***2) Title Page (with author details)**

Efficacy of three therapeutic taping configurations for children with brachial plexus birth palsy

Stephanie A Russo, MD, PhD[a], Dan A Zlotolow, MD[b], Ross S Chafetz, DPT, PhD[b], Luisa M Rodriguez, OTR/L[b], Devin Kelly, MS[c], Holly Linamen, OTR/L[d], James G Richards, PhD[e], John D Lubahn[a], MD, and Scott H Kozin, MD[b]

[a]University of Pittsburgh Medical Center – Hamot, Erie, PA; [b]Upper Extremity Center of Excellence, Shriners Hospital for Children, Philadelphia, PA; [c]Movement Analysis Laboratory, Shriners Hospital for Children, Erie, PA; [d]Department of Physical and Occupational Therapy, Shriners Hospital for Children, Erie, PA; [e]Department of Kinesiology and Applied Physiology, University of Delaware, Newark, DE

[a]University of Pittsburgh Medical Center – Hamot
201 State Street
Erie, PA 16550

[b]Shriners Hospital for Children
3551 N. Broad Street
Philadelphia, PA 19140

[c,d]Shriners Hospital for Children
1645 W. 8th St.
Erie, PA 16505

[e]University of Delaware
102 STAR Annex
Newark, DE 19711

Corresponding Author:

Stephanie Russo
201 State Street
Erie, PA 16550
sarusso@udel.edu

ABSTRACT

Study Design: Cross-sectional clinical measurement

Introduction: Scapular winging is a frequent complaint among children with brachial plexus birth palsy (BPBP). Therapeutic taping for scapular stabilization has been reported to decrease scapular winging.

Purpose: This study aimed to determine which therapeutic taping construct was most effective for children with BPBP.

Methods: Twenty-eight children with BPBP participated in motion capture assessment with: (1) no tape, (2) rhomboid major and rhomboid minor, (3) middle and lower trapezius, and (4) combined rhomboids and trapezius taping. The participants held their arms in four positions: (1) neutral with arms by their sides, (2) hand to mouth, (3) hand to belly, and (4) maximum cross-body adduction. The scapulothoracic, glenohumeral and humerothoracic joint angles and joint angular displacements were compared between conditions utilizing multivariate analyses of variance with Bonferroni corrections.

Results: Scapular winging was significantly decreased in both the trapezius and combined taping conditions in all positions compared to no tape. Rhomboids taping had no effect. Combined taping reduced humerothoracic cross-body adduction in the cross-body adduction position.

Conclusions: Rhomboid taping cannot be recommended for treatment of children with BPBP. Both trapezius and combined taping approaches reduced scapular winging, but humerothoracic cross-body adduction was limited with combined taping. Therefore, therapeutic taping of middle and lower trapezius was the most effective configuration for scapular stabilization in children with BPBP.

Key Words: kinesio tape; therapeutic tape; brachial plexus birth palsy; scapulothoracic and glenohumeral kinematics; scapular winging

Level of Evidence: Level II

1 INTRODUCTION

Children with brachial plexus birth palsy (BPBP) demonstrate complete, spontaneous recovery approximately two-thirds of the time,[1,2] while roughly one in every 1000 live births results in BPBP with sustained deficits.[3] The long-term effects of BPBP include decreased limb length [4-6] and girth,[4,5] abnormal scapular morphology,[7-14] glenohumeral (GH) dysplasia,[8-11,13-19] muscle weakness, and reduced range of motion.[4,11,20-23] A common complaint among children with BPBP and their caretakers is the appearance and frustration associated with scapular winging.[24-28] Scapular winging is a visible indication of the child's injury and also causes difficulty maintaining clothing, such as a bra strap or bathing suit top, for female patients. The etiology of scapular winging in the BPBP population is unclear as the long thoracic and dorsal scapular nerves are expected to be intact in most children with C5-C6 or C5-C7 injuries.[24-26] Scapular winging in the BPBP population is thought to serve as a compensatory mechanism for lack of GH motion, including decreased GH cross-body adduction,[26] and it is typically managed conservatively.

Non-surgical treatments for scapular winging include passive and active range of motion exercises, recreational activities that involve use of the upper extremities, electrical stimulation and therapeutic taping [29]. The goals of these interventions are to strengthen muscles, alleviate muscle tightness and prevent joint contracture formation or progression. While these interventions are frequently utilized, objective evidence demonstrating their efficacy is lacking.

Previous studies investigating the effect of therapeutic taping of the scapula are inconsistent.[30-42] Additionally, they encompass different types of tape and tape application methodology.[35] One randomized trial comparing therapeutic Kinesio® taping with sham taping (Kinesio® tape applied without any tension) in young adults with rotator cuff tendonitis/impingement found no significant differences in goniometer-measured scapular range of motion during active abduction, forward flexion, or elevation in the scapular plane.[38] However, other previous reports identified changes in scapular kinematics,[32,39,42] muscle activity,[32,34] and proprioception.[34] According to the manufacturer, Kinesio®

tape encourages muscle strengthening, decreases muscle fatigue by providing support, and provides proprioceptive input to improve awareness.[43] Kinesio® tape may also promote functional improvement by maintaining optimal alignment for movement.[43]

In the BPBP population, Walsh (2010) reported a case study of a child with BPBP who demonstrated improved GH congruity and scapular orientation, based on radiographic evaluation, following a therapeutic taping intervention with Kinesio® tape.[40] However, radiographic imaging is not frequently utilized to evaluate GH joint morphology as unossified articular structures cannot be visualized; magnetic resonance imaging is typically the imaging modality of choice.[10,11,14,19] Another study utilized motion capture technology to assess twenty-six children with BPBP before and after applying Kinesio® tape to facilitate middle and lower trapezius.[42] Scapulothoracic (ST), GH and humerothoracic (HT) joint orientations and angular displacements were measured at rest and in each of the modified Mallet positions, a set of six tasks utilized to assess upper extremity function in the pediatric BPBP population (Figure 1).[42,44] The therapeutic taping for middle and lower trapezius resulted in clinically small, but statistically significant decreases in scapular winging in six out of seven tested positions.[42] Additionally, GH cross-body adduction and/or internal rotation increased significantly in four positions. However, the only change in HT function was a statistically significant decrease of three degrees of external rotation in the external rotation position.[42]

Although the long-term outcome of therapeutic Kinesio® taping remains unknown, the results of this prior study suggested that consistent, although clinically small, changes in ST and GH joint function could be achieved with therapeutic taping to facilitate middle and lower trapezius.[42] Demonstrating that a baseline change in ST and GH joint resting orientations can be achieved with therapeutic tape and largely maintained during upper extremity motion was the first step in objectively assessing the efficacy of therapeutic taping for scapular stabilization in children with BPBP. The next step is to determine the most effective taping construct, which is the premise of the current work. This information will help

inform treatment for children with BPBP. The objective of this study is to quantitatively measure the changes in ST, GH, and HT joint orientations and angular displacements with three different therapeutic taping constructs for scapular stabilization in children with BPBP: (1) facilitation of rhomboid major and minor, (2) facilitation of middle and lower trapezius, and (3) combined facilitation of rhomboid major and minor as well as middle and lower trapezius. We hypothesized that a combined taping approach to facilitate multiple scapular stabilizing muscles would have the greatest impact due to an additive effect of the two individual taping approaches.

2 MATERIALS and METHODS

2.1 Participants

Twenty-eight children with BPBP participated in this study. Informed consent was obtained in accordance with the institution's human subjects review board. Each child was assessed by a licensed and registered occupational therapist (OTR/L) experienced in pediatric occupational therapy to confirm suitability for scapular stabilization with therapeutic taping. The occupational therapy assessment consisted of a subjective evaluation of increased scapular winging (compared to the contralateral limb) that was readily improved with manual manipulation. Since one method of therapeutic taping was intended to facilitate the trapezius muscle, children who had spinal accessory nerve transfers or lower trapezius tendon transfers were excluded due to potential compromise of trapezius function. In addition, open wounds or poor skin integrity were considered contraindications for therapeutic taping and, thus, children with these conditions were excluded from the study. The final exclusion criterion was excessive soft tissue that would potentially hinder palpation and placement of anatomic markers on the scapula.

2.2. Data Collection

Retroreflective markers were applied to the following anatomic landmarks: spinous processes of T2 and T8, sternal notch, acromion process, trigonum spinae (intersection of the scapular spine and

96 medial border of the scapula), inferior angle of the scapula, and medial and lateral epicondyles of the
97 humerus. Three-dimensional coordinates of these markers were recorded with a 10 camera motion
98 capture system (Vicon, Centennial, CO; Motion Analysis Corporation, Santa Rosa, CA). Participants were
99 seated and asked to hold their arms by their sides in a neutral, resting position with their hands hanging
100 free. The trigonum spinae and inferior angle scapular markers were palpated and placed with the
101 participants in this position. The participants were then asked to hold their arms in the following
102 positions: hand to mouth (Figure 2a), internal rotation, and cross-body adduction. The scapular
103 markers on the trigonum spinae and inferior angle were re-palpated and placed while the children held
104 their arms in each position to ensure accurate measurement of ST orientations. The hand to mouth and
105 internal rotation (hand to belly) modified Mallet positions (Figure 1) were chosen because they
106 demonstrated the greatest decreases in scapular winging with therapeutic taping in a previous study
107 that assessed each of the modified Mallet positions.[42] Maximal cross-body adduction (Figure 3) was
108 selected because lack of GH cross-body adduction is associated with scapular winging.[26]
109 Motion capture data were collected for four taping conditions: (1) no tape, (2) facilitation of
110 rhomboid major and rhomboid minor, (3) facilitation of middle and lower trapezius, and (4) facilitation
111 of rhomboid major, rhomboid minor, and middle and lower trapezius (combination of both 2 and 3,
112 referred to as "combined" taping). For the rhomboids taping, participants were asked to place their
113 hands on the opposite shoulders while the scapular motion was manually augmented by the therapist
114 during application of the tape with paper-off tension (Figure 2b). For the trapezius taping, participants
115 retracted their scapulae towards the spine, and the therapist manually augmented this scapular motion
116 during application of the tape with paper-off tension (Figure 2c). In the combined taping condition, the
117 rhomboids tape was applied first and then the trapezius tape was applied following the same steps
118 described above (Figure 2d). The order of taping conditions was rotated for each participant to limit the
119 impact of a potential learning effect associated with performing the positions multiple times.

120 *2.3 Data Analysis*

121 Custom-written software (LabVIEW 2014, National Instruments, Austin, Texas) was utilized for
122 data analysis. Thoracic, scapular, and humeral coordinate systems were generated so that the axes
123 aligned with those recommended by the International Society of Biomechanics.[45] Scapulothoracic, GH
124 and HT joint angles were calculated for each trial. Scapulothoracic joint angles (Figure 4a) were
125 computed utilizing an order-independent, helical angle approach.[42,46] The GH and HT joint angles
126 (Figure 4b and 4c) were calculated using an order-independent, modified globe method.[26,42,47,48] The
127 modification utilized for this study was calculating internal/external rotation as the degrees of rotation
128 about the long axis of the humerus between the neutral trial and each of the tested positions. The
129 International Society of Biomechanics recommends using Euler angles to determine ST, GH and HT joint
130 angles[45]; however, the joint angles calculated with Euler angles best match clinical observations when
131 the first rotation occurs about the axis of greatest motion and the last rotation occurs about the long
132 axis of the distal segment. Due to this constraint, a single Euler sequence would not produce clinically
133 applicable results for the different positions tested in this study. Therefore, the order-independent
134 helical and globe methods were selected. Additionally, the ST, GH and HT joint angular displacements
135 were calculated from the neutral trial to each of the other tested positions in each taping condition.

136 *2.4 Statistical Analysis*

137 The ST, GH and HT joint orientations were compared in each of the taping conditions using a
138 one-way, repeated measure multivariate analyses of variance (MANOVAs) with SPSS statistical software
139 (SPSS v23, IBM, Armonk, NY). The factor levels consisted of taping condition (no tape, rhomboids tape,
140 middle and lower trapezius tape, and combined tape), and the dependent variables were each of the
141 three joint angles (rotation about each anatomic axis). A Bonferroni correction was utilized to account
142 for examining multiple joints, which brought the alpha level to 0.017. Following a significant Wilk's
143 lambda ($\alpha = 0.017$), univariate analyses of variance (ANOVAs) were performed to determine which joint

orientations reached significance. A Bonferroni correction was also applied to the univariate ANOVAs ($\alpha = 0.017$). Pairwise comparisons ($\alpha = 0.05$) were then performed for the significant univariate ANOVAs. The same statistical approach was repeated for each of the tested positions, as well as for the joint angular displacements in each of the tested positions.

3 RESULTS

3.1 Demographics

Participant demographic information and relevant surgical history are shown in Table 1.

3.2 Joint Orientations

The ST, GH and HT joint orientations are shown in Figure 5 and Table 2 for each position and taping condition. Both the trapezius taping and combined taping demonstrated significant ($p < 0.001$, p-values listed in the text represent the pairwise comparisons unless otherwise noted) decreases in scapular winging as compared to no tape and/or rhomboids taping ranging from 4.2 to 6.9 degrees in all positions (Figure 6). There were also significant differences in ST posterior tilt in all positions except hand to mouth, as shown in Figure 5. Glenohumeral internal rotation was significantly decreased in the internal rotation position for trapezius ($p = 0.003$) and combined ($p = 0.016$) tapings versus no tape. The participants also demonstrated significantly less ($p = 0.027$) GH elevation in the cross-body adduction position with combined taping compared to the rhomboids taping condition. Of the significant differences in HT joint angles shown in Figure 5, only two were greater than five degrees: HT internal rotation in the neutral position in the trapezius compared to rhomboids taping conditions (5.3 degrees, $p = 0.002$) and HT cross-body adduction in the cross-body adduction position in the combined versus no tape conditions (5.9 degrees, $p = 0.026$).

3.3 Joint Angular Displacement

The only significant ($p = 0.004$, univariate ANOVA) change in joint angular displacement was less glenohumeral elevation in the trapezius (4.8 degrees, $p = 0.033$) and combined (5.9 degrees, $p = 0.009$) conditions compared to the rhomboid condition in the cross-body adduction position.

4 DISCUSSION

Scapulothoracic, GH and HT joint functions were similar for the no tape and rhomboids tape conditions with no significant differences between them. Similarly, the only significant difference in joint function between the trapezius and combined taping conditions was decreased HT cross-body adduction in the cross-body adduction position (3.0 degrees less with combined taping, $p = 0.033$). Combined taping also significantly decreased HT cross-body adduction in the cross-body adduction position compared to the other taping conditions (no tape: $p = 0.025$, rhomboids tape: $p = 0.001$). Additionally, combined taping significantly decreased ($p = 0.027$) GH elevation in the cross-body adduction position compared to rhomboids taping. Decreased HT cross-body adduction in the cross-body adduction position with combined taping represents less global shoulder cross-body adduction than the no tape, rhomboids taping, and trapezius taping conditions. Conversely, trapezius taping resulted in a modestly greater reduction in scapular winging when compared to combined taping, but without decreasing HT cross-body adduction in the cross-body adduction position. The combined taping may have excessively limited overall shoulder motion leading to an undesired decrease in HT cross-body adduction.

Regarding the trapezius taping condition, there were only two significant findings that were not similarly reflected in the combined taping condition: a significant ($p = 0.008$) decrease in ST posterior tilt in the neutral position compared to rhomboids taping and a significant decrease in HT internal rotation (approximately four to five degrees) in the neutral position compared to both the no tape ($p = 0.011$) and rhomboid ($p = 0.002$) tape conditions. The clinical significance of the change in ST posterior tilt is unclear. It is likely related to the decrease in scapular winging as similar changes were found for the

trapezius and/or combined conditions in the other tested positions. Decreased HT internal rotation in the neutral position represents an improvement in the typical HT internal rotation posturing of children with BPBP. This trend was also reflected in the combined tape condition. Trapezius taping resulted in similar statistically significant reductions in ST internal rotation (cross-body adduction motion of the scapula) in all positions without a significant loss in HT cross-body adduction in the cross-body adduction position.

Only one significant difference in the joint angular displacements (decreased GH elevation in the cross-body adduction position) was found. This indicates that the joint arcs of motion remained essentially unchanged for all other joints and positions. The resting orientations were altered with the application of trapezius and combined tape (demonstrated by the significant differences in the neutral position). These changes were largely maintained throughout the other motions evaluated in this study.

Overall, therapeutic taping to facilitate middle and lower trapezius was the most effective and beneficial scapular taping assessed in this study. There was no improvement in overall ability to perform the positions assessed in this study in the trapezius taping condition, aside from improved posture in the neutral position. Although trapezius taping was associated with decreased HT internal rotation in the internal rotation position compared to rhomboids taping, and in the cross-body adduction position compared to no tape (2.7 and 4.3 degrees, respectively), the clinical significance of changes of these magnitudes was minimal. The findings of this investigation agree with previous findings of clinically small, but statistically significant decreases in scapular winging with the application of Kinesio® tape to facilitate the middle and lower trapezius.[42] Additionally, while there were more statistically significant changes in HT joint orientations in this study, most of them occurred in conditions that were not evaluated in the previous literature.[42] The remainder were either clinically favorable (less HT internal rotation in the neutral position) or very small changes (less than three degrees decrease in HT internal rotation in the internal rotation position). There were fewer significant difference in GH

joint orientation in the current study than in previously reported findings.[42] This raises the question of whether or not therapeutic Kinesio® taping for scapular stabilization has the potential to exert a positive effect on GH joint development as suggested in a previous study[42] and demonstrated in a case study by Walsh (2010).[40] Finally, the previous study investigating the effect of trapezius taping also found no significant changes in joint angular displacement.[42]

There were limitations associated with this study. The participants performed the same arm positions four times (once for each taping condition), which theoretically could result in improved performance due to a learning effect. To mitigate this potential effect, the order that the positions were collected in was rotated for each child. Additionally, the possibility of a placebo effect with application of therapeutic tape was not investigated. However, the lack of significant differences in the rhomboids taping condition suggests that there was no placebo effect.

Based on the findings of this study, therapeutic taping to facilitate the middle and lower trapezius consistently decreases scapular winging in children with BPBP and has small, but beneficial, effects on ST and GH joint function. Rhomboids taping should be avoided as no benefit was found in isolation or in combination with trapezius taping. With no statistically significant decreases in scapular winging demonstrated, use of rhomboids taping may increase cost and comorbidities (i.e. potential for skin irritation) without any clinical benefit. In general, therapeutic taping for facilitation of middle and lower trapezius decreased scapular winging in the neutral position, and this change in the resting ST orientation was maintained throughout the other tested positions. Although middle and lower trapezius taping consistently decreases scapular winging, the clinical change is small and long-term benefits remain unknown. Patient-specific factors, such as cost, time, potential for skin irritation, patient motivation, etc., need to be considered for each child when considering this treatment modality.

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Table 1. Each participant's diagnosis (Erb's palsy, extended Erb's palsy, or total plexus palsy), age and relevant surgical history are shown. Shoulder tendon transfers were either teres major or both teres major and latissimus dorsi.

Diagnosis	Patient	Age	Primary nerve surgery	Shoulder tendon transfer	Arthroscopic release	Humeral Osteotomy
Erbs	1	12				
	2	10			X	
	3	13			X	
	4	13				X
	5	14				
	6	12		X		
	7	7		X		
	8	15				
	9	5				
	10	7				
	11	13				X
	12	10			X	X
	13	5				
	14	7		X		
	15	14			X	
	16	13				
	17	7		X		
	18	9				
	19	6				
	20	5				
Extended	21	8		X	X	X
	22	11		X	X	
	23	6	X	X		
	24	7			X	
	25	17	X	X		
	26	7	X			
	27	15		X		X
Total	28	8			X	

Table 2. The mean plus or minus (±) the standard deviation (SD) scapulothoracic (ST), glenohumeral (GH), and humerothoracic (HT) joint angles are shown in degrees for each position and taping condition. The Wilks' lambda is shown for the multivariate analyses of variance, along with the univariate analyses of variance (ANOVA) p-values. Bonferroni corrections for multiple comparisons were applied to both making the significance level 0.017. Significant p-values are indicated by an asterisk (*).

Position	Joint Angle	No Tape Mean ± SD	Rhomboid Mean ± SD	Trapezius Mean ± SD	Combined Mean ± SD	Wilks' Lambda	ANOVA P-value
Neutral	ST Up Rot	0.8 ± 6.3	2.7 ± 7.7	4.2 ± 10.5	2.9 ± 9.5		0.096
	ST IR	43.8 ± 5.6	43.0 ± 7.3	36.9 ± 6.5	37.0 ± 5.7	<0.001*	<0.001*
	ST Post Tilt	-6.1 ± 6.6	-7.4 ± 7.0	-5.0 ± 6.6	-5.8 ± 7.1		0.003*
	GH Elevation	27.0 ± 12.6	24.8 ± 13.3	26.5 ± 14.9	26.6 ± 15.1		0.321
	GH CBA	10.8 ± 29.8	14.4 ± 33.0	24.9 ± 37.7	20.2 ± 29.6	0.013*	0.044
	GH ER	8.1 ± 18.0	7.0 ± 17.5	5.9 ± 16.8	4.5 ± 17.8		0.019
	HT Elevation	23.8 ± 10.2	22.7 ± 9.6	25.9 ± 9.8	25.1 ± 10.0		0.001*
	HT CBA	42.9 ± 19.5	40.1 ± 20.6	45.1 ± 18.2	38.1 ± 6.1	<0.001*	0.143
	HT IR	36.3 ± 19.1	37.1 ± 19.2	31.8 ± 18.6	33.3 ± 18.1		<0.001*
Hand to Mouth	ST Up Rot	27.6 ± 18.5	29.9 ± 17.6	29.6 ± 17.6	30.1 ± 17.6		0.664
	ST IR	54.8 ± 13.2	52.7 ± 12.6	49.5 ± 13.3	48.5 ± 11.2	<0.001*	<0.001*
	ST Post Tilt	0.6 ± 7.9	-0.1 ± 6.6	3.2 ± 7.2	2.1 ± 8.7		0.032
	GH Elevation	57.6 ± 22.8	57.1 ± 24.1	56.8 ± 24.6	55.7 ± 20.6		0.736
	GH CBA	19.1 ± 28.7	21.8 ± 30.1	23.4 ± 25.6	19.1 ± 23.2	0.136	0.305
	GH ER	14.0 ± 15.9	14.3 ± 17.4	11.2 ± 14.9	11.8 ± 16.2		0.113
	HT Elevation	79.3 ± 23.1	79.2 ± 24.4	80.8 ± 21.7	80.8 ± 23.7		0.640
	HT CBA	68.8 ± 16.0	68.4 ± 18.4	66.9 ± 18.1	64.9 ± 17.4	0.504	0.131
	HT IR	37.8 ± 13.3	36.8 ± 17.4	37.4 ± 15.9	35.5 ± 15.4		0.515
Internal Rotation	ST Up Rot	1.0 ± 11.9	2.8 ± 11.1	1.5 ± 12.2	2.4 ± 12.4		0.387
	ST IR	46.3 ± 7.1	44.1 ± 6.2	40.4 ± 7.4	40.5 ± 6.4	<0.001*	<0.001*
	ST Post Tilt	-6.9 ± 7.2	-8.6 ± 7.8	-4.8 ± 7.3	-5.3 ± 7.9		<0.001*
	GH Elevation	38.4 ± 22.7	34.7 ± 20.9	36.9 ± 21.1	36.8 ± 22.0		0.059
	GH CBA	5.1 ± 34.9	10.2 ± 32.2	7.8 ± 34.3	6.3 ± 32.3	0.001*	0.296
	GH IR	2.6 ± 15.1	4.2 ± 14.3	6.2 ± 14.9	5.4 ± 15.7		0.002*
	HT Elevation	34.8 ± 16.6	32.4 ± 14.7	34.1 ± 13.7	34.7 ± 15.3		0.124
	HT CBA	41.1 ± 27.3	39.8 ± 25.5	39.4 ± 24.3	38.8 ± 23.0	0.002*	0.613
	HT IR	49.2 ± 16.9	49.4 ± 14.6	46.5 ± 15.6	45.9 ± 15.3		0.016*
Crossbody Adduction	ST Up Rot	39.3 ± 11.8	38.6 ± 10.1	41.8 ± 8.8	40.0 ± 10.0		0.364
	ST IR	68.6 ± 11.1	66.8 ± 9.3	61.8 ± 10.9	62.6 ± 8.9	<0.001*	<0.001*
	ST Post Tilt	-1.2 ± 8.3	-2.3 ± 7.9	1.7 ± 10.7	2.4 ± 9.3		<0.001*

GH Elevation	53.4 ± 18.8	54.6 ± 21.0	51.9 ± 18.9	50.3 ± 20.2		0.009*
GH CBA	34.0 ± 23.9	36.6 ± 24.9	39.2 ± 21.5	34.4 ± 21.1	0.004*	0.105
GH ER	2.4 ± 15.3	0.7 ± 16.5	2.5 ± 14.7	0.1 ± 15.5		0.258
HT Elevation	79.9 ± 17.3	78.6 ± 17.5	79.3 ± 15.6	78.5 ± 18.8		0.678
HT CBA	91.4 ± 13.0	90.3 ± 13.9	88.5 ± 14.3	85.5 ± 14.4	<0.001*	<0.001*
HT IR	73.2 ± 18.5	73.8 ± 20.2	68.9 ± 17.8	68.7 ± 19.8		0.003*

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Highlights

- The effects of three therapeutic taping configurations for scapular stabilization in children with brachial plexus birth palsy were assessed using motion capture measurements of scapulothoracic, glenohumeral and humerothoracic joint angles and joint angular displacements.
- The scapulothoracic, glenohumeral and humerothoracic joints were re-oriented at rest in the trapezius and combined taping conditions and these changes were largely maintained during the tested positions.
- The arcs of motion for each joint were largely unchanged.
- Rhomboids taping had little effect and cannot be recommended for treatment of scapular winging in children with BPBP.
- Trapezius and combined trapezius and rhomboids taping produced similar changes in scapulothoracic, glenohumeral and humerothoracic joint angles; however the combined condition resulted in significantly decreased humerothoracic crossbody adduction.
- The long-term effects need further evaluation; however, for patients with BPBP interested in therapeutic taping for scapular winging, taping to facilitate middle and lower trapezius should be selected.

Figure 1
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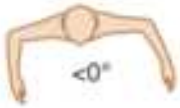
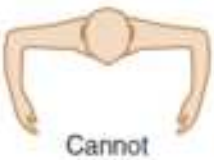
Modified Mallet classification (grade I = no function, Grade V = normal function)						
		Grade I	Grade II	Grade III	Grade IV	Grade V
Global abduction	Not testable	No function	 <30°	 30° to 90°	 >90°	Normal
Global external rotation	Not testable	No function	 <0°	 0° to 20°	 >20°	Normal
Hand to neck	Not testable	No function	 Not possible	 Difficult	 Easy	Normal
Hand on spine	Not testable	No function	 Not possible	 S1	 T12	Normal
Hand to mouth	Not testable	No function	 Marked trumpet sign	 Partial trumpet sign	 <40° of abduction	Normal
Internal rotation	Not testable	No function	 Cannot touch	 Can touch with wrist flexion	 Palm on belly, no wrist flexion	

Figure 2
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Figure 3
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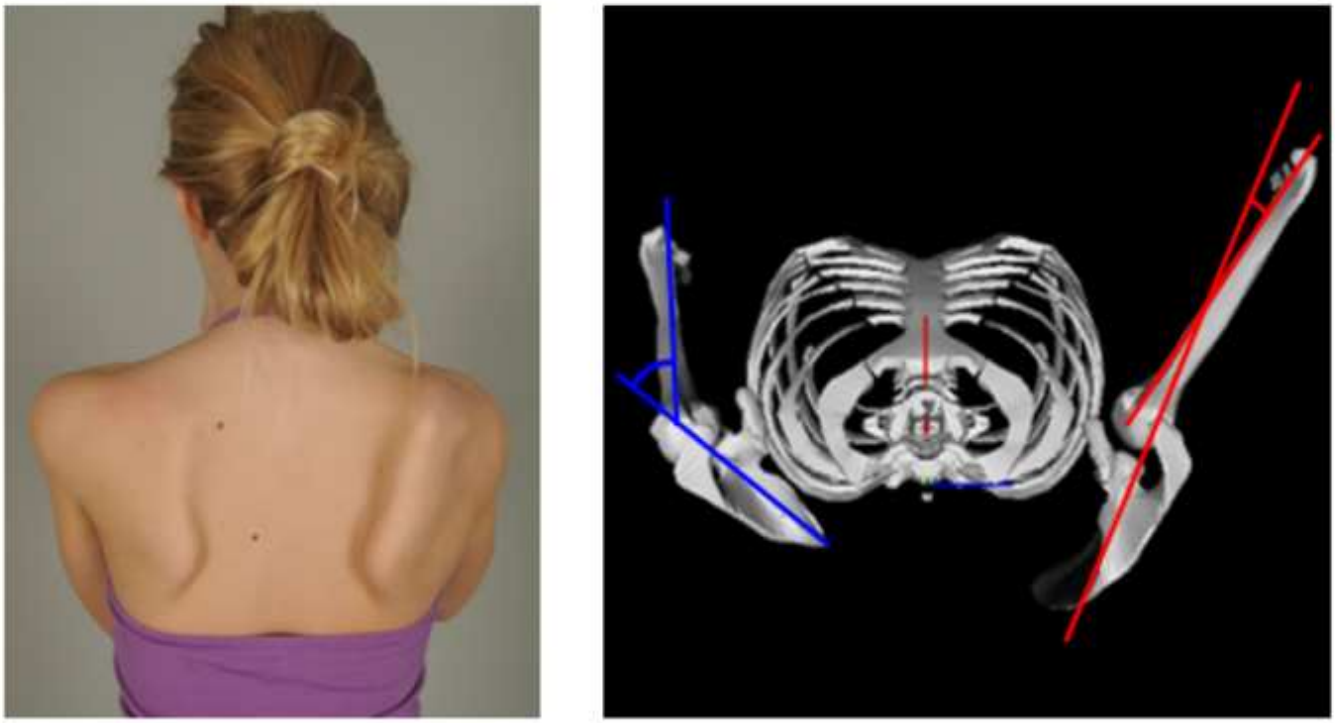

a

b

Figure 4
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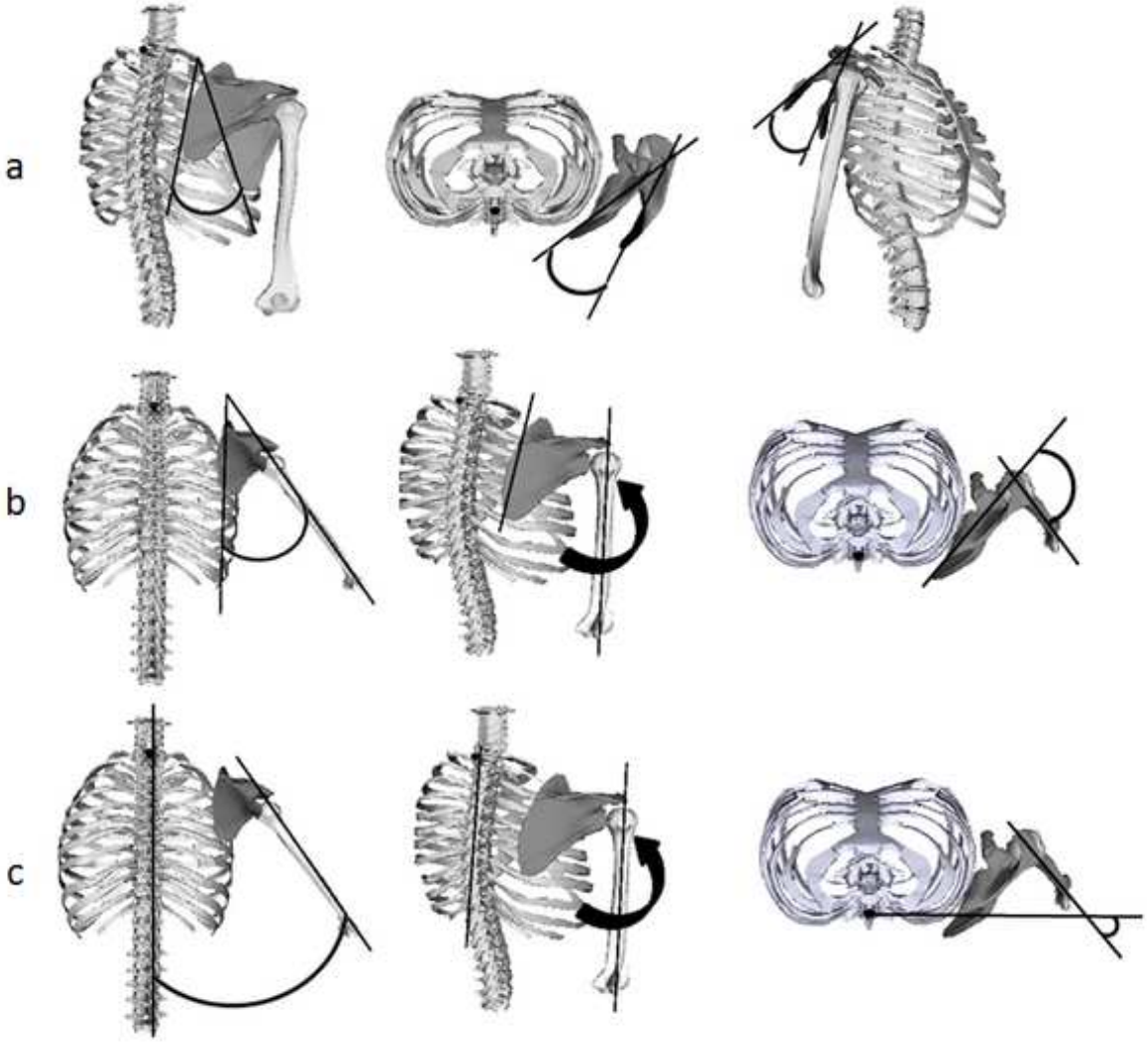

Figure 5

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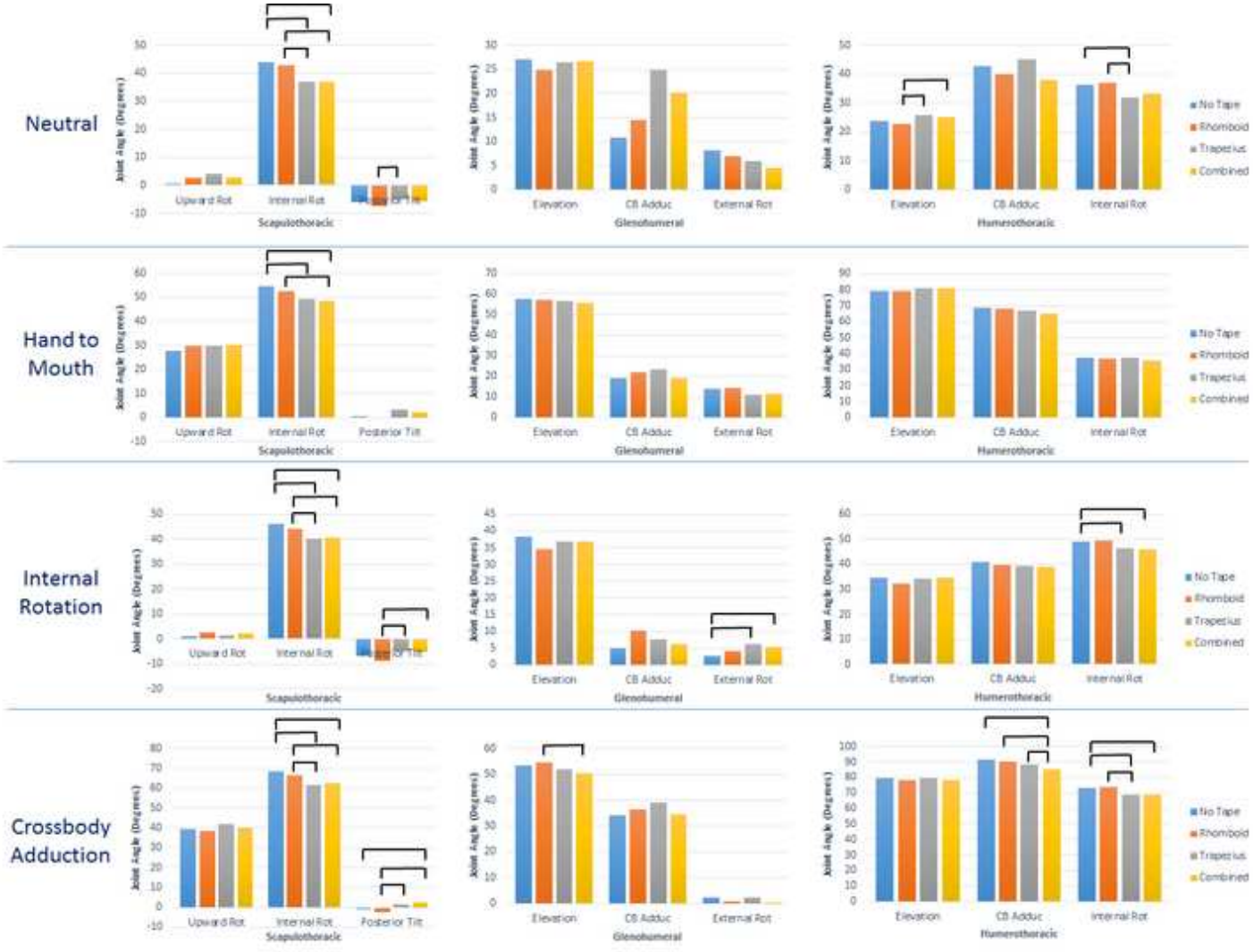

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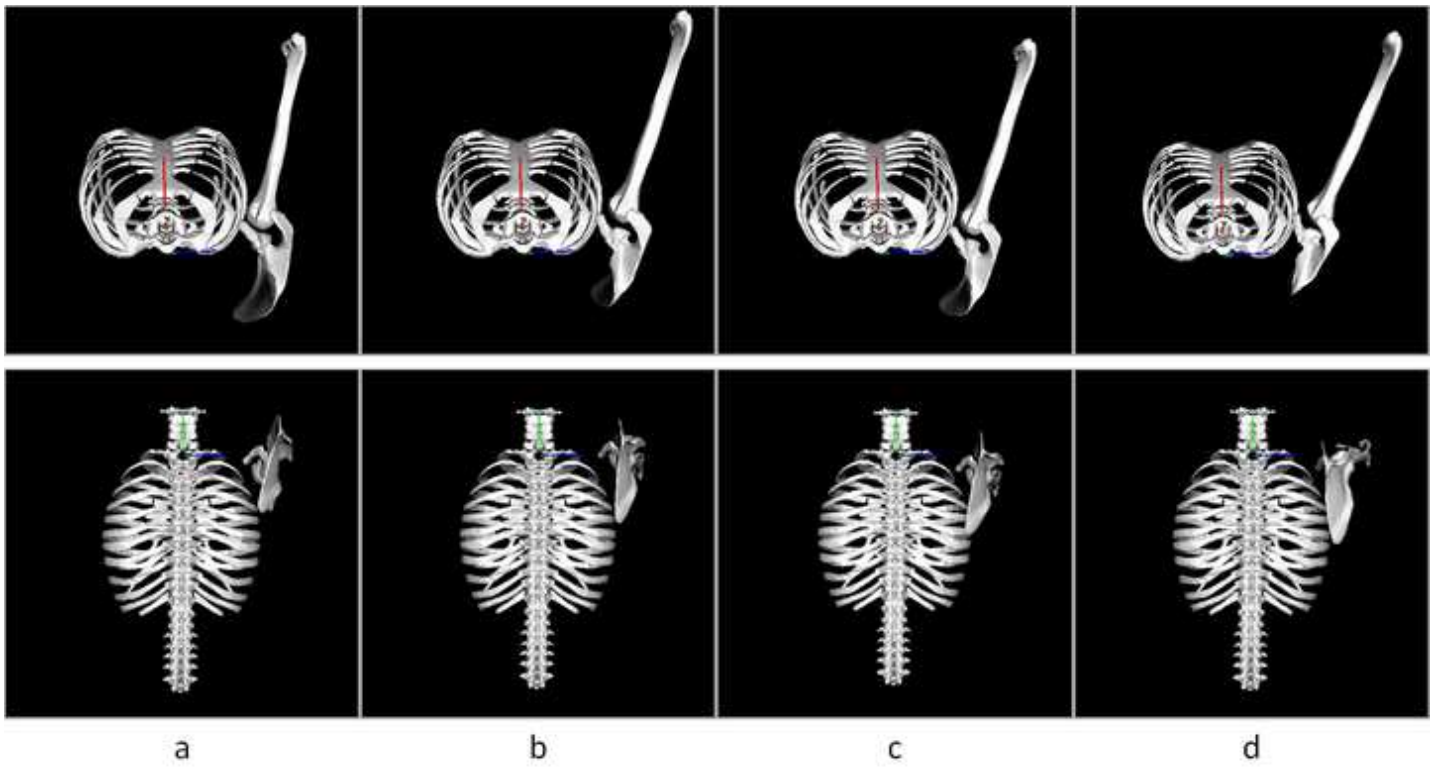

FIGURE LEGENDS

Figure 1. The modified Mallet classification is a functional assessment used to evaluate overall upper extremity performance in children with brachial plexus birth palsy [29].

Figure 2. Marker positions are shown in the hand to mouth position for the (a) no tape, (b) rhomboid major and rhomboid minor facilitation tape, (c) middle and lower trapezius facilitation tape, and (d) combined rhomboids and trapezius facilitation tape.

Figure 3. (a) Clinical photo a patient with BPBP performing the hand to mouth position bilaterally. The right side is affected. The same patient's motion capture data from a superior view is shown in (b) illustrating the lack of glenohumeral cross-body adduction on the affected, right side (the glenohumeral joint is actually demonstrating counter-productive glenohumeral cross-body abduction as shown by the red angle) and associated increased scapular winging compared to the contralateral side. The left, unaffected glenohumeral joint is oriented in glenohumeral cross-body adduction, which is depicted by the blue angle.

Figure 4. (a) The scapulothoracic joint angles from left to right are: upward/downward rotation, internal/external rotation (scapular winging is numerically represented by increased scapulothoracic internal rotation), and anterior/posterior tilt. (b) The glenohumeral and (c) humerothoracic joint angles from left to right are: elevation, internal/external rotation, cross-body adduction/abduction.

Figure 5. The scapulothoracic, glenohumeral and humerothoracic joint angles are shown for each of the tested positions. Each taping condition is represented by a separate bar. The significantly different joint angles are indicated by the black brackets. All p values for the multivariate analyses of variance and univariate analyses of variance were less than 0.017. The p values for the post hoc, Bonferroni, pairwise comparisons (shown by the black brackets) were all less than 0.05.

Figure 6. Three-dimensional representations of the hand to mouth position of the same patient shown in Figure 3. Superior views (top row) and posterior views (bottom row) are shown for the (a) no tape, (b) rhomboids tape, (c) trapezius tape, and (d) combined taping conditions.

Figure 1 Permission

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Institute/company: UPMC Hamot
Address: 201 State Street
Post/Zip Code: 16550
City: Erie
State/Territory: Pennsylvania
Country: United States
Telephone: 814-877-2684
Email: sarusso@udel.edu

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