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CONTRIBUTIONS OF MUSCLE FATIGUE TO A NEUROMUSCULAR
NECK INJURY IN FEMALE STANDARD BALLROOM DANCERS

by

Teri J. Riding

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Exercise Sciences

Brigham Young University

August 2006

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BRIGHAM YOUNG UNIVERSITY

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This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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ABSTRACT

CONTRIBUTIONS OF MUSCLE FATIGUE TO A NEUROMUSCULAR NECK INJURY IN FEMALE STANDARD BALLROOM DANCERS

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Master of Science

Objective: To investigate the potential etiology of a loss of neck control injury in female standard ballroom dancers. The median frequency (MF) as measured by electromyography (EMG) of the left upper trapezius (UT), left splenius capitiis (SPL), and right sternocleidomastoid (SCM) of injured dancers was compared to non-injured dancers. This comparison was performed to identify whether dancers with a history of loss of neck control have a greater amount of fatigue than those with no history of this particular injury. **Design and Setting:** A 2 x 6 factorial design was used for this investigation. The independent variables were group (injured vs. non-injured) and time (before and after the three rounds of dancing). The dependent variables were MF as measured by EMG, range of motion, and neck length. All testing was performed at the university biomechanics laboratory and ballroom dance studio. **Subjects:** Twenty female subjects (10 injured group {mean height 167.40 ± 4.12 cm and weight 59.30 ± 5.41 kg},

10 non-injured group {mean height 166.76 ± 4.62 cm and weight 58.93 ± 5.30 kg}), with at least one year experience in competitive ballroom dancing, in the standard division participated in this study. All subjects competed at a Dancesport competition either in the novice, pre-championship, and/or amateur standard classifications. Inclusion criteria for the injured group included female ballroom dancers who had a loss of neck control episode. **Measurements:** Surface EMG activity was recorded from the left UT, left SPL, and right SCM muscles before and after dancing the five standard dances. **Results:** The decrease in EMG MF was not significant between groups. There was no difference in neck lengths from the external occipital protuberance to inferior angle of the scapula between groups. There were also no significant differences in range of motion of left and right lateral flexion and extension in either group from pre to post dancing. **Conclusions:** Based on the results of this study, subjects with a history of neuromuscular neck injury did not appear to have acute fatigue of the three muscles studied here following the routine used in this study. **Key Words:** ballroom dancing, neck injuries, electromyography, and muscular fatigue

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CONTRIBUTIONS OF MUSCLE FATIGUE TO A NEUROMUSCULAR NECK
INJURY IN FEMALE STANDARD BALLROOM DANCERS

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ABSTRACT

Objective: To investigate the potential etiology of a loss of neck control injury in female standard ballroom dancers. The median frequency (MF) as measured by electromyography (EMG) of the left upper trapezius (UT), left splenius capitus (SPL), and right sternocleidomastoid (SCM) of injured dancers was compared to non-injured dancers. This comparison was performed to identify whether dancers with a history of loss of neck control have a greater amount of fatigue than those with no history of this particular injury. **Design and Setting:** A 2 x 6 factorial design was used for this investigation. The independent variables were group (injured vs. non-injured) and time (before and after the three rounds of dancing). The dependent variables were MF as measured by EMG, range of motion, and neck length. All testing was performed at the university biomechanics laboratory and ballroom dance studio. **Subjects:** Twenty female subjects (10 injured group {mean height 167.40 ± 4.12 cm and weight 59.30 ± 5.41 kg}, 10 non-injured group {mean height 166.76 ± 4.62 cm and weight 58.93 ± 5.30 kg}), with at least one year experience in competitive ballroom dancing, in the standard division participated in this study. All subjects competed at a Dancesport competition either in the novice, pre-championship, and/or amateur standard classifications. Inclusion criteria for the injured group included: female ballroom dancers who had a loss of neck control episode. **Measurements:** Surface EMG activity was recorded from the left UT, left SPL, and right SCM muscles before and after dancing the five standard dances. **Results:** The decrease in EMG MF was not significant between groups. There was no difference in neck lengths from the external occipital protuberance to inferior angle of the scapula

between groups. There were also no significant differences in range of motion of left and right lateral flexion and extension in either group from pre to post dancing. **Conclusions:** Based on the results of this study subjects with a history of neuromuscular neck injury did not appear to have acute fatigue of the three muscles studied here following the routine used in this study. **Key Words:** ballroom dancing, neck injuries, electromyography, and muscular fatigue

INTRODUCTION

The female dancer's technique in international style standard (or modern in Europe) ballroom dancing involves keeping the upper body and head poised slightly back and a little to the left.¹ This position is described as an extended poise and "arched look".² The female dancer begins with an erect and supported spine, then softly flexes the knees forward and upward to carry the body weight over the front of the feet, and lastly stretch the neck to the left.² A correctly held dance frame uses all the muscles of the back to carry the arms and neck.³

During competitions some female dancers are unable to maintain this position, and the head falls into a paralysis-like condition.⁴ The cause of this loss of neck control is unknown at this time. It may be due to an acute onset of fatigue in the cervical flexor and lateral rotation muscles, resulting in uncontrollable inability to sustain static posture of the neck. When female dancers lose control of their necks their head flops back into extension and they cannot return the head to an upright position. Female ballroom dancers may also experience loss of neck control during competition due to faulty technique, blood flow, and amount of centripetal force during turns (e.g. Viennese Waltz).

It may be possible to determine a contributing cause of loss of neck control injuries using electromyography (EMG), which measures muscle activity.⁵⁻¹⁷ Several researchers have used EMG to identify which muscles are active during specific dance motions.¹⁶⁻²² However, these researchers have not utilized EMG during fatiguing muscle contractions following simulated dance routines. The median frequency (MF) from an

EMG signal is the most reliable and valid method to estimate muscle fatigue during contraction.^{6, 23-25} Muscular fatigue is measured as a decrease in the MF during a sustained contraction.²⁶ The power spectrum of the EMG signal is compressed to lower frequencies during sustained contractions, thus the MF will decrease with fatigue.²⁶ This can possibly be credited to a slowing of muscle conduction velocity.²⁷ Gogia and Sabbahi⁸ reported that MF of the myoelectric spectral shifts can be measured in the cervical paraspinal extensor muscles.

The objective of this study was to compare shifts in MF of female standard ballroom dancers with previous loss of neck control injury to dancers with no previous history of this injury. This comparison was performed to answer the question of whether dancers with a history of loss of neck control demonstrate greater fatigue of the upper trapezius, left splenius capitus, and right sternocleidomastoid muscles than dancers with no history of injury. It was hypothesized that injured dancers would have a greater shift in the EMG MF in these three muscles, and therefore greater fatigue, compared to non-injured dancers.

METHODS

Twenty female standard ballroom dancers performed three rounds of five international style dances. Electromyographic activity of three neck muscles was measured before and after each round.

Experimental Design

A 2 x 6 design was used to determine if differences existed between groups over time. The independent variables were group (injured and non-injured) and time (EMG was measured before and after each of the three rounds of dancing). The dependent variables were MF measured using EMG, range of motion for neck extension (EXT), left and right lateral flexion (LLF and RLF) and neck length between the external occipital protuberance (O), cervical 7 spinous process (C7), acromioclavicular joint (AC), and inferior angle of the scapula (IA).

Subjects

Subjects were informed of the testing procedures and possible risks associated with the study. University IRB approval was obtained and the subjects provided informed consent prior to participating in the study.

Twenty female subjects, with at least one year experience in competitive ballroom dancing (standard division), were recruited to participate in this study. Their demographic data is listed in Table 1. The subjects had competed at a Dancesport competition either in the novice, pre-championship, and/or amateur standard classifications according to National Dance Council of America (NDCA) rules.²⁸ Female participants were accepted with or without previous loss of neck control injury. Existing or previous neck injuries

must have been related to ballroom dancing. Dancers who had neck injury due to other causes were excluded. A questionnaire asking about dance history, injury history, and partner history was used to assign subjects into previously injured and non-injured groups (questionnaire A). Results of the questionnaire are listed in Tables 1 and 2. We assumed that the subjects involved in this study represented the population of standard female dancers that often experience loss of neck control.

Inclusion criteria for dancers placed in the injured group included having a loss of neck control episode related to ballroom dancing (Table 3). Dancers with a history of neck injury related to other causes were excluded. Dancers who had no previous loss of neck control injuries or episodes were placed in the non-injured group. Dancers with previous or current neurological neck injury or other injuries that would preclude participation were excluded. All participants used their most recent standard male partners. The non-injured group reported that they have been dancing 0.87 ± 0.78 years together, whereas the injured group had been dancing together for 1.68 ± 2.14 years (Table 3).

Orientation

On the day of data collection, prior to participation, all potential female participants and their partners attended an orientation meeting and screening which included a general explanation of the study, completion of questionnaires, obtaining informed consent, measurement of height, weight, neck length, neck range of motion, learning the choreography, and assignment to groups. The male dance partners also read

and signed an informed consent, completed part of the questionnaire, and were measured for height and weight.

Subjects and their partners watched a video to learn the standardized novice level choreography that was to be performed for each dance. The subjects and their partners practiced the choreography in the lab and dance studio before they performed it for the study.

Instruments and Measurements

Electromyography and Median Frequency. The Biopac MP150 system (BIOPAC Systems, Inc., Santa Barbara, CA) was used to measure muscle activity. Signals were amplified from 1 cm diameter pregelled Ag-AgCl surface electrodes with a fixed interelectrode distance of 2 cm (Product # 272 Noraxon Dual Electrodes, disposable, self-adhesive, Noraxon USA, Inc., Scottsdale, AZ). The ground electrode was also a circular 1 cm diameter pregelled Ag-AgCl surface electrode (Type M-00-S Blue Sensor disposable electrodes Medicotest, Inc., Rugmarken, Denmark). The EMG measurements were collected at 1000 Hz. The input impedance of the amplifier was 1.0 mega ohm, with a common mode rejection ration of 90 dB, bandpass filter of 10 Hz to 500 Hz, a signal to noise ratio of 70 dB, and a gain of 1000. Raw EMG signals were processed using a root mean square (RMS) algorithm with a 5 msec moving window. A Microsoft Visual Basic 6.0 (Microsoft Corporation, Redmond, WA) custom program identified the MF curve for each trial (data set) in the data analysis. The equation used to calculate the MF was:

$$\int_{x_1}^{x_{Median}} S(x)dx = \int_{x_{Median}}^{x_2} S(x)dx$$

Where $S(f)$ is the spectral density of the EMG signal, x_1 is the lowest frequency of the spectrum, x_2 is the highest frequency in the spectrum, and x_{median} is the MF of the spectrum. An average of 4.979 seconds or 4979 samples of the 5 seconds of collected data was used in data reduction.

Goniometer. Active neck EXT, RLF, and LLF range of motion (ROM) was measured with a fluid goniometer (Medical Research Ltd., Leeds, UK) prior to and after completion of the dance routine. To measure ROM, the head was in neutral (anatomical position) and the goniometer was placed on the top of the head, set to zero. Range of motion was measured as the subjects moved their head into RLF, LLF, and EXT. The subjects were reminded to stand up straight.

Neck length was the distance between the following structures: 1) O to C7; 2) C7 to AC; and 3) AC to IA. The IA is approximately the male partner's hand placement when dancing. A basic measuring tape using centimeters was utilized. This measurement was performed to find out if there was a difference in neck length between the injured and non-injured subjects.

Testing Procedures

The subjects participated in this study for one day (approximately three to four hours). The same testing procedures were performed for all participants. The subjects did not wear their competition costume. The subjects also did not use competition hair styles which can be elaborate and affect the EXT or lateral flexion of the neck.

The electrode sites were cleansed with gauze and isopropyl alcohol. Surface electrodes were placed on the following four locations:

- Left upper trapezius (UT) just lateral to and even with the C2 spinous process.
- Left splenius capitis (SPL) between the UT and upper sternocleidomastoid (SCM) below the occipital bone.
- Middle half of the right SCM muscle.
- The ground electrode was placed over the C7 spinous process.

Correct placement was confirmed with manual muscle testing and visual inspection of the raw EMG signal. After the electrodes were attached, they were outlined by black marker to be sure of correct replacement if they fell off while dancing.

The EMG recordings were taken prior to and immediately after each round of dancing. A total of six EMG recordings were obtained from each female dancer. Subjects were instructed to stand in dance position with their partners while muscle activity was recorded for five seconds. Range of motion was again measured at the end of dancing for neck EXT and lateral flexion.

Dance Routine

The dance routine simulated a ballroom competition following NDCA rules for competition.²⁸ Each dance partnership performed to the same timed music and video taped choreography for each group. Five dances using international style were performed for each round. These dances included (in order) the Waltz, Tango, Viennese Waltz, Slow Foxtrot, and Quickstep. All partnerships performed all 5 dances with a 30 second break between dances for each round. Each dance was 1:30 long with a fade out, except for the Viennese Waltz which was 1:15 long. The tempo (measures per minute; mpm) for

the waltz, tango, Viennese waltz, slow foxtrot, and quickstep were 28 bpm, 32 bpm, 56-58 bpm, 28 bpm, and 50-52 bpm respectively. To simulate competition, the subjects performed three rounds of the five dances with a 20 minute break between each round. During the 30 second break between dances the participants walked to their next starting position. For the 20 minute break between rounds the dancers were told to do what they normally do during competition. Some participants ate, drank, practiced the routines, or sat and rested.

Statistical Analysis

The data were analyzed with a 2 x 6 factorial ANOVA with repeated measures on time. Follow up testing was performed with a Tukey's honestly significant differences test to detect specific changes post hoc. Alpha level was set at $p < .05$.

The independent variables were group (injured and non-injured) and time (before and after three rounds of dancing). The dependent variable was MF analysis measured using EMG, ROM, and neck length.

RESULTS

A total of 20 subjects (10 injured, 10 non-injured) were recruited, participant demographics are shown in Tables 1, 2, and 3. No analysis was completed on the subjects' ballroom experience, but the descriptive information is provided in Table 2.

The means and SDs of the MF in all three muscles are shown in Table 4, and Figures 1, 2 and 3. No group by time MF differences were detected for any of the muscles (UT, $F_{1,18} = 0.874$, $P = 0.363$; SCM, $F_{1,18} = 0.335$, $P = 0.570$; SPL, $F_{1,18} = 1.721$, $P = 0.207$; Table 5).

Range of motion for neck Ext, LLF, and RLF are reported in Table 3. A group by time analysis for ROM revealed no differences (Ext, $F_{1,18} = 0.061$, $P = 0.808$; LLF, $F_{1,18} = 2.246$, $P = 0.151$; RLF, $F_{1,18} = 0.166$, $P = 0.688$; Table 6).

Length between O and C7, C7 and AC, and AC to IA and pre- and post LLF and RLF and Ext ROM values of the neck are reported in Table 3. An independent t test was performed to compare neck length in both groups. No significant differences were found (O to C7 $F_{1,18}=1.448$, $P=0.244$, $t = 0.891$, Sig.(2-tailed) = 0.385; C7 to AC $F_{1,18}=1.519$, $P = 0.234$, $t = 1.158$, Sig.(2-tailed)=0.262; AC to IA $F_{1,18} = 0.004$, $P = 0.953$, $t = 1.169$, Sig.(2-tailed) = 0.258; Table 7).

DISCUSSION

The hypothesis of this study was that the acute loss of neck control in female standard ballroom dancers was caused by fatigue in the right SCM, left UT, and left SPL muscles and those changes in the MF of the EMG would be an accurate indicator of muscle fatigue and acute injury. Although the results of this study revealed an overall decrease in MF for both groups there were no significant difference in MF between injured and uninjured dancers before or after dancing (Tables 4 and 5, and Figures 1, 2, and 3).

There are several possible explanations for the lack of significant differences in the EMG activity between groups reported in this study. From clinical observation, the only time this loss of control injury has occurred is during competitions. This might be due to the fact that during concerts or rehearsals, the dancers may not have their necks in the dancing position for the same amount of time as during competition and/or the dances may not be in the same order. Although the dance routine used in this study was selected to simulate a competitive experience, it likely lacked some of the components of a competition routine. A sample of some of the components missing would be: costumes, hair styles, adrenaline rush of competition, the audience, and no other couples to compete against.

Qualitative differences in experience existed between dancers in the injured and non-injured groups in this study (Table 3). Dancers in the injured group had been ballroom dancing for an average of 7.18 years compared to the 4.41 years of experience of dancers in the non-injured group. Differences in experience were also reflected in the

competitive level of the dancers in each group. Dancers in the injured group were competing at a Pre-Champ/Amateur level, whereas dancers in the non-injured group were competing at a Novice/Pre-Champ level. This may have affected our estimates of fatigue as more experienced dancers would certainly have built a stronger neuromuscular base for the activity.

The results of this study also suggest that the dance routine may not have presented a neuromuscular challenge of the magnitude necessary to result in significant changes in EMG activity and loss of neck control. None of the dancers experienced loss of neck control (as explained earlier) during this study. Although the MF of dancers in both groups decreased (non-significantly) over time, there were no differences in the changes in MF between groups (Figures 1, 2, and 3). The choreography for this study was at a novice level. The dancers in the injured group commented that the choreography was not difficult for them and wanted to make it harder, this may have been because they compete at a higher level. The dancers in the non-injured group commented that the choreography was at or exceeded what they were use to, because they compete at the same level as the choreography (Table 2).

Dancers in the injured group indicated that they had experienced loss of neck control injury with their current partner an average of 2.71 times (Table 3). The age at which the injury first occurred, nature of rehabilitative treatments, training, coaching, and frequency of loss of neck control prior to their current dance partner were not determined. This information could have provided insights into contributing factors to loss of neck control injuries.

Neck length (Table 2) was measured with the speculation that neck length might contribute to faulty technique and loss of neck control injury.^{2,3} However, there was no difference in neck length between the two groups. Dance medicine professionals agree that poor technique is one of the primary causes of dance injuries.²⁹ Howse³⁰ maintains that when determining the cause of a dance injury, the first question should be what technical flaw caused the injury. Technical errors can occur because of anatomical causes, lack of knowledge, incorrect instructions, not applying the correct technique, and environmental causes.³⁰ Fatigue may also affect a dancer's technique.³⁰

The primary idea underlying this loss of neck control injury focuses around fatigue of the neck muscles. The results suggested that fatigue of the UT, SPL, and SCM might not be the contributing factor to this condition (Figures 1, 2, and 3); however, that does not completely rule out fatigue as a possible etiology of this condition. Fatigue of postural muscles during ballroom dance may be caused by a number of factors. A decrease in blood supply to the muscles is one factor. Hagberg⁹ examined arm elevations in industrial workers and found a decrease in action potentials because of a decrease in blood flow. A decrease in blood flow prevents muscles from receiving the necessary oxygen and nutrients required for muscle contractions and the removal of lactic acid.^{9,31} Although Hagberg's³² research was with muscles of the shoulder, a reduction in blood flow to the neck may result in loss of neck control in ballroom dancers. In the ballroom dance position, the arms are at a 90 degree angle for up to 7 to 10 minutes in one round of competition, possibly reducing blood flow to the neck. This would prevent removal of lactic acid from the neck muscles resulting in fatigue.

Some researchers have suggested that intramuscular pressure exceeding 30 to 50 mmHg reduces local muscle blood flow.¹¹ Järholm et al¹¹ found that if the supraspinatus intramuscular pressure exceeded 42 mmHg or 16% of MVC it would impede muscle blood flow. They concluded that when the arms are elevated during high intensity working conditions, obstructed blood flow can cause localized muscle fatigue.¹¹

Another factor which could contribute to muscular fatigue is the sustained intensity at which the dancers compete. Ballroom dancing can be considered a high intensity working condition. Blanksby and Reidy³³ found that male and female standard dancers had mean heart rates of 170 bpm and 173 bpm, respectively.³³ The Viennese waltz (VW) resulted in the highest heart rate in males (181 bpm) and females (185 bpm).³³ This would be considered in the extremely high category.³⁴ The loss of neck control injury occurs most often during the VW, possibly due to the centripetal forces produced during the VW.

An alternate idea as to why female ballroom dancers experience loss of neck control during competition may be the amount of centripetal force during turns (e.g. VW). It is possible that compared to other dances, the turns in the VW produce a greater amount of centripetal force on the neck. For this reason, the EMG activity of the right SCM was measured in this study. We speculated that the right SCM would fatigue more because of its role in stabilization the head during VW turns (Table 4). The results of this study indicate that the SCM did not fatigue at a significant rate. In ballroom dancing, natural turns are a turn to the right and reverse turns are a turn to the left.³⁵ In performing the VW turns, the dancers stay in dance position and perform reverse or natural turns

every two seconds²⁸. It is unknown how much centripetal force is placed upon the head during reverse or natural turn, however, it must produce enough force during a competition for females to experience loss of neck control more than when performing any other move. The dancer holds the neck in the same static position whether the turn is a natural or reverse turn. For this reason, we measured left lateral flexion and extension range of motion in this study. The results of this study indicate that there were no significant differences in lateral flexion and extension range of motion between the two groups (Table 2). Most choreography in the VW includes only natural or reverse turns. Choreography of the other four dances allows the dancer to move her head in different positions.¹ This head position in the VW could be considered an isometric contraction with a constant force output. Moritani et al²⁶ suggested that an isometric contraction can be influenced by the excitation-contraction coupling, which can decrease the pH from lactate production and cause fatigue. Since ballroom dance position is an isometric contraction, especially with possible increase in forces during VW turns, fatigue could still be the etiology of this injury. During the other four dances the female dancer holds her head a little to the left and moves her head in response to her partner's lead. In the VW, the head is held in a constant position.³⁶

To the best of our knowledge, we are the first to conduct research on the loss of neck control injuries in female ballroom dancers. A literary search in the medical databases produced only one incidence of a neck injury of a ballroom dancer. It was a case study of cervical radiculopathy in a 52-year-old woman who had been standard ballroom dancing for three years.³⁷ Cervical radiculopathy is produced by compression

and inflammation of a cervical spinal root.^{37,38} Radicular distribution in one or both upper extremities occurring in episodes often lasting for a few weeks can occur with varying degrees of sensory, motor and reflex changes.³⁹ The most common level is at C6 and C7, the latter is the level the 52-year-old ballroom dancer sustained.³⁷⁻⁴¹ Lesion to the C7 nerve root level include the following symptoms: tingling or numbness down the long and ring fingers;³⁸ loss of triceps reflex; pain in the interscapular forearm, chest, and ulnar hand areas; motor weakness in elbow extension, wrist flexion, and finger extension; and possible scapular winging bilaterally or only on affected side.³⁸ Wainner and Gill⁴¹ reported that most incidents occur in 40 - 50 year olds. The case study subject was 52 years old and had been dancing for three years.³⁷ The subjects in this study had an average age of 22 years old and have been dancing an average of 5 years (Tables 1 and 3). None of the participants in this study complained of symptoms for cervical radiculopathy.

Although there were no other reports of neck injuries in female ballroom dancers found in the literature, it is possible that neck injuries in female ballroom dancers occur more often than they are reported. This may be due to a lack of medical professionals that supervise ballroom dance competitions.

While the results of this study suggested that fatigue of the UT, SPL, and SCM in dancers with a history of loss of neck control were no different than dancers without a history, a few limitations should be summarized. Only three neck muscles were studied. Other muscles that also execute extension and lateral flexion should be studied. It is acceptable to use surface electrodes for superficial muscle, but needle electrodes should

be used for deeper muscles, such as the splenius capitus. Also the EMG measurements were recorded before and after all five dances were concluded, instead of before and after each individual dance. Another limitation is choreography. The choreography for this study was at the novice level, however the injured subjects competed in the pre-championship/amateur category. A suggestion would be to have the dancers use their own choreography. This study accepted subjects from three competition categories, which was a less than ideal sample of subjects. Additionally, the dancers did not have the fancy hair styles common to competitions, which would add to the weight carried during the dances.

CONCLUSION

Fatigue may not be the primary cause of this common neck injury. There was no significant difference in median frequency for all three muscles, range of motion for all three motions, and neck length. It is still possible that fatigue, technique, choreography, and experience are contributors to this loss of neck control injury. More data are needed to rule out fatigue as a primary cause of this injury.

Future research can compare fatigue rates for all five dances. This may reveal the contribution of each of the dances to the occurrence of loss of neck control. EMG activity of different muscles or combination of muscles, such as, the levator scapulae, scalenes, platysma or other neck muscles can also be studied. Future studies may have the dancers perform their own choreography or set the choreography to the pre-championship or amateur level.

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Table 1. Subject and Partner Data Means and SD

	Non-Injured	Injured
Subject Height (cm)	166.76 ± 4.62	167.40 ± 4.12
Subject Weight (kg)	58.93 ± 5.30	59.30 ± 5.41
Partner Height (cm)	181.40 ± 4.10	183.44 ± 5.78
Partner Weight (kg)	78.03 ± 11.13	76.43 ± 8.46
Subject Age	22.20 ± 3.05	20.90 ± 2.92
Partner Age	23.10 ± 2.69	23.00 ± 3.46

Table 2. Subjects Ballroom Experience Means and SD

	Non-Injured	Injured
How long have you been ballroom dancing? (years)	4.41 ± 1.57	7.18 ± 2.84
How long have you been dancing together? (years)	0.87 ± 0.78	1.68 ± 2.14
How many dance partners have you had?	4.50 ± 2.84	4.10 ± 1.52
How many times have you had this injury?		2.71 ± 1.70
How long have you been competing as a Standard dancer? (years)	3.02 ± 1.24	6.43 ± 2.44
What level are you currently competing?	2.90 ± 1.29	4.10 ± 0.74
How long have you been at this level? (years)	1.72 ± 1.40	2.60 ± 2.02

Key for competition level: Novice = 1, Novice/Pre-Champ = 2, Pre-Champ = 3,

Pre-Champ/Amateur = 4, Amateur = 5.

Table 3. Neck Lengths and ROM Means and SD

	Non-Injured	Injured
O to C7 (cm)	10.95 ± 1.42	10.44 ± 1.12
C7 to AC (cm)	19.45 ± 1.30	18.85 ± 1.00
AC to IA (cm)	22.38 ± 1.84	21.49 ± 1.56
Pre LLF (degrees)	55.30 ± 12.78	55.40 ± 18.64
Pre RLF (degrees)	52.70 ± 11.81	52.30 ± 16.90
Pre Ext (degrees)	84.70 ± 14.53	85.60 ± 9.79
Post LLF (degrees)	54.10 ± 9.57	62.00 ± 12.98
Post RLF (degrees)	55.40 ± 11.36	57.38 ± 9.55
Post Ext (degrees)	86.80 ± 17.20	88.75 ± 13.56

Table 4. Injured and Non-Injured Median Frequency Means and SD

	UT		SCM		SPL	
	Injured	Non-Injured	Injured	Non-Injured	Injured	Non-Injured
Pre 1	13.36 ± 7.88	13.39 ± 7.07	9.14 ± 5.34	9.92 ± 6.45	11.53 ± 7.32	8.25 ± 5.84
Pre 2	12.40 ± 8.85	12.21 ± 7.31	10.39 ± 5.64	8.75 ± 3.89	12.57 ± 7.56	8.53 ± 4.15
Pre 3	11.01 ± 7.50	10.44 ± 7.02	9.98 ± 4.22	9.01 ± 5.04	10.43 ± 6.52	8.71 ± 5.20
post 1	12.08 ± 8.95	11.99 ± 8.86	9.62 ± 5.80	7.53 ± 3.04	9.14 ± 6.20	5.07 ± 1.46
post 2	12.60 ± 8.35	8.55 ± 6.29	6.96 ± 1.75	6.90 ± 2.66	7.10 ± 6.13	8.09 ± 5.39
post 3	8.27 ± 5.53	8.66 ± 5.30	7.45 ± 3.36	6.46 ± 1.89	6.47 ± 4.17	6.10 ± 2.53

Table 5. Median Frequency ANOVA

	Df	F	ρ	Eta Squared
UT	1,18	0.874	0.363	0.049
SCM	1,18	0.335	0.57	0.019
SPL	1,18	1.721	0.207	0.092

Table 6. ROM ANOVA

	Df	F	ρ	Eta Squared
LLF	1,18	2.246	0.151	0.111
RLF	1,18	0.166	0.688	0.009
Ext	1,18	0.061	0.808	0.003

Table 7. Neck Length Independent *t* Test

	Df	F	<i>P</i>	<i>t</i>	Sig. (2-tailed)
O to C7	1,18	1.448	0.244	0.891	0.385
C7 to AC	1,18	1.519	0.234	1.158	0.262
AC to IA	1,18	0.004	0.953	1.169	0.258

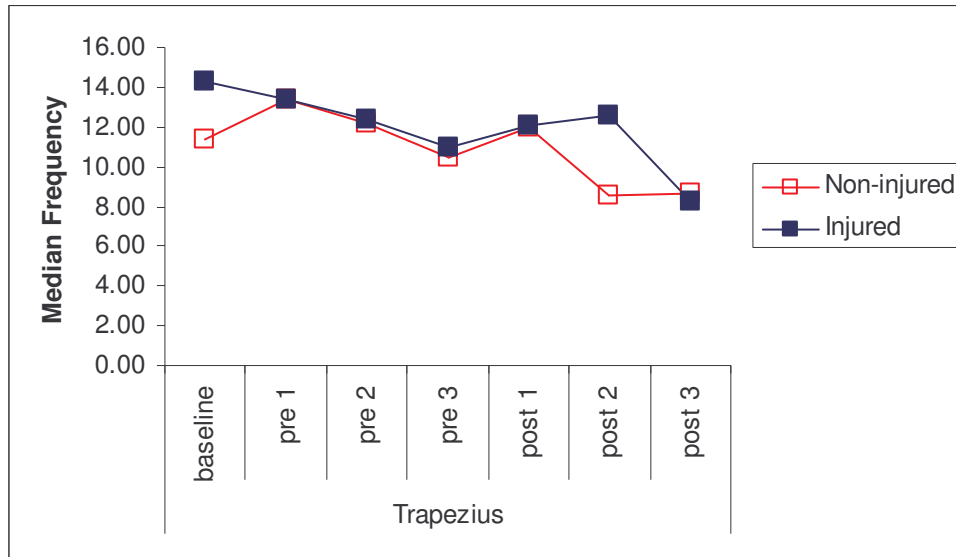


Figure 1. Upper Trapezius Median Frequency

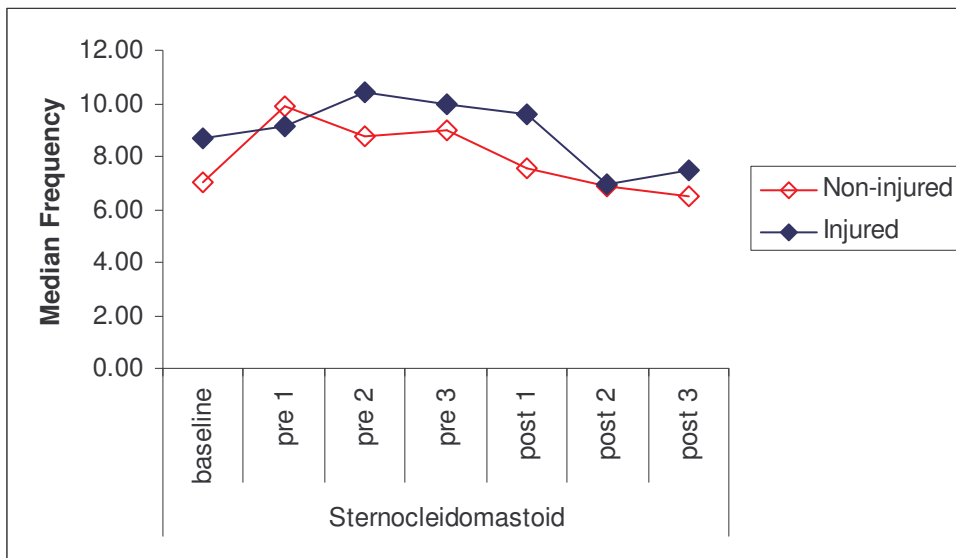


Figure 2. Sternocleidomastoid Median Frequency

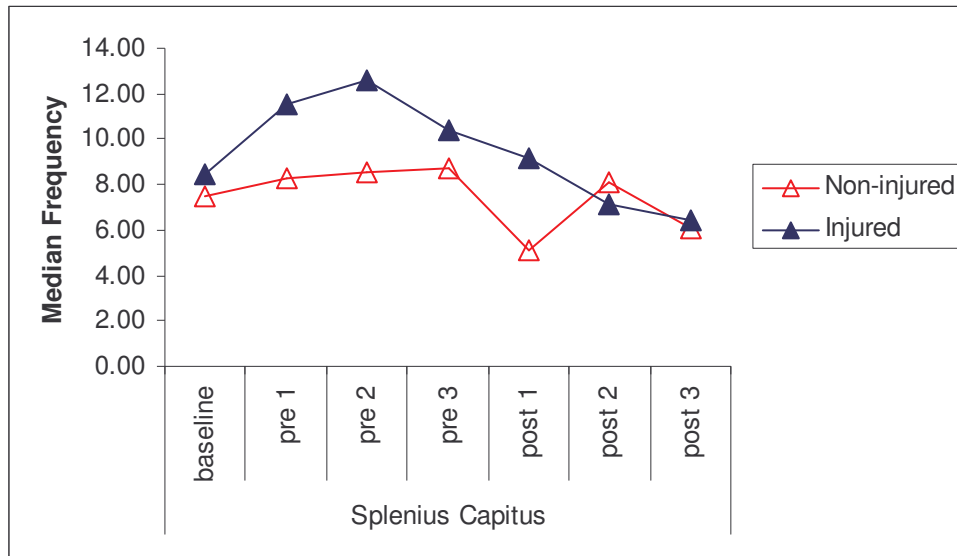


Figure 3. Splenius Capitus Median Frequency

Appendix A

Prospectus

Chapter 1

Introduction

Ballroom dancing has evolved over the centuries from being performed in the royal courts into what is now recreational and competitive ballroom dancing.¹ When dancing, the female standard dancers hold their neck in left lateral flexion and extension with the shoulders in abduction.² Standard dancing is a style of ballroom dancing. The Waltz, Tango, Viennese Waltz, Slow Foxtrot, and Quickstep are examples of standard dances. The Imperial Society of Teachers of Dancing (ISTD) ballroom technique book² briefly mentions how the female dancers upper body should be in a position of poise. It states the female should²:

- stand in an upright position
- brace body at the waist
- keep the upper body and head poised slightly back and a little to the left
- hold weight over the balls of the feet
- hold knees slightly flexed

The centrifugal forces placed upon the neck while holding the head in this position makes the female dancers susceptible to a soft tissue neck injury. This “loss of neck control” injury can be described as an acute onset of fatigue in the cervical flexor and lateral rotation muscles accompanied by a rapid, uncontrollable inability to sustain static posture of the neck. When the female dancers lose control of their neck their head flops back into extension and they cannot return the head to an upright position.

The ballroom community recognizes this problem by shortening the time of the Viennese Waltz.³ In the Viennese Waltz, reverse turns place a great amount of force on the neck. There are many contributing factors to the loss of neck control experienced by female ballroom dancers, including, the male partner's hand position on her back, decreased core strength, dance position of arms, neck, and back, and fatigue in the neck muscles. When the dancers have extravagant hair styles this adds to the weight of the head and may contribute to fatigue of the neck muscles. Loss of neck control in female ballroom dancers only occurs during competitions, not rehearsals or concerts.

Only one documented case of a neck injury in a ballroom dancer was found in the literature.⁴ However, neck injuries in female ballroom dancers occur more often than they are reported due to lack of medical professionals that supervise competitions.

In this study we will examine muscle fatigue as a possible contributing factor to injuries related to loss of neck control in standard female ballroom dancers.

Electromyography (EMG) will be used to measure and analyze median frequency as an indicator of muscle fatigue in the left upper trapezius, left splenius capitiis, and right sternocleidomastoid.

Research Question

Do female standard ballroom dancers with previous neck injury have a greater shift in median frequency in the left upper trapezius, left splenius capitiis, and right sternocleidomastoid compared to non-injured female standard ballroom dancers?

Hypothesis

Electromyography will identify a shift in lower median frequency in the left upper trapezius, left splenius capitiis, and right sternocleidomastoid muscles in previously injured female standard ballroom dancers compared to non-injured female standard ballroom dancers.

Null Hypothesis

Electromyography will not show in a shift in median frequency in the left upper trapezius, left splenius capitiis, and right sternocleidomastoid muscles in previously injured female standard ballroom dancers compared to non-injured female standard ballroom dancers.

Definitions

Amateur Ballroom Dancer: An amateur, non-teenager, by NDCA rules, is considered a dancer over the age of sixteen years and who dances strictly for an avocation, a recreational activity, or competitive sport, and who participates in dancing without seeking or receiving financial gain. This includes the novice, pre-championship, and amateur classifications.³

Electromyography (EMG): A technique used to record action potentials originating from skeletal muscle.⁵

Imperial Society of Teachers of Dancing (ISTD): A professional teachers' society that has codified the International style of ballroom dance.⁶

Injured Dancer: A female standard dancer who has previously experienced a loss of neck control during a ballroom competition in the last eighteen months.

International Style Standard Ballroom: International is a style of standard ballroom dancing. The dances that are included are Waltz, Tango, Viennese Waltz, Slow Foxtrot, and Quickstep. This is the style that will be performed during the electromyography of this research.⁶

Loss of Neck Control: This injury can be described as an acute onset of fatigue in the cervical flexor and lateral rotation muscles accompanied by a rapid, uncontrollable inability to sustain static posture of the neck. When the female dancers lose control of their neck their head flops back into extension and they cannot return the head to an upright position. The cause of this loss of neck control is unknown at this time.

Median Frequency: The frequency content of an EMG signal detects the shape of action potentials. The frequency content of the signal spans a range of frequencies with varying shapes. When the shape of an action potential changes so does the shape of the frequency content.

During a fatiguing contraction the action potentials decline in amplitude and increase in duration and the power density spectrum shifts to the left. Shifts in the power density spectrum are characterized by changes in the median frequency. Median frequency divides the spectrum into two halves based on the energy content of the signal. When the power density spectrum shifts to the left, as in fatiguing contractions, the median frequency will decrease.⁵

Muscle Fatigue: Muscle fatigue results in an exercise induced reduction in the maximum force that a muscle can exert or the ability to maintain a given amount of work. Fatigued muscles have a decrease in EMG median frequency.⁵

National Dance Council of America (NDCA): A non-profit organization founded in 1948 whose purpose is to represent the interests of those in the dance profession and other dance-related entities and organizations. It also acts as the agency for cooperation with similar councils in other countries. It is the governing body of ballroom dance in the United States.⁶

Non-injured Dancer: A female standard dancer who has not experienced loss of neck control in the last eighteen months.

World Dance and Dancesport Council (WD&DSC or Dancesport): Founded in 1950 as the International Council of Ballroom Dancing, this dance organization is the governing body of the affairs of professional ballroom dancing throughout the world.⁶

Assumptions

Loss of neck control in female standard ballroom dancers can be caused by fatigue in the neck muscles. Median frequency changes are an indicator of muscle fatigue. The subjects represent the population of standard female dancers that develop this loss of neck control.

Delimitations

Only females who compete in novice, pre-championship, and amateur standard and/or are in the Dance 384R, 483R, and 484R classes during Fall 2004 semester will participate in this study.

Female participants will be accepted with or without previous loss of neck control injury.

Existing or previous neck injuries must be related to ballroom dancing. Dancers who have neck injury due to other causes will be excluded.

Limitations

Participating subjects' ballroom dancing or other fitness activities will not be controlled.

Since ballroom dancers tend to change competitive partners frequently, the data will be repeated if the subjects change partners during testing for a competition.

Most of the neck injuries occur in teenage female dancers and beginning dancers, but only collegiate female dancers with varied experience will participate in this study. Participating dancers may have developed the ability to control their head better, thereby limiting the prevalence of injury in this study. With the varied experience of the female subjects some may have the risk of this loss of neck control more than others. Since we are dividing the subjects into injured and non-injured groups it is possible the injured or the non-injured subjects will have more or less experience than the other group. Note: If the dancers have an injury during testing, the BYU Dance Medicine Training Facility personnel will treat it.

Significance of the study

This is the first attempt to explain the etiology surrounding loss of neck control in female standard ballroom dancers. If we are successful in identifying muscle fatigue in left upper trapezius, left splenius capitiis, and right sternocleidomastoid muscles as a contributing factor to injuries related to loss of neck control, we can facilitate possible prevention by dance educators and treatment by dance medicine personnel.

Chapter 2

Review of Literature

Literature Searched

Databases, years, and keywords searched are summarized below:

Database	Years Searched	Keyword(s) in Search
PubMed	1950-Present	Dance injuries
PubMed	1950-Present	Ballroom dancing
Web of Science	1984- Present	Ballroom dancing
PubMed	1950-Present	Ballroom injuries
PubMed	1950-Present	Cervical radiculopathy
PubMed	1950-Present	Sports neck injuries
PubMed	1950-Present	Sternocleidomastoid muscle
PubMed	1950-Present	Trapezius muscle
PubMed	1950-Present	Splenius capitis muscle
PubMed	1950-Present	Electromyography of neck muscles
PubMed	1950-Present	Median frequency
Web of Science	1984- Present	(used for reference chasing)

Organizations Governing Ballroom

The National Dance Council of America (NDCA) was founded in 1948, when ballroom became a popular dance form.^{3,6} The NDCA was formed to represent the interests of American dancers in the international setting.^{3,6} The World Dance and Dancesport Council (Dancesport) was founded in 1950 to govern the affairs of professional ballroom dancing throughout the world.⁶

There are also organizations that certify ballroom dance teachers. The Imperial Society of Teachers of Dancing (ISTD) was formed as a professional teachers' society that has codified the International style of ballroom dance.² The ballroom dancers at

Brigham Young University (BYU) must be members of NDCA to compete. The ballroom technique classes at BYU use the textbooks published by ISTD.

Ballroom Dancing Technique

Most technique books teach correct foot positions and step patterns, yet little attention is given to the head and neck position of the female ballroom dancer. The ISTD ballroom dance technique book² states that the upper body should be in positions of poise and holds for the female dancers. In the poise position, the lady should stand in an upright position, body braced at the waist with the upper part of body and head poised slightly back and a little to the left. The dancer's weight held over the balls of the feet with the knees held slightly flexed.²

The inclination for the female standard dancers is to hold their neck in left lateral flexion and extension with the shoulders in abduction.² This position of the head while dancing makes the female dancers susceptible to a soft tissue neck injury.⁴ This loss of neck control injury can be described as losing control of the neck or a whiplash. When the female dancers lose control of their neck their head flops back into extension and they cannot return the head to dance position or upright.

Ballroom Injuries

A literary search in the medical databases (PubMed and Web of Science) produced only two articles on ballroom dance injuries. Both were case studies of female ballroom dancers. One article was of a young amateur female dancer who stepped

incorrectly during a syncopated spin in the waltz.⁷ The other injury was cervical radiculopathy in a 52-year-old woman who had only been standard ballroom dancing for three years.⁴

Cervical radiculopathy is produced by compression and inflammation of a cervical spinal root.^{4,8} The most common level is at C7⁸, which is the level the 52-year-old ballroom dancer sustained.⁴ Since this occurs at the C7 nerve root level, symptoms include tingling or numbness down in the long and ring fingers.⁸ Other manifestations may be a decrease in the triceps reflex, pain in the interscapular forearm, chest, and ulnar hand areas, motor weakness in elbow, wrist, and fingers, and possible scapular winging.⁸ The collegiate ballroom dancers we are going to study so far have not had these symptoms. Their only complaint is being unable to hold their head in dance position.

Sports Neck Injuries

During a literature review of neck injuries in sports that would be similar to female ballroom dancers, cycling is the only sport found to have non-impact related neck injury that is similar to what the female ballroom dancers' experience. Neck injuries occur in cyclists who typically ride in a position of neck hyperextension. Wilber et al⁹ and Weiss¹⁰ reported that of all the overuse injuries in cyclists, neck and shoulder were the most common. Mellion¹¹ reported that a combination of increased load on the arms and shoulders necessary to support the rider and hyperextension of the neck in the horizontal riding position contributes to cyclists' neck injuries. The following suggestions were made so that cyclists can reduce the incidence of injury: having the bicycle fitted to

the rider, technique adjustments, changing hand positions frequently, varying head positions, riding with unlocked elbows, using padded gloves and handlebars, and riding on wider tires.¹¹

Ergonomic Neck Injuries

The literature sites many articles referring to the use and position of the elbows, arms, shoulders, neck joints and muscles in work place settings. Overuse neck injuries have occurred in assembly line workers and office workers who use a computer the majority of their time. These are commonly called repetitive strain injuries.¹² The etiology of repetitive strain injuries are not due to the extreme motions or forces that dancers or athletes undergo, but the muscles are in continuous low contraction doing the same actions for hours at a time. This leads to similar symptoms as those found in dancers and athletes.

Neck injuries are not as costly to employers compared to low back pain, but they are on the rise.¹³ Yassi¹² lists trapezius myalgia, cervical syndrome, rotator cuff tendonitis, and thoracic outlet syndrome as common injuries to workers. Järvholm et al¹⁴ studied the influence of muscle contraction on the local blood flow of the supraspinatus. They found that blood flow to the supraspinatus was significantly impeded at 5.6 kPA (42 mm Hg) or more, which can be equal to 16% maximal voluntary contraction.¹⁴ Therefore, with the arms working in an elevated position could cause the supraspinatus to fatigue or have permanent disease with prolonged elevation.¹⁴ Bjelle et al¹⁵ found shoulder load to have an effect in shoulder and neck disorders. Hagberg¹⁶ studied which

muscles showed fatigue during shoulder elevation. Using electromyography found that the trapezius and supraspinatus muscles fatigue developed rapidly.¹⁶

Electromyography

Electromyography (EMG) has been used to measure muscle activity and fatigue.^{13, 14, 16} Three studies were found using EMG for muscle activity in dancers in the literature search.¹⁷⁻¹⁹ Two of the studies were combined to determine which muscles were active in the different cycles of plié and grand-plié compared to standing.^{17, 18} In the other study, patterns of muscular involvement were measured for the grand battement devant.¹⁹ Researchers have used EMG for motion analysis,^{17, 18, 20, 21} mechanical modeling,²² angular momentum measurements,²³ and force plate analysis^{19, 20} to analyze different dance motions.

Electromyography, essentially, is the measurement of action potentials.⁵ Seroussi²⁴ and Enoka⁵ suggested areas for which EMG is useful: ergonomics, diagnosing neurologic disorders, patient's response to physical therapy, research in exercise physiology, and biomechanics. There is various research for detecting which muscles are active during specific motions.^{17, 18}

Enoka⁵ defined muscle fatigue as an exercise induced reduction in the maximum force that a muscle can exert. During a fatiguing muscle contraction the EMG decreases in amplitude and the frequency at which motor units fire decreases.⁵ This is caused by the fast twitch muscle fibers fatiguing more rapidly and slow twitch fibers being recruited to compensate.⁵ Hagberg¹⁶ examined arm elevations and found a decrease in action

potentials because of a decrease in blood flow. This decrease in blood flow will prevent the muscles from receiving the nutrients for muscle contractions.^{16, 25}

Filtering, by Enoka,⁵ is defined by a signal processing term that describes the alteration of the frequency content of a signal. Examples of filtering are low-pass, high-pass, and band-pass. The filters can remove the high, low, or both high and low frequencies, making the resulting EMG signal much smoother.⁵ Most researchers utilized band pass filter when measuring SPL, SCM, and UT. The filter ranged from 5-500 Hz.²⁶⁻³² However, Kumar et al³³ used a low pass of 8 Hz.

Normalization has been defined as the expression of an outcome measure relative to a factor that contributes to differences in the measure among individuals.⁵ EMG is usually normalized with an isometric contraction.^{16, 34, 35} Feinberg³⁴ suggests that a minimum of 20% MVC is needed to compare.

The median frequency is the best way to measure energy content in the myoelectric signal.^{5, 34, 36, 37} Median frequency divides the spectrum into two halves based on the energy content of the signal.^{5, 36} When the action potentials in the EMG change, so does the frequency content of the EMG signal.⁵ This happens in a fatiguing contraction, as the action potentials decline in amplitude and increase in duration the power density spectrum shifts to the left.⁵ Shifts in the power density spectrum produce a decrease in median frequencies.⁵ Gogia and Sabbahi¹³ studied if the myoelectric spectral changes could be measured in cervical musculature. They found that median frequency of the myoelectric spectral shifts can be measured in cervical paraspinal extensor musculature.¹³

Inter-electrode distance (IED) is the space between a pair of electrodes.⁵ Many different distances are used. For example, 1 cm,^{27, 33} 2 cm,³⁰ 3 cm,²⁹ 5 mm,^{31, 32} or 15 mm²⁶ apart. Farina et al³² studied the effects that IED had on electrode placement. The results suggest that an IED of 20 mm should be used for global muscle analysis.³²

There were a few studies that measured the SPL, SCM, and UT, but most measured them separately. Portero et al³⁰ used only the right SCM and UT because that is the way their machine was set up. Kumar et al³³ measured the SCM and UT in lateral flexion. Portero et al³⁰ placed the surface electrodes for the SCM on the upper part of the sternal head and Kumar et al³³ placed them anteriorly in the inferior half. Watson and Colebatch³⁸ used bilateral SCM and placed the electrodes on the medial portions of the clavicles. Although they were measuring vestibulocollic reflexes with short-duration galvanic stimulus, the electrodes were 20-30 mm lower than used in previous studies.³⁸

The electrodes for the UT are placed in many different positions. Kumar et al³³ placed them level with the C4 spinous process. Queisser et al²⁶ stated he positioned the electrodes even with C5/6 process. Farina et al³² determined to standardize electrode placement and IED for the UT. They placed the electrodes equal to C7 spinous process on the lateral edge of the acromion.³² Farina et al's next experiment,³¹ Madeleine,²⁸ Cools,²⁷ and Portero³⁰ also located them even with the spinous process of C7. Madeleine et al²⁸ measured electrode placement as 20 mm lateral from C7. Schüldt and Harms-Ringdahl³⁹ measured three places for the UT and one for the SPL. The UT pars descendens electrode placement was level with C2-3 spinous process with the matching electrode 30-35 mm caudally, UT pars descends at the anterolateral margin about the

middle third of the distance between occiput and acromion, and the middle trapezius pars transversa was placed level with the supraspinatus muscle on both the left and right sides.³⁹ The SPL electrodes were placed level with C2-3 between the uppermost parts of trapezius and SCM.³⁹ Kumar et al³³ also measured SPL. They placed the electrodes on the upper SPL in the lower portion of the apex made by the SCM and UT.³³ Cools et al²⁷ and Farina et al^{31,32} also tested the middle and lower trapezius. She was studying the latency and recruitment pattern of the trapezius in fatigued situations. Queisser et al²⁶ also measured the semispinalis, splenius capitis, and levator scapulae to find which EMG will predict torque in neck extensor muscles.

From the literature reviewed it has been determined for this study the median frequency will be used to analyze the EMG. The UT electrodes will be placed level with the C4 spinous process, the SPL will be placed level with C2-3 between the uppermost parts of trapezius and SCM, and the SCM electrodes will be located on the middle to superior portion of the muscle. A manual muscle test will be performed to confirm correct placement of the electrodes. The electrodes will have a fixed inter-electrode distance of 2 cm for all muscles. Normalization will be used by attaching a weighted harness to the head and having the dancer assume dance position with their partner. The EMG signal will be filtered using a bandpass of 5 to 500 Hz. This method of EMG will assist in identifying which neck muscle is fatiguing when ballroom dancing.

Purpose of the Study

In this study we will examine the possible contributing factor of muscle fatigue that may result in a neck loss of control injury in standard female ballroom dancers using electromyography. Female dancers are more susceptible to this loss of neck control injury during competition than during rehearsals or performances.

During a concert or rehearsal, a dancer may perform a standard dance for up to 6 minutes before doing a costume change prior to the next dance. Also, the choreography may not have their necks in the dancing position for the same amount of time as during competition.

During competitions, the NDCA rules³ state that an amateur couple will need to perform the 5 standard dances (Waltz, Tango, Viennese Waltz, Slow Foxtrot, and Quickstep) during one round of the competition with a minimum of a 20-30 second break between each dance.³ Yet, because of the number of couples in each round some may have breaks for up to two minutes. The Waltz, Tango, Slow Foxtrot, and Quickstep music is required to be a minimum of one minute and thirty seconds and a maximum of two minutes long with the Viennese Waltz lasting a minimum of one minute and fifteen seconds and maximum of one minute and thirty seconds long.³ The couple is allowed 20-60 minutes between rounds.³ For some dancers they may not be familiar holding their head in dance position for this amount of time. Therefore, their neck muscles will become fatigued and lose control of the neck. An amateur (including novice, pre-championship, and amateur classifications), non-teenager, by NDCA rules, is considered a dancer over the age of sixteen years and who dances strictly for an avocation, a recreational activity,

or competitive sport, and who participates in dancing without seeking or receiving financial gain.³

Summary

There are many theories/ideas why female ballroom dancers lose control of their neck during competition; even the ballroom community recognizes this problem by having Viennese Waltz time shorter than the other dances. A few of the other theories include the partner's hand position on her back, decreased core strength, and dance position of arms, neck, and back. However, we are only studying muscle fatigue in three neck muscles.

If this study can identify some of the fatiguing muscles that possible contribute to this loss of control neck injury then we can prevent this loss of neck control from happening during competition and the dancer instructors and dance medicine personnel can understand the technique and treatment of this loss of neck control injury.

Chapter 3

Methods

Research Design

A 2 x 6 design will be used for this investigation. The independent variables will be group (injured and non-injured) and time (3 pre and 3 post before and after each round of dancing). The dependent variable will be median frequency analysis measured using electromyography (EMG). The control variable will be range of motion (ROM).

Subjects

Only females who compete in novice, pre-championship, and amateur standard and/or are in the Dance 384R, 483R, and 484R classes during Fall 2004 semester at Brigham Young University will be eligible to participate in this study. Approximately 50 female subjects, with at least one year experience in competitive ballroom dancing, in the standard division, will be recruited to participate in this study.

A questionnaire asking about dance history, injury history, and partner history will be used to assign subjects into previously injured and non-injured groups (see appendix B). Each group will have approximately 25 participants.

Exclusion factors include previous loss of neck control injury other than from ballroom dancing, any previous or current neck neurological injury, and other injuries that will preclude ballroom dancers from participating. For instance, a shoulder or lower extremity injury that prevents them from competing or dancing correctly.

Inclusion criteria for the injured group include: female ballroom dancers who have had a loss of neck control injury in the last 18 months. Inclusion criteria for the non-injured group: dancers who have not had a loss of neck control injury in the last 18 months.

Subjects will be informed of the testing procedures and possible risks associated with the study. University IRB approval will be obtained prior to commencement of the study. The subjects will be required to give informed consent prior to participating in the study.

Instruments

The Biopac MP150 system (BIOPAC Systems, Inc., Santa Barbara, CA) will measure muscle activity. Signals will be amplified from pregelled Ag-AgCl surface electrodes (Product # 272 Noraxon Dual Electrodes, disposable, self-adhesive, Noraxon USA, Inc., Scottsdale, AZ, USA). The ground electrode will be a pregelled Ag-AgCl surface electrode (Type M-00-S Blue Sensor disposable electrodes Medicotest, Inc., Rugmarken, Denmark). The EMG measurements will be collected at 1000 Hz. The input impedance of the amplifier will be 1.0 mega ohm, with a common mode rejection ration of 90 dB, bandpass filter of 5 Hz to 500 Hz, a signal to noise ratio of 70 dB, and a gain of 1000. Raw EMG signals will be processed using a root mean square (RMS) algorithm with a 5 msec moving window. A Microsoft Visual Basic 6.0 (Microsoft Corporation, Redmond, WA) custom program will identify a median frequency curve for each trial (data set) to be used in analysis.

Orientation

An orientation meeting and screening will be held for all subjects and their dance partners prior to testing. A general explanation of the study, completion of questionnaires, obtaining informed consent, measurement of height, weight, neck length measurements, neck range of motion, learning the choreography, and group determination for each subject will be done at this time. The male dance partners will also read and sign an informed consent, complete part of the questionnaire, and have their height and weight measured.

Neck length will be measured as the distance between occipital process to C7 spinous process, and acromial clavicular (AC) joint to C7 spinous process. This will be done to find correct placement of the electrodes.

Range of motion of neck extension and lateral flexion will be measured with a fluid goniometer (Medical Research Ltd., Leeds, UK) at the beginning and at the end of EMG measuring. To measure range of motion the head will be in neutral and the goniometer will be placed on the top of the head, set to zero, then the subjects will move their head into lateral flexion and extension.

Subjects and their partners will watch a video to learn the standardized choreography that will be performed for each dance.

Testing Procedures

The subjects will participate in this study for one day. The same testing procedures will be performed for all participants. The subjects will not be wearing their competition costume, but they will be required to wear their competition shoes.

The skin will be cleaned with gauze and isopropyl alcohol. Surface electrodes will be placed on the following four locations:

- Upper trapezius (UT) will be even with the C2 spinous process just lateral to the spine.
- Splenius capitis (SPL) will be between the UT and upper sternocleidomastoid (SCM) below the occipital bone.
- SCM will be on the superior to middle half of the muscle.
- The ground electrode will be on the C7 spinous process.

Correct placement will be confirmed with manual muscle testing in resisted neck flexion, extension, and lateral flexion. After the electrodes have been placed they will be outlined by black marker to be sure of correct placement if they fall off while dancing. The electrodes will have a fixed interelectrode distance of 2 cm for all muscles.

Normalization of EMG for UT, SPL and SCM will also be done by recording activity from an isometric reference position (IRP). The IRP will be performed by attaching a one kilogram weighted harness to the head and having the dancer assume dance position with their partner. The EMG will be measured for 5 seconds.

The EMG recordings will be taken prior to and immediately after each round of dancing. Subjects will be instructed to stand in dance position with their partners while muscle activity is recorded for five seconds.

Range of motion will again be measured at the end of dancing for neck extension and lateral flexion will be measured with the same fluid goniometer.

Dance Routine

Prior to testing, subjects will perform a warm-up program. This will include stretching the neck, shoulders, and legs and practicing the choreography.

The design of the dancing has been formatted to simulate a ballroom competition. Dancing will be performed to the same timed music and video taped choreography for each group. Five dances using International style will be performed for each round. These dances include (in order) the Waltz, Tango, Viennese Waltz, Slow Foxtrot, and Quickstep. All groups will perform all 5 dances with a 30 second break between dances for each round. Each dance will be 1:30 long with a fade out, except for the Viennese Waltz which will be 1:15 long. The tempo for music will follow NDCA³ rules with Waltz as 28 measures per minute (mpm), Tango as 32 mpm, Viennese Waltz as 56-58 mpm, Slow Foxtrot as 28 mpm, and Quickstep as 50-52 mpm. The subjects will perform the 5 dances for 3 rounds with a 20 minute break between each round, which is similar to competition order.

Statistical Analysis

The data will be analyzed with a 2 x 6 factorial ANOVA with repeated measures on time. Follow up testing will be performed with a Tukey's honestly significant differences test will be used to detect specific changes post hoc. Alpha level will be set at $p < .05$.

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Appendix A-1

Forms

Questionnaire A

Name Phone Number Age

Partner's Name Phone Number Age

How long have you been dancing together? _____ years / months

How many dance partners have you had? _____ years / months

What year in school are you and your partner? Myself My Partner

- | | | |
|------------------|--------------------------|--------------------------|
| Freshman | <input type="checkbox"/> | <input type="checkbox"/> |
| Sophomore | <input type="checkbox"/> | <input type="checkbox"/> |
| Junior | <input type="checkbox"/> | <input type="checkbox"/> |
| Senior | <input type="checkbox"/> | <input type="checkbox"/> |
| Graduate Student | <input type="checkbox"/> | <input type="checkbox"/> |

How long have you been . . . ballroom dancing? _____ years / months

 competing in ballroom dancing? _____ years / months

 a Standard dancer? _____ years / months

 a Latin dancer? _____ years / months

At what level are you currently competing? (circle one)

Amateur Pre-Champ Novice

How long have you been at this competition level? _____ years / months

Do you compete in ten dance? (circle one) Y N

Are you on a formation team? (circle one) Y N

Is your partner on that formation team? (circle one) Y N

Are there other styles of ballroom that you dance? (circle one) Y N

(i.e., social, country, swing, cabaret, theatre arts, American smooth, other)

 If so, how long have you been dancing in each of these other styles of ballroom?

Have you had training in other styles of dance? Y N

(i.e., ballet, folk, modern, jazz, other)

 If so, how long have you been dancing in each of these styles?

Do you do any other types of exercise besides ballroom? Use the space below to describe what you do and how often.

Questionnaire B

Name Phone Number Age

Please answer the following questions about injuries that you currently have or have had in the past. An injury is any bone or soft tissue (muscle, tendons, etc...) damage that has resulted in pain. Please include injuries whether you have sought or received treatment or not.

Are you currently injured? Yes No
If "yes", describe your current injury?

This injury occurred . . . while rehearsing a dance.
 while performing in a dance concert.
 while competing in dance.
 during some activity other than dance.

Have you had injuries in the last 6 months?
Please describe the injuries.

Have you ever had a neck injury? Yes No
If "yes", did the neck injury occur Yes No
during ballroom dancing?
How many times have you had a
neck injury while dancing? _____
If the neck injury did not occur
during ballroom dancing, describe
how/when it occurred.

Have you had a neck injury with Yes No
your current partner?
Have you had a neck injury with Yes No
another partner?
Have you had a numbness, tingling, or a nerve injured? Yes No
If yes, how long ago? _____
Are you currently taking any medications Yes No
for a nerve or muscular disorders?

Consent to be a Research Subject

We are performing research to measure muscle activity in the neck muscles of female ballroom dancers. The study will be conducted by Teri Riding, ATC a master's degree seeking student at BYU, Dr. Ty Hopkins, ATC, Dr. Pat Vehrs, and Dr. David Draper, ATC.

As a participant you will be asked to participate in one session that will be 3 hours in duration in the Biomechanics Lab and room 270 in the Richards Building. During the first hour of the session you will be asked to have the following measurements recorded: height, weight, the distance between the back of your head to the end of your neck, the distance between your shoulder to the end of your neck, the distance between your shoulder and where your partner's hand is placed, and range of motion of your neck. The next two hours you will be asked to have the muscle activity in three front and back muscles of your neck along with having you participate in a choreographed routine, the five international style ballroom standard dances three times. This will follow the NDCA rules of competition. You will not be required to wear your competition costume, but you will be required to wear your competition shoes.

The risk during participation of this research is the same as when you participate in ballroom competitions. The possibility of injury is always present during any competition. If such an event occurs during this investigation you should know that the investigators are certified in First Aid, CPR, AED, and Athletic Training and will provide the necessary first aid. If serious injury does occur the BYU Emergency Medical Services

will be notified. You, the subject, will be responsible for any medical bills which should occur. You may withdraw from this study at any time.

To be a participant you must not have any current medical conditions which may limit your current level of activity, including musculoskeletal injuries, cardiovascular problems, pregnancy, neurological diseases, or any respiratory diseases. You should be between the ages of 18 and 30 years. You are responsible to fully disclose any injury to the investigational staff. There will be no monetary compensation for participating in this study. You will not be required to bear any monetary cost for your participation although you are responsible for reporting to your sessions at the appropriate time.

Your decision whether or not to participate in this study is entirely voluntary and will not prejudice your future relation with Brigham Young University or the investigators. If you decide to participate, you are free to withdraw from the study and discontinue participation at any time. The investigator may terminate your participation at any time.

You may be excluded from participating in this study if you have certain conditions or injuries that increase risk of participation. Questions about these conditions or injuries are asked in the pre-participation questionnaire.

Your results will be held in confidence as you will be assigned a number and no names will be reported in the results. The results of this study will be reported in a Master's Thesis written by Teri Riding, Dr. Ty Hopkins, Dr. Pat Vehrs, and Dr. David Draper. Questions regarding the research can be addressed by Teri Riding at 375-0032 or 422-1628 or Ty Hopkins 422-1573. Should you have any questions regarding your rights

as a participant, contact Dr. Renea Beckstrand, Chair of the Institutional Review Board, Brigham Young University, Provo, UT 84602 (422-3873).

I have read, understood, and received a copy of the above consent, and desire of my own free will and volition to participate in this study.

Date Participant Signature _____ _____
Date Witness Signature

Parental Consent to be a Research Participant

As your child has competed in ballroom dancing your daughter may previously have experienced a neck injury. I am conducting research to measure muscle activity in the neck muscles of female ballroom dancers following a competitive-like dance routine. Your child has been requested to participate in this study because they compete in either Novice, Pre-Championship, or Amateur category of ballroom dancing.

As a participant your child will be asked to participate in one session that will total 3 hours in duration in the Biomechanics Laboratory (124 RB) and room 270 in the Richards Building. During the first hour of the session we will record the following measurements: height, weight, the distance between the back of the head to the end of the neck, the distance between the shoulder to the end of the neck, the distance between the shoulder and where the partner's hand is placed, and motion of the neck. You will also help fill out a questionnaire asking about your child's medical history. Over the next two hours your child will be asked to participate in a choreographed routine, the five international style ballroom standard dances three times. This will follow the NDCA rules of competition. Between routines we will measure muscle activity while your daughter holds a dance position. Your child will not be required to wear their competition costume, but they will be required to wear their competition shoes.

The risks during participation of this research are the same as when they participate in ballroom competitions, such as musculoskeletal injuries. The possibility of injury is always present during any competition. If such an event occurs during this investigation you should know that the investigators are certified in First Aid, CPR, AED,

and Athletic Training and will provide the necessary first aid. If serious injury does occur the BYU Emergency Medical Services will be notified. You, the parent/guardian, will be responsible for any medical bills which could occur. You may withdraw your child from this study at any time.

To be a participant your child must not have any current medical conditions which may limit their current level of activity, including musculoskeletal injuries, cardiovascular problems, pregnancy, neurological diseases, or any respiratory diseases. Your child should be between the ages of 14 and 18 years. You and your child are responsible to fully disclose any injury to the investigational staff. There will be no monetary compensation for participating in this study. You will not be required to bear any monetary cost for your child's participation.

Your decision whether or not to allow your child to participate in this study is entirely voluntary and will not prejudice you or your child's future relation with Brigham Young University or the investigators. If you decide to participate, you are free to withdraw your child from the study and discontinue participation at any time. The investigator may terminate your child's participation at any time.

Your child may be excluded from participating in this study if he/she has certain conditions or injuries that increase risk of participation. Questions about these conditions or injuries are asked in the pre-participation questionnaire.

The results will be held in confidence as your child will be assigned a number and no names will be reported in the results. The results of this study will be reported in a Master's Thesis written by Teri Riding, Dr. Ty Hopkins, Dr. Pat Vehrs, and Dr. David

Draper. Questions regarding the research can be addressed by Teri Riding at 801-918-3359 or Ty Hopkins 422-1573. Should you have any questions regarding your rights as a participant, contact Dr. Renea Beckstrand, Chair of the Institutional Review Board, Brigham Young University, Provo, UT 84602 (422-3873).

I have read, understood, and received a copy of the above consent, and desire of my own free will and volition to allow my child to participate in this study.

_____	_____	_____	_____
Date	Parent/Guardian Signature	Date	Witness Signature

Adolescent Assent to be a Research Participant

My parent/guardian has given permission for me to take part in this research study. I understand that this study will require me to participate in one session that will be 3 hours long in the Biomechanics Lab and the ballroom room in the Richards Building.

During the first hour of the study you will be asked to have the following measurements recorded: height, weight, the length of your neck, the length of your shoulder, the distance between your shoulder and where the partner's hand is placed, and the motion of your neck. You will also fill out a questionnaire asking about your ballroom dancing history.

The next two hours we will measure the activity of three neck muscles measured. You will also participate in a choreographed routine; the five international style ballroom standard dances (waltz, tango, Viennese waltz, foxtrot, and quickstep) three times. This will follow the NDCA rules of competition. You will not need to wear your competition costume, but you will need to wear your competition shoes.

The risks to participate in this research are the same as when you participate in ballroom competitions, such as muscle injury. The possibility of injury is always present during any competition. You may leave this study at any time.

To be a participant you must not have any current medical conditions which may limit your current level of activity, including injuries to your muscles or joints, heart problems, pregnancy, or other diseases. You should be between the ages of 14 and 18 years. You need to tell us about any injuries that you have had before. You will receive

no money for participating in this study and you will not be required to pay any money to participate.

Your decision whether or not to participate in this study is up to you and will not risk your possible future with Brigham Young University or the researchers. If you decide to participate, you are free to leave the study at any time and the researchers may end your participation at any time.

You may be stopped from participating in this study if you have certain conditions or injuries that raise the risk of participation. Questions about these conditions or injuries are asked in the questionnaire.

The results will be kept secret because you will be assigned a number and no names will be reported in the results. The results of this study will be reported in a Master's Thesis written by Teri Riding, Dr. Ty Hopkins, Dr. Pat Vehrs, and Dr. David Draper. Questions about the research can be asked to Teri Riding at 801-918-3359 or Ty Hopkins 422-1573. Should you have any questions about your rights as a participant, contact Dr. Renea Beckstrand, Chair of the Institutional Review Board, Brigham Young University, Provo, UT 84602 (422-3873).

I understand that I may withdraw participation in this study at any time without being penalized.

_____	_____	_____	_____
Date	Adolescent's Signature	Date	Witness Signature

Appendix B
Subject Photographs



Photo 1. EMG Equipment

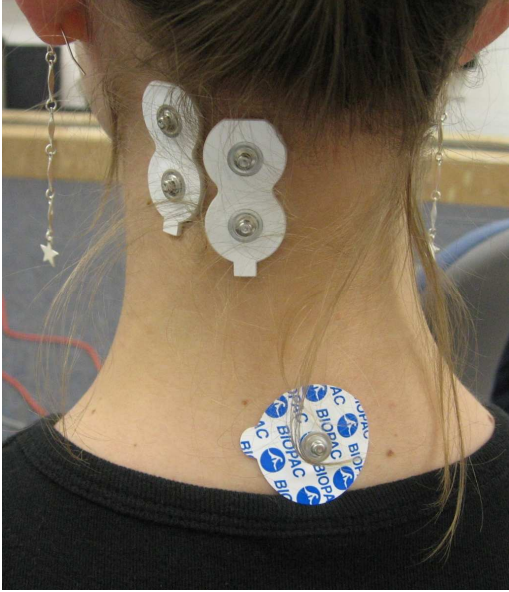


Photo 2. Posterior Neck Electrode Placement

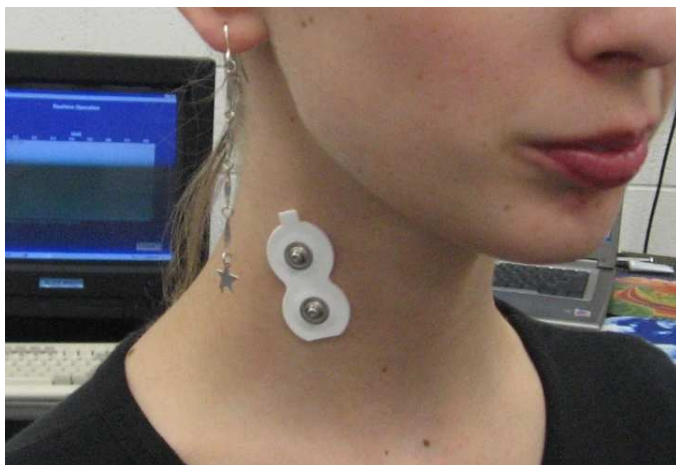


Photo 3. Anterior Neck Electrode Placement

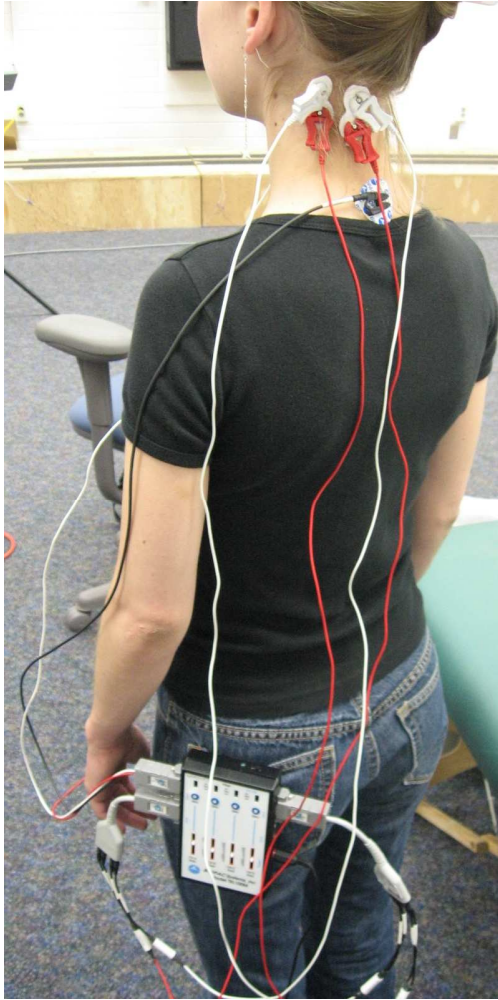


Photo 4. Subject Connected to the EMG Equipment Posterior View

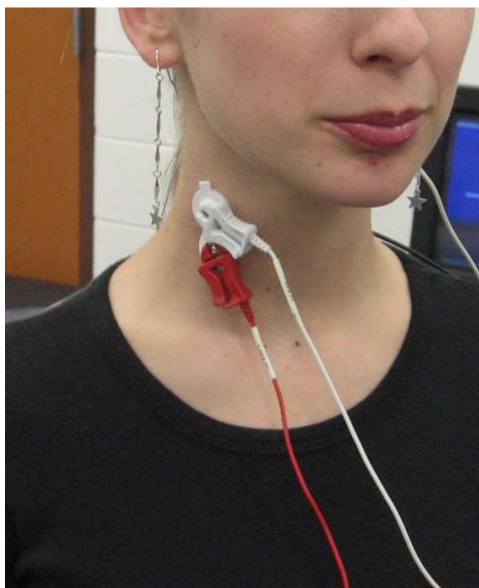


Photo 5. Subject Connected to EMG Equipment Anterior View

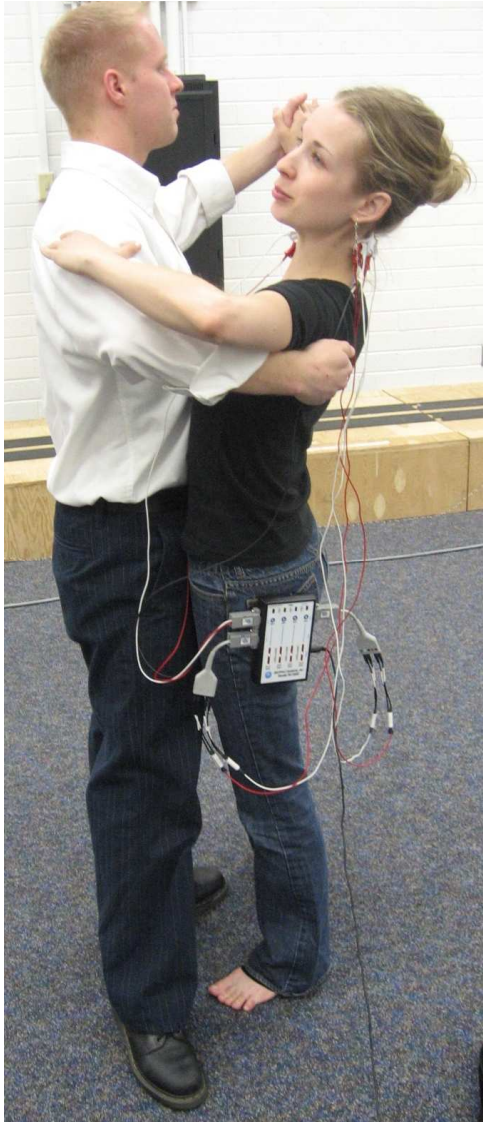


Photo 6. Subject and Partner Connected to EMG in Dance Position



Photo 7. Fluid Goinometer Posterior View



Photo 8. Fluid Goinometer Left Lateral Flexion

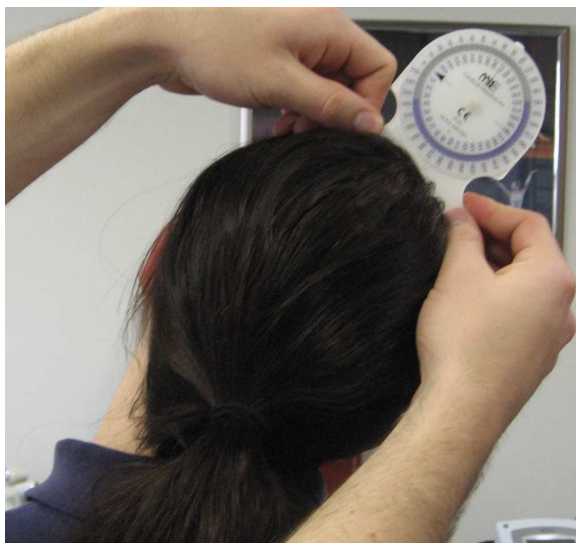


Photo 9. Fluid Goinometer Right Lateral Flexion



Photo 10. Fluid Goinometer Lateral View



Photo 11. Fluid Goinometer Extension



Photo 12. Neck Length O to C7

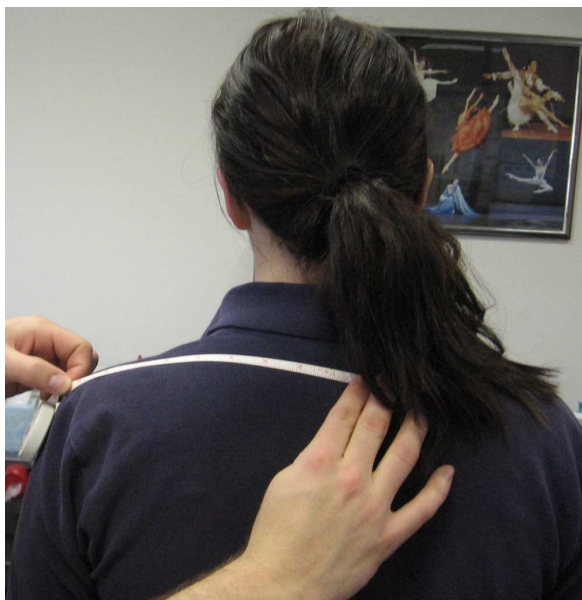


Photo 13. Neck Length C7 to AC



Photo 14. Neck Length AC to IA



Photo 15. Head Harness for Isometric Reference Position Posterior View

Appendix C
Suggestions for Future Research

Future Research Suggestions Include:

1. Comparing fatigue rates for all five dances to each other. This may help find out if one dance is causing the dancers' necks to fatigue more than another dance. The VW is suspected to be the culprit with the tango close behind.
2. Study different muscles, such as, the levator scapulae, scalenes, platysma or other neck muscles. There may be more than one muscle that is the etiology.
3. Have the dancers perform their own choreography. This study did not fatigue the dancers' necks as was hoped. It may be the choreography was at a novice level instead of at the level of injured group, which was pre-championship to amateur.
4. Compare amateurs to professionals. This may help with standardized technique for dance position in ballroom dancing.
5. Determine the velocity of VW reverse and natural turns. This may reveal the speed of VW turns and if the VW is the etiology of this loss of neck control injury.