to the Kinesio Taping method, the tape application from origin to insertion with 10-15% of tension can facilitate muscle function and provide more support by increasing the sensory stimulation without performing the functional correction (mechanical support) (Donec *et al.*, 2012). Furthermore, also according to the method, applying the tape with the stretched muscle generates convolutions on the skin when the patient returns to neutral position, which can increase the sensory input (Silva Parreira Pdo *et al.*, 2013). The sham tape was placed similarly to the elastic tape with the patient in the same position.

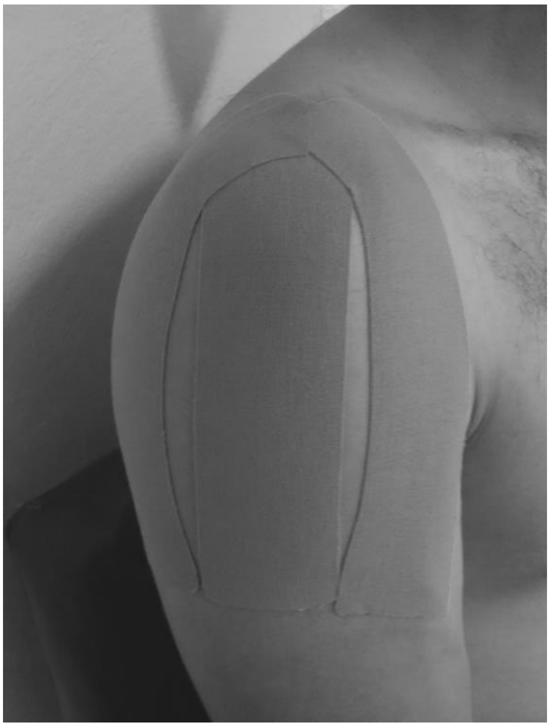

Figure 2. Elastic tape application.

Perceived effects

An assessment of the perceived effects was carried out during the first session after the JPS for both groups. The aim of this assessment was to verify whether the applied sham intervention was a plausible comparator for this study. Three questions were asked to the volunteers, which were the following: "Do you think the effects of the treatment that you received: 1 - improved your perception of the limb in space? 2 - improved using the limb? 3- improved the sensitivity of the limb?", with response options of yes or no. Each response was ranked as 0 or 1, corresponding to no or yes, respectively, and resulting in a total score ranging from 0 (no treatment effect) to 3 (maximum treatment effect) (Michener *et al.*, 2013; Michener *et al.*, 2015).

Outcome measures

The primary outcome variable in this study was shoulder JPS impairment, expressed by the absolute error in degrees for paretic and non-paretic limbs measured before and after interventions in the first and second sessions. Secondary outcome variables were the grades of subluxation measured using a caliper, the upper extremity sensorimotor impairment quantified by the Fugl-Meyer Assessment (FMA) and the scores for motor function, sensitivity and coordination/velocity measured by the FMA subscales. These secondary outcome variables were measured on the first day during clinical assessment. Another secondary variable was the subjective perception of the effects measured by the number of patients who received a different total score (0, 1, 2 or 3) after the JPS test during the first session.

Statistical analysis

A mixed model, two-way analysis of variance (group and evaluation time) with repeated measurements (evaluation time: pre- and post-sham or elastic tape) with Bonferroni's correction was used to examine the effect of group-by-evaluation time interaction, group (sham tape first and elastic tape first), and evaluation time (after and before sham and elastic tape). This analysis was performed for the paretic and non-paretic sides for both groups. Furthermore, partial eta (η^2) was used to determine the effect size of the interaction and quantify the proportion of total variance (from 0 to 1) which explains the dependent variable (Olejnik e Algina, 2000; Levine e Hullett, 2002). By convention, an η^2 around 0.2, 0.5, and 0.8 was considered small, medium, and large, respectively (Cohen, 1988). The effect of elastic tape in each group was estimated as the difference of means pre and post intervention (effect size: ES) and 95% confidence interval (95% CI) (Faraone, 2008).

The difference between the absolute error average at pre and post-elastic tape intervention was calculated for the shoulder abduction and flexion, and was referred to as the 'potential effect'. This change in each angle (30° and 60°) per movement (abduction and flexion) was correlated to the subluxation grade, total FMA score, subscale scores for the motor function, sensitivity, and coordination/velocity of the FMA using the Spearman test. The magnitude of correlations was analyzed based on the Munro classification (Munro, 2005): low (0.26-0.49), moderate (0.50-0.69), high (0.70-0.89), and very high (0.90-1.00). All statistical tests were carried out using SPSS software version 17.0 (SPSS Inc, Chicago, IL, USA), and a significance level was set at 0.05.

Results

Participants

The sample size was calculated using pilot data from four subjects with chronic hemiparesis from the elastic tape group and four subjects with chronic hemiparesis from the sham tape group using G.Power 3.1 software (Faul *et al.*, 2007). For this calculation, the absolute error was considered during abduction at 30° because it was the variable that presented the highest sample size after calculating it. The average and standard deviation from these pilot data were presented in Table 1. For this calculation, the F-test (repeated measures ANOVA, within and between factors) was used and a power of 0.80 and alpha of 0.05 were considered. In addition, a loss of 15% of the data were considered, requiring a total sample size of 10.

Table 1. Pilot data for sample size calculation.

	Elastic tape intervention		**Sham tape intervention**	
Group	**Pre**	**Post**	**Pre**	**Post**
ET	9.92 (±3.63)	2.75 (±2.23)	10.92 (±5.44)	10.67 (±4.15)
ST	7.58 (±4.15)	2.17 (±0.64)	7.67 (±5.60)	7.42 (±5.96)

ET: elastic tape group. ST: Sham tape group. Data expressed as mean and standard deviation.

From July 2014 to July 2015, 249 subjects with chronic hemiparesis from a hospital list in São Carlos were assessed for eligibility. However, 236 participants were excluded. Among the excluded patients, 65 declined to participate, 74 did not meet the inclusion criteria and 97 were excluded for other reasons (they did not answer the phone or the number did not exist). Thus, 13 subjects (3 women and 10 men) were randomly allocated to the two groups: sham followed by elastic tape (n=7, ST) or elastic tape followed by sham (n=6, ET). All included patients completed the crossover experiment. The data analysis was successfully conducted for all the participants (Fig. 3).

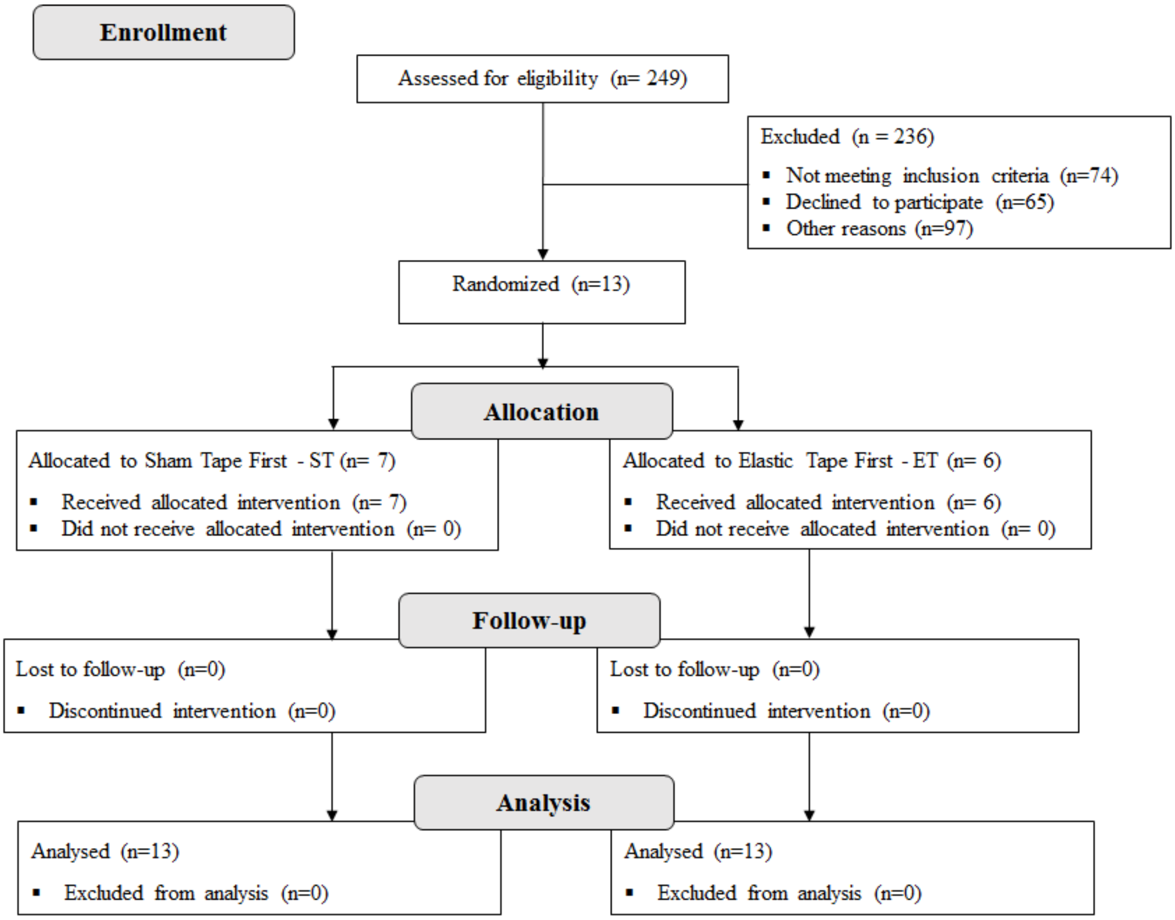

Figure 3. Flow diagram of the study.

The demographic characteristics of the participants are presented in Table 2. The range of age was 45 to 73 years with a BMI within the normal range. The range of post-stroke time was 24 to 158 months. All patients were right-handed before the stroke. However, the stroke occurred approximately at the same proportion in the right and left hemispheres. Shoulder assessment revealed that eleven patients presented subluxation with muscle tone of 0, 1 or 1+.

Table 2. Demographic characteristics of participants.

Demographics outcomes	**Values**
Age (years)	59.46 (±8.88)
Weight (Kg)	67.43 (±12.68)
Height (m)	1.66 (±0.10)
BMI (Kg/m^2)	24.37 (±2.64)
Time post-stroke (months, min-max)	75.23 (24-158)

Dominant side (R/ L)	13/0
Hemiparesis side (R/L)	6/7
Shoulder subluxation grade (0/1+/2+/3+)	4/2/6/1
Passive ROM of shoulder abduction (°)	132.31 (±24.05)
Passive ROM of shoulder flexion (°)	122.69 (±31.69)
MAS of shoulder abduction (0/1/1+/2/3/4)	6/4/3/0/0/0
MAS of shoulder flexion (0/1/1+/2/3/4)	6/4/3/0/0/0
Total score of FMA (median, min-max)	49 (32-57)
Subscale score of motor function (median, min-max)	43 (28-51)
Subscale score of sensibility (median, min-max)	8 (3-12)
Subscale score of coordination/velocity (median, min-max)	5 (3-6)

BMI: Body Mass Index. R: Right. L: Left. MAS: Modified Ashworth Scale. FMA: Fugl-Meyer Assessment. Data expressed as mean and standard deviation, except time post-stroke expressed as mean (minimum-maximum), total and subscales score of FMA as median (maximum-minimum).

Effects of elastic tape on paretic side

The results revealed interaction between the group (sham first and elastic tape first) and evaluation time (pre and post-intervention) for abduction at 30° (F=57.21, p<0.001, η^{2} =0.51), abduction at 60° (F=89.35, p<0.001, η^{2} = 0.58), flexion at 30° (F=45.07, p<0.001, η^{2} =0.59), and flexion at 60° (F= 41.09, p<0.001, η^{2} =0.55) (Fig 2).

For both groups, there was an elastic tape effect characterized by a decrease in the average absolute error for all movements and angles (Fig 2). For the ET group, the data analysis highlighted differences between pre and post-elastic tape in the first session for abduction at 30° (ES: 9.39, 95% CI: 4.90-13.87, p<0.001), abduction at 60° (ES: 7.05, 95% CI: 4.34-9.76, p<0.001), flexion at 30° (ES: 6.72, 95% CI: 2.24-11.19, p<0.001), and flexion at 60° (ES: 7.06, 95% CI: 2.53-11.59, p<0.001,). For the ST group, differences between pre and post-elastic tape in the second session for abduction at 30° (ES: 6.850, 95% CI: 2.73-9.35, p<0.001), abduction at 60° (ES: 5.14, 95% CI: 1.60-8.69, p<0.001), flexion at 30° (ES: 6.47, 95% CI: 3.01-9.93, p<0.001), and flexion at 60° (ES: 4.70, 95% CI: 3.18-6.21, p<0.001) were found.

In contrast, there was no effect of sham tape intervention for both groups during all the movements and angles (Fig. 4). For the ET group, no differences between pre and post-sham tape in the second session for abduction at 30° (p=1.00), abduction at 60° (p=1.00), flexion at 30° (p=1.00) and flexion at 60° (p=0.398) were observed. These differences were also not observed for the ST group in the first session during abduction at 30° (p=0.554), abduction at 60° (p=0.408), flexion at 30° (p=1.00), and flexion at 60° (p=1.00).

In addition, no differences between the pre-intervention of both sessions for all groups were observed (Fig. 4), demonstrating that the order of intervention did not influence the results. For the ET group, no differences between the pre-intervention in the first and second sessions were observed for abduction at 30° (p=0.249), abduction at 60° (p=0.263), flexion at 30° (p=0.425) and flexion at 60° (p=1.00). For the ST group, no differences between pre-intervention in the first and second sessions were observed for abduction at 30° (p=1.00), abduction at 60° (p=1.00), flexion at 30° (p=0.194) and flexion at 60° (p=0.639).

After comparing the groups at baseline in both sessions, no differences were observed between the ET and ST groups for all the movements and angles (Fig. 4). In the first session before intervention, the ST and ET were not different for abduction at 30° (p=0.805), abduction at 60° (p=0.509), flexion at 30° (p=0.872) and flexion at 60° (p=0.853). In the second session before intervention, the ST and ET were not different for abduction at 30° (p=0.951), abduction at 60° (p=0.799), flexion at 30° (p=0.897) and flexion at 60° (p=0.970). However, the groups were different after intervention in the first and second sessions for abduction at 30° (p=0.022; p=0.010), abduction at 60° (p=0.020; p=0.001), flexion at 30° (p=0.004; p=0.018) and flexion at 60° (p=0.011; p=0.014).

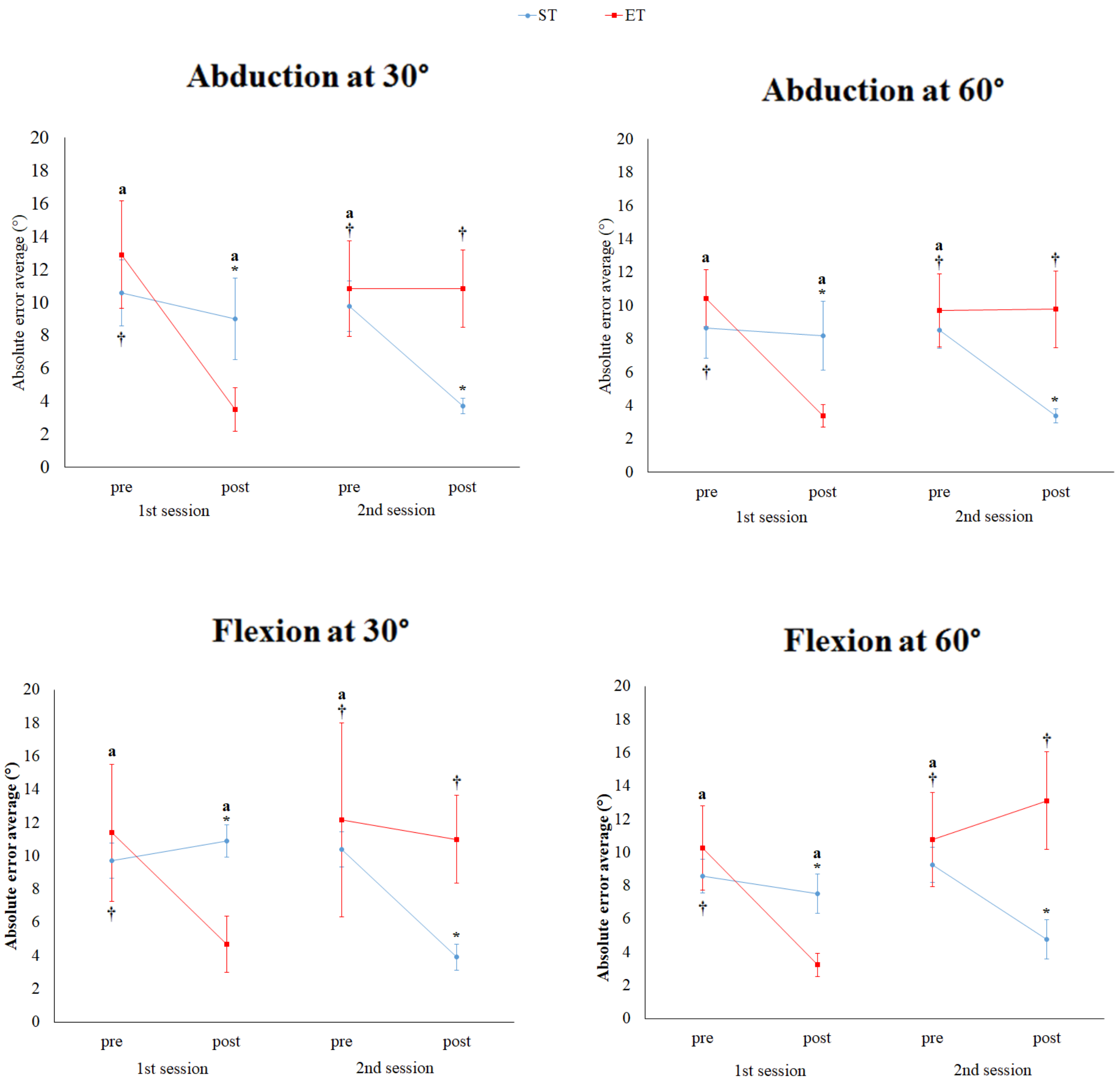

Figure 4. Average absolute error of paretic side for abduction and flexion at 30° and 60° for sham tape first (ST) and elastic tape first (ET) pre and post-intervention for the patient group. No differences at baseline (pre-intervention in the first and second sessions) between the ST and ET were observed for all movements and angles. For ST, in the post-intervention in the second session (post-elastic tape), a lower absolute error was observed compared to another evaluation time. For ET, in the post-intervention in the first session (post-elastic tape), a lower absolute error was observed compared to another evaluation time. *Significant differences compared to ET ($p<0.05$). †For the ET group, significant differences compared to the post-intervention in the first session ($p<0.05$). ^{a}For the ST group, significant differences compared to the post-intervention in the second session ($p<0.05$). Data were expressed as the mean and standard error.

Correlations between effects of elastic tape for paretic side

The correlations between the potential effect (difference between average absolute error at pre and post elastic tape) during flexion at 30° with subluxation measurement (p=0.339), the total score of FMA (p=0.409), the subscale score of motor function (p=0.502), the sensibility (p=0.720), and the coordination/velocity (p=0.502) did not reach statistical significance for this sample size. Moreover, the correlation between the potential effect during flexion at 60° with subluxation measurement (p=0.779), the total score of FMA (p=0.137), the subscale score of motor function (p=0.118), the sensibility (p=0.671), and the coordination/velocity (p=0.118) did not reach statistical significance.

For abduction at 30°, no correlations were found with the total score of FMA (p=0.470), the subscale score of motor function (p=0.423), the sensibility (p=0.645) and the coordination/velocity (p=0.423). The correlation between the potential effect during abduction at 60° with the total score of FMA (p=0.481), the subscale score of motor function (p=0.401), the sensibility (p=0.811) and the coordination/velocity (p=0.401) was not observed. However, there was a significant negative and high correlation between the baseline subluxation measurement with the potential effect during abduction at 30° (p=0.001, r=-0.92; Fig 3) and abduction at 60° (p=0.020, r=-0.75; Fig 5).

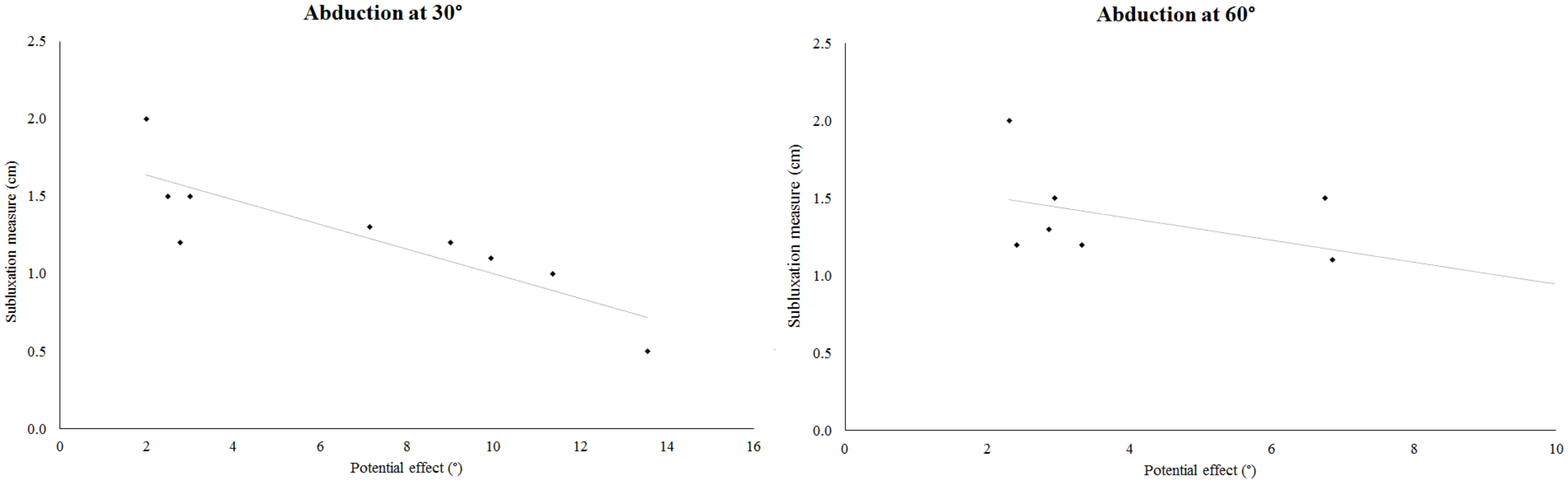

Figure 5. Correlations of the potential effect during abduction at 30° and 60° with the shoulder subluxation grade. A significant high correlation was observed during abduction at 30°, while a (non-significant) moderate correlation was found at 60°.

Effects of elastic tape for non-paretic side

Both interventions (elastic and sham tape) did not present effects on the non-paretic side for both groups (Fig 6). No interactions between the group (sham first and elastic tape first) and evaluation time (pre and post-intervention) for abduction at 30° (F=1.19, p=0.322), abduction at 60° (F=2.38, p=0.087), flexion at 30° (F=3.06, p=0.086) and flexion at 60° (F=1.69, p=0.214) were observed. In addition, no differences between the evaluation time for abduction at 30° (F=1.53, p=0.239), abduction at 60° (F=1.87, p=0.154), flexion at 30° (F=3.06, p=0.086) and flexion at 60° (F=1.40, p=0.268) were found. Furthermore, no differences between the ET and ST groups were observed for abduction at 30° (F=0.31, p=0.587), abduction at 60° (F=1.07, p=0.158), flexion at 30° (F=0.00, p=0.986) and flexion at 60° (F=1.86, p=0.200).

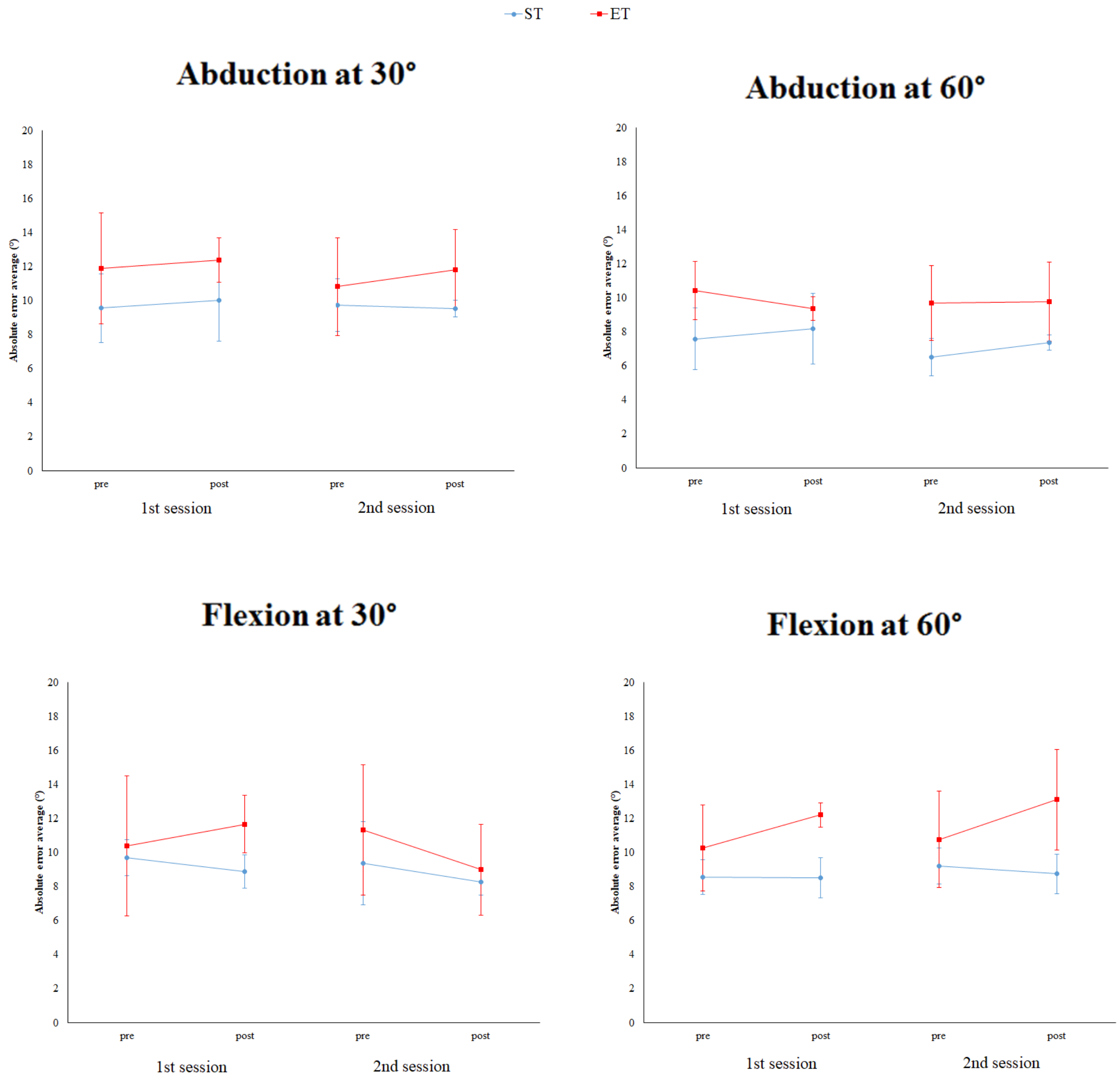

Figure 6. Average absolute error of non-paretic side for abduction and flexion at 30° and 60° for sham tape first (ST) and elastic tape first (ET) pre and post-intervention. No differences were found between the ST and ET in pre and post-interventions in the second and first sessions for all movements and angles ($p>0.05$). In addition, for both groups, no differences between the time evaluation were observed for all the movements and angles. Data were expressed as mean and standard errors.

Perceived effects

Fig 7 shows that the number of patients in each total score was similar after intervention for both groups, demonstrating that the sham intervention was a plausible comparator for this study.

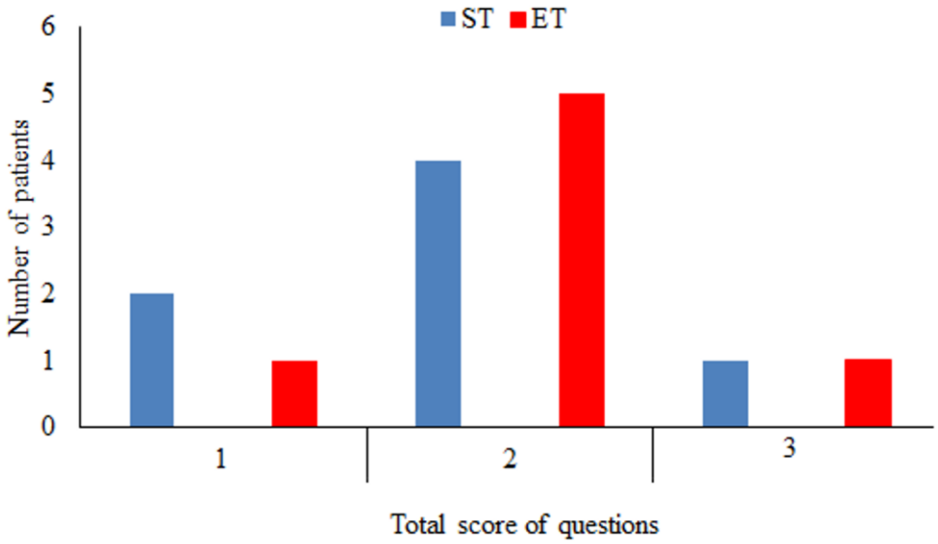

Figure 7. Number of patients with total score of 1, 2, and 3 in questions about perceived effects after the JPS test for sham tape first (ST) and elastic tape first (ET) during the first session. The number of patients in each total score was similar after the interventions for both groups, demonstrating the analogous subject's feelings, regardless of the intervention.

Adverse effects

No adverse effects (redness or itching) were observed during data collection.

Discussion

Although elastic tape has been widely used as a therapeutic tool in clinical practice, there is little evidence that supports this type of intervention in stroke patients. Furthermore, in accordance with systematic reviews and meta-analyses, the current available evidence is of low quality and insufficient to draw conclusions about the effects of elastic tape on different populations and/or pathologies (Parreira Pdo *et al.*, 2014; Taylor *et al.*, 2014; Chang *et al.*, 2015; Grampurohit *et al.*, 2015; Vanti *et al.*, 2015; Wu *et al.*, 2015). Thus, to the best of our knowledge, this is the first randomized sham-controlled crossover study that has verified immediate effects of elastic tape applied to the paretic shoulder, on JPS of the paretic and non-paretic side during abduction and flexion in subjects with chronic hemiparesis, compared to rigid tape.

The results of the present study revealed that elastic tape only improves JPS on the paretic side for all analyzed movements and angles characterized by a decreased absolute error. These findings confirm the first hypothesis. However, these results are not in line with previous studies that did not observe any effects of elastic tape on shoulder proprioception in athletes (Halseth *et al.*, 2004; Aarseth *et al.*, 2015) and healthy subjects (Zanca *et al.*, 2015). These conflicting results may be partially explained by differences between the evaluated populations and assessment tools, such as the use of the inclinometer versus an optoelectronic system for three-dimensional analyses. On the other hand, our results are in agreement with previous studies that used the same measurements on the knees of healthy subjects. These studies observed an improvement in JPS after using elastic tape in participants with poor proprioception compared to the good proprioception group (Callaghan *et al.*, 2002; Hosp *et al.*, 2015). In addition, facilitators´ effects were also observed when elastic tape was used on the knees of healthy subjects (Callaghan *et al.*, 2012) and in patients with patellofemoral pain syndrome (Callaghan *et al.*, 2008), and on the shoulders of healthy subjects (Lin *et al.*, 2011; Burfeind e Chimera, 2015).

Based on previous literature (Callaghan *et al.*, 2002; Callaghan *et al.*, 2008; Callaghan *et al.*, 2012; Hosp *et al.*, 2015) and neuroscience knowledge (Kandel *et al.*, 2000), it can be suggested that a possible explanation for the effect of elastic taping may be related to the neural activation and biomechanics support. Elastic tape produces tactile stimulation, which increases sensory input from mechanoreceptors to the cortex contralateral primary somatosensory via thalamus (Kandel *et al.*, 2000; Clark *et al.*, 2015; Roijezon *et al.*, 2015). The primary somatosensory cortex has a connection with multimodal association areas, which integrates information from different sensory modalities such as visual and proprioceptive information. These areas are linked to multimodal motor association areas that transform sensory information into planned movements and calculate the necessary programs for movements (feedforward and feedback control). In addition, these motor multimodal areas are linked to the primary motor cortex and premotor areas (Kandel *et al.*, 2000). This possible central neural influence of the elastic tape was demonstrated by a previous study (Callaghan *et al.*, 2012), that observed the increase in bilateral activation of sensory and sensorimotor areas and bilateral decrease in areas related to decision making and planning, and coordination of the some aspects of proprioception, such as cerebellum and the cingulate motor area.

Because the sham intervention (rigid tape) had no effect in the position sense, it can be suggested that the effects of the elastic tape may be due to its elastic property. This property can produce mechanical changes on the skin, such as stretching and compression, thereby increasing the sensory input (Callaghan *et al.*, 2012; Clark *et al.*, 2015; Roijezon *et al.*, 2015). It is worth highlighting that the sham intervention was considered a plausible comparator for this study. Finally, as there were no changes in the JPS between the two evaluations on the non-paretic (i.e. non-treated) side, it can be concluded that there was no learning effect. Moreover, although the elastic tape may improve shoulder girdle stability (Burfeind e Chimera, 2015), which can improve body position and perception bilaterally, these results demonstrate that the immediate effects of the elastic tape were limited to the applied part of the body. Furthermore, while previous study demonstrated that elastic tape provided a bilateral activation in the sensorimotor cortex (Callaghan *et al.*, 2012), it did not reflect immediate changes on the shoulder JPS on the non-paretic side, reinforcing that short-term effects of the tape are local.

Another important result of this study is related to a negative correlation between the potential effect (difference between the absolute average error in the pre and post elastic tape intervention) and the measurement of shoulder subluxation during abduction. According to the literature, subluxation impairs the abduction motion more than the flexion motion, due to anatomical and biomechanical aspects (Phadke *et al.*, 2009; Huang *et al.*, 2012). However, no correlations between the sensorimotor impairment (FMA score) for all the movements and angles were observed, which refutes the second hypothesis of the study. The lack of correlation demonstrated that patients with mild or moderate UL sensorimotor impairment can benefit from using elastic tape, regardless of the impairment level.

Overall, the results of this study demonstrated that elastic tape could be considered as an important intervention strategy for post-stroke subjects in chronic phases, regardless of the UL sensorimotor impairment level. Apart from the relationship between the effect of elastic tape during abduction and the baseline shoulder degree of subluxation, this intervention strategy also provided an improvement for this movement. Moreover, shoulder JPS plays an important role in feedback and feedforward controls during motor action to achieve specific roles for movement acuity, joint stability and coordination (Riemann e Lephart, 2002a; b; Roijezon *et al.*, 2015), which influence the upper limb performance. Thus, these improvement in shoulder JPS provided by elastic tape can improve joint stability and control of movement of UL. Furthermore, elastic tape would be an important strategy to facilitate the increase in sensory input, and should be associated with more repetitive task-specific training.

It is worth noting that the results of the present study are limited to the immediate effects of the elastic tape on shoulder JPS in subjects with chronic hemiparesis post-stroke with mild or moderate UL sensorimotor impairment. Thus, future studies that verify the effects of long-term elastic tape on joint position sense, as well as studies that verify short and long-term effects in other submodalities of proprioception, and/ or other phases of stroke are needed. In addition, the present study did not evaluate the effect of elastic tape on UL functional movements. Therefore, future studies are needed to verify the relationship between improvement in JPS and performance in the UL movements, as well as the effect of the elastic tape on daily UL activities. Furthermore, although an adequate sample size and large effect size were observed in the present study, for the correlation analysis, a larger sample size is required to further generalize our findings.

Conclusions

Elastic tape applied to the paretic shoulder (anterior, middle, and posterior deltoid) improved JPS during abduction and flexion in chronic hemiparetic subjects, regardless of the level of UL sensorimotor impairment. However, these effects of elastic tape were influenced by the subluxation grade for shoulder abduction movements.

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ESTUDO II

Elastic tape improves joint angular parameters during a functional task in chronic hemiparetic subjects: a randomized sham-controlled crossover trial

Artigo submetido a Journal of Physiotherapy (Qualis A1, fator de impacto 4.083)

Santos GL, Silva ESM, Desloovere K, Russo TL. Elastic tape improves joint angular parameters during a functional task in chronic hemiparetic subjects: a randomized sham-controlled crossover trial.

Abstract

Question: Can elastic tape used on paretic shoulders improve upper limb (UL) sensorimotor performance during a drinking task?

Design: Single-center randomized sham-controlled crossover trial.

Participants: Thirteen chronic hemiparetic subjects with mild to moderate UL impairment.

Intervention: Patients underwent elastic and non-elastic tape interventions used on the paretic shoulder with one month wash-out period between them. Elastic tape was used with 10-15% of tension from the origin to the insertion.

Outcome measures: Kinematic measures of a drinking task were taken before and after each intervention (elastic and sham tape), using Three-Dimensional Motion Analysis, and studied by means of feature and Statistical Parametric Mapping analysis. Outcome measures included spatiotemporal variables, scalar kinematic parameters (starting angles, range of motion - ROM, and angles at the end) and time-normalized kinematic waveforms of trunk and UL joint angles (scapulothoracic, humerothoracic and elbow).

Results: The elastic tape improved the shoulder position (more towards midline), reduced scapula protraction and trunk flexion at the beginning, during, and the end of the task, however without changing the spatiotemporal parameters. Moreover, an improvement in joint movement of shoulder elevation, scapula rotation and elbow extension was observed at specific time-instants during the task, for example, elbow extension from the middle of reaching and the transport phase from cup to table was increased. However, the effect size ranged from small to medium.

Conclusion: The elastic tape improved UL joint motions and posture during a drinking task in chronic hemiparetic subjects, which defines its role as adjuvant therapy.

Trial registration: NCT02390115

Introduction

Stroke is the most frequent cause of adult disability worldwide(Langhorne *et al.*, 2011). Approximately 50-70% of stroke survivors in the chronic phase have upper limb (UL) impairments (i.e. motor, sensory, perceptual and cognitive deficits). UL impairments may cause limitation in activities of daily living (ADL) and reduce their functional independence, social participation and quality of life (Parker *et al.*, 1986; Hatem *et al.*, 2016). According to the literature, chronic hemiparetic subjects performed slow and non-rectilinear UL movements with a greater number of adjustments along the motion trajectory during functional activities (i.e. reach-to-grasp and drinking tasks) (Alt Murphy *et al.*, 2011; Robertson *et al.*, 2012; Aprile *et al.*, 2014; Santos, Russo*, et al.*, 2017). These altered movement patterns have been associated with alterations in range of joint motion (ROM) (Alt Murphy *et al.*, 2011; Aprile *et al.*, 2014; Kim *et al.*, 2014) and in the joint angles at static initial and final positions (Robertson *et al.*, 2012; Santos, Russo*, et al.*, 2017).

Besides these alterations in kinematic scalar parameters, an alternative approach for continuous field analysis, called Statistical Parametric Mapping (SPM) investigates kinematic data in a continuous way, taking into account the interdependence of the data points (time instances of the movements) (Santos, Russo*, et al.*, 2017; Simon-Martinez *et al.*, 2017). Therefore, this analysis provides a better understanding of movement strategies throughout the task and reduces the risk of Type I error (Nieuwenhuys *et al.*, 2016; Santos, Russo*, et al.*, 2017). These analyses demonstrated that chronic hemiparetic subjects presented a higher number of joint angle alterations at the static starting position and reaching phase. Thereby, some common deviations for all phases of the task were observed, including increased scapula protraction, homolateral trunk flexion, and trunk anterior flexion. In addition, this analysis showed reduced elbow extension when a glass was near the table, reduced shoulder elevation in the middle of transporting the glass to the mouth, and a shoulder position that was less toward the midline around the first and last 25% of the time of reaching and returning phases (Santos, Russo*, et al.*, 2017).

Given these UL alterations during a functional task and their impact on the movements in stroke survivors, some interventions have been proposed, even in the chronic stroke stage, as some degree of recovery can still be observed in this late-stage phase (Nithianantharajah e Hannan, 2006; Buma *et al.*, 2013). An adjuvant technique widely adopted in neurorehabilitation to improve sensorimotor control is using elastic tape (taping), which can provide mechanical support (Callaghan *et al.*, 2012) and enhanced sensory stimulus (Callaghan *et al.*, 2012; Santos, Souza, *et al.*, 2017). Interestingly, Callaghan et al. demonstrated that taping increased the activation of the primary sensorimotor cortex and primary sensory cortex, and decreased the involvement of neural areas related to decision making, complex planning, coordinated tasks and unconscious aspects of proprioception during knee proprioceptive tasks (Callaghan *et al.*, 2012), suggesting other effects of elastic taping, which involved brain activity modulation.

Regarding post-stroke subjects, we recently observed that taping improved the shoulder joint position sense, a submodality of proprioception, with moderate effects compared to non-elastic tape (sham) (Santos, Souza, *et al.*, 2017). Since our previous findings suggested proprioception as an important component of feedforward and feedback control (Roijezon *et al.*, 2015), it is assumed that taping may influence motor action. However, studies in the literature related to the effects of taping on UL motor function are still controversial (Pandian *et al.*, 2013; Kim e Kim, 2015; Huang *et al.*, 2016). Huang et al. (Huang *et al.*, 2016) and Kim et al. (Kim e Kim, 2015) observed improvements in UL measured by Fugl-Meyer assessment and the Modified Motor Assessment Scale, respectively. On other hand, Pandian et al. did not observe the effects quantified by Shoulder Pain and Disability Index (Pandian *et al.*, 2013). The lack of agreement in the literature can be attributed to applied assessment scales. Furthermore, so far, none of the studies have verified taping effects on UL performance during functional tasks. Therefore, the aim of the present study was to verify the effects of taping used on paretic shoulders on the spatiotemporal and joint kinematics parameters during a standardized drinking task in chronic hemiparetic subjects, taking the non-elastic tape condition as a reference. The research questions were as follows:

1. Does taping reduce movement time duration, increase velocity and smoothness during a drinking task, as well as change UL joint position?
2. Does taping alter joint motions during a drinking task?

Method

Design

The study was a single-center randomized sham-controlled crossover study. The study was approved by the Ethics Committee in Brazil (Number: 966636) and registered in the Clinical Trials (URL: http://www.clinicaltrials.gov. Unique identifier: NCT02390115). All participants gave written informed consent.

Assessments were performed at the university and planned over three days. On the first day, a screening and an initial evaluation was performed to select the study sample according to the inclusion and exclusion criteria and to characterize the sample. On the same day, an independent staff member randomly assigned participants to one of two groups to receive Sham Tape (ST) first or Elastic tape (ET) first in opaque sealed envelopes. Data analysis was performed by an evaluator who was blinded to the groups. On the other two days, Three-dimensional Motion Analysis (3DMA) of the drinking task was performed without and with the intervention (sham or elastic tape). A wash-out period of one month was given between the second and third evaluation days (Santos, Souza, *et al.*, 2017). The experimental design is shown in Figure 8.

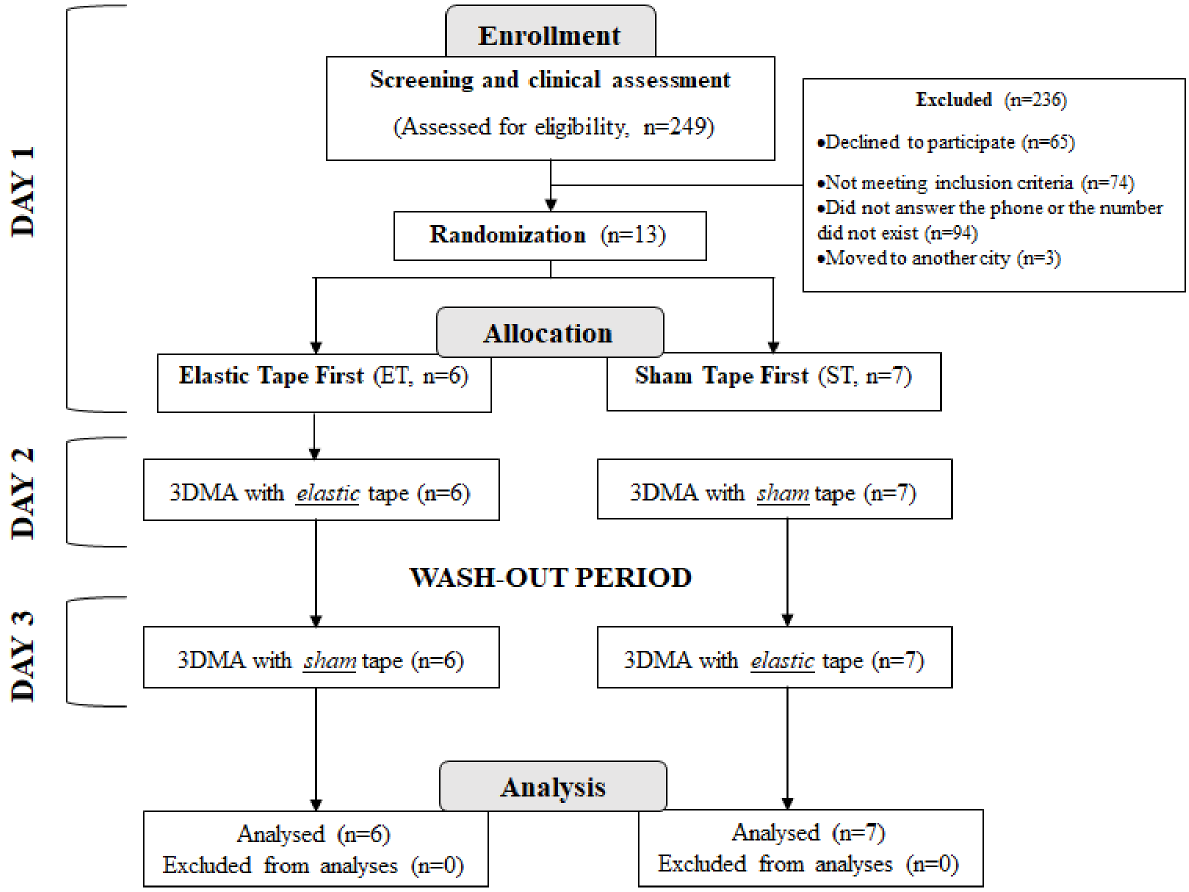

Figure 8. Schematic representation of the experimental design and flowchart.

Participants

The sample size was calculated using pilot data from four subjects with chronic hemiparesis from each group, using G.Power 3.1 software. For this calculation, we considered the scapula protraction/retraction angle as a primary outcome, because of its involvement in proximal adjustments and its sensitivity to treatment observed in a previous study (Santos, Russo, *et al.*, 2017). The F-test (repeated measures ANOVA, within and between factors) was used and a power of 0.80, alpha of 0.05, and effect size (η^2) of 0.44 were considered. In addition, a loss of 20% of the data was taken into account, requiring a total sample size of 12 participants.

The following inclusion criteria were considered (Santos, Russo, *et al.*, 2017; Santos, Souza, *et al.*, 2017): chronic hemiparetic subjects (post-stroke time greater than 6 months) due to unilateral ischemic stroke of any hemisphere with lesions restricted to the anterior vascular territory (anterior and medium cerebral arteries) observed in the medical report of the MRI; aged between 40 and 75 years; minimum score on the Mini

Mental State Examination according to the patient's educational level (Folstein *et al.*, 1975; Brucki *et al.*, 2003); proper trunk control, assessed by the ability to remain seated on a chair without trunk and arm support for one minute; spasticity level for shoulder abductor and flexor muscle level of less than 3 on the Modified Ashworth Scale (MAS); and a score of ≥ 30 in the Fugl-Meyer Assessment (FMA) (Platz *et al.*, 2005). Moreover, the patients needed to present a minimum passive range of motion of 90° for shoulder flexion, and 30º for shoulder extension and adduction, which were necessary to standardize the use of elastic tape.

The exclusion criteria were tape adverse reactions (redness and/or itchiness); skin alterations (ulcers or lesions); diabetes mellitus; understanding aphasia, apraxia, unilateral neglect and/or hemiplegia; botulinum toxin application up to six months before the study; shoulder pain; history of muscle or joint injuries at the shoulder complex or cervical joints (fractures or surgery); any other orthopedic or neurological diseases that affected the data collection; and serious cardiovascular or peripheral vascular disease (heart failure, arrhythmias, angina pectoris or myocardial infarction) (Santos, Russo, *et al.*, 2017; Santos, Souza, *et al.*, 2017).

Screening and clinical assessment

Participants were interviewed, which included collecting personal and stroke data (time post-stroke and injury side), as well as carrying out a physical examination (anthropometric measures, passive range of motion and spasticity level of shoulder abduction and flexion muscles using MAS) and UL sensorimotor impairment assessment quantified by FMA. Moreover, the manual preference before the stroke was evaluated using the Edinburgh Handedness Inventory (Oldfield, 1971).

3DMA of drinking task

All participants were submitted to 3DMA of a drinking task at the Multidisciplinary Center of Movement Analysis (UFSCar, São Carlos, Brazil) using the optoelectronic ProReflex Motion Capture System (Qualisys Medical AB, Gothenburg, Sweden) with eight high-speed cameras at a sampling frequency of 120 Hz. The analysis was performed by one trained physiotherapist following a previously described standardized protocol (Santos, Russo, *et al.*, 2017). At the beginning of the motion task (starting position), patients were seated with 90° of knee and hip flexion without trunk support and hands pronated on the thigh.

A cluster of markers and eighteen anatomical landmarks were placed bilaterally on the trunk, scapula, upper arm and forearm, following the guidelines of the International Society of Biomechanics (ISB) (Wu *et al.*, 2005). Thereafter, static trials were collected to record the reference position and to calibrate the anatomical markers (Cappozzo *et al.*, 1995). Ten passive shoulder circumduction movements were performed to determine the glenohumeral joint center (Gamage e Lasenby, 2002). These data collection steps were performed before and after the intervention. Afterwards, the anatomical landmarkers were removed and the participants were instructed to perform a drinking task at a self-selected speed and return to the starting position. The task was repeated three times with the paretic side before and after interventions (six trials per evaluation day) with one-minute rest intervals between trials. One familiarization trial was performed at the beginning of the pre-3DMA.

3DMA processing

Data analysis was performed by one evaluator using Qualisys Track Manager Software. The drinking task was divided into four phases: reaching for the glass (including grasping), transporting the glass to the mouth (including sipping), returning it to the table (including releasing the grasp), and returning the hand to the initial position. The onset and end of each phase was visually identified using a frame-by-frame movement inspection (Santos, Russo, *et al.*, 2017).

UL kinematics calculations were computed with Upper Limb Evaluation in Motion Analysis (ULEMA) software (https://github.com/u0078867/ulema-ul-analyzer)(Jaspers *et al.*, 2014) according to ISB recommendations. Four segments (trunk, scapula, humerus, forearm) were included and eleven joint angles were extracted: trunk (flexion-extension, lateral flexion and rotation), scapula (tilting, rotation, pro-retraction), shoulder (elevation plane, elevation and rotation), and elbow (flexion-extension and pro-supination). These parameters were expressed relative to the static posture.

Outcome measures

The primary outcome parameters were spatiotemporal and kinematic extracted from the joint angle waveforms, calculated per phase (Santos, Russo, *et al.*, 2017). Spatiotemporal parameters included phase duration (PD, second), relative phase duration (%PD, ratio between phase duration and total task duration, expressed in percentage), peak velocity (PV, mm/s), time to peak velocity (%TPV), and trajectory deviation (Santos, Russo, *et al.*, 2017) (TD, ratio between the length of the travelled wrist path and the length of a straight line connecting start and endpoint). The TD variable was not calculated for the return phase because there was no clear target to reach. The extracted kinematic parameters included starting angles, range of motion (ROM, difference between minimum and maximum angle), and joint angles at the point of task achievement (PTA, final angle to complete the task). Secondary outcomes were the kinematic waveforms time-normalized of different angles of trunk, scapulothoracic, humerothoracic and elbow per phase.

Interventions

A physiotherapist certified in Kinesio Taping Method made the interventions on the paretic shoulder. For elastic and sham tape intervention, a blue Kinesio® Tex Gold Finger Print tape (5 cm wide) and Cremer non-elastic tape (5 cm wide) (Cremer S/A, São Paulo, Brazil) were used respectively. Both interventions were made immediately after the pre-3DMA and were kept during the post-3DMA. After the application, the patient remained seated for 10 minutes. The elastic tape was applied with 10-15% of the total elastic tape tension (“paper-off”) on the deltoid (anterior, middle and posterior) from the origin to the insertion. The sham tape was placed similarly to the elastic tape with the patient in the same position. More details about the intervention protocol and sham validation have been previously described (Santos, Souza, *et al.*, 2017).

Statistical analysis

All extracted kinematic scalars and spatiotemporal parameters showed normal and homogeneous distribution according to the Shapiro-Wilk and Levene tests, respectively. Thus, two-way ANOVA with repeated measures using Bonferroni’s correction was adopted to verify the effect of interaction (group and evaluation time), group (ST and ET), and evaluation time (after and before sham and elastic tape). A significance level was set at 0.05. Moreover, the effect size of interaction was determined through partial eta squared calculation (η^2) (Olejnik e Algina, 2000; Levine e Hullett, 2002). A η^2 around 0.2, 0.5, and 0.8 correspond to a small, medium and large effect, respectively(Cohen, 1988). The mean difference from pre and post elastic tape and the corresponding 95% confidence interval (95% CI) were calculated for each group (ET and ST) in order to estimate the effect of the intervention (Faraone, 2008).

As complementary analysis, the mean kinematic waveforms of all joint angles for each time-normalized phase were compared before and after the elastic and sham conditions using the SPM paired t test. For these analyses, statistical significance was set to alpha at 0.05. In this analysis, the scalar output (SPM{t}) at each point normalized time series was calculated for each SPM t test, which indicates the magnitude of differences. Thereafter, the critical threshold (Tcritical) for which only 5% of the smoothed random curves would be expected to exceed and the probability with which supra-threshold regions could have been produced by a random field process with the same temporal smoothness were calculated (Adler e Taylor, 2009; Pataky *et al.*, 2013). One example of the SPM results is shown in the supplementary material (Figure 9). SPM analyses were performed using the open-source SPM1d code (version 0.4, http://www.spm1d.org) in MATLAB (R2017b, The Mathworks Inc, Natick, MA).

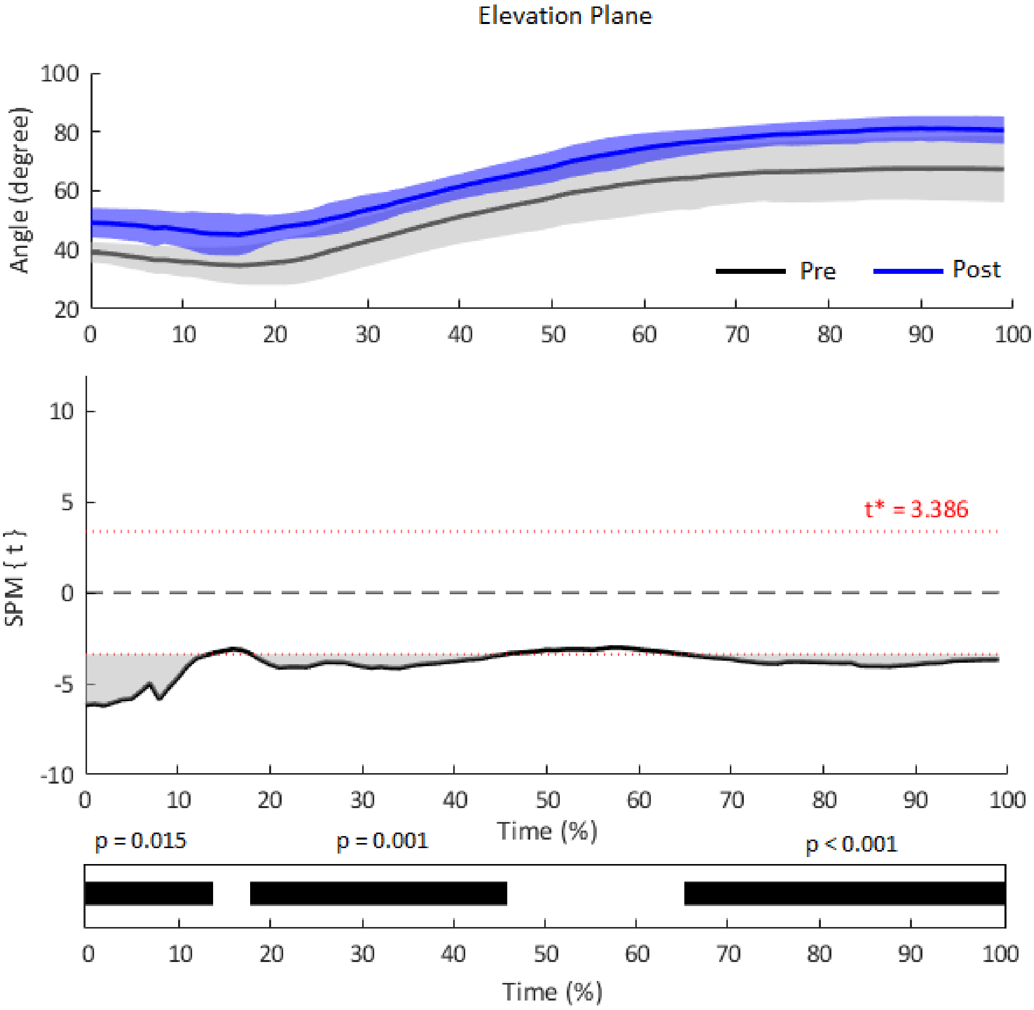

Figure 9. Summarized presentation of SPM results (one example). The first graph shows the mean kinematic value of the elevation plane during waveforms when reaching for a glass at pre (black line) and post (blue line) elastic tape intervention. The middle graph presents SPM{t} as a function of the reaching phase. The critical threshold (t*=3.386) was exceeded between 0-16%, 19-46% and 66-00% of the reaching phase. The black bar below the graph represents the time during which the differences between the evaluation time occur ($p<0.05$), which was indicated by the SPM{t} statistic.

Results

Participants

Patients were recruited from July, 2014 to July, 2015 from the lists of rehabilitation centers in São Carlos. During this period, 249 post-stroke subjects were assessed for eligibility. However, 65 declined to participate, 74 did not meet the inclusion criteria and 97 were excluded for other reasons. Thus, 13 subjects were randomly allocated to one of two groups to receive Elastic tape first (n=6, ET) or Sham Tape first (n=7, ST). All included patients completed the crossover experiment and the data analysis was successfully conducted for all the participants (Figure 1). Seven patients presented hemiparesis to the right and six to the left without limitations in passive ROM of shoulder (abduction and flexion) and with a spasticity level of 0 to +1 in the shoulder muscles (abductors and flexors) (Table 3).

Table 3. Demographic characteristics of patients.

Demographic variables	**Values**
Age (years)	59.46 (8.88)
Gender (women/men)	3/10
Time post-stroke (months)	75.23 (24-158)
Side of the injured hemisphere (R/L)	7/6
Dominant side before stroke (R/L)	13/6
Total score of FMA	49 (32-57)

Ages expressed as mean (standard deviation), time post-stroke as mean (minimum-maximum) and total score of FMA as median (maximum-minimum).

Spatiotemporal and scalar kinematic parameters

Table 4 shows mean and standard deviation of spatiotemporal variables of all phases. Tables 5, 6, 7, and 8 present the mean and standard deviations of the extracted kinematic parameters of reaching, transporting the glass to the mouth, transporting the glass to the table, and returning to the initial position phases, respectively. There were no interaction effects for all spatiotemporal parameters (Table 4) and ROM of all joint angles (Table 5-8) in each phase. On the other hand, the results revealed small to medium interaction effects for starting angles of the elevation plane ($p<0.001$, $\eta^2=0.41$, more towards midline), scapula protraction-retraction ($p=0.002$, $\eta^2=0.33$, less protraction), and trunk flexion-extension ($p=0.002$, $\eta^2=0.37$, less flexion) with effects for both groups (Table 5).

Table 4. Spatiotemporal variables pre and post interventions (elastic and sham tape) for all phases.

		Interventions			
	Group	**Elastic Tape**		**Sham tape**	
		Pre	**Post**	**Pre**	**Post**
Reaching for the glass					
PD (s)	ET	1.52 (0.14)	1.49 (0.27)	1.39 (0.08)	1.42 (0.21)
	ST	1.53 (0.23)	1.58 (0.37)	1.70 (0.34)	1.59 (0.36)
%PD	ET	26.30 (1.76)	26.31 (2.48)	25.42 (1.85)	26.93 (2.49)
	ST	24.97 (1.99)	26.07 (2.05)	26.12 (1.42)	26.18 (1.63)
%TPV	ET	39.36 (4.36)	36.99 (4.09)	41.24 (5.32)	37.68 (6.11)
	ST	42.02 (4.03)	37.51 (6.47)	39.04 (4.11)	37.35 (2.31)
PV (mm/s)	ET	531.92 (29.49)	520.75 (37.94)	513.91 (41.17)	562.73 (56.11)
	ST	514.57 (70.18)	553.84 (75.02)	516.84 (81.17)	515.19 (19.94)
TD	ET	1.46 (0.06)	1.42 (0.16)	1.41 (0.15)	1.42 (0.21)
	ST	1.45 (0.16)	1.38 (0.15)	1.60 (0.27)	1.39 (0.27)
Transporting the glass to the mouth					
PD (s)	ET	1.52 (0.21)	1.52 (0.11)	1.53 (0.29)	1.50 (0.22)
	ST	1.50 (0.12)	1.51 (0.18)	1.52 (0.26)	1.50 (0.10)
%PD	ET	24.93 (1.43)	24.76 (1.21)	24.61 (1.71)	24.76 (1.20)
	ST	24.15 (0.92)	24.90 (3.43)	25.19 (0.72)	24.79 (2.26)
%TPV	ET	24.53 (1.38)	25.91 (3.98)	26.55 (3.32)	24.51 (1.67)
	ST	26.04 (2.64)	24.75 (2.99)	24.81 (2.43)	24.53 (1.38)
PV (mm/s)	ET	345.78 (79.92)	343.91 (66.79)	345.67 (76.46)	344.06 (65.00)
	ST	345.08 (71.04)	345.17 (52.16)	345.00 (83.27)	345.62 (89.49)
TD	ET	1.11 (0.07)	1.13 (0.09)	1.11 (0.08)	1.11 (0.12)
	ST	1.12 (0.04)	1.13 (0.03)	1.12 (0.04)	1.11 (0.02)
Transporting the glass to the table					
PD (s)	ET	1.75 (0.12)	1.74 (0.14)	1.76 (0.18)	1.75 (0.42)
	ST	1.75 (0.30)	1.74 (0.36)	1.74 (0.22)	1.75 (0.11)
%PD	ET	26.76 (2.39)	27.33 (1.12)	27.16 (1.69)	26.88 (0.95)
	ST	26.71 (3.69)	27.09 (3.09)	26.76 (2.41)	27.20 (1.86)
%TPV	ET	40.29 (10.01)	40.52 (10.58)	40.27 (9.02)	40.12 (9.61)

	ST	40.73 (9.67)	40.79 (10.80)	40.30 (11.84)	39.80 (12.22)
PV (mm/s)	ET	354.97 (82.95)	354.79 (70.30)	354.62 (80.74)	355.75 (90.12)
	ST	354.98 (64.72)	354.82 (72.99)	354.97 (82.95)	354.00 (82.24)
TD	ET	1.12 (0.03)	1.11 (0.06)	1.11 (0.04)	1.11 (0.09)
	ST	1.12 (0.05)	1.12 (0.04)	1.11 (0.04)	1.11 (0.06)
Returning to initial position					
PD (s)	ET	1.29 (0.24)	1.30 (0.13)	1.32 (0.24)	1.31 (0.34)
	ST	1.28 (0.24)	1.31 (0.27)	1.30 (0.28)	1.31 (0.29)
%PD	ET	21.42 (1.88)	21.55 (2.24)	21.98 (2.97)	21.94 (2.94)
	ST	21.83 (2.99)	21.42 (2.90)	21.72 (1.14)	21.31 (1.47)
%TPV	ET	51.78 (6.29)	51.68 (4.55)	51.50 (7.22)	51.44 (6.85)
	ST	51.64 (7.79)	51.60 (8.11)	51.62 (8.67)	51.24 (7.34)
PV (mm/s)	ET	518.24 (48.72)	518.16 (57.79)	519.46 (44.46)	519.18 (43.73)
	ST	519.26 (48.41)	519.11 (48.94)	519.33 (45.85)	518.26 (45.17)

Data expressed as mean and standard deviation. ET: Elastic tape first group. ST: Sham Tape first group. PD: phase duration. %PD: relative phase duration. PV: peak velocity. %TPV: time to peak velocity. TD: trajectory deviation.

Table 5. ROM, starting angles, and PTA for all joints assessed while reaching for a glass for both groups (ET and ST) pre and post-interventions (elastic and sham tape).

		Interventions					
	Group	**Elastic Tape**		**Sham Tape**		**Mean difference (95% CI)**	**p-value**
		Pre	**Post**	**Pre**	**Post**		
Elevation Plane							
Start	ET	39.52 (3.28)	47.02 (5.45)*	40.54 (4.64)	39.09 (2.60)	-7.50 (-14.19 to -0.81)	0.025
	ST	39.74 (1.67)	46.72 (1.18)*	39.16 (3.28)	40.55 (3.49)	-6.98 (-10.52 to -3.44)	<0.001
ROM	ET	42.34 (6.88)	31.09 (8.54)	41.56 (8.62)	40.74 (15.20)	------------	NS
	ST	41.50 (9.84)	38.21 (11.24)	42.03 (9.34)	41.43 (9.83)	------------	NS
PTA	ET	73.33 (1.70)	82.07 (6.18)*	72.52 (3.68)	74.88 (4.19)	-10.75 (-17.59 to -3.91)	0.002
	ST	73.22 (3.82)	80.07 (5.64)*	73.35 (2.39)	72.81 (4.24)	-8.86 (-13.76 to -3.95)	0.001
Shoulder Elevation							
Start	ET	-22.80 (2.09)	-21.55 (6.67)	-21.79 (9.84)	-21.72 (9.83)	------------	NS
	ST	-21.56 (8.56)	-21.88 (8.64)	-22.77 (3.03)	-23.48 (5.12)	------------	NS
ROM	ET	34.81 (4.11)	34.02 (3.85)	45.00 (3.74)	36.74 (3.93)	------------	NS
	ST	36.28 (4.54)	37.52 (3.47)	34.98 (4.32)	34.59 (3.67)	------------	NS
PTA	ET	-51.40 (2.58)	-54.25 (6.44)	-52.25 (2.26)	-52.56 (7.85)	------------	NS
	ST	-51.40 (5.04)	-53.57 (7.95)	-51.26 (2.10)	-51.04 (4.16)	------------	NS
Shoulder Rotation							
Start	ET	-43.35 (6.29)	-44.35 (12.84)	-44.77 (4.29)	-44.18 (6.09)	------------	NS
	ST	-44.76 (7.31)	-45.15 (7.78)	-43.68 (5.59)	-44.21 (5.36)	------------	NS
ROM	ET	26.71 (5.09)	27.29 (4.90)	26.31 (4.50)	26.12 (4.67)	------------	NS
	ST	26.05 (7.00)	26.26 (5.08)	26.61 (7.54)	27.22 (5.23)	------------	NS
PTA	ET	-56.62 (8.31)	-56.83 (1.60)	-55.11 (5.47)	-56.25 (6.29)	------------	NS
	ST	-56.53 (2.76)	-57.28 (2.35)	-57.35 (4.65)	-56.49 (2.31)	------------	NS
Scapula Protraction-Retraction							
Start	ET	34.76 (3.57)	29.30 (2.69)*	35.03 (3.94)	31.85 (3.41)	5.46 (0.41 to 10.51)	0.031
	ST	34.59 (2.01)	29.80 (2.27)*	34.90 (2.45)	34.31 (3.54)	5.23 (3.02 to 7.45)	<0.001
ROM	ET	6.70 (2.00)	6.65 (2.08)	6.39 (1.28)	6.41 (1.80)	------------	NS
	ST	6.83 (1.14)	6.45 (1.62)	6.46 (0.81)	6.56 (1.13)	------------	NS
PTA	ET	41.87 (4.50)	36.74 (3.67)*	41.29 (3.39)	41.15 (3.69)	5.13 (0.96 to 9.31)	0.014

	ST	41.13 (4.20)	36.53 (2.06)*	41.99 (3.82)	41.28 (3.14)	4.61 (1.70 to 7.51)	0.002
Scapula Rotation							
Start	ET	3.80 (2.06)	2.50 (0.80)	3.39 (0.55)	3.18 (0.56)	------------	NS
	ST	3.80 (0.82)	2.72 (0.73)	3.54 (1.06)	3.65 (1.12)	------------	NS
ROM	ET	11.27 (1.43)	11.67 (2.08)	11.31 (0.99)	11.69 (1.64)	------------	NS
	ST	11.72 (2.15)	11.33 (0.82)	11.95 (0.79)	11.51 (1.25)	------------	NS
PTA	ET	-5.03 (0.80)	-7.32 (1.49)*	-5.06 (1.29)	-5.08 (0.68)	2.88 (0.12 to 4.45)	0.036
	ST	-5.01 (0.83)	-7.08 (0.46)*	-5.06 (1.02)	-5.07 (0.80)	2.02 (0.93 to 3.11)	0.001
Scapula Tilting							
Start	ET	-16.17 (2.97)	-16.08 (2.52)	-16.23 (1.92)	-15.25 (3.17)	------------	NS
	ST	-16.11 (3.92)	-15.68 (3.02)	-16.25 (2.93)	16.09 (3.73)	------------	NS
ROM	ET	7.21 (1.83)	7.87 (2.32)	7.62 (3.11)	7.88 (2.04)	------------	NS
	ST	7.77 (3.26)	7.63 (1.72)	7.42 (2.43)	7.75 (2.84)	------------	NS
PTA	ET	-11.28 (1.32)	-10.09 (0.61)	-11.98 (1.23)	-11.61 (1.87)	------------	NS
	ST	-11.28 (1.16)	-11.56 (2.50)	-11.24 (2.40)	-10.31(2.15)	------------	NS
Elbow Flexion-Extension							
Start	ET	71.40 (3.52)	70.44 (19.63)	70.92 (13.16)	70.76 (13.56)	------------	NS
	ST	70.78 (6.25)	71.16 (4.70)	71.40 (3.51)	70.48 (4.75)	------------	NS
ROM	ET	27.28 (7.08)	26.25 (5.56)	26.95 (3.23)	29.84 (7.93)	------------	NS
	ST	27.47 (5.24)	28.31 (3.86)	27.17 (6.89)	27.45 (12.18)	------------	NS
PTA	ET	72.25 (7.10)	59.68 (6.41)*	72.96 (5.37)	72.13 (6.69)	12.57 (6.90 to 18.17)	<0.001
	ST	72.44 (6.99)	59.55 (6.70)*	71.69 (6.88)	71.17 (6.03)	12.89 (6.79 to 18.98)	<0.001
Elbow Pronation-Supination							
Start	ET	121.39 (5.61)	121.25 (11.42)	122.03 (13.21)	122.14 (14.76)	------------	NS
	ST	122.09 (13.90)	122.20 (12.77)	121.49 (8.15)	121.76 (12.34)	------------	NS
ROM	ET	13.33 (1.29)	13.33 (1.30)	13.97(1.34)	13.88 (2.75)	------------	NS
	ST	13.29 (1.10)	13.84 (1.11)	13.75 (0.60)	13.35 (1.58)	------------	NS
PTA	ET	112.67 (6.30)	112.84 (7.65)	112.54 (11.10)	112.86 (10.70)	------------	NS
	ST	112.27 (16.33)	113.03 (8.14)	113.96 (3.61)	111.79 (6.97)	------------	NS
Trunk Flexion-Extension							
Start	ET	7.28 (0.48)	5.98 (0.82)*	7.41 (1.49)	7.37 (1.10)	1.16 (0.09 to 2.23)	0.031
	ST	7.36 (0.68)	6.20 (0.54)*	7.32 (0.73)	7.57 (0.65)	1.30 (0.29 to 2.31)	0.010
ROM	ET	2.66 (0.45)	2.58 (0.31)	2.65 (1.05)	2.61 (0.76)	NS	

	ST	2.70 (0.27)	2.62 (0.81)	2.65 (0.20)	2.60 (0.21)	NS	
PTA	ET	7.24 (0.40)	6.12 (0.63)*	7.54 (0.63)	7.43 (0.54)	1.04 (0.50 to 1.57)	<0.001
	ST	7.33 (0.40)	6.30 (0.62)*	7.18 (0.47)	7.33 (0.69)	1.03 (0.55 to 1.53)	<0.001
Trunk Lateral Flexion							
Start	ET	0.58 (0.23)	0.62 (0.18)	0.63 (0.28)	0.64 (0.23)	------------	NS
	ST	0.61 (0.30)	0.65 (0.21)	0.60 (0.18)	0.61 (0.25)	------------	NS
ROM	ET	2.91 (1.06)	2.91 (0.88)	2.92 (0.72)	2.96 (0.81)	------------	NS
	ST	3.01 (0.60)	2.99 (0.45)	2.89 (0.60)	2.96 (0.65)	------------	NS
PTA	ET	-1.16 (0.65)	-1.01 (0.64)	-1.18 (0.51)	-1.19 (0.80)	------------	NS
	ST	-1.14 (0.76)	-1.04 (0.48)	-1.14 (0.76)	-1.16 (0.62)	------------	NS
Trunk Axial Rotation							
Start	ET	0.48 (0.34)	0.46 (0.33)	0.42 (0.26)	0.48 (0.25)	------------	NS
	ST	0.44 (0.22)	0.48 (0.22)	0.44 (0.34)	0.46 (0.32)	------------	NS
ROM	ET	6.89 (1.52)	6.61 (1.03)	6.77 (2.02)	7.24 (2.48)	------------	NS
	ST	6.78 (2.00)	7.21 (1.16)	6.92 (1.48)	6.71 (1.79)	------------	NS
PTA	ET	4.84 (0.47)	5.01 (1.72)	5.00 (1.72)	4.85 (2.65)	------------	NS
	ST	4.79 (1.68)	4.84 (2.37)	4.75 (1.15)	4.79 (1.68)	------------	NS

Data expressed as mean and standard deviation. ET: Elastic tape first group. ST: Sham Tape first group. Start: Starting angle. PTA: Point of Task Achievement. ROM: Range of Motion. CI: confidence interval (just for variable with significant interaction effect). p-value of comparison between pre and post elastic tape intervention for each group (ET and ST). ------------: when p-value of interaction, group and time evaluation effects were not significant. NS: not significant (interaction, group and time evaluation effects). *p<0.05 compared to pre-intervention.

Table 6. ROM and PTA for all joints assessed while transporting the glass to the mouth for both groups (ET and ST) pre and post-interventions (elastic and sham tape).

		Interventions					
	Group	**Elastic Tape**		**Sham Tape**		**Mean difference (95% CI)**	**p-value**
		Pre	**Post**	**Pre**	**Post**		
Elevation Plane							
ROM	ET	16.49 (6.77)	14.20 (4.12)	15.55 (6.81)	14.31 (5.83)	------------	NS
	ST	16.26 (4.66)	14.49 (4.40)	15.61 (5.43)	16.16 (3.94)	------------	NS
PTA	ET	60.88 (3.36)	68.51 (2.41)*	62.36 (2.76)	61.24 (4.29)	-7.63 (-11.63 to -3.63)	<0.001
	ST	61.04 (7.39)	69.40 (4.44)*	60.96 (5.20)	60.47 (3.06)	-8.36 (-14.01 to-2.72)	0.004
Shoulder Elevation							
ROM	ET	10.48 (2.67)	10.10 (7.57)	10.71 (5.55)	10.82 (2.65)	------------	NS
	ST	10.87 (3.96)	10.74 (6.72)	10.90 (2.89)	10.37 (3.67)	------------	NS
PTA	ET	-44.11 (12.08)	-60.51 (11.49)*	-45.68 (5.47)	-46.21 (4.69)	16.40 (4.28 to 28.52)	0.007
	ST	-44.74 (6.53)	-59.88 (8.30)*	-43.34 (11.92)	-44.41 (9.33)	15.13 (5.79 to 24.48)	0.002
Shoulder Rotation							
ROM	ET	14.91 (5.22)	15.39 (4.35)	15.18 (7.88)	14.04 (3.90)	------------	NS
	ST	11.43 (4.02)	14.50 (6.03)	15.18 (5.78)	14.91 (5.22)	------------	NS
PTA	ET	-45.98 (9.15)	-46.30 (12.41)	-45.23 (7.05)	-45.22 (7.36)	------------	NS
	ST	-45.14 (18.03)	-45.22 (7.36)	-46.00 (6.08)	-45.77 (9.77)	------------	NS
Scapula Protraction-Retraction							
ROM	ET	3.45 (0.81)	3.11 (1.93)	3.90 (1.50)	3.89 (0.93)	------------	NS
	ST	3.74 (1.50)	3.79 (1.48)	3.62 (1.40)	3.52 (0.68)	------------	NS
PTA	ET	42.27 (2.74)	33.77 (3.17)*	41.59 (3.28)	40.50 (2.84)	-4.85 (-7.97 to -1.73)	0.002
	ST	40.26 (3.55)	35.02 (3.06)*	40.95 (3.01)	40.00 (3.13)	-4.99 (-7.90 to -2.08)	0.001
Scapula Rotation							
ROM	ET	5.77 (2.63)	4.16 (1.59)	4.98 (2.01)	4.69 (1.55)	------------	NS
	ST	4.92 (1.76)	5.00 (2.51)	4.89 (1.88)	4.34 (1.42)	------------	NS
PTA	ET	-12.88 (2.24)	-7.89 (2.43)*	-12.73 (2.22)	-13.68 (2.25)	-4.85 (-7.97 to -1.73)	0.002
	ST	-12.85 (3.83)	-8.00 (2.82)*	-12.44 (4.80)	-12.55 (4.84)	-4.99 (-7.90, -2.08)	0.001
Scapula Tilting							
ROM	ET	2.66 (0.82)	2.94 (0.55)	2.72 (1.28)	2.55 (0.71)	-----------	NS

	ST	2.39 (0.59)	2.86 (0.63)	2.43 (0.68)	2.30 (0.41)	------------	NS
PTA	ET	-9.66 (4.73)	-9.51 (2.97)	-9.70 (1.45)	-9.70 (2.58)	------------	NS
	ST	-9.73 *4.48)	-9.19 (7.05)	-9.51 (4.16)	-10.14 (3.95)	------------	NS
Elbow Flexion-Extension							
ROM	ET	56.08 (13.85)	57.97 (6.68)	59.12 (11.15)	58.43 (8.03)	------------	NS
	ST	54.52 (7.78)	58.18 (9.94)	58.89 (6.11)	59.35 (10.83)	------------	NS
PTA	ET	127.53 (4.96)	126.78 (2.58)	127.95 (10.38)	128.36 (6.56)	------------	NS
	ST	125.96 (9.64)	128.22 (5.96)	127.53 (4.96)	125.30 (6.30)	------------	NS
Elbow Pronation-Supination							
ROM	ET	15.56 (2.54)	17.86 (3.23)	17.72 (3.16)	18.27 (2.88)	------------	NS
	ST	16.58 (4.39)	16.88 (4.24)	15.39 (2.50)	16.32 (2.35)	------------	NS
PTA	ET	103.53 (10.95)	104.79 (6.73)	104.05 (13.42)	107.18 (9.29)	------------	NS
	ST	104.96 (15.83)	104.65 (9.18)	102.64 (11.06)	104.48 (9.42)	------------	NS
Trunk Flexion-Extension							
ROM	ET	2.18 (0.69)	2.18 (0.96)	2.35 (0.69)	2.44 (1.03)	------------	NS
	ST	2.20 (1.14)	2.14 (0.89)	2.26 (0.85)	2.15 (0.63)	------------	NS
PTA	ET	4.34 (0.97)	2.37 (0.80)*	4.49 (0.97)	4.34 (0.77)	1.98 (0.74 to 3.21)	0.002
	ST	4.28 (0.90)	2.33 (0.75)*	4.27 (0.70)	4.32 (1.00)	1.94 (0.38 to 3.50)	0.013
Trunk Lateral Flexion							
ROM	ET	2.55 (1.50)	3.46 (1.14)	2.66 (1.49)	2.44 (1.10)	------------	NS
	ST	2.71 (1.26)	2.24 (0.85)	2.63 (0.79)	2.46 (1.43)	------------	NS
PTA	ET	0.57 (2.98)	0.54 (2.74)	0.53 (2.48)	0.55 (2.45)	------------	NS
	ST	0.44 (3.25)	0.50 (2.66)	0.52 (2.77)	0.62 (2.55)	------------	NS
Trunk Axial Rotation							
ROM	ET	6.26 (2.79)	6.24 (1.86)	6.45 (2.37)	6.62 (1.97)	------------	NS
	ST	6.15 (1.08)	6.07 (0.95)	5.77 (1.21)	6.39 (1.01)	------------	NS
PTA	ET	1.80 (1.42)	1.79 (0.90)	1.81 (0.68)	1.84 (0.77)	------------	NS
	ST	1.81 (1.00)	1.80 (0.99)	1.78 (0.75)	1.76 (0.66)	------------	NS

Data expressed as mean and standard deviation. ET: Elastic tape first group. ST: Sham Tape first group. Start: Starting angle. PTA: Point of Task Achievement. ROM: Range of Motion. CI: confidence interval (just for variable with significant interaction effect). p-value of comparison between pre and post elastic tape intervention for each group (ET and ST). ------------: when p-value of interaction, group and time evaluation effects were not significant. NS: not significant (interaction, group and time evaluation effects). *p<0.05 compared to pre-intervention.

Table 7. ROM and PTA for all joints assessed while transporting the glass to the table for both groups (ET and ST) pre and post-interventions (elastic and sham tape).

		Interventions					
	Group	**Elastic Tape**		**Sham Tape**		**Mean difference (95% CI)**	**p-value**
		Pre	**Post**	**Pre**	**Post**		
Elevation Plane							
ROM	ET	10.07 (2.56)	10.94 (2.36)	9.85 (2.18)	10.61 (2.94)	------------	NS
	ST	10.81 (4.14)	9.89 (0.99)	10.23 (3.15)	10.95 (2.65)	------------	NS
PTA	ET	71.29 (0.83)	80.31 (1.40)*	72.10 (3.82)	71.06 (2.42)	-9.02 (-12.89 to -5.15)	<0.001
	ST	71.20 (2.76)	79.93 (3.98)*	71.34 (0.60)	71.71 (4.16)	-8.73 (-13.04 to -4.43)	<0.001
Shoulder Elevation							
ROM	ET	10.62 (4.07)	10.91 (1.82)	10.34 (2.87)	10.92 (3.88)	------------	NS
	ST	10.63 (1.83)	10.86 (4.85)	10.96 (3.03)	10.68 (1.59)	------------	NS
PTA	ET	-54.86 (4.00)	-54.12 (2.32)	-54.12 (2.32)	-54.68 (3.01)	------------	NS
	ST	-54.47 (3.48)	-54.43 (1.59)	-54.21 (2.92)	-54.83 (2.94)	------------	NS
Shoulder Rotation							
ROM	ET	11.58 (3.98)	11.47 (2.13)	11.45 (3.41)	11.12 (4.08)	------------	NS
	ST	11.13 (4.14)	11.36 (3.98)	11.91 (6.38)	11.23 (6.46)	------------	NS
PTA	ET	-61.74 (12.60)	-62.57 (12.13)	-61.63 (9.88)	-62.49 (9.64)	------------	NS
	ST	-62.88 (11.23)	-61.69 (10.30)	-61.17 (11.22)	-61.82 (11.52)	------------	NS
Scapula Protraction-Retraction							
ROM	ET	4.32 (1.21)	4.22 (0.56)	4.51 (1.80)	4.36 (1.67)	------------	NS
	ST	4.24 (0.83)	4.16 (1.37)	4.18 (1.04)	4.30 (1.36)	------------	NS
PTA	ET	45.41 (4.78)	37.98 (6.47)*	45.15 (3.41)	44.58 (2.94)	7.43 (3.51 to 11.34)	0.001
	ST	45.22 (2.64)	37.36 (2.97)*	45.73 (2.98)	44.76 (4.19)	7.86 (1.30 to 14.41)	0.016
Scapula Rotation							
ROM	ET	4.26 (0.42)	4.21 (0.42)	4.48 (1.47)	4.11 (0.86)	------------	NS
	ST	4.34 (0.78)	4.28 (0.85)	4.12 (1.54)	4.32 (1.38)	------------	NS
PTA	ET	-11.56 (2.95)	-11.51 (2.22)	-11.68 (2.22)	-11.72 (2.56)	------------	NS
	ST	-11.97 (2.24)	-11.47 (3.01)	-10.96 (2.91)	-11.06 (4.63)	------------	NS
Scapula Tilting							
ROM	ET	2.73 (0.80)	2.75 (0.72)	2.76 (0.91)	2.73 (1.08)	------------	NS

	ST	2.73 (0.59)	2.72 (0.66)	2.75 (0.84)	2.70 (0.40)	------------	NS
PTA	ET	-11.93 (2.46)	-11.50 (1.41)	-10.86 (1.97)	-11.41 (1.19)	------------	NS
	ST	-11.10 (2.08)	-11.36 (0.72)	-11.44 (3.16)	-11.27 (2.03)	------------	NS
Elbow Flexion-Extension							
ROM	ET	58.74 (6.45)	58.86 (2.30)	58.20 (5.91)	58.59 (7.77)	------------	NS
	ST	58.25 (7.89)	58.08 (7.53)	58.49 (8.34)	58.91 (8.56)	------------	NS
PTA	ET	69.43 (3.16)	61.30 (2.40)*	68.61 (3.86)	69.98 (3.86)	8.13 (1.48 to 14.79)	0.014
	ST	69.56 (5.38)	61.36 (3.12)*	69.27 (3.03)	69.16 (7.53)	8.20 (4.03 to 12.38	<0.001
Elbow Pronation-Supination							
ROM	ET	12.76 (5.13)	12.83 (5.13)	12.52 (3.19)	12.95 (5.02)	------------	NS
	ST	12.63 (4.90)	12.38 (3.47)	12.78 (5.42)	12.81 (5.75)	------------	NS
PTA	ET	115.09 (9.93)	116.25 (14.75)	115.40 (12.41)	115.31 (8.56)	------------	NS
	ST	115.99 (9.95)	116.28 (10.56)	115.29 (10.59)	114.74 (14.46)	------------	NS
Trunk Flexion-Extension							
ROM	ET	2.87 (1.08)	2.86 (0.92)	2.86 (1.03)	2.84 (1.35)	------------	NS
	ST	2.87 (0.94)	2.86 (1.09)	2.86 (1.14)	2.89 (1.47)	------------	NS
PTA	ET	6.37 (3.29)	4.27 (1.95)*	6.27 (2.94)	6.29 (3.34)	3.74 (1.21 to 6.27)	0.004
	ST	6.25 (1.37)	4.25 (1.19)*	6.23 (2.41)	6.22 (2.07)	2.00 (0.34 to 3.65)	0.016
Trunk Lateral Flexion							
ROM	ET	1.90 (0.75)	2.07 (0.84)	1.83 (1.20)	1.75 (0.77)	------------	NS
	ST	2.05 (1.06)	2.02 (0.63)	1.94 (0.73)	1.82 (1.02)	------------	NS
PTA	ET	1.14 (0.48)	1.20 (0.53)	1.20 (0.30)	1.25 (0.51)	------------	NS
	ST	1.31 (0.58)	1.29 (0.53)	1.24 (0.46)	1.40 (0.58)	------------	NS
Trunk Axial Rotation							
ROM	ET	4.06 (1.05)	3.79 (1.17)	4.10 (1.23)	3.94 (1.15)	------------	NS
	ST	4.31 (1.71)	4.32 (1.11)	4.17 (1.46)	3.90 (1.69)	------------	NS
PTA	ET	4.82 (1.46)	4.55 (1.24)	4.37 (1.47)	4.43 (1.36)	------------	NS
	ST	4.81 (1.48)	4.70 (1.60)	5.22 (1.37)	4.96 (1.70)	------------	NS

Data expressed as mean and standard deviation. ET: Elastic tape first group. ST: Sham Tape first group. Start: Starting angle. PTA: Point of Task Achievement. ROM: Range of Motion. CI: confidence interval (just for variable with significant interaction effect). p-value of comparison between pre and post elastic tape intervention for each group (ET and ST). ------------: when p-value of interaction, group and time evaluation effects were not significant. NS: not significant (interaction, group and time evaluation effects). *$p<0.05$ compared to pre-intervention.

Table 6 – ROM and PTA for all joints assessed while returning to the initial position for both groups (ET and ST) pre and post-interventions (elastic and sham tape).

		Interventions					
	Group	**Elastic Tape**		**Sham Tape**		**Mean difference (95% CI)**	**p-value**
		Pre	**Post**	**Pre**	**Post**		
Elevation Plane							
ROM	ET	49.03 (11.68)	47.34 (11.67)	48.45 (10.20)	48.62 (11.22)	------------	NS
	ST	49.32 (12.53)	47.99 (12.53)	48.66 (13.48)	48.30 (12.74)	------------	NS
PTA	ET	19.99 (12.19)	35.72 (17.21)*	21.55 (11.34)	23.49 (11.97)	-15.73 (-30.54 to -0.92)	0.034
	ST	21.96 (12.07	36.13 (12.50)*	18.11 (11.76)	20.63 (10.73)	-14.18 (-20.15 to -8.20)	<0.001
Shoulder Elevation							
ROM	ET	35.30 (4.08)	35.98 (2.37)	35.17 (5.33)	36.08 (1.93)	------------	NS
	ST	35.81 (6.69)	33.52 (2.42)	35.17 (7.26)	35.72 (5.34)	------------	NS
PTA	ET	-18.91 (2.81)	-20.66 (3.30)	-22.35 (5.26)	-18.53 (3.23)	------------	NS
	ST	-19.12 (3.86)	-16.79 (1.73)	-18.85 (2.09)	-21.62 (1.94)	------------	NS
Shoulder Rotation							
ROM	ET	28.79 (3.13)	28.30 (0.92)	28.20 (9.32)	29.46 (4.92)	------------	NS
	ST	26.61 (2.66)	26.95 (4.42)	26.79 (7.39)	29.36 (5.54)	------------	NS
PTA	ET	-35.44 (11.52)	-35.23 (6.10)	-37.34 (5.73)	-36.36 (6.04)	------------	NS
	ST	-36.30 (4.81)	-35.32 (4.84)	-35,82 (5.06)	-36.30 (4.81)	------------	NS
Scapula Protraction-Retraction							
ROM	ET	6.96 (2.08)	6.55 (2.02)	7.38 (1.91)	7.55 (2.23)	------------	NS
	ST	6.82 (1.64)	7.37 (2.08)	6.37 (1.81)	7.05 (1.85)	------------	NS
PTA	ET	38.15 (1.93)	32.61 (2.60)*	38.40 (5.53)	37.60 (5.85)	5.53 (1.15 to 9.91)	0.012
	ST	39.57 (3.88)	30.86 (1.34)*	38.11 (6.35)	38.16 (5.81)	8.70 (0.47 to 16.94)	0.036
Scapula Rotation							
ROM	ET	11.86 (1.60)	12.70 (1.18)	12.67 (4.26)	10.93 (1.29)	------------	NS
	ST	12.01 (3.87)	12.14 (2.02)	11.80 (2.03)	12.22 (2.24)	------------	NS
PTA	ET	-1.65 (2.22)	-1.81 (1.58)	-1.77 (3.18)	-1.55 (2.99)	------------	NS
	ST	-1.52 (4.65)	-1.29 (4.83)	-1.61 (3.83)	-1.39 (3.53)	------------	NS
Scapula Tilting							
ROM	ET	4.81 (1.87)	4.93 (1.92)	4.24 (1.65)	4.74 (2.08)	------------	NS

	ST	4.95 (2.12)	4.67 (2.65)	4.90 (1.50)	2.95 (1.35)	------------	NS
PTA	ET	-14.06 (2.26)	-12.90 (0.20)	-13.92 (3.22)	-12.88 (1.56)	------------	NS
	ST	-12.66 (1.89)	-13.89 (3.85)	-13.56 (0.60)	-13.16 (0.81)	------------	NS
Elbow Flexion-Extension							
ROM	ET	27.71 (12.78)	27.04 (10.37)	26.67 (10.36)	27.65 (9.97)	------------	NS
	ST	27.84 (5.02)	28.50 (10.38)	27.21 (9.94)	26.84 (5.22)	------------	NS
PTA	ET	75.12 (14.16)	74.67 (8.62)	75.29 (7.72)	77.13 (10.17)	------------	NS
	ST	77.40 (12.21)	76.26 (15.32)	76.46 (10.79)	75.56 (15.15)	------------	NS
Elbow Pronation-Supination							
ROM	ET	12.98 (2.53)	12.21 (4.02)	12.19 (4.29)	12.30 (4.52)	------------	NS
	ST	12.48 (4.28)	11.83 (4.42)	12.37 (2.96)	12.02 (3.43)	------------	NS
PTA	ET	122.18 (10.74)	121.15 (12.12)	122.89 (14.64)	121.15 (11.84)	------------	NS
	ST	120.07 (17.94)	121.47 (10.89)	121.66 (15.27)	122.11 (12.87)	------------	NS
Trunk Flexion-Extension							
ROM	ET	3.36 (0.45)	3.44 (0.47)	3.32 (0.36)	3.15 (1.10)	------------	NS
	ST	3.25 (0.35)	3.33 (0.50)	3.31 (0.65)	3.20 (0.49)	------------	NS
PTA	ET	6.24 (1.19)	3.86 (0.86)*	6.32 (1.69)	6.17 (1.92)	------------	NS
	ST	6.27 (1.24)	3.08 (1.14)*	6.23 (1.04)	6.13 (1.15)	------------	NS
Trunk Lateral Flexion							
ROM	ET	1.80 (1.19)	1.83 (0.87)	1.79 (0.50)	1.81 (0.79)	------------	NS
	ST	1.82 (0.98)	1.89 (1.17)	1.80 (1.16)	1.78 (0.89)	------------	NS
PTA	ET	1.55 (1.08)	1.59 (0.88)	1.56 (1.11)	1.74 (1.28)	2.58 (1.09 to 4.08)	0.001
	ST	1.62 (1.13)	1.56 (0.87)	1.73 (1.37)	1.56 (0.97)	3.19 (2.03 to 4.35)	<0.001
Trunk Axial Rotation							
ROM	ET	4.37 (0.27)	3.76 (0.55)	4.20 (1.88)	4.52 (1.62)	------------	NS
	ST	3.47 (0.88)	4.56 (2.20)	4.15 (1.48)	4.22 (1.94)	------------	NS
PTA	ET	0.85 (1.62)	0.91 (1.98)	0.78 (2.21)	0.87 (2.48)	------------	NS
	ST	0.81 (2.94)	0.79 (2.97)	0.82 (2.07)	0.77 (3.32)	------------	NS

Data expressed as mean and standard deviation. ET: Elastic tape first group. ST: Sham Tape first group. Start: Starting angle. PTA: Point of Task Achievement. ROM: Range of Motion. CI: confidence interval (just for variable with significant interaction effect). p-value of comparison between pre and post elastic tape intervention for each group (ET and ST). ------------: when p-value of interaction, group and time evaluation effects were not significant. NS: not significant (interaction, group and time evaluation effects). *p<0.05 compared to pre-intervention.

For the <u>PTA angles,</u> common interaction effects for all phases were observed (5-8), which consisted of more shoulder motion towards midline (for all phases: $p<0.001$, $\eta^2=0.32$ [reaching], $\eta^2=0.41$ [transporting to the mouth and returning]; $\eta^2=0.52$ [transporting to the table]), less scapula protraction (for all phases: $p=0.002$, $\eta^2=0.32$ [reaching]; $p=0.001$, $\eta^2=0.33$ [transporting to the mouth]; $p<0.001$, $\eta^2=0.32$ [transporting to the table]; $p=0.004$, $\eta^2=0.26$ [returning]), and less trunk anterior flexion (for all phases: $p<0.001$, $\eta^2=0.48$ [reaching], $\eta^2=0.42$ [transporting to the mouth]; $\eta^2=0.44$ [transporting to the table], $\eta^2=0.41$ [returning]) when elastic tape intervention was made compared to sham intervention.

Other specific interaction effects for <u>PTA angles</u> (Tables 5-8) were observed per phase. During the reaching phase, the elastic tape increased the scapula lateral rotation ($p<0.001$, $\eta^2=0.40$) and elbow extension ($p<0.001$, $\eta^2= 0.46$). At the end of transporting the glass to the mouth, patients who underwent the elastic tape intervention presented more shoulder elevation ($p=0.001$, $\eta^2=0.35$) and less scapula lateral rotation ($p=0.001$, $\eta^2=0.43$). In addition, a medium elastic tape effect was observed at the elbow, an indication for increased elbow extension at the end of transporting the glass to the mouth ($p<0.001$ $\eta^2=0.44$).

Kinematic waveforms

Figures 10-13 show the kinematic waveforms of joint motions with indications of significant differences between pre- and post-taping intervention while reaching, transporting the glass to the mouth, transporting the glass to the table, and returning to the initial position phases, respectively. SPM analysis revealed common differences between pre- and post-taping intervention for the elevation plane (more towards midline), less scapula protraction and trunk flexion while reaching (≈0-46% and 66-100%; 0-32% and 49-100%; 0-64% and 79-100%, respectively, Figure 10), transporting to the mouth (51-100%; 66-100%; 83-100%, respectively, Figure 11), transporting to the table (36-100%; 37-100%; 53-100%, respectively, Figure 12) and returning (69-100%; 87-100%; 90-100%, respectively, Figure 13). Moreover, more shoulder elevation and scapula lateral rotation during reaching (25-65% and 81-100%, respectively) (Figure 10), as well as more shoulder elevation and less scapula lateral rotation while transporting to the mouth (20-100% and 15-100%, respectively, Figure 11). Intervention effects were also observed for elbow joint (more extension) during reaching (54-100%, Figure 10) and transporting to the table (84-100%, Figure 12).

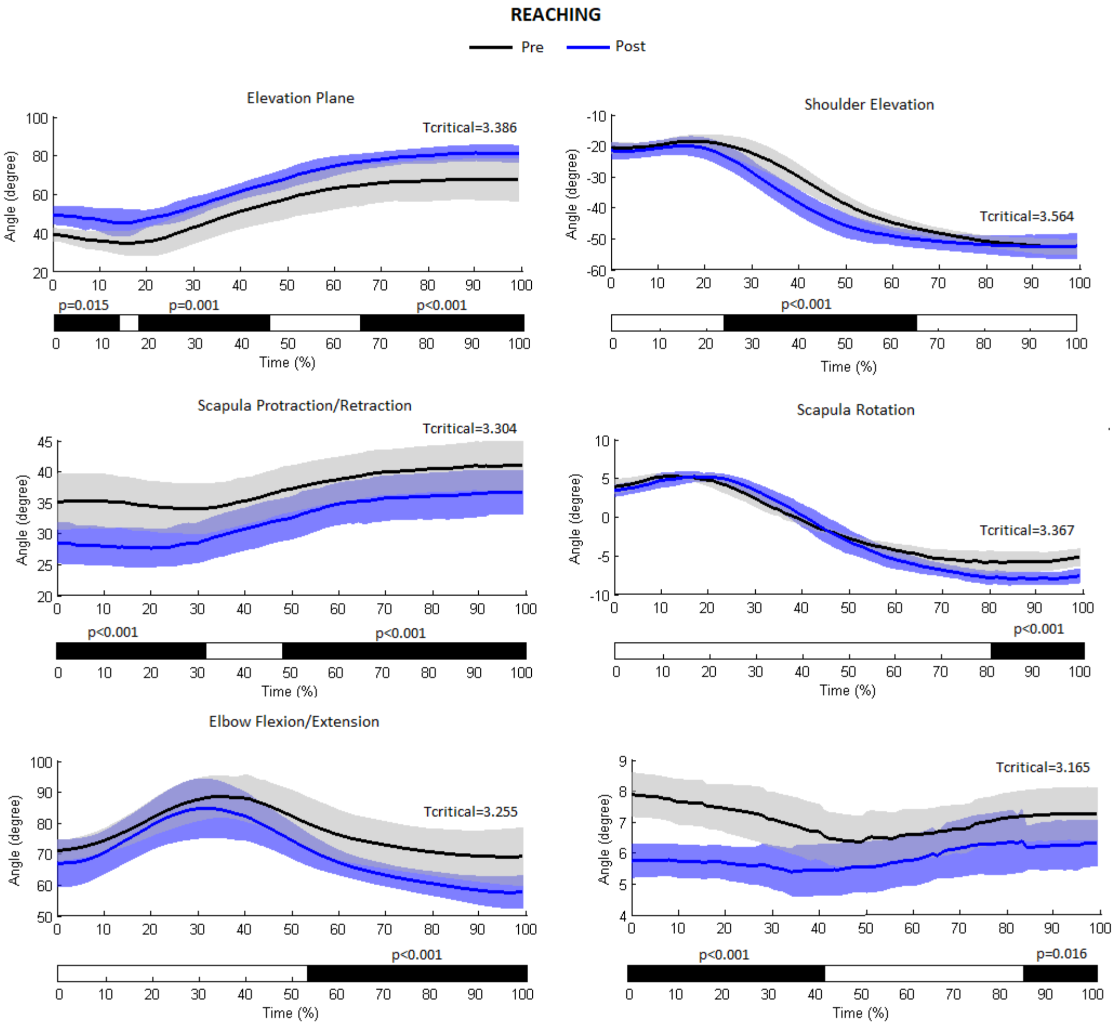

Figure 10. Upper limb joint angle waveforms while reaching for a glass at pre (black line) and post (blue line) elastic tape intervention. The black bar below the graph represents the time during which the differences between the evaluation time occur (p<0.05).

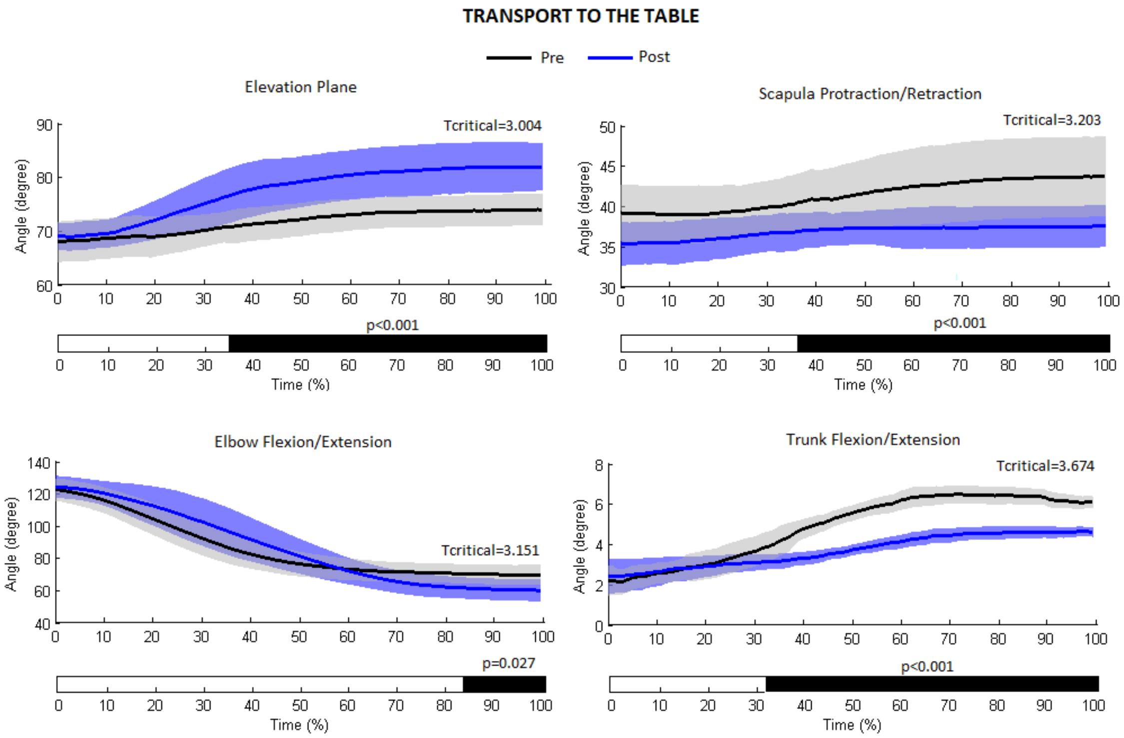

Figure 11. Upper limb joint angle waveforms during transporting the glass to the mouth at pre (black line) and post (blue line) elastic tape intervention. The black bar below the graph represents the time during which the differences between the evaluation time occur (p<0.05).

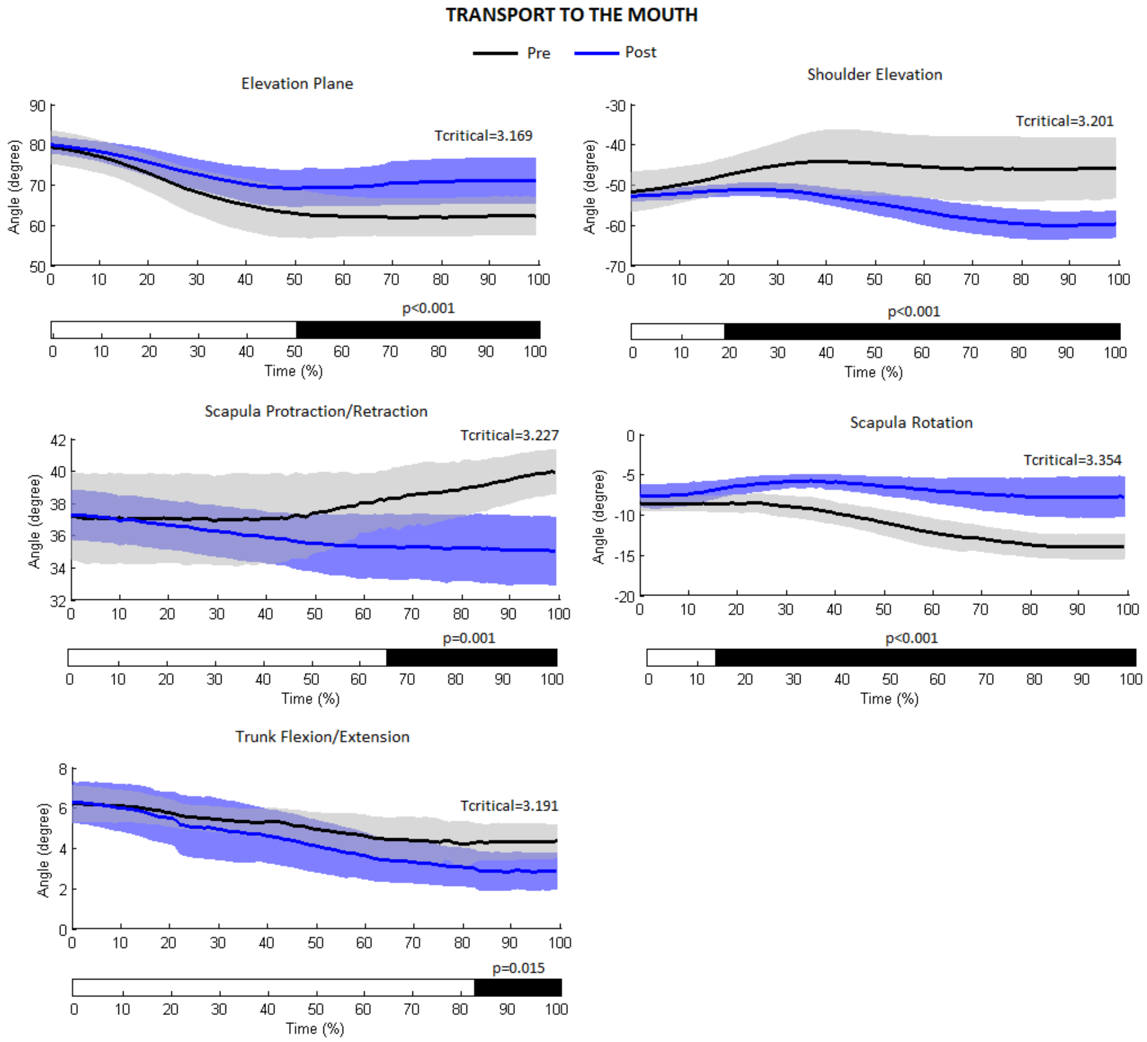

Figure 12. Upper limb joint angle waveforms during transporting the glass to the mouth at pre (black line) and post (blue line) elastic tape intervention. The black bar below the graph represents the time during which the differences between the evaluation time occur (p<0.05).

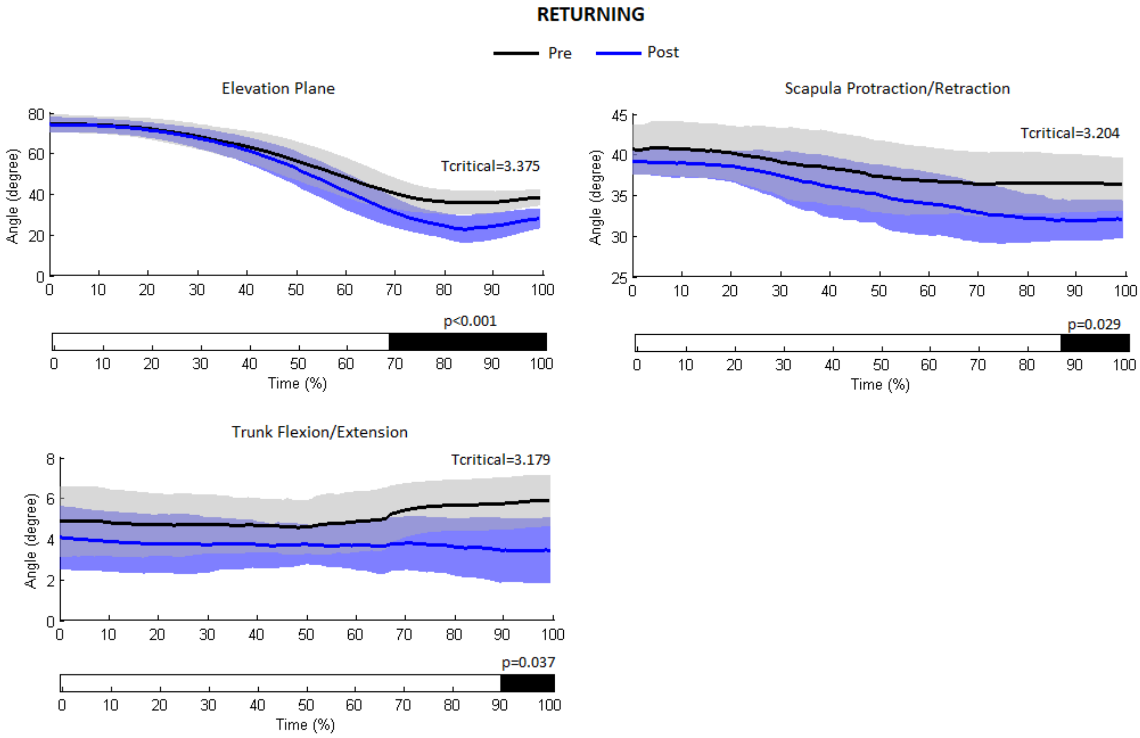

Figure 13. Upper limb joint angle waveforms while returning to the initial position at pre (black line) and post (blue line) elastic tape intervention. The black bar below the graph represents the time during which the differences between the evaluation time occur ($p<0.05$).

Discussion

Although elastic tape has been widely used by physiotherapists, its effect on UL movements has been studied only recently (Bell e Muller, 2013; Pandian *et al.*, 2013; Kim e Kim, 2015; Lee *et al.*, 2015; Huang *et al.*, 2016; Kalichman *et al.*, 2016; Pillastrini *et al.*, 2016). To the best of our knowledge, this is the first study that evaluated its effect on movement strategies during a functional task. The results of the present study revealed that elastic tape did not immediately influence the spatiotemporal parameters of the drinking task in chronic hemiparetic subjects with mild to moderate UL impairments. However, this intervention improved the shoulder position (more towards midline) and reduced scapula protraction and trunk flexion at the beginning, throughout, and at the end of the task, with small and medium effects. Moreover, using elastic tape increased shoulder elevation during reaching (for half the phase) and transporting the glass to the mouth increased the elbow extension near the table without and with the glass, increased the scapula lateral rotation (upward rotation) at the end of the reaching phase and decreased the scapula lateral rotation throughout the movement of bringing the glass to the mouth. Overall, these results demonstrated that elastic taping could alter UL movement strategies, thereby decreasing movement deviations in chronic hemiparetic individuals, taking age-gender matched healthy individuals as a reference (Santos, Russo, *et al.*, 2017).

The results of the present study are in line with the study by van Herzeele et al., who observed changes in scapular motion (i.e. higher posterior tilting and upward rotation) during humeral elevations in the sagittal, frontal, and scapular plane in athletes with elastic tape used from the coracoid process to the thoracic spine process over the upper trapezius muscle compared to the condition without intervention (Van Herzeele *et al.*, 2013). Camerota et al. verified the effects of elastic tape on UL performance during reaching tasks in children with Cerebral Palsy. After 2 weeks of treatment, they observed a decreased movement duration, and improved smoothness, straightness of motion and ROM of the shoulder and elbow (Camerota *et al.*, 2014). For stroke survivors, previous studies reported improved UL motor function, measured by FMA-UL (Huang *et al.*, 2016) and Manual Function Task (Kim e Kim, 2015), after three and 28 weeks of elastic tape treatment, respectively. Along the same lines, a large effect of elastic tape was observed resulting in improved shoulder joint position sense in chronic hemiparetic after 10 minutes of using it (Santos, Souza, *et al.*, 2017).

These previous studies, combined with neuroscience paradigms suggest that the change in UL movement strategies when using elastic tape occurs due to mechanical support, sensory stimulus and brain activity modulation (Callaghan *et al.*, 2012; Camerota *et al.*, 2014; Santos, Souza, *et al.*, 2017). Mechanical support might be related to improvements in neuromotor control of the shoulder girdle stabilizing muscles (Mcconnell *et al.*, 2011; Callaghan *et al.*, 2012). In other words, this intervention probably increases the sensitive input by tactile stimulation, which is processed and integrated by the central nervous system that transforms sensory information into planned movements and calculates the necessary programs for movements (feedforward and feedback control). This process is known as sensorimotor integration. All these mechanisms may favor the motor schemes (greater perception of the UL in space), performance and (re) learning of more physiological movements (Kandel *et al.*, 2000; Callaghan *et al.*, 2012; Camerota *et al.*, 2014; Roijezon *et al.*, 2015; Santos, Souza, *et* *al.*, 2017). Furthermore, these effects can be attributed to the elastic property of tape as these improvements in UL performance were not observed when the patients were treated with non-elastic tape.

However, it is important to highlight that the elastic tape influence on UL joint motions were expressed as small to medium effects, without effects on spatiotemporal variables. This points towards two important clinical aspects. First, the elastic tape should be used as an adjuvant intervention. It is especially important for taping to be combined with movement therapy. Generating movements increases the sensory stimulation by the tape and other factors (i.e. visual stimulus), which reinforce all the previously mentioned mechanisms. Second, although the effects were only small to moderate, they were observed 10 minutes after application, which corresponds to a very short period with the tape. Hence, it is suggested that the tape should be used at the beginning of the therapy session in order to generate immediate mechanical, sensory and neural effects, which could maximize the gains obtained by motor learning. In other words, taping could 'prime' the central nervous system for subsequent motor tasks (Stoykov e Madhavan, 2015).

While the overall results suggest the benefits of using elastic tape as an intervention associated with other therapies in chronic hemiparetic subjects with mild to moderate UL impairments, it should be noted that the findings are task-specific. The results were limited to the immediate effects of the elastic tape on motor performance during a drinking task. More-over, the sample size of chronic hemiparetic subjects was small, with mild or moderate UL sensorimotor impairment. Future studies should include larger sample sizes and should focus on the effect of long-term elastic tape on UL performance, during different functional tasks, as well as on its effect as adjuvant therapy, and its effect on stroke survivors with various degrees of UL impairment.

While it was not the primary aim of the present study to compare the methods of analyzing the data, it is important to highlight that the SPM analysis demonstrated the effects of the tape along the entire movement cycle. This extra analysis revealed information that was not observed by means of the extracted scalar kinematic parameters. For example, increased shoulder elevation was observed between 25% and 65% of the reach phase time, while no changes in extracted kinematic parameters were found. This underlines the benefits of including this complementary analysis to verify the joint motion strategies used during a UL task.

Conclusion

Elastic tape improved angular parameters during functional tasks in chronic stroke patients, after 10 minutes of use. However, only small to moderate effects were observed. In addition, elastic tape did not alter spatiotemporal parameters and ROM of trunk, scapulothoracic, humerothoracic and elbow motions. These results point to the inclusion of elastic tape as an adjuvant therapy and a ‘prime’ of the brain for subsequent motor training.

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CONSIDERAÇÕES FINAIS

Em resumo, os resultados da presente tese demonstraram que, após 10 minutos, a BE pode ser considerada como uma importante estratégia coadjuvante de intervenção para pacientes pós-AVC em fase crônico com comprometimento moderado do MS, proporcionando a melhorar do senso de posição articular do ombro e desempenho sensório-motor do MS durante a atividade de beber. Destacando-se que o senso de posição articular desempenha um papel importante nos controles de *feedback* e *feedforward* durante uma ação motora visando alcançar uma maior precisão, estabilidade articular e coordenação, o que pode ter influenciado nas alterações articulares durante a atividade de beber. Assim, estes estudos apontam para necessidade de pesquisas envolvendo os efeitos da BE associado à outras terapias, como o treino tarefa-especifica, bem como os efeitos em longo prazo e em pacientes pós-AVC com diferentes níveis de comprometimento.

Além disso, o segundo estudo apontou para a importância da inclusão da SPM análise ao proporcionar uma visão mais ampla e compreensiva dos efeitos da BE ao longo da atividade e ao revelar informações que não foram observadas a partir dos parâmetros escalares extraídas das curvas de movimento. Assim, recomenda-se a utilização desta análise complementar para verificar as estratégias de movimentos utilizadas durante as atividades do MS.

ATIVIDADES NO PERÍODO

No início do período do doutorado (01/2014), fui docente responsável pela disciplina e supervisão de estágio em Fisioterapia em Neurologia Adulto no Centro Universitário de Araraquara (UNIARA), o que proporcionou um pouco da experiência didática. No segundo semestre de 2014, a bolsa de doutorado no país foi aprovada pela FAPESP e me desvinculei da UNIARA para me dedicar somente ao doutorado e poder solicitar a Bolsa de Estágio de Pesquisa no Exterior (BEPE) à Fapesp, uma vez que eu sempre almejei a experiência internacional. Além disso, como descrito anterior na apresentação da tese, a parceria internacional foi estabelecida durante o mestrado, o que foi fundamental para o desenvolvimento do doutorado. E, no final de 2015, a BEPE também foi aprovada.

Desta forma, no ano de 2016 realizei o doutorado sanduíche na Universidade de Leuven (KU Leuven, Bélgica) sob supervisão da Prof^{a}. Dr^{a}. Kaat Desloovere, onde também estive vinculada à pesquisas envolvendo análise de movimento em crianças, além do projeto do doutorado. Também participei de outras atividades como cursos, palestras e seminários não vinculados ao tema da tese. Assim, além dos artigos apresentados nesta tese, foram produzidos um artigo que foi aceito para publicação em 2017 na *Archives of Physical Medicine and Rehabilitation* (ANEXO 3) e um artigo que está submetido à PLoS ONE (ANEXO 4), o qual envolveu a análise cinemática do MS de crianças durante diferentes atividades funcionais. Ainda como fruto desta parceria e do projeto de doutorado, outros artigos estão em elaboração.

Além de me envolver com o projeto do doutorado, durante este período, finalizei as análises e elaboração dos artigos do mestrado, os quais foram publicados na *Topics in Stroke Rehabilitation* (2015) (ANEXO 1), *Journal of Electromiography and Kinesiology* (2016) (ANEXO 2) e *Journal of Stroke and Cerebrovascular Diseases* (2016) (ANEXO 5); além de participar de outros projetos do laboratório, o qual culminou em artigo submetido à *American Journal of Physical Medicine Rehabilitation* (ANEXO 6), bem como em artigos que estão em elaboração. Estes projetos envolveram diversos assuntos vinculados, como efeito da crioterapia no senso de posição articular do tornozelo e espasticidade; efeito da terapia robótica no desempeno sensório-motor do tornozelo (*steadiness*); efeito da utilidade funcional de um objeto no desempenho do membro superior; e revisão sistemática sobre os efeitos da associação do exercício aeróbio e treino tarefa-específica na função motora do membro superior. Todos realizados com indivíduos pós-AVC.

Neste período, foram publicados artigos na *Developmental Neurorehabilitation* (2014) (ANEXO 7) e na *Journal of Motor Behavior* (2017) (ANEXO 8) como fruto de co-orientações de alunas da especialização em Neuropediatria da UFSCar. Também durante esses quatro anos, me envolvi com outros projetos nas áreas de Neuropediatria e Cardiologia, os quais culminaram na publicação de artigos na *Brazilian Journal of Physical Therapy* (2014) (ANEXO 9), *Journal of Motor Behavior* (2017) (ANEXO 10) e *Autonomic Neuroscience Basic and Clinical* (2017) (ANEXO 11). Além das publicações, durante o doutorado realizei cursos como do Método *Kinesio Taping*, Terapia por Contensão Induzida e *Statistical Parametric Mapping*; co-orientei outros alunos de graduação e pós-graduação; participei de projetos de extensão, supervisionei o estágio do Curso de Aprimoramento de Intervenção Precoce da UFSCar; e ministrei aulas na graduação (UFSCar e UNIT) e pós-graduação (UFSCar e Barão de Mauá). Além disso, foi publicado um capítulo de livro sobre bandagens nas disfunções neurológicas.

ANEXO 1 – Artigo publicado na *Topics in Stroke Rehabilitation.*

Joint position sense is bilaterally reduced for shoulder abduction and flexion in chronic hemiparetic individuals

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Background: The stroke is the leading cause of adult disability in the world. One of the main complaints of individuals post-stroke refers to the loss of function of the upper limb, as evidenced during the performance of activities of daily living. This difficulty may be related to an important component of sensorimotor control, joint position sense, a submodality of proprioception.

Objectives: To investigate whether the proprioception of both shoulders of chronic hemiparetic patients is altered during abduction and flexion.

Methods: Thirteen subjects with chronic hemiparesis due to ischemic stroke and 13 healthy subjects matched for gender and age was included. The joint sense position was assessed using a dynamometer. Absolute error for shoulder abduction and flexion at the 30 and 60° was calculated.

Results: No difference was found between the paretic and non-paretic limbs in movements at both 30 and 60°. Higher values of absolute error for both paretic and non-paretic limbs compared to the control were observed during abduction at 30 and at 60°.

Conclusions: Chronic ischemic post-stroke patients have bilateral proprioceptive deficits in the shoulder during abduction and flexion. But these deficits are dependent on the movement performed and the angle tested. The results demonstrate the need to include bilateral exercises and/or visual feedback in the rehabilitation program.

Keywords: Activities of daily living, Assessment, Cerebrovascular disorders, Chronic disability, Neurological disability

Introduction

One of the most common symptoms of stroke is hemiparesis contralateral to the site of damage, characterized by reduced motor control, muscle weakness, and abnormal muscle tone and movement patterns.[1] These symptoms cause deficits in the execution of movements of the upper limbs, such as reaching and grasping, and thus affect the ability to perform daily life activities.[2–4]

Reaching is a key functional activity of the upper extremities[5–7] and requires highly coordinated muscle actions to promote temporal and sequential adjustments of joint movements, which are constantly regulated by sensory afferents. The shoulder and elbow joints act as the prime regulators of the reaching movement and are thus responsible for the final position of the hand, making the necessary corrections for placement.[8]

Furthermore, reaching movements require adequate sensorimotor control to provide highly specialized and skilled use of the muscles of the upper limb[1,9] and for maintenance of the shoulder joint in a position that allows proper positioning of the arm and hand during reaching.[8,10] One of the most important components of the sensorimotor system is proprioception, which consists of afferent information arriving from the periphery and contributes to joint stability and to postural and motor controls.[11] Thus, proprioception is important for generating coordinated movements, such reaching and grasping,[12–15] confirmed by the previous studies, which observed the proprioception is related with Functional Independence Measurement (FIM).[13]

Proprioception can be divided into three submodalities: joint position sense, kinesthesia (perception of passive movement), and sense of force.[1,16,17]

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ANEXO 2 – Artigo publicado na *Journal of Electromiography and Kinesiology*.

Journal of Electromyography and Kinesiology 30 (2016) 151–160

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Torque steadiness and muscle activation are bilaterally impaired during shoulder abduction and flexion in chronic post-stroke subjects

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ABSTRACT

Objective: To characterize sensorimotor control and muscle activation in the shoulder of chronic hemiparetic during abduction and flexion in maximal and submaximal isometric contractions. Furthermore, to correlate submaximal sensorimotor control with motor impairment and degree of shoulder subluxation.

Methods: Thirteen chronic hemiparetic post-stroke age-gender matched with healthy were included. Isometric torques were assessed using a dynamometer. Electromyographic activity of the anterior and middle deltoid, upper trapezius, pectoralis major and serratus anterior muscles were collected. Variables were calculated for torque: peak, time to target, standard deviation (SD), coefficient of variation (CV), and standard error (RMSE); for muscle activity: maximum and minimum values, range and coefficient of activation. Motor impairment was determined by Fugl-Meyer and shoulder subluxation was measured with a caliper.

Results: Paretic and non-paretic limbs reduced peak and muscle activation during maximal isometric contraction. Paretic limb generated lower force when compared with non-paretic and control. Paretic and non-paretic presented higher values of SD, CV, RMSE, and CV for prime mover muscles and minimum values for all muscles during steadiness. No correlation was found between sensorimotor control, motor impairment and shoulder subluxation.

Conclusion: Chronic hemiparetic presented bilateral deficits in sensorimotor and muscle control during maximal and submaximal shoulder abduction and flexion.

1. Introduction

Stroke is the second leading cause of death and the first of disability in the adult population (Feigin et al., 2014). Although spontaneous motor recovery can be observed in hemiparetic subjects, 50–70% of these individuals present residual deficits in the upper extremities even 2–4 years post-stroke (Hunter and Crome, 2002). These deficits may be related to sensorimotor control disruption that includes impairments in strength (Andrews and Bohannon, 2000; Avila et al., 2013; Colebatch and Gandevia, 1989; Jung et al., 2002; McCrea et al., 2003; Turner et al., 2012), proprioception (Niessen et al., 2008; Santos et al., 2015), coordination (Murphy et al., 2006), and muscle synergies (Rueda et al., 2012).

A good method to evaluate sensorimotor control during activities of the upper limbs is the steadiness assessment (Chow and Stokic, 2011). This test evaluates the muscle's ability to maintain and modulate submaximal torques over time, which affects the performance of activities of daily living (Chow and Stokic, 2011; Lodha et al., 2010). Some studies have identified that post-stroke individuals present deficits in sensorimotor control during submaximal activities of both lower (Chow and Stokic, 2011, 2013, 2014) and upper extremities (elbow, wrist, and fingers) (Lodha et al., 2013; Lodha et al., 2010; Naik et al., 2011), which are correlated with the degree of motor impairment (Lodha et al., 2010).

Likewise, understanding muscle activation patterns is also important to clarify the sensorimotor deficits present in this population, since fluctuations in force are related to alterations in muscle activation (Graves et al., 2000; Shinohara et al., 2003). During sustained submaximal voluntary contractions of wrist and elbow

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ANEXO 3 – Publicação na *Archives of Physical Medicine and Rehabilitation*

ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation
journal homepage: www.archives-pmr.org
Archives of Physical Medicine and Rehabilitation 2017;■:■■■-■■■

ORIGINAL RESEARCH

Kinematic Analysis of a Drinking Task in Chronic Hemiparetic Patients Using Features Analysis and Statistical Parametric Mapping

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Abstract

Objective: To compare sitting posture and movement strategies between chronic hemiparetic and healthy subjects while performing a drinking task, using statistical parametric mapping (SPM) and feature analysis.

Design: Cross-sectional study.

Setting: A university physical therapy department.

Participants: Participants (N=26) consisted of chronic hemiparetic (n=13) and healthy individuals (n=13) matched for sex and age.

Interventions: Not applicable.

Main Outcome Measures: The drinking task was divided into phases: reaching, transporting the glass to mouth, transporting the glass to table, and returning to initial position. An SPM 2-sample t test was used to compare the entire kinematic waveforms of different joint angles (trunk, scapulothoracic, humerothoracic, elbow). Joint angles at the beginning and end of the motion, movement time, peak velocity timing, trajectory deviation, normalized integrated jerk, and range of motion were extracted from the motion data. Group differences for these parameters were analyzed using independent t tests.

Results: At the static posture and beginning of the reaching phase, patients showed a shoulder position more deviated from the midline and externally rotated with increased scapula protraction, medial rotation, anterior tilting, trunk anterior flexion and inclination to the paretic side. Altered spatiotemporal variables throughout the task were found in all phases, except for the returning phase. Patients returned to a similar posture as the task onset, except for the scapula, which was normalized after the reaching phase.

Conclusions: Chronic hemiparetic subjects showed more deviations in the proximal joints during seated posture and reaching. However, the scapular movement drew nearer to the healthy individuals' patterns after the first phase, showing an interesting point to consider in rehabilitation programs.

Archives of Physical Medicine and Rehabilitation 2017;■:■■■-■■■

More than 50% of poststroke individuals have chronic upper limb (UL) motor deficits,[1-4] which impair the performance of activities of daily living and functional independence.[5,6] Given the impact of these impairments, various studies[7-11] have assessed the UL performance during functional tasks, such as reaching and drinking. A tool widely used for analyzing such gross movements is 3-dimensional motion analysis (3DMA), which provides an objective and precise assessment of movement patterns, quality, and strategies.[7,8,12]

By using 3DMA, previous studies indicated an increased movement time,[7,8,11] time for the peak velocity of the hand, and number of movement units[8] during functional tasks (reaching or drinking) for hemiparetic subjects (paretic side) compared with

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ANEXO 4 – Artigo submetido à *PLoS ONE*.

PLOS ONE

Age-related changes in upper limb motion during typical development

--Manuscript Draft--

Manuscript Number:	
Article Type:	Research Article
Full Title:	Age-related changes in upper limb motion during typical development
Short Title:	Age-related upper limb movement characteristics
Corresponding Author:	Cristina Simon-Martinez, MSc KU Leuven Leuven, BELGIUM
Keywords:	upper extremity, movement patterns, motion analysis, maturation, typically developing children, neurodevelopmental disorders
Abstract:	Understanding the maturation of upper limb (UL) movement characteristics in typically developing (TD) children is key to explore UL deficits in those with neurodevelopmental disorders. Three-dimensional motion analysis (3DMA) offers a reliable tool to comprehensively evaluate UL motion. However, studies thus far mainly focused on specific pre-defined parameters extracted from kinematic waveforms. Here, we investigated age-related differences in UL movement characteristics over the entire movement cycle in TD children. We assessed the non-dominant UL of 60 TD children (mean age 10y3m±3y1m) using 3DMA during eight tasks: reaching (forwards (RF), upwards (RU), sideways (RS)), reach-to-grasp (sphere (RGS), vertical cylinder (RGV)) and activities-of-daily-living mimicking tasks (hand-to-head (HTH), hand-to-mouth (HTM), hand-to-shoulder (HTS)). We investigated differences between four age-groups (5-7y, 8-10y, 11-12y, 13-15y) in: (1) spatiotemporal parameters (movement duration, peak velocity, time-to-peak velocity and trajectory straightness), and (2) 12 UL joint angles, using Statistical Parametric Mapping (SPM). We found that the 5-7y children moved with lower peak velocity and less straight trajectories compared to the 11-12y group (peak velocity: RS, HTS, $p<0.01$; trajectory: RU, RS, RGV, HTS, $p<0.01$) and the 13-15y group (peak velocity: RF, RS, RGS, RGV, HTH, HTS, $p<0.01$; trajectory, all tasks, $p<0.01$). The 5-7y children showed increased scapular protraction compared to older children (8-10y and 11-12y, HTS), as well as increased scapular medial rotation compared to the 13-15y group (RGS). During RU, the 5-7y children moved more towards the frontal plane (shoulder), unlike the 13-15y group. Lastly, the 5-7y group used less elbow flexion than older children (11-12y and 13-15y) during HTH and HTS. In conclusion, we found a maturation in UL movement characteristics up to age 11-12y, when UL motion seemed to reach a plateau. The reference values provided in this study will help to further optimize the interpretation of UL deficits in children with neurodevelopmental disorders.
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	Hilde Feys
Opposed Reviewers:	
Additional Information:	

ANEXO 5 – Artigo publicado na *Journal of Stroke and Cerebrovascular Diseases.*

Decreased Brain-Derived Neurotrophic Factor Serum Concentrations in Chronic Post-Stroke Subjects

Gabriela Lopes Santos, MSc, Carolina Carmona Alcântara, MSc,
Marcela Abreu Silva-Couto, MSc, Luisa Fernanda García-Salazar, MSc, and
Thiago Luiz Russo, PhD

Background: Brain-derived neurotrophic factor (BDNF) plays a critical role in sensorimotor recovery after a stroke. However, few studies have assessed the circulating BDNF levels in post-stroke humans to understand its changes. This study was conducted to measure BDNF serum concentrations in subjects with chronic hemiparesis, as well as to correlate serum concentrations with age, post-stroke time, total score of Stroke Specific Quality of Life Scale (SS-QOL), mobility subscale score, and motor function of SS-QOL. *Methods:* Seventeen chronic post-stroke subjects matched by age and gender with healthy controls took part in the study. Personal data (age, hemiparesis side, and post-stroke time) were collected, and a physical examination (weight, height, body mass index) and SS-QOL assessment were carried out. On the same day, after the initial evaluation, venous blood samples were collected from the chronic post-stroke subjects and the healthy subjects. The BDNF serum concentrations were measured blindly by enzyme-linked immunosorbent assay. *Results:* Subjects with chronic hemiparesis presented a decrease in BDNF serum compared with healthy subjects ($P < .01$). There was no correlation between BDNF serum levels with post-stroke time, age or quality of life, mobility, and the upper extremity motor function ($P > .05$). BDNF concentrations are related to structural and functional recovery after stroke; thus, this reduction is important to understand the rehabilitation process more clearly. However, more studies are needed considering the genetic variations and other tools to assess motor impairment and functional independence. *Conclusion:* Chronic post-stroke subjects presented a decrease in BDNF serum concentrations, without a correlation with post-stroke time, age, and quality of life. **Key Words:** Brain-derived neurotrophic factor—stroke—neuronal plasticity—rehabilitation.

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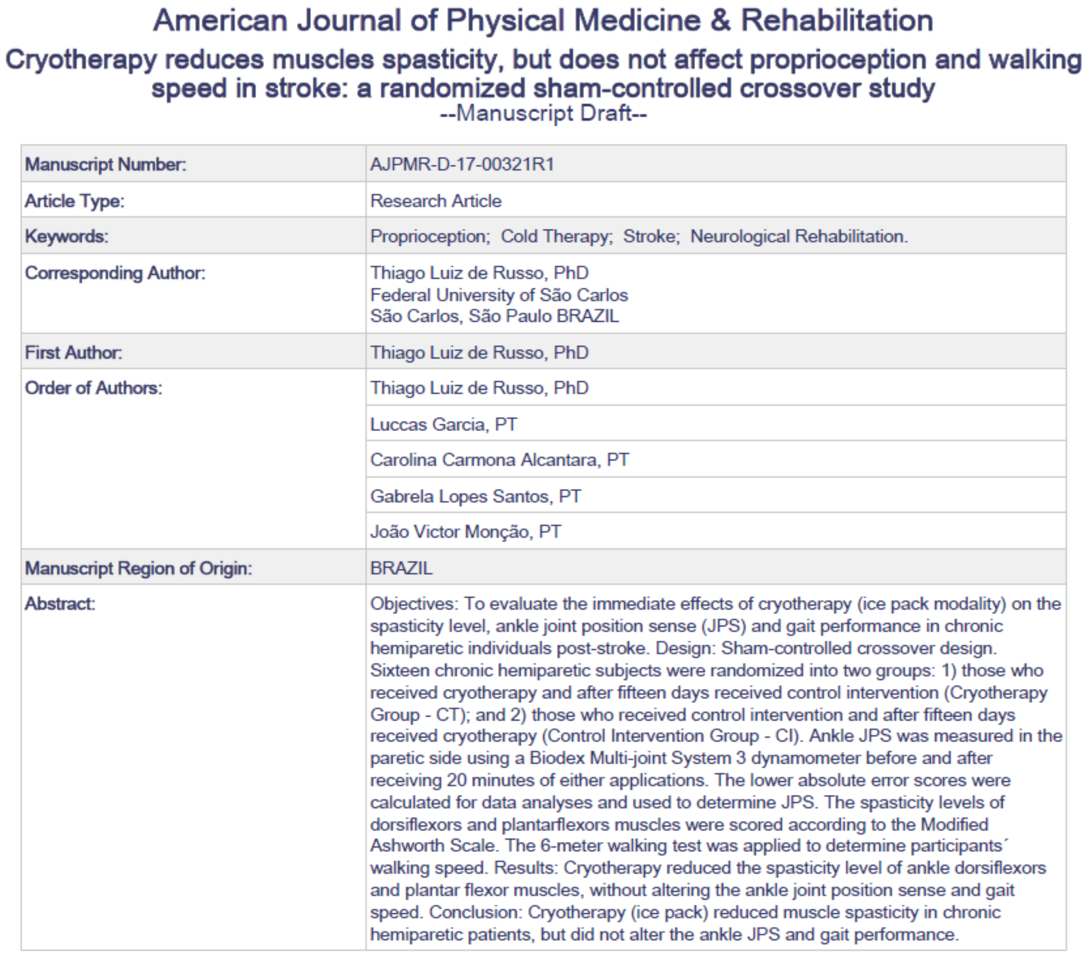
ANEXO 6 – Artigo submetido à *American Journal of Physical Medicine Rehabilitation.*



American Journal of Physical Medicine & Rehabilitation

Cryotherapy reduces muscles spasticity, but does not affect proprioception and walking speed in stroke: a randomized sham-controlled crossover study

--Manuscript Draft--

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Article Type:	Research Article
Keywords:	Proprioception; Cold Therapy; Stroke; Neurological Rehabilitation.
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	Gabrela Lopes Santos, PT
	João Victor Monção, PT
Manuscript Region of Origin:	BRAZIL
Abstract:	Objectives: To evaluate the immediate effects of cryotherapy (ice pack modality) on the spasticity level, ankle joint position sense (JPS) and gait performance in chronic hemiparetic individuals post-stroke. Design: Sham-controlled crossover design. Sixteen chronic hemiparetic subjects were randomized into two groups: 1) those who received cryotherapy and after fifteen days received control intervention (Cryotherapy Group - CT); and 2) those who received control intervention and after fifteen days received cryotherapy (Control Intervention Group - CI). Ankle JPS was measured in the paretic side using a Biodex Multi-joint System 3 dynamometer before and after receiving 20 minutes of either applications. The lower absolute error scores were calculated for data analyses and used to determine JPS. The spasticity levels of dorsiflexors and plantarflexors muscles were scored according to the Modified Ashworth Scale. The 6-meter walking test was applied to determine participants´ walking speed. Results: Cryotherapy reduced the spasticity level of ankle dorsiflexors and plantar flexor muscles, without altering the ankle joint position sense and gait speed. Conclusion: Cryotherapy (ice pack) reduced muscle spasticity in chronic hemiparetic patients, but did not alter the ankle JPS and gait performance.

ANEXO 7 – Artigo publicado na *Developmental Neurorehabilitation.*

DEVELOPMENTAL
NEUROREHABILITATION

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healthcare

SUBJECT REVIEW

Intrinsic properties and functional changes in spastic muscle after application of BTX-A in children with cerebral palsy: Systematic review

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Abstract

Objective: This article aimed to review the literature to verify the effect of botulinum toxin type A (BTX-A) on the intrinsic properties of spastic muscles and functionality in children with cerebral palsy (CP). *Methods*: A literature search was conducted in the following databases: CINAHL, SCOPUS, Web of Science and PubMed. Database searches were limited to the period from January 1993 to March 2014. *Results*: A total of 2182 papers were identified, and 17 met the inclusion criteria. Only one study analyzed the effect of the toxin on muscle intrinsic properties and others analyzed the effect on functionality. *Conclusion*: BTX-A application demonstrated no changes in the passive stiffness of spastic muscle. In relation to functional level, the evidence of BTX-A effect was controversial. These studies showed methodological quality limitations that restrict the interpretation of the results for the entire CP population, which justifies the need for further randomized controlled trials.

Keywords

Botulinum toxin, functionality, motor developmental, muscle spasticity, rehabilitation

History

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Introduction

Cerebral palsy (CP) is a group of permanent disorders of movement and posture caused by non-progressive lesions that occur during fetal development or in the infant brain [1]. Although the lesions have static characteristics, the secondary dysfunction in the musculoskeletal system following the lesion is progressive. This dysfunction includes decreased muscle strength [2, 3], deficits in coordination and postural control [4, 5] and altered muscle tone [6].

Among the changes in muscle tone, spasticity is the most prevalent, with 80% of children being affected [7, 8]. Spasticity is clinically defined as a velocity-dependent increase in muscle response to imposed stretch, with the reduced inhibition of the stretch reflex [9, 10]. In addition to being characterized by increased tone, spasticity presents with hyperreflexia, which consists of an increase in reflex activity at rest and reduced presynaptic and reciprocal inhibition. These alterations cause inadequate modulations during voluntary contraction, which in turn cause deficits in the execution of movement and impair functionality [11, 12].

In addition to the neuromotor changes observed in children with spastic CP, intrinsic properties such as increased passive muscle stiffness, neurally mediated reflex stiffness of skeletal muscle and increased active muscle stiffness are also altered [13]. This can be observed by the resistance to stretch presented by these individuals during passive movement [14].

The increased muscle stiffness can be determined by changes in the properties of the titin protein [13], increased extracellular matrix (ECM) stiffness arising from higher concentrations of collagen [14, 15] or by increased sarcomere longitudinal length [14].

Therefore, the altered spastic muscle in association with the neural deficits in CP [16] might be related to impaired functionality in children with CP, such as limitations in the activities of self-care and mobility [13, 14].

In this sense, due to the dramatic impaired functionality caused by secondary disorders resulting from spasticity, different types of treatment have been developed to control the increase in muscular tone, such as the neurorehabilitative therapies [17], phenol [18], baclofen [19] and botulinum toxin type A (BTX-A) [19]. Among these treatments, BTX-A has been considered the gold standard for controlling spasticity, and it is widely used in clinical practice [20].

BTX-A consists of a microbial protein from the bacterium *Clostridium botulinum* that is able to block the release of acetylcholine at the neuromuscular junctions, resulting in selective, temporal muscle denervation. This denervation restricts nerve transmission [19] and therefore reduces muscle tone [21], facilitating motor control.

However, the use of BTX-A in managing spasticity is relatively new, without extensive knowledge about the effects on spastic muscle. Some studies have suggested side effects after using BTX-A, such as decreased muscle strength [22–24] or impair muscle fiber growth [25]. Gough and

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ANEXO 8 – Artigo publicado na *Journal of Motor Behavior*.

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RESEARCH ARTICLE

Influence of Different Sitting Positions on Healthy Infants' Reaching Movements

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ABSTRACT. The authors analyze the influence of different sitting positions (ring and flexion) on the reaching performance (spatiotemporal variables) of full-term infants 6 and 7 months old. In addition, they correlated level of trunk control, measured by the Segmental Assessment of Trunk Control, with performance during reaching. The different sitting positions only influenced the reaching movements of 6-month-old infants, who showed the best performance in the ring position. However, this influence was observed only for the trunk displacement, deceleration time, movement units, straightness index and mean velocity. In contrast, there was no influence of positions on 7-month-old infants' reaching performance. Regarding the correlations, it was observed that infants with more level of trunk control showed a better performance when reaching, regardless of position and the age assessed.

Keywords: child development, motor skills, postural balance, upper extremity

The first year of life is a period in which infants acquire and develop various motor skills such as controlling their head, reaching for an object, sitting, and walking (Bly, 1994; van Balen, Dijkstra, & Hadders-Algra, 2012). Among these, reaching and sitting can be highlighted as they are interrelated motor milestones and are progressively acquired throughout their development (Harbourne, Lobo, Karst, & Galloway, 2013), favoring interaction and exploration of the environment (Kyvelidou, Harbourne, Willett, & Stergiou, 2013).

Reaching consists of the infant's skill of locating an object in the space, veering their look at it and then touching it, using upper limb movements (Thelen et al., 1993; Thelen, Corbetta, & Spencer, 1996). The ability to reach appears when infants are approximately 3–5 months old (Cunha, Woollacott, & Tudella, 2013; Thelen et al., 1996; Van der Fits, Otten, Klip, Van Eykern, & Hadders-Algra, 1999), and is characterized by irregular trajectories, various movement units (phases of acceleration and deceleration) and not grasping (Fetters & Todd, 1987; Van der Fits et al., 1999). Over time, reaching becomes more rectilinear, with smoother and more precise regular trajectories (Carvalho, Tudella, & Savelsbergh, 2007; Rocha, Silva, & Tudella, 2006; Toledo & Tudella, 2008).

However, although reaching becomes more skillful over the months, this skill is influenced by the infant's capacity to control the sitting position (Hopkins & Ronnqvist, 2002; Rachwani et al., 2013). Acquiring trunk control is a continuous process that begins when infants are approximately 2–3 months old and can hold their head in an upright position (Assaiante, 1998; Thelen & Spencer, 1998; van Balen et al., 2012). When infants are approximately 4–5 months old, they are able to remain seated with trunk support. When infants are 5–6 months old, they acquire trunk control at head and upper thoracic level, and therefore they are able to prop sit or independently sit for short periods, enabling them to start reaching in this position (Shumway-Cook, Woollacott, & de Lourdes Gianini, 2003). Furthermore, at 6 months old, hip joint mobility increases, allowing infants to sit with their thighs resting on a surface, characterizing the ring-sit position (hips symmetrically flexed, abducted and externally rotated and knees flexed) (Bly, 1994; Harbourne et al., 2013). Moreover, the muscle activation is highly variable, with a greater use of the muscles of the legs than trunk (Harbourne et al., 2013) and neck (Van Der Fits & Hadders-Algra, 1998). The maintenance of balance in a sitting posture requires muscle coordination of the trunk and pelvis in a top-down recruitment order, i.e., progressing in a cephalo-caudal direction, using the legs and buttocks as support base (Harbourne et al., 2013).

At 7 months old, infants are able to reach objects with both hands sitting independently without losing their balance (Harbourne et al., 2013). Although there is variability in muscle activation sequence, the reaching occurs after activation of postural muscles (Harbourne et al., 2013). Finally, at 8–9 months old, infants acquire the sitting position without support (Shumway-Cook et al., 2003) and begin to experiment new positions using lower limbs, allowing for a narrower base, as well as better use of the upper limbs (Assaiante, 1998; Bly, 1994; Harbourne et al., 2013; Van der Fits et al., 1999; von Hofsten, Vishton, Spelke, Feng, & Rosander, 1998). Therefore, acquiring the independent sitting position changes the way infants interact with the world (Harbourne et al., 2013; Saavedra, van Donkelaar, & Woollacott, 2012), as well as their influence on reaching movements (Hopkins & Ronnqvist, 2002). In addition, the independent sit facilitates the exploitation and manipulation of objects (Bornstein & Lamb, 2010) and provides the spatial orientation (Soska, Robinson, & Adolph, 2015). The body orientation may be facilitated through the transition from quadruped to sitting position during the

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ANEXO 9 – Artigo publicado na *Brazilian Journal of Physical Therapy*.

original article

BJPT Brazilian Journal of Physical Therapy

Influence of additional weight on the frequency of kicks in infants with Down syndrome and infants with typical development

Gabriela L. Santos[1], Thaís B. Bueno[1], Eloisa Tudella[1], Jadiane Dionisio[2]

ABSTRACT | **Background:** Infants with Down syndrome present with organic and neurological changes that may lead to a delay in the acquisition of motor skills such as kicking, a fundamental skill that is a precursor of gait and is influenced by intrinsic and extrinsic factors. Therefore, this movement should be taken into account in early physical therapy interventions in infants. **Objective:** To analyze and to compare the effect of additional weight on the frequency of kicks in infants with Down syndrome and infants with typical development at 3 and 4 months of age. **Method:** Five infants with Down syndrome and five with typical development at 3 and 4 months of age were filmed. The experiment was divided into four experimental conditions lasting 1 minute each: training, baseline, weight (addition of ankle weight with 1/3 the weight of the lower limb), and post-weight. **Results:** There were significant differences between groups for all variables ($p<0.05$), with lower frequencies observed for infants with Down syndrome in all variables. There were significant differences between the experimental conditions baseline and post-weight ($p<0.001$) for both groups in the frequency of contact and success, with a higher frequency in the post-weight condition. **Conclusions:** The weight acted as an important stimulus for both groups, directing the kicks toward the target and improving the infants' performance in the task through repetition, however, the infants with Down syndrome had lower frequencies of kicks.

Keywords: early intervention; child development; rehabilitation.

HOW TO CITE THIS ARTICLE

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Introduction

Down syndrome is caused by a trisomy of chromosome 21, with an incidence of approximately 1/700 live births[1], and it is associated with various complex clinical phenotypes, such as a smaller size of the cerebellum and the temporal and frontal lobes[1,2]. Some neuromotor changes are also observed, such as muscular hypotonia, joint hyperextensibility, and disturbance in the postural control and balance mechanism, which restrict the proper execution of voluntary movements[3-5]. Moreover, infants with Down syndrome may have cognitive deficits which can influence the performance of motor tasks[6]. These characteristics or organic changes can lead to a delay in the acquisition of motor skills such as reaching, sitting, and kicking, which are precursors to the development of more complex skills such as crawling and walking[7-9].

The kick is one of the earliest motor behaviors, being observed from intrauterine life[10]. It is characterized by the cycle of flexion movement of the joints of one or both lower limbs, followed by extension and flexion again[11,12]. Between the age of 1 and 4 months, there is a marked decline in the number of alternating leg movements followed by a period in which there is the emergence of unilateral kicking and, at about 4-5 months, the new patterns of bilateral coordination become more prominent[13]. Moreover, around 5 months, the infants prefer to reach to explore the environment, reducing the frequency of kicks[14]. Thus, throughout the development of this ability, infants present in-phase and out-of-phase movements and intra- and interlimb coordination, which favors increased strength and limb coordination[13]. Thus, with a more developed movement pattern, the infant is able to perform complex tasks such as crawling and walking[10,15-18].

The movement of kicking as a motor ability is influenced by the interaction between elements of

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ANEXO 9 – Artigo publicado na *Journal of Motor Behavior*.

RESEARCH ARTICLE

Influence of Additional Ankle Weights on Kinematic Variables of Late Preterm Infants Aged 3–4 Months

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ABSTRACT. The authors analyzed and compared the effect of additional weight on the spatiotemporal parameters of the kicking movement of late preterm and full-term infants. The experiment was divided into 4 conditions: training, baseline, weight, and postweight. In the W condition, a weight of one third the lower limb mass was added to the infant's ankle. During the baseline and postweight conditions, the ankle weight was removed. Late preterm infants do not differ from full-term infants in relation to spatiotemporal variables at 3 and 4 months. However, during the weight condition, the straightness index and the hip-ankle and knee-ankle correlations decreased in the preterm infants at both ages. In contrast, the straightness index increased in the postweight condition compared to the baseline values at both ages.

Keywords: additional weight, development, kicks, preterm

Preterm infants are considered a major risk group for changes and delays in the acquisition of motor skills caused by several factors such as decreased flexor pattern, decreased muscle fibers, and generalized hypotonia (Ayache & Coríntio, 2003; Dionisio, dos Santos, de Fátima Landgraf, & Tudella, 2012; Graziano & Leone, 2005; Halpern, Brand, & Malone, 2001; Lekskulchai & Cole, 2001; Miceli et al., 2000; Tavares & Rego, 2007; Weiss, 2005). Low muscle tone impairs antigravity movements and when the infant tries to perform active movements, muscle tone rises beyond what is necessary, hindering the performance of organized movements (Morison et al., 2003; Piek, 2001). However, preterm infants go through the same stages of acquisition of gross motor skills as full-term infants, but at a slower pace (Jeng, Chen, & Yau, 2002; Miceli et al., 2000; Weiss, 2005).

An important gross motor skill during motor development is the kicking movement, consisting of a primitive voluntary movement present since intrauterine life. This movement favors strength gain, dissociation, and coordination of the lower limbs, which are essential for the acquisition of more complex motor skills such as climbing, crawling, and walking (Landgraf & Tudella, 2008; Magill & da Costa, 2008; Piek, 1996, 2001; Thelen, Bradshaw, & Ward, 1981; Thelen & Fisher, 1983), being influenced by intrinsic and extrinsic factors over time (Dionisio et al., 2012; Santos, Bueno, Tudella, & Dionisio, 2014).

Intrinsic factors involve, for example, strength and muscle tone, and these factors are altered in preterm infants, which may adversely affect the motor development of the lower limbs (Jeng et al., 2002; Piek & Gasson 1999; Weiss, 2005; Wilson & Cradock, 2004). By investigating the behavior of preterm infants at 2–4 months of corrected age, Jeng et al. found that these infants showed higher frequency of kicks and shorter duration of the flexion phase at four months of corrected age. Furthermore, the authors found higher correlation between hip and knee and lower variability in the interlimb coordination pattern at 2–4 months old (Jeng et al., 2002). Vaal, van Soest, Hopkins, and Sie (2002) analyzed the kicks of preterm infants at 6, 12, 18, and 26 weeks old and found that younger infants showed greater changes in the spatiotemporal parameters, characterized by lower amplitude, lower frequency, slower speed, and intralimb coordination. Vaal et al. attributed these changes in the kicking movement to the physical conditions and neurological development of preterm infants, highlighting the importance of the influence of intrinsic factors in this motor skill.

In addition to intrinsic factors, extrinsic factors such as gravity, use of visual and audio stimuli (mobiles), practice, and weight added to the infant's ankle can also influence the kicking movement (Musselman & Yang, 2007, 2008; Sargent, Schweighofer, Kubo, & Fetters, 2014; Thelen, Skala, & Kelso, 1987; Ulrich, Ulrich, Angulo-Kinzler, & Chapman, 1997; Vaal, Van Soest, Hopkins, Sie, & Van der Knaap, 2000). Accordingly, Thelen et al. (1987) added weight to the lower limbs of term infants at 6 weeks old and found a decrease in the frequency of kicks in the limb added of weight without changes in the movement amplitude and speed. In contrast, in the limb without additional weight, infants made the necessary adjustments, and an increase in the frequency of kicks and amplitude and speed of movements was observed (Thelen et al., 1987). This influence of the additional weight was also observed in the lower limbs of preterm infants at 3 and 4 months old, providing a decrease in the movement time and frequency of kicks, contact of foot with the panel and successfully raising the panel, with increased success after weight removal compared to baseline (Dionisio et al., 2012). However, studies assessing the effect of additional weight on the kinematic variables of the kicking movements of preterm infants were not found in literature, which could serve as a basis for using this resource in early intervention programs.

Thus, in the present study we analyzed and compared the effects of additional weight on the spatiotemporal variables of the kicking movement of late preterm and full-term

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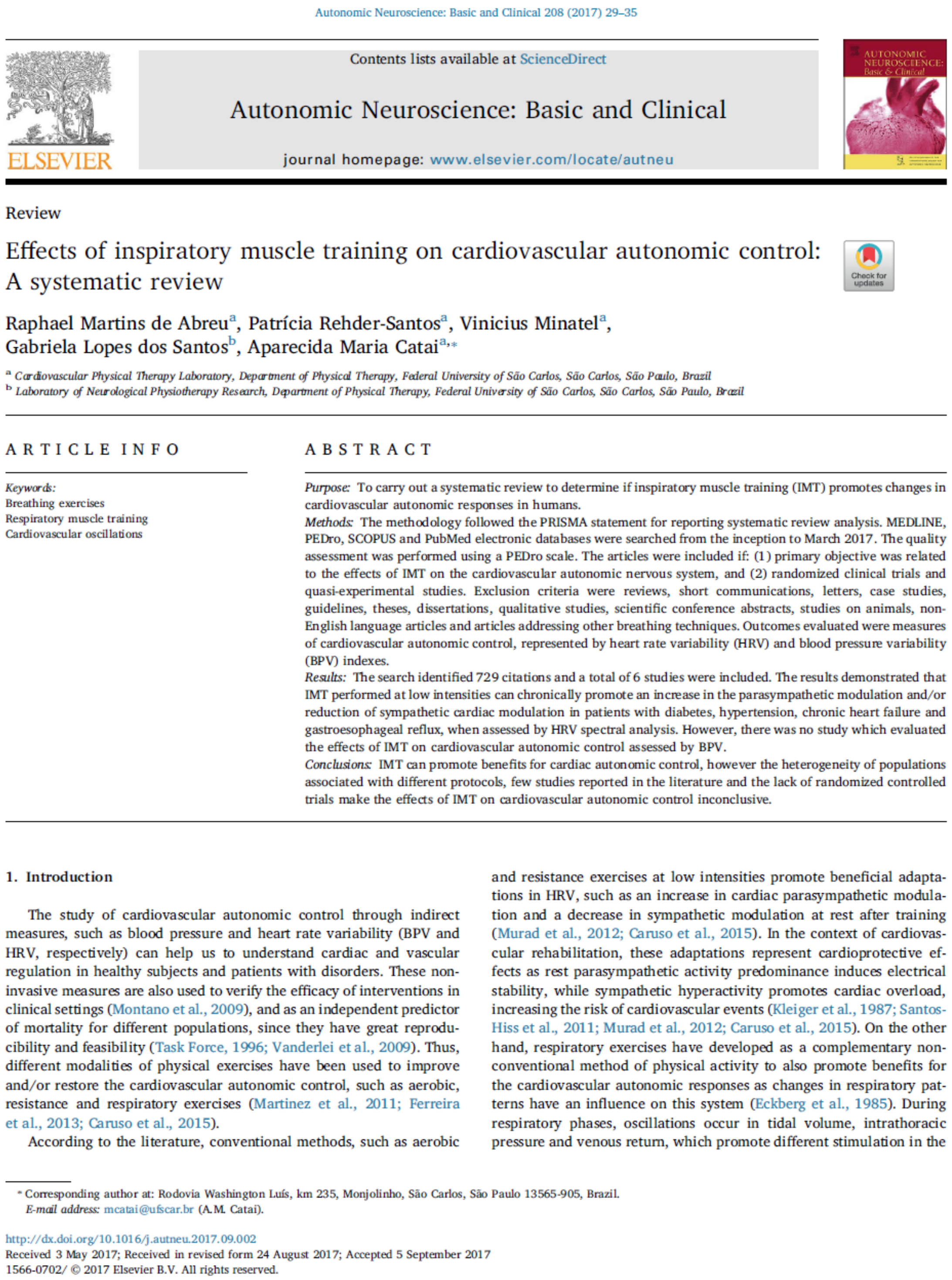
ANEXO 11 – Artigo publicado na *Autonomic Neuroscience Basic and Clinical.*



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Review

Effects of inspiratory muscle training on cardiovascular autonomic control: A systematic review

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ABSTRACT

Purpose: To carry out a systematic review to determine if inspiratory muscle training (IMT) promotes changes in cardiovascular autonomic responses in humans.

Methods: The methodology followed the PRISMA statement for reporting systematic review analysis. MEDLINE, PEDro, SCOPUS and PubMed electronic databases were searched from the inception to March 2017. The quality assessment was performed using a PEDro scale. The articles were included if: (1) primary objective was related to the effects of IMT on the cardiovascular autonomic nervous system, and (2) randomized clinical trials and quasi-experimental studies. Exclusion criteria were reviews, short communications, letters, case studies, guidelines, theses, dissertations, qualitative studies, scientific conference abstracts, studies on animals, non-English language articles and articles addressing other breathing techniques. Outcomes evaluated were measures of cardiovascular autonomic control, represented by heart rate variability (HRV) and blood pressure variability (BPV) indexes.

Results: The search identified 729 citations and a total of 6 studies were included. The results demonstrated that IMT performed at low intensities can chronically promote an increase in the parasympathetic modulation and/or reduction of sympathetic cardiac modulation in patients with diabetes, hypertension, chronic heart failure and gastroesophageal reflux, when assessed by HRV spectral analysis. However, there was no study which evaluated the effects of IMT on cardiovascular autonomic control assessed by BPV.

Conclusions: IMT can promote benefits for cardiac autonomic control, however the heterogeneity of populations associated with different protocols, few studies reported in the literature and the lack of randomized controlled trials make the effects of IMT on cardiovascular autonomic control inconclusive.

1. Introduction

The study of cardiovascular autonomic control through indirect measures, such as blood pressure and heart rate variability (BPV and HRV, respectively) can help us to understand cardiac and vascular regulation in healthy subjects and patients with disorders. These non-invasive measures are also used to verify the efficacy of interventions in clinical settings (Montano et al., 2009), and as an independent predictor of mortality for different populations, since they have great reproducibility and feasibility (Task Force, 1996; Vanderlei et al., 2009). Thus, different modalities of physical exercises have been used to improve and/or restore the cardiovascular autonomic control, such as aerobic, resistance and respiratory exercises (Martinez et al., 2011; Ferreira et al., 2013; Caruso et al., 2015).

According to the literature, conventional methods, such as aerobic and resistance exercises at low intensities promote beneficial adaptations in HRV, such as an increase in cardiac parasympathetic modulation and a decrease in sympathetic modulation at rest after training (Murad et al., 2012; Caruso et al., 2015). In the context of cardiovascular rehabilitation, these adaptations represent cardioprotective effects as rest parasympathetic activity predominance induces electrical stability, while sympathetic hyperactivity promotes cardiac overload, increasing the risk of cardiovascular events (Kleiger et al., 1987; Santos-Hiss et al., 2011; Murad et al., 2012; Caruso et al., 2015). On the other hand, respiratory exercises have developed as a complementary non-conventional method of physical activity to also promote benefits for the cardiovascular autonomic responses as changes in respiratory patterns have an influence on this system (Eckberg et al., 1985). During respiratory phases, oscillations occur in tidal volume, intrathoracic pressure and venous return, which promote different stimulation in the

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