



Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Effects of Kinesio taping on scapular kinematics of overhead athletes following muscle fatigue

Gisele Garcia Zanca*, Bruno Grüniger, Stela Márcia Mattiello

Department of Physical Therapy, Federal University of São Carlos, São Carlos, SP, Brazil

ARTICLE INFO

Article history:

Received 15 December 2014

Received in revised form 12 June 2015

Accepted 15 June 2015

Available online xxx

Keywords:

Shoulder

Electromyography

Throwing

Injury prevention

ABSTRACT

Scapular kinematics alterations have been found following muscle fatigue. Considering the importance of the lower trapezius in coordinated scapular movement, this study aimed to investigate the effects of elastic taping (Kinesio taping, KT) for muscle facilitation on scapular kinematics of healthy overhead athletes following muscle fatigue. Twenty-eight athletes were evaluated in a crossover, single-blind, randomized design, in three sessions: control (no taping), KT (KT with tension) and sham (KT without tension). Scapular tridimensional kinematics and EMG of clavicular and acromial portions of upper trapezius, lower trapezius and serratus anterior were evaluated during arm elevation and lowering, before and after a fatigue protocol involving repetitive throwing. Median power frequency decline of serratus anterior was significantly lower in KT session compared to sham, possibly indicating lower muscle fatigue. However, the effects of muscle fatigue on scapular kinematics were not altered by taping conditions. Although significant changes were found in scapular kinematics following muscle fatigue, they were small and not considered relevant. It was concluded that healthy overhead athletes seem to present an adaptive mechanism that avoids the disruption of scapular movement pattern following muscle fatigue. Therefore, these athletes do not benefit from the use of KT to assist scapular movement under the conditions tested.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Overhead throwing places high forces in the shoulder muscles and ligaments due to the wide range of motion and high speed required, predisposing overhead athletes to shoulder injuries (Wilk et al., 2009). Proper scapular movement and control is essential to provide a stable basis for humeral movement and suggested to help in the transfer of kinetic energy produced in the trunk and lower limb muscles to the arm and the ball during throwing (Sciascia et al., 2012).

The actions of serratus anterior and lower trapezius form an important force couple for coordinated scapular movement. The serratus anterior produces scapular upward rotation, posterior tilting and external rotation (Phadke et al., 2009). The lower trapezius is a scapular external rotator, an important synergist of serratus anterior for scapular upward rotation, and promotes scapular medial stabilization (Johnson et al., 1994; Phadke et al., 2009). Decreased activity of lower trapezius has been found in overhead

athletes with impingement symptoms (Cools et al., 2004, 2007), which may be related to the increased scapular internal rotation and decreased upward rotation found during arm elevation in subjects with shoulder impingement (Ludewig and Reynolds, 2009). The lower trapezius and serratus anterior are highly active during the throwing movement (Escamilla and Andrews, 2009) and, therefore, predisposed to muscle fatigue during sports activities. Several studies have investigated the effects of muscle fatigue on scapular kinematics using protocols involving isometric push-up associated with scapular protraction (Borstad et al., 2009), repetitive shoulder external rotation and arm elevation tasks (Chopp et al., 2011; Ebaugh et al., 2006; Joshi et al., 2011). However, the alterations found in scapular kinematics varied depending on the task performed during the fatigue protocol. A fatigue protocol simulating overhead throwing could more accurately represent the scapular kinematics alterations caused by muscle fatigue in overhead athletes during sports practice.

Interventions able to decrease scapular movement alterations caused by muscle fatigue could potentially contribute to shoulder injury prevention in overhead athletes. Different taping techniques have been proposed aiming to assist scapular function and change muscle activation in the shoulder complex of healthy and injured

* Corresponding author at: Department of Physical Therapy, Federal University of São Carlos Rodovia Washington Luis, km 235, 13565-905 São Carlos, SP, Brazil.

E-mail address: gisele_gz@yahoo.com.br (G.G. Zanca).

subjects (Hsu et al., 2009; Lin et al., 2011; Shaheen et al., 2014; Van Herzele et al., 2013). It has been suggested that these techniques can be helpful for shoulder injuries prevention and rehabilitation in overhead athletes (Hsu et al., 2009; Van Herzele et al., 2013). Kinesio taping (KT) is a technique that uses an elastic adhesive tape which causes minimal movement restriction and continual skin traction, stimulating cutaneous mechanoreceptors, which has been suggested to drive a facilitatory effect to the muscle (Firth et al., 2010; Konishi, 2013).

A KT technique for scapular stabilization has been shown to increase scapular upward rotation and posterior tilt in healthy handball players (Van Herzele et al., 2013). In a study of baseball players with shoulder impingement, a KT technique for lower trapezius facilitation increased muscle activity during arm lowering and scapular posterior tilt during arm elevation (Hsu et al., 2009). These effects were considered positive, but it is unknown if they would also occur in healthy overhead athletes following muscle fatigue. Therefore, the purpose of this study was to investigate the effect of KT for lower trapezius facilitation on scapular kinematics and muscle activation of healthy overhead athletes following muscle fatigue induced by throwing. It was hypothesized that KT for lower trapezius could facilitate its action during throwing, consequently assisting serratus anterior function and minimizing scapular alterations following muscle fatigue. This effect could potentially contribute for shoulder injury prevention in the overhead athletes population.

2. Methods

This investigation used a repeated-measures, crossover, sham-controlled, randomized, single-blinded (subject) study design. Participants were evaluated in three sessions, in random order: control (no taping), KT (KT with tension) and sham (KT without tension). There was one-week interval between sessions, in order to avoid cumulative effects of the taping (Hsu et al., 2009) and muscle fatigue (Myers et al., 1999).

2.1. Participants

Twenty-eight healthy overhead athletes (19 males and 9 females) with mean \pm SD age 20.7 ± 2.5 years, mean height 172 ± 11 cm and mean body mass 71 ± 14 kg, volunteered after giving their informed consent. Inclusion criteria were participation in regular sports training (at least three times per week) and no symptoms involving the shoulder. Exclusion criteria were shoulder injuries in the last year, previous shoulder surgery, shoulder dislocation, and the performance of upper-body exercises in the 24 h prior to each evaluation session. The included athletes were involved in regular training of handball ($n = 20$), baseball ($n = 4$)

or softball ($n = 4$) on average 5.5 ± 3.9 years and participated in university-level competitions. This study was conducted in agreement with the declaration of Helsinki and approved by the Ethics Committee of the University.

2.2. Instrumentation

Surface EMG data were collected using an 8-channel Bagnoli EMG System (DelSys, Boston, USA), which provided voltage gain of 1000, bandwidth of 20–450 Hz and noise ≤ 1.2 μ V (RMS). Active double differential electrodes (#DE 3.1, DelSys, Boston, USA), with three parallel bars (1 mm \times 1 cm) geometry, 1 cm of distance between the contacts, composed of 99.9% Ag were used. The electrodes had input impedance of 10^{15} ohms in parallel, with 0.2 pF; common mode rejection ratio of 92 dB; noise ≤ 1.2 μ V (RMS); and preamplifier gain of 10. The EMG system was interfaced with a computer via a 16-channel, 12-bit A/D card (Computer Boards, Inc., Middleboro, MA) and recorded using the MotionMonitor software (Innovative Sports Training, Chicago IL, USA). The sampling rate was set at 2000 Hz per channel. Three-dimensional kinematics of the thorax, scapula and humerus were collected at 100 Hz with the Flock of Birds electromagnetic tracking system (Ascension Technology Corporation, Burlington, VT) integrated with the Motion Monitor software.

2.3. Procedures

2.3.1. Three-dimensional kinematics and EMG acquisition

The EMG signal was collected from the clavicular and acromial portions of upper trapezius, lower trapezius and serratus anterior of the dominant arm. The electrodes were positioned parallel to the length of the along muscle fibers, in the sites described in Table 1. Before electrode positioning, the skin was shaved and cleaned with alcohol in order to reduce resistance and ensure good signal conduction. A reference electrode was positioned on the contralateral wrist. Initially, EMG signal was recorded at rest, with the subjects sitting on a chair, with the arms relaxed at the trunk side and the head in neutral position, during 5-s. Maximal voluntary isometric contractions (MVIC) were performed in order to determine the peak EMG to be used for signal normalization. Three MVIC of 5 s of duration each, with 30-s interval between them were performed for each muscle portion, in the positions described in Table 1.

The sensors for three-dimensional kinematics evaluation were fixed on anatomical landmarks. The first sensor was placed on sternum, just inferior to the sternal notch, the second one on the flat surface of the posterior acromion process, and the third one was fixed on a thermoplastic cuff and attached to the distal humerus. A fourth sensor was attached to a stylus and used to palpate and digitize the anatomical landmarks, in order to determine the

Table 1

Electrode position and maximal voluntary isometric contractions (MVIC) tests for each muscle portion evaluated.

Muscle portion	Electrode position	MVIC test
Acromial portion of upper trapezius	Midway between C7 spinous process and the acromion (Hermens et al., 2000)	Seated position, dominant arm at 90° of abduction, head rotation to the opposite side and ipsilateral lateral flexion. Resistance was applied against shoulder abduction and head lateral flexion (Ekstrom et al., 2005; Zanca et al., 2014)
Clavicular portion of upper trapezius	20% lateral to the midpoint between C3 and the most lateral point of the clavicle (Zanca et al., 2014)	
Lower trapezius	2/3 on the line from scapular root spine and T8 spinous process (Hermens et al., 2000)	Prone position, with the arm in abduction, aligned with the muscle fibers. Resistance was applied in the direction of the floor (Ekstrom et al., 2005)
Serratus anterior	On the level of xiphoid process, in the lateral trunk, in a 45° angle from anterior to posterior direction (Anders et al., 2004)	Seated position, arm at 90° of flexion and resistance applied against scapular protraction (Ekstrom et al., 2005)

anatomical coordinate systems, following the International Society of Biomechanics (ISB) recommendations (Wu et al., 2005). For the thorax, the anatomical landmarks were C7 and T8 spinous processes, sternal notch and xiphoid process. For the scapula, the landmarks were the root of the spine of the scapula, the posterolateral angle of the acromion and the inferior angle of the scapula. Landmarks for the humerus were medial and lateral epicondyles and the center of the humeral head, estimated as the point that moved the least during midrange passive glenohumeral motion through short arcs ($<45^\circ$) (An et al., 1990).

Before movement data collection, EMG signal was recorded at rest during a 5-s trial, with the participants standing with the arms at the trunk side and head in neutral position. Then, participants performed three trials of arm elevation in scapular plane, before and after the fatigue protocol, in each evaluation session, for kinematics and EMG data recording. The plane of elevation (45° anterior to the frontal plane) was determined with the arm at 90° of humerothoracic elevation. After the plane determination, the arm movement was guided by a wood apparatus, on which the participants were instructed to maintain light touch of the fingers and thumb up during the elevation trials. The participants were evaluated in standing position and performed each phase of the movement (arm elevation and lowering, from the start position to the maximum range of motion, returning to the initial position) in approximately 3 s, following verbal time cues of the examiner.

2.3.2. Taping application

In both taping sessions (sham and KT), a Y-shaped strip of Kinesio Tex Gold Standard (Kinesio USA, LLC, Albuquerque, NM), 5 cm width, was applied over the lower trapezius, from origin to insertion, as previously used by Hsu et al. (2009) (Fig. 1). In the KT session, the tape size was measured from T12 spinal process to the root spine of the scapula, while the subject stayed with the arm at the trunk side, relaxed. The base of the tape was applied with the subject at this position, initiating at T12 in the direction to the root spine of the scapula. The subject was then instructed to



Fig. 1. Taping application over the lower trapezius.

move the arm into horizontal adduction overhead. At this position, the tape was applied involving the lower trapezius, ending on the root of the scapular spine, with light tension (approximately 25%, correspondent to the tension of KT application on the paper, according to the manufacturer), as recommended for this technique (Kase et al., 2003). For the sham application, the tape length was measured with the participant's arm at horizontal adduction overhead and the tape was applied at this same position, with no tension. The subjects were blinded to the intervention they were receiving, only informed that the study was testing two different techniques, with no further details. The taping was applied after the initial arm elevation trials for data collection and removed only at the end of the evaluation session, after the subjects completed the fatigue protocol and all the reassessments.

2.3.3. EMG fatigue quantification

Immediately before and after the fatigue protocol, the participants performed a submaximal isometric contraction at 90° of shoulder flexion with extended elbow, holding a weighted bag corresponding to 15% MVIC of flexion (Chopp et al., 2011) determined in the first session. The MVIC for this purpose was assessed in the first session, using a digital dynamometer model DDK (Kratos, São Paulo, Brazil). Participants performed three MVIC of 5 s each, with 1 min of rest between them, and the peak force was considered.

2.3.4. Fatiguing protocol

The functional fatiguing protocol consisted of consecutive throwing while sitting on a chair, in order to isolate the upper body and ensure shoulder fatigue (Bowman et al., 2006). The athletes were instructed to throw a rubber ball (8 cm diameter and 80 g mass) against a wall at approximately 2.5 m away, with enough force and speed to the ball return to their hands.

Before starting the fatigue protocol, the subjects received instructions about the modified Borg's Rate of Perceived Exertion Scale (Borg, 1990). This scale has been used for fatigue determination considering the close relationship between subjective perception and EMG indicatives of muscle fatigue (Hummel et al., 2005). Subjects were asked at each one-minute interval to indicate their level of fatigue on the shoulder and scapular region, in a scale from 0 to 10. The fatigue protocol was interrupted when they reached a rating equal or higher than 8 (Fuller et al., 2009), and subjects were not aware about this criteria.

2.4. Data reduction

Scapular orientation at humerothoracic elevation angles of 30° , 60° , 90° and 120° , during arm elevation and lowering, was averaged across the three trials, before and after the fatigue protocol. Data above 120° of humerothoracic elevation were discarded due to the higher errors of measure reported for scapular surface sensors at these ranges (Karduna et al., 2001). This method presents excellent within-day reliability, with standard error of measurement, i.e., repeated-measures variability, ranging from 1.23° to 1.85° for internal rotation, from 1.58° to 3.07° for upward rotation and from 0.86° to 1.49° for scapular tilting (Haik et al., 2014).

EMG data were processed using a customized program generated in MatLab software (version 7.6.0, MathWorks Inc., Natick, USA). All EMG signals were band-pass filtered from 30 Hz to 450 Hz, with a fourth order, zero-lag, Butterworth filter. The 30 Hz cutoff was used in order to reduce heart muscle electrical activity contamination in the EMG signal (Drake and Callaghan, 2006). Band-stop filters were applied at 60 Hz and harmonics, in order to reduce the main noise artifact originated from the electromagnetic tracking system (Hsu et al., 2009; Zanca et al., 2014).

Root mean square (RMS) EMG was calculated using a 20-ms moving window with 50% overlap (Zanca et al., 2014). EMG signal

recorded during the rest trials was used for noise calculation. Noise subtraction was performed by calculating the square root of the squared measured EMG amplitude minus the squared amplitude of the noise (Hansson et al., 1997). The peak RMS value of the MVIC trial was used to normalize the signal collected during the arm elevation. The RMS was averaged in windows of 30° of humerorhombic elevation, from 30° to 120° and expressed as a percentage of peak RMS during MVIC. EMG amplitude of serratus anterior and trapezius muscles normalized by MVIC presents excellent within-day reliability, with standard error of the measure ranging from 1% to 1.7% of MVIC (Seitz and Uhl, 2012).

The median power frequency (MPF) was calculated from raw EMG signal collected during the submaximal isometric contractions. A Fast Fourier Transformation algorithm was applied to the signal from the second to the fourth seconds, in order to establish a power density spectrum. The MPF decline was calculated as the relative change expressed in percent of the initial MPF. A minimum decline of 8% in the MPF has been considered an indicator of local muscle fatigue (Borstad et al., 2009; Ebaugh et al., 2006; Oberg et al., 1990).

2.5. Data analysis

Statistical analyses were performed using SPSS version 22 (IBM, Chicago, IL). The MPF change and the fatigue protocol duration time were compared between taping conditions using one-way repeated-measures analyses of variance (ANOVA). Three-way repeated-measures ANOVAs were run for arm elevation and lowering, in order to analyze the effects of taping on scapular kinematics and muscle activation, considering within-subject factors: taping condition (KT, sham and control), humeral angle (30°, 60°, 90° and 120°) and time (pre and post fatigue). Mauchly's test of sphericity was performed for all measures and Greenhouse-Geisser correction was used if this assumption was violated. Significance level was set as 5%. When a significant interaction was found, the simple effects were calculated using the Sidak correction for multiple comparisons (Cardinal and Aitken, 2005). The effect size was calculated using Cohen's *d* statistic, considering ≤ 0.2 small, 0.5 moderate and > 0.8 large (Cohen, 1988).

3. Results

3.1. Muscle fatigue and amplitude

There was no difference in the fatiguing protocol duration time between sessions ($p = 0.42$), with 8.8 ± 1.1 min for the control session, 9.7 ± 1.3 min for the sham session and 9.2 ± 1.4 min for the KT session. The MPF decline of serratus anterior EMG was significantly lower in the KT condition compared to the sham ($p = 0.02$; Cohen's *d* effect size = 0.59; Fig. 2), but not between KT condition and control. There was no significant difference between taping conditions for MPF change of all the trapezius portions ($p > 0.05$).

There was no main effect or interaction for taping condition on muscle activity amplitude (Fig. 3). A significant interaction of time by humeral angle was found for all the muscle portions evaluated. Simple effect analyses showed a significant increase in mean RMS for all the muscle portions following the fatigue protocol, in most part of the range of motion (Table 2).

3.2. Scapular three-dimensional kinematics

There was no main effect or interaction involving taping ($p > 0.05$) (Fig. 4). A significant interaction of time by humeral angle was found for upward and internal rotation during arm elevation ($p < 0.001$) and for tilting during arm elevation ($p = 0.001$) and lowering ($p = 0.005$). Simple effects analyses showed significant changes following fatigue for upward rotation at 30°, 90°

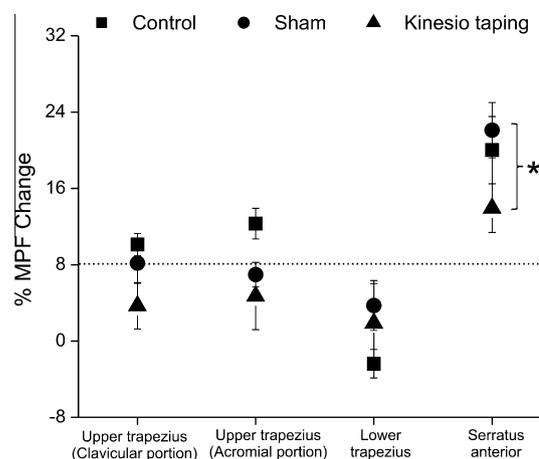


Fig. 2. Median power frequency (MPF) percent change following the fatigue protocol, for each taping condition. The dotted line represents the fatigue threshold ($> 8\%$ of MPF decline). *Statistical significance ($p = 0.02$) between sham and Kinesio taping conditions, but not between control and Kinesio taping.

and 120° of humeral elevation; internal rotation at 30° and 60° of humeral elevation; and for posterior tilting at 30° of humeral elevation during arm elevation and 30° and 60° of humeral elevation during arm lowering (Table 3). A main effect of time was found for internal rotation during arm lowering ($p = 0.038$).

4. Discussion

This study aimed to investigate the effects of a KT technique for lower trapezius facilitation on scapular kinematics and muscle activation of healthy overhead athletes following muscle fatigue. The hypothesis of this study was partially confirmed, since the serratus anterior presented a lower MPF decline in the KT condition compared to sham, possibly indicating a lower intensity of local muscle fatigue (De Luca, 1984). The sham application used the same material, but no tension was applied, removing the main characteristic of the KT technique. Therefore, the difference found between the taping conditions may be attributed to the recoil effect of KT and its continual traction on the skin. Previous studies have suggested that cutaneous afferent stimulation provided by KT might change motor unit recruitment (Firth et al., 2010; Konishi, 2013). However, the mechanism that caused a lower MPF decline of serratus anterior remains to be elucidated. It could be speculated that KT increased lower trapezius activation, as occurred in a previous study (Hsu et al., 2009), consequently decreasing serratus anterior overload during throwing. However, it is not possible to confirm this hypothesis, since there was no effect of taping condition on muscle activation during the arm elevation trials and EMG was not recorded during the fatigue protocol. Furthermore, although the MPF decline of serratus anterior EMG was lower in KT condition, the mean decline was greater than 8% in all the sessions, i.e., KT did not prevent myoelectric fatigue development.

Despite the effect on serratus anterior myoelectric fatigue, there was no effect of taping on scapular kinematics, which presented similar alterations following muscle fatigue in all the sessions. Although statistically significant, these changes presented effect sizes close to small, except for internal rotation at 30° of humeral elevation, which presented a moderate effect size. Furthermore, the mean changes between pre and post fatigue were smaller or very close to the within-day standard error of measurement reported for scapular kinematics assessment, which represents the intrinsic variability of repeated measures (Haik et al., 2014). Therefore, these alterations were not considered relevant. This is an unexpected finding, considering that the fatigue protocol was

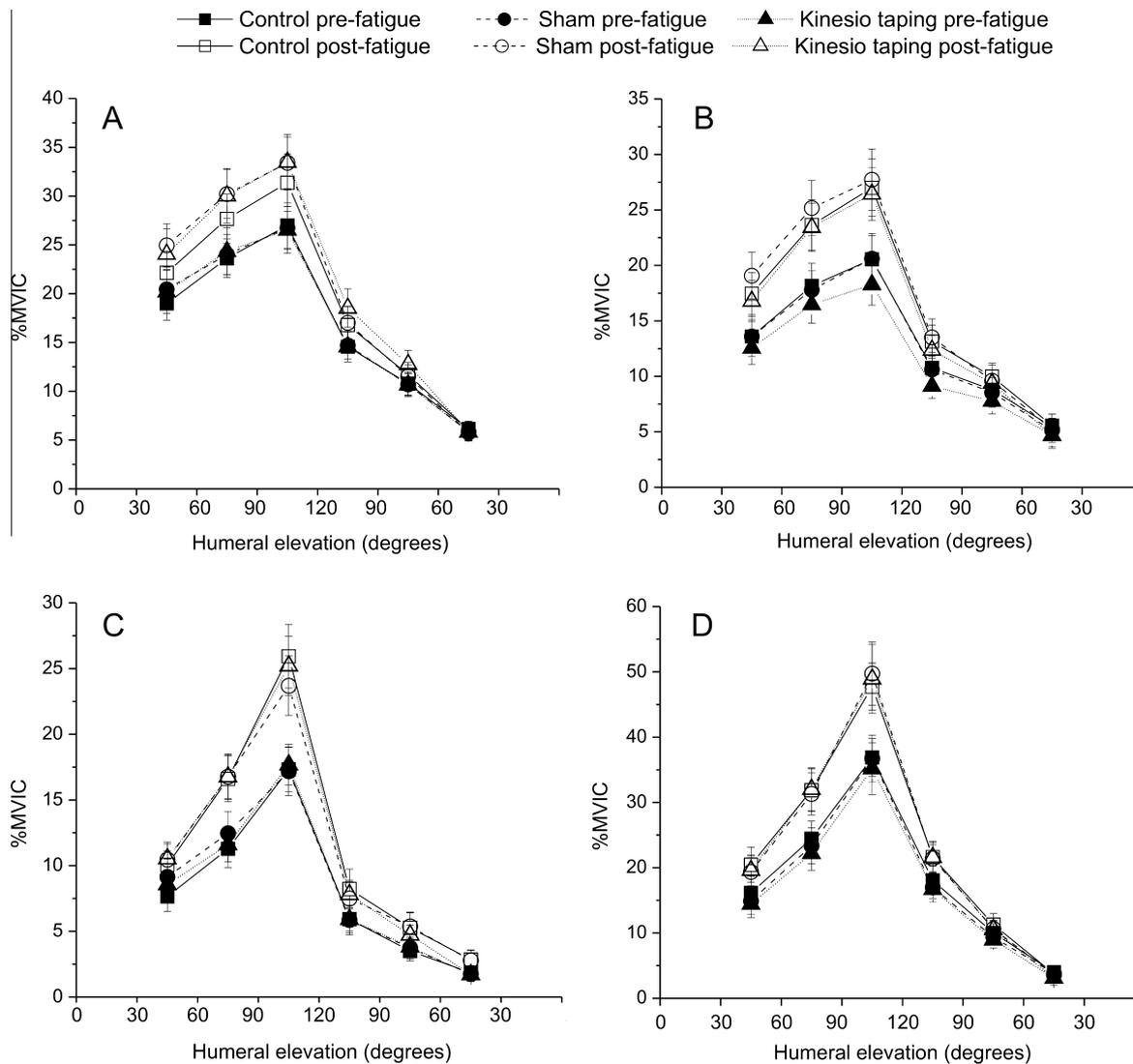


Fig. 3. Mean (\pm standard error) of RMS for (A) acromial portion of upper trapezius, (B) clavicular portion of upper trapezius, (C) lower trapezius and (D) serratus anterior, pre and post fatigue, at each taping condition.

intense compared to the actual sport practice of these athletes. The protocol consisted of consecutive throwing and limited the use of the kinetic chain, imposing higher demand to the shoulder. Other studies have found no or small alterations in scapular kinematics and position in healthy overhead athletes following muscle fatigue induced by swimming practice (Crotty and Smith, 2000; Su et al., 2004) and a shoulder external rotation task (Joshi et al., 2011). It may be suggested that healthy overhead athletes present some

adaptive mechanisms in muscle activation that maintain proper scapular movement, even at fatiguing conditions. In this study, all the muscle portions presented a significant increase in EMG amplitude following the fatigue protocol. Increases in EMG amplitude and frequency shift are both myoelectric manifestations of fatigue (De Luca, 1984), although the spectral compression (MPF decrease) alone has been often used as the indicative parameter of muscle fatigue (Borstad et al., 2009; Ebaugh et al., 2006;

Table 2

Mean change in muscle activation (RMS; %MVIC) following fatigue and Cohen's d effect size for each muscle portion and phase of movement.

Phase	Upper trapezius (clavicular portion)		Upper trapezius (acromial portion)		Lower trapezius		Serratus anterior	
	Mean (95% CI)	d	Mean (95% CI)	d	Mean (95% CI)	d	Mean (95% CI)	d
<i>Elevation</i>								
30–60°	4.5 (3.3; 5.8)*	0.83	3.8 (2.7; 4.9)*	0.81	1.9 (1.0; 2.8)*	0.45	4.7 (3.5; 5.8)*	0.88
60–90°	6.6 (5.0; 8.2)*	0.94	5.3 (3.9; 6.7)*	0.85	4.9 (3.7; 6.2)*	0.86	8.4 (6.6; 10.2)*	1.08
90–120°	7.2 (5.4; 9.1)*	0.91	6.0 (4.2; 7.8)*	0.79	7.6 (6.0; 9.1)*	1.08	12.5 (9.8; 15.3)*	1.04
<i>Lowering</i>								
120–90°	2.3 (0.8; 3.7)*	0.35	2.8 (1.9; 3.7)*	0.72	1.9 (1.0; 2.9)*	0.45	4.3 (3.0; 5.6)*	0.76
90–60°	1.3 (–0.1; 2.6)	0.21	1.3 (0.5; 2.0)*	0.40	1.4 (0.6; 2.2)*	0.40	1.4 (0.4; 2.4)*	0.31
60–30°	1.1 (–0.5; 2.8)	0.16	0.1 (–0.5; 0.7)	0.04	0.8 (0.2; 1.4)	0.29	0.1 (–0.9; 1.0)	0.02

* Significant difference ($p < 0.05$) between pre and post fatigue in the simple effect analyses (follow-up for the interaction time by angle).

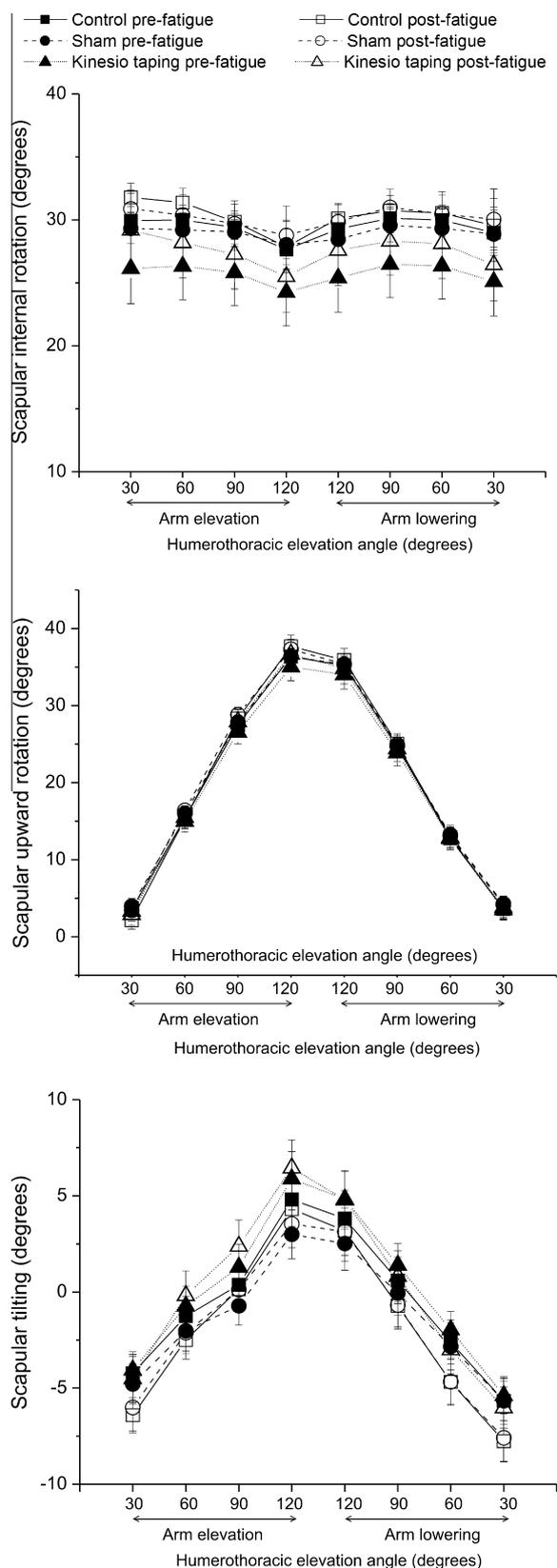


Fig. 4. Mean (\pm standard error) scapular rotations relative to humeral elevation angles, at each taping condition, pre and post fatigue.

Hummel et al., 2005), as performed in the present study. The increase in EMG amplitude of serratus anterior, especially during the concentric contractions of the arm elevation trials, is probably an indicative of muscle fatigue (Potvin, 1997). However, since the

Table 3

Mean change (95% confidence interval) of scapular kinematics following the fatigue protocol and Cohen's *d* effect size.

Phase	Internal rotation		Upward rotation		Posterior tilting	
	Mean (95% CI)	<i>d</i>	Mean (95% CI)	<i>d</i>	Mean (95% CI)	<i>d</i>
<i>Elevation</i>						
30°	2.2 (1.3; 3.5) [*]	0.53	-0.8 (-1.5; -0.1) [*]	0.24	-1.3 (-2.1; -0.5) [*]	0.35
60°	1.5 (0.5; 2.4) [*]	0.34	0.3 (-0.5; 1.0)	0.08	-0.3 (-1.1; 0.5)	0.07
90°	0.9 (-0.2; 1.9)	0.18	1.1 (0.2; 1.9) [*]	0.27	0.6 (-0.3; 1.4)	0.15
120°	0.7 (-0.4; 1.8)	0.14	1.3 (0.4; 2.3) [*]	0.30	0.2 (-0.7; 1.1)	0.05
<i>Lowering</i>						
120°	1.02 (0; 2.5) [#]	0.22	0.5 (-0.4; 1.4)	0.12	-0.02 (-1.0; 0.9)	<0.01
90°	1.2 (0.2; 2.1) [#]	0.26	0.4 (-0.4; 1.1)	0.10	-0.84 (-1.7; 0.1)	0.20
60°	1.3 (0.4; 2.2) [#]	0.30	0.03 (-0.7; 0.8)	0.01	-1.6 (-2.5; -0.7) [*]	0.39
30°	1.5 (0.6; 2.4) [#]	0.36	0.04 (-0.7; 0.7)	0.01	-1.5 (-2.4; -0.7) [*]	0.38

^{*} Significant difference ($p < 0.05$) between pre and post fatigue in the simple effect analyses (follow-up for the interaction time by angle).

[#] Significant main effect of time ($p < 0.05$).

lower trapezius EMG presented only a small decline in MPF, the increase in its EMG amplitude during arm elevation might also be interpreted as an increase in muscle recruitment to compensate for the serratus anterior fatigue. The lower trapezius is a scapular external rotator (Johnson et al., 1994) and its increased activation at higher angles of elevation may have contributed to maintain the adequate scapular movement in the transverse plane following the fatigue protocol. This hypothesis is reinforced by the moderate increase in scapular internal rotation at 30° of humeral elevation, position at which the lower trapezius presented the lowest increase in muscle activity. Previous studies have found alterations in the shoulder of asymptomatic overhead athletes that were considered beneficial adaptations for injury prevention and sports performance, as a decrease in the functional strength rotators ratio and an increase in torque fluctuation (Zanca et al., 2011, 2013). The lack of significant alterations in scapular kinematics following muscle fatigue could be interpreted in the same direction, as a possible positive adaptation.

Although scapular kinematics presented small alterations following the fatigue protocol, other aspects that were not evaluated in this study may have been affected by muscle fatigue and might contribute to shoulder injury risk, as rotator cuff activation and sensorimotor control. The rotator cuff muscles are highly active during throwing movement (Escamilla and Andrews, 2009) and have been shown to be fatigued following repetitive throwing (Dale et al., 2007). Muscle fatigue of rotator cuff can decrease the ability of humeral head centralization, leading to higher translations in the glenoid cavity, increasing the risk of impingement (Chopp et al., 2010). Sensorimotor system has also been shown to be altered following muscle fatigue and be related with shoulder injuries (Bowman et al., 2006; Myers et al., 1999). Previous studies have found an increase in acromiohumeral distance (Luque-Suarez et al., 2013) and shoulder proprioception (Lin et al., 2011) using KT techniques for asymptomatic subjects. The effects of KT on humeral translations and proprioceptive deficits caused by muscle fatigue could be object of future studies.

This study presents some limitations that should be addressed. First, since the EMG was not collected during the fatigue protocol, it was not possible to affirm whether the lower trapezius activity was increased during the throwing movement. Second, the throwing protocol performed in the seated position may have altered the neuromuscular coordination among the scapular muscles, considering the importance of the kinetic chain during throwing (Sciascia et al., 2012). However, this position was chosen in order to increase the load over the shoulder and guarantee muscle fatigue development. This study evaluated the effects of a KT technique proposed by Kase et al. (2003) for muscle facilitation, applied from the origin to the insertion of lower trapezius. To

our knowledge, this is the only KT configuration for lower trapezius facilitation, but other techniques might present different outcomes.

Furthermore, the findings of this study should not be generalized for injured populations. Hsu et al. (2009) have found a small increase in lower trapezius activity using the same KT technique in baseball players with shoulder impingement, suggesting that KT could have effects only in the presence of activation deficits. The lower fatigue intensity of serratus anterior found in the KT condition could possibly benefit symptomatic athletes, aiming at minimizing the perpetuation of scapular alterations, as those found in swimmers with shoulder impingement following muscle fatigue (Su et al., 2004). However, this is only speculative and further studies are necessary in order to investigate this hypothesis.

5. Conclusion

This study showed that a KT technique for lower trapezius facilitation does not alter the effects of muscle fatigue on scapular kinematics of healthy overhead athletes. Since the athletes presented no relevant alterations in scapular kinematics following muscle fatigue, it was suggested that this population does not benefit from taping techniques to assist scapular function.

Acknowledgements

The authors acknowledge the research fellowships from the São Paulo Research Foundation (FAPESP) (#2012/05146-0) and the National Council for Scientific and Technological Development (CNPq) (#477699/2012-0).

References

- An KN, Korinek SL, Kilpela T, Edis S. Kinematic and kinetic analysis of push-up exercise. *Biomed Sci Instrum* 1990;26:53–7.
- Anders C, Bretschneider S, Bernsdorf A, Erler K, Schneider W. Activation of shoulder muscles in healthy men and women under isometric conditions. *J Electromyogr Kinesiol* 2004;14:699–707.
- Borg G. Psychophysical scaling with applications in physical work and the perception of exertion. *Scand J Work Environ Health* 1990;16(Suppl 1):55–8.
- Borstad JD, Szucs K, Navalgund A. Scapula kinematic alterations following a modified push-up plus task. *Hum Mov Sci* 2009;28:738–51.
- Bowman TG, Hart JM, McGuire BA, Palmieri RM, Ingersoll CD. A functional fatiguing protocol and deceleration time of the shoulder from an internal rotation perturbation. *J Athl Train* 2006;41:275–9.
- Cardinal RN, Aitken MRF. ANOVA for the behavioral sciences researcher. Mahwah, NJ: Psychology Press; 2005.
- Chopp JN, O'Neill JM, Hurley K, Dickerson CR. Superior humeral head migration occurs after a protocol designed to fatigue the rotator cuff: a radiographic analysis. *J Shoulder Elbow Surg* 2010;19:1137–44.
- Chopp JN, Fischer SL, Dickerson CR. The specificity of fatiguing protocols affects scapular orientation: implications for subacromial impingement. *Clin Biomech (Bristol, Avon)* 2011;26:40–5.
- Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
- Cools AM, Witvrouw EE, Declercq GA, Vanderstraeten GG, Cambier DC. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction–retraction movement in overhead athletes with impingement symptoms. *Br J Sports Med* 2004;38:64–8.
- Cools AM, Declercq GA, Cambier DC, Mahieu NN, Witvrouw EE. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scand J Med Sci Sports* 2007;17:25–33.
- Crotty NM, Smith J. Alterations in scapular position with fatigue: a study in swimmers. *Clin J Sport Med* 2000;10:251–8.
- Dale RB, Kovaleski JE, Ogletree T, Heitman RJ, Norrell PM. The effects of repetitive overhead throwing on shoulder rotator isokinetic work-fatigue. *N Am J Sports Phys Ther* 2007;2:74–80.
- De Luca CJ. Myoelectrical manifestations of localized muscular fatigue in humans. *Crit Rev Biomed Eng* 1984;11:251–79.
- Drake JD, Callaghan JP. Elimination of electrocardiogram contamination from electromyogram signals: an evaluation of currently used removal techniques. *J Electromyogr Kinesiol* 2006;16:175–87.
- Ebaugh DD, McClure PW, Karduna AR. Effects of shoulder muscle fatigue caused by repetitive overhead activities on scapulothoracic and glenohumeral kinematics. *J Electromyogr Kinesiol* 2006;16:224–35.
- Ekstrom RA, Soderberg GL, Donatelli RA. Normalization procedures using maximum voluntary isometric contractions for the serratus anterior and trapezius muscles during surface EMG analysis. *J Electromyogr Kinesiol* 2005;15:418–28.
- Escamilla RF, Andrews JR. Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. *Sports Med* 2009;39:569–90.
- Firth BL, Dingley P, Davies ER, Lewis JS, Alexander CM. The effect of kinesiotape on function, pain, and motoneuronal excitability in healthy people and people with Achilles tendinopathy. *Clin J Sport Med* 2010;20:416–21.
- Fuller JR, Lomond KV, Fung J, Côté JN. Posture-movement changes following repetitive motion-induced shoulder muscle fatigue. *J Electromyogr Kinesiol* 2009;19:1043–52.
- Haik MN, Albuquerque-Sendín F, Camargo PR. Reliability and minimal detectable change of 3-dimensional scapular orientation in individuals with and without shoulder impingement. *J Orthop Sports Phys Ther* 2014;44:341–9.
- Hansson GA, Asterland P, Skerfving S. Acquisition and analysis of whole-day electromyographic field recordings. In: Hermens HJ, Hagg G, Freriks B, editors. European applications of surface electromyography. Stockholm: SENIAM/Roessingh Research and Development; 1997. p. 19–27.
- Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. *J Electromyogr Kinesiol* 2000;10:361–74.
- Hsu YH, Chen WY, Lin HC, Wang WT, Shih YF. The effects of taping on scapular kinematics and muscle performance in baseball players with shoulder impingement syndrome. *J Electromyogr Kinesiol* 2009;19:1092–9.
- Hummel A, Läubli T, Pozzo M, Schenk P, Spillmann S, Klipstein A. Relationship between perceived exertion and mean power frequency of the EMG signal from the upper trapezius muscle during isometric shoulder elevation. *Eur J Appl Physiol* 2005;95:321–6.
- Johnson G, Bogduk N, Nowitzke A, House D. Anatomy and actions of the trapezius muscle. *Clin Biomech (Bristol, Avon)* 1994;9:44–50.
- Joshi M, Thigpen CA, Bunn K, Karas SG, Padua DA. Shoulder external rotation fatigue and scapular muscle activation and kinematics in overhead athletes. *J Athl Train* 2011;46:349–57.
- Karduna AR, McClure PW, Michener LA, Sennett B. Dynamic measurements of three-dimensional scapular kinematics: a validation study. *J Biomech Eng* 2001;123:184–90.
- Kase K, Wallis J, Kase T. Clinical therapeutic applications of the Kinesio taping method. 2nd ed. Tokyo, Japan: Ken Ikai; 2003.
- Konishi Y. Tactile stimulation with kinesiology tape alleviates muscle weakness attributable to attenuation of Ia afferents. *J Sci Med Sport* 2013;16:45–8.
- Lin JJ, Hung CJ, Yang PL. The effects of scapular taping on electromyographic muscle activity and proprioception feedback in healthy shoulders. *J Orthop Res* 2011;29:53–7.
- Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther* 2009;39:90–104.
- Luque-Suarez A, Navarro-Ledesma S, Petocz P, Hancock MJ, Hush J. Short term effects of kinesiotaping on acromiohumeral distance in asymptomatic subjects: a randomised controlled trial. *Man Ther* 2013;18:573–7.
- Myers JB, Guskiewicz KM, Schneider RA, Prentice WE. Proprioception and neuromuscular control of the shoulder after muscle fatigue. *J Athl Train* 1999;34:362–7.
- Oberg T, Sandsjö L, Kadefors R. Electromyogram mean power frequency in non-fatigued trapezius muscle. *Eur J Appl Physiol Occup Physiol* 1990;61:362–9.
- Phadke V, Camargo P, Ludewig P. Scapular and rotator cuff muscle activity during arm elevation: a review of normal function and alterations with shoulder impingement. *Rev Bras Fisioter* 2009;13:1–9.
- Potvin JR. Effects of muscle kinematics on surface EMG amplitude and frequency during fatiguing dynamic contractions. *J Appl Physiol* 1997;82:144–51.
- Sciascia A, Thigpen C, Namdari S, Baldwin K. Kinetic chain abnormalities in the athletic shoulder. *Sports Med Arthrosc* 2012;20:16–21.
- Seitz AL, Uhl TL. Reliability and minimal detectable change in scapulothoracic neuromuscular activity. *J Electromyogr Kinesiol* 2012;22:968–74.
- Shaheen AF, Bull AM, Alexander CM. Rigid and elastic taping changes scapular kinematics and pain in subjects with shoulder impingement syndrome: an experimental study. *J Electromyogr Kinesiol* 2014.
- Su KP, Johnson MP, Gracely EJ, Karduna AR. Scapular rotation in swimmers with and without impingement syndrome: practice effects. *Med Sci Sports Exerc* 2004;36:1117–23.
- Van Herzele M, van Cingel R, Maenhout A, De Mey K, Cools A. Does the application of kinesiotape change scapular kinematics in healthy female handball players? *Int J Sports Med* 2013;34:950–5.
- Wilke KE, Obama P, Simpson CD, Cain EL, Dugas JR, Andrews JR. Shoulder injuries in the overhead athlete. *J Orthop Sports Phys Ther* 2009;39:38–54.
- Wu G, van der Helm FC, Veeger HE, Makhosm M, Van Roy P, Anliin C, et al. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion – Part II: shoulder, elbow, wrist and hand. *J Biomech* 2005;38:981–92.
- Zanca GG, Oliveira AB, Saccol MF, Eijnisman B, Mattiello-Rosa SM. Functional torque ratios and torque curve analysis of shoulder rotations in overhead athletes with and without impingement symptoms. *J Sports Sci* 2011;29:1603–11.
- Zanca GG, Saccol MF, Oliveira AB, Mattiello SM. Shoulder internal and external rotations torque steadiness in overhead athletes with and without impingement symptoms. *J Sci Med Sport* 2013;16:433–7.

Zanca GG, Oliveira AB, Anselmo W, Barros FC, Mattiello SM. EMG of upper trapezius – electrode sites and association with clavicular kinematics. *J Electromyogr Kinesiol* 2014;24:868–74.



Gisele Garcia Zanca received her bachelor's (2007), Master's (2010) and PhD in Physical Therapy (2014) from the Federal University of São Carlos (Brazil). In 2014, she underwent a research internship in the Orthopaedic Biomechanics Laboratory, at the University of Oregon (USA). Currently, she is a Professor in the undergraduate and Master's Program in Physical Therapy at the Sagrado Coração University (Brazil). Her main research interests are shoulder biomechanics and sensorimotor assessment and rehabilitation.



Stela Márcia Mattiello received her bachelor's degree in Physical Therapy from the Federal University of São Carlos (1984), a Master's degree in Bioengineering (1990) and PhD in Experimental and Comparative Pathology from the University of São Paulo (1999). She is currently an Associate Professor in the Department of Physical Therapy at the Federal University of São Carlos, Brazil. Her main research interests are shoulder and osteoarthritis rehabilitation and biomechanics.



Bruno Grüninger received his bachelor's degree in Physical Therapy from the Federal University of São Carlos in 2012. Currently, he is a Master's student in Physical Therapy at the same institution.