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A Biomechanical Study of Work-Related Shoulder Disorder

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Abstract

In the United States, there are over 50,000 new cases of atraumatic occupational shoulder injuries reported annually, with an enormous financial impact due to utilization of healthcare services, lost workdays and worker disability costs. Although the etiology of these injuries is clearly multifactorial, based on the available epidemiologic evidence, NIOSH has concluded that there is a direct link between repetitive work activities and occupational shoulder disorders. Furthermore, MRI data have confirmed that a high level of lifetime shoulder elevation represents a significant risk factor for damage to the rotator cuff tendons. While the mechanisms leading from repetitive elevation tasks to shoulder injuries are still under investigation, laboratory research has consistently shown that fatigue resulting from repetitive arm motion leads to deficits in proprioception and kinematics, which could ultimately result in abnormal joint loading and soft tissue injury. However, there is a gap in our knowledge regarding the relationship between these deficits and compromised rotator cuff function, especially in workplace settings.

Dental hygienists suffer a high incidence of shoulder pathology that seems to increase with job longevity. It has been hypothesized that occupational injuries could be due to local muscle fatigue caused by repetitive low level work and awkward and constrained working postures. We studied shoulder motion patterns of dental hygienists before, during and after a typical workday. While we did not find any changes in proprioception (the ability to know where their shoulder was in space), we did find that they adapted a more forward leaning posture of their shoulder blade at the end of the workday. Additionally, they used their shoulders at higher elevation angles and with higher speeds than typical office workers for the same duration of work.

The rotator cuff muscles are primarily responsible for stabilizing the humeral head at the shoulder joint, helping to prevent unwanted translations that could lead to impingement or dislocations. We studied the effects of a muscle paralysis of some of the rotator cuff muscles with the use of a nerve block (injection of lidocaine). The result showed that there is a compensatory increase in humeral head translation, shoulder blade rotation and deltoid muscle activation due to the nerve block.

Taken together, these outcomes suggest that increasing muscular strength and endurance of the shoulder muscles could prevent abnormal shoulder motion patterns. This may be beneficial in preventing overuse injuries in workers that use their shoulders in an elevated posture.

Section 1

Significant (Key) Findings

- Following a typical workday, there was an increase in forward tilting of the shoulder blade in dental hygienists. Greater differences were found for subjects with greater job longevity.

- Following a typical workday, there was no change in shoulder proprioception in dental hygienists. However, there were larger joint position errors in dental hygienists with shoulder pain, when compared with those without pain.

- Dental hygienists had bilateral arm elevations above 60 degrees that was more than two times the exposure of office workers for the same duration of work. Additionally, dental hygiene work was found to consist of more dynamics arm motions.

- Using x-rays and electromyography, humeral head translation and muscle activation were measured before and after a nerve block affecting the muscles of the rotator cuff. The humeral head was higher and the shoulder blade was more rotated after the block. Additionally, the deltoid muscle group demonstrated increased muscle activation after the nerve block.

Translation of Findings

- Dental hygienists have a high incidence of shoulder injuries, which may be related to arm elevation exposure. Based on our results, ergonomic interventions should be based on reducing the total arm elevation exposure in dental hygiene. Further, interventions should be designed to reduce the repetitive tasks performed by dental hygienists.

- Ergonomic interventions should be based on reducing the total arm elevation exposure in dental hygiene. Further, interventions should be designed to reduce the repetitive tasks performed by dental hygienists.

- Exercises focusing on strengthening and increasing muscular endurance of the rotator cuff musculature may help prevent weak and dysfunctional rotator cuff muscles. This could help avoid symptoms of shoulder impingement like pain during shoulder elevation due to an increase superior translation of the humeral head. Increasing muscular strength and endurance would be beneficial for workers and athletes that perform numerous overhead activities that predispose them to experience shoulder impingement over time.

Outcomes/Impact

In terms of potential outcomes, dental hygienists should be mindful of their working posture and incorporate breaks where necessary to avoid prolonged static postures. Ergonomic modifications to work station layout or patient scheduling may also be necessary in order to reduce the physical loads and demands of the dental worker. In addition, ergonomic devices and proper equipment may help to limit the amount of time hygienists spend with their extremities in static abduction and elevation. There are currently no intermediate or end outcomes that we are aware of.

Section 2

Background for Project

Work-related musculoskeletal disorders of the upper extremities have been targeted as a priority area for the National Occupational Research Agenda (NORA) of the National Institute for Occupational Safety and Health (NIOSH). According to NORA, this problem accounts for over $2 billion in workers' compensation costs annually in the United States.[1] Total direct medical costs may be as high as $4 billion dollars annually.[2] In recent years, there has been a dramatic rise in the number of occupational shoulder injuries,[3] with the Bureau of Labor Statistics reporting that for the most recent data set available (2003), shoulder problems account for almost 85,000 occupational injuries involving days away from work annually.[1] In fact, the clinical occurrence of shoulder pain is second only to back and neck pain.[4] Clinically, occupational shoulder disorders may present to a physician in the form of occupational cerviobrachial disorder, impingement syndrome (tendinitis) or degenerative joint disease.[5] Although the underlying mechanisms of occupational shoulder injuries have not been well established, a comprehensive review by NIOSH has found that there "is evidence for a positive association between highly repetitive work and shoulder musculoskeletal disorders."[6] Additionally, the National Academy of Sciences has concluded that there is a link between musculoskeletal disorders and repetitive motion at work.[7] Overuse injuries of the shoulder affect a variety of manual laborers, including sewing machine operators,[8,9] mail carriers,[10,11] assembly workers,[12] welders,[13] and dental care workers.[14,15]

Although many professions are affected by work-related disorders of the shoulder, dental hygienists appear to be particularly at risk, with approximately two out of every three hygienists reporting some degree of shoulder pain within the past year of being surveyed.[16] This is perhaps not surprising, given that working as a dental hygienist involves repeated and sustained arm elevation, with a recent study revealing that hygienists work with at least one shoulder abducted over 50% of their workday.[17] Numerous studies have investigated the prevalence of shoulder disorders in this population. On the low end are studies reporting incidences ranging from 26 to 48%.[16,18-20] At the other extreme, many studies report an incidence of at least 60%,[21-24] with Öberg and Öberg reporting that in their study of Swedish dental hygienists, "81% had complaints from one or both shoulder."[15] The discrepancy between studies is probably a combination of differing populations, health care systems, sample sizes, methodology and classification of shoulder problems. Regardless of the exact numbers, the shoulder appears to be a high-risk area for injury in this population. In fact, the incidence of shoulder tendinitis in dental hygienists is comparable to that of industrial workers.[25] The high incidence of shoulder pathologies in hygienists may be attributable in part to deficits this population demonstrates in shoulder flexibility,[26] posture,[27] and muscle fatigue.[28] Although ergonomic interventions have resulted in a positive impact on some of these variables,[29-31] the problem still remains. We believe that this population represents an excellent model in which to study shoulder overuse injuries because of the repetitive nature of their work, high incidence of shoulder injuries and accessibility of subjects. Additionally, as heath care workers, this population falls under one of the NORA Industry Sector Emphasis Areas.

Specific Aim 1 Establish the biomechanical response to high-risk occupational work.
Our hypothesis was that changes in shoulder kinematics and proprioception due to a typical workday for dental hygienists would be correlated with fatigue due to arm exposure.

Methodology

Data were collected before and after a typical workday for dental hygienists. Data collection took place within the place of employment of the subject in order to minimize travel time and time between the end of a workday and kinematic measurements. Subjects arrived for data collection approximately one hour before their first patient arrived and were asked to stay one additional hour after their last patient left at the end of the day. On the day prior to the experiment, subjects were be asked to fill out a self-report questionnaire and measurements of endurance and posterior capsule tightness were be made. On the day of the experiment, measures of fatigue (Borg scale and isometric force) and biomechanics (scapular kinematics and joint position sense) were made twice - once prior to the start of the workday and once at the end of the workday. During the workday, exposure measurements were made with a Virtual Corset (triaxial accelerometer).

Results

Kinematics
For scapular tilting, a significant interaction was found between workday (pre–post) and group ($p = 0.043$). For scapular tilting, no significant interactions were found between humeral elevation angle and group ($p = 0.369$) or for humeral elevation angle and workday ($p = 0.873$). For post hoc analysis, scapular tilting angles were averaged by humeral elevation as humeral elevation had no effect on workday or group. The results of the post hoc independent sample t-tests indicate that hygienists with greater than 20 years of work experience have significantly more ($p = 0.008$) scapular anterior tilting post workday. However, hygienists with less than 20 years of work experience had no significant changes ($p=0.951$) in scapular tilting post workday. No significant interactions or main effects (other than by humeral elevation angle) were found for scapular upward or internal rotation.

Joint Position Sense
Pre workday proprioceptive errors were $3.8^o \pm 3.0^o$ and post workday errors were $3.7^o \pm 2.6^o$. Results of a one-way ANOVA indicate that there was no significant influence of workday exposure on shoulder proprioceptive acuity in dental hygienists $p = 0.95$. To test for differences in shoulder proprioceptive acuity in dental hygienists with and without shoulder pain, all proprioceptive errors were averaged by trial and by workday condition. Dental hygienists were classified as having shoulder pain or having no shoulder pain. Results of an independent samples t-test indicate that dental hygienists with pain had significantly greater proprioceptive errors (mean total errors of $4.4^o \pm 2.4^o$) than dental hygienists with no pain (mean total errors of $3.1^o \pm 1.0^o$) ($p = 0.021$).

Arm Elevation Exposure
A significant interaction was observed between humeral elevation angles and occupation on exposure ($p = 0.002$). Further significant main effects for both angle ($p = 0.001$) and occupation ($p = 0.002$) were detected. Three independent samples t-tests were used post hoc to test for bilateral occupational arm exposure differences at 30°, 60° and 90° of humeral elevation. Post hoc comparisons indicate that bilaterally (collapsed by arm dominance), significant differences exist between dental hygienists and computer worker's arm elevation exposure above 30° and 60

degrees but not above 90 degrees. No significant interactions were found between occupation and arm dominance for static ($p = 0.920$), slow ($p = 0.951$) or fast ($p = 0.851$) conditions. A significant main effect of occupation was found for all conditions (static, slow and fast). There was no significant main effects of arm dominance for any static ($p = 0.801$), slow ($p = 0.804$) or fast ($p = 0.808$) conditions.

Discussion

Kinematics

The three main risk factors that lead to the development of MSDs in the workplace are force (intensity and duration), posture (awkward and constrained) and repetition.[6] The total number of years of work exposure has additionally been suggested as an occupational risk factor in MSDs, where dental hygienists with more than 20 years of work exposure have significantly more complaints of musculoskeletal pain.[23] Our data suggest that hygienists with more than 20 years of work exposure experienced significant changes in scapular anterior tilting post workday. Upper extremity MSDs in dental hygienists may therefore be associated with changes in scapular kinematics that occur during a workday and cumulate over a lifetime of work. Anton et al., described dental hygienists with greater than 22 years of work exposure as having a higher incidence of upper extremities injuries.[23] Results of our study suggest that dental hygienists with greater than 20 years of work exposure had a 5.2° change in scapular tilt where the less experienced cohort had no changes in scapular tilt. Scapular anterior tilting may have an association with work-related symptoms of the shoulder due to the narrowing of the subacromial space. [32] The change in scapular tilting in the greater than 20 years work experience cohort are similar in magnitude and direction to differences reported by Ludwig et al., in patients diagnosed with shoulder impingement syndrome.[33] While the source of symptoms of shoulder impingement syndrome is believed to be a degeneration of the rotator cuff tendons and bursa within the subacromial space, the actual cause of degeneration is debated.[34] Localized ischemia is thought to occur as a result of the compression forces exerted on the subacromial tissues. However, based on rat model experiments by Soslowsky et al., external compression alone may not suffice to produce tendon degeneration. Their data suggest that external compression must be combined with prolonged overuse to produce tendinous breakdown.[35]

Joint Position Sense

Previous studies indicate that exposure to repetitive work may lead to decreased proprioceptive acuity, especially in female workers.[36] We have previously shown that dental hygienists are exposed to a high degree of repetitive motion during various work related tasks.[37] Results from the current study indicate that exposure to a single workday did not significantly influence joint position sense in dental hygienists. We hypothesized that dental hygienists would have a reduction in proprioceptive acuity as measured by greater errors in joint position sense post workday. Thus, we conclude that in general, exposure to a single day of dental work, does not impair joint position sense for dental hygienists. In an attempt to quantify the resistance to shoulder fatigue, we measured the time to fatigue during an external rotator fatiguing protocol. Despite the range in time to fatigue measured (34 - 142 seconds), we found no differences in terms of proprioceptive acuity by workday with respect to time to fatigue. This indicates that even in hygienists who are quick to fatigue, workday exposure had no influence on joint position sense. It is possible that our joint position sense task was not sensitive enough to measure

changes in proprioceptive errors from a single day of work exposure. It is also possible that dental hygienists recovered from workday fatigue before data were collected post-workday.

Arm Elevation Exposure

We hypothesized that dental hygienists would have greater arm elevation exposure and would work with faster arm velocities than office workers. The inclusion of computer workers served as a basis for comparison, since this group has relatively low rates of occupational shoulder injury. Our results indicate that dental hygienists may spend as much as 7% of their workday with their arm elevated above 60 degrees. When compared to office workers, dental hygienists experienced more than two times the exposure duration to elevated arm postures above 60 degrees, thus supporting our hypothesis. These differences suggest that dental hygienists have greater exposure to shoulder torque, given the larger elevation angles of the arm. Our results additionally indicate that dental work requires less static arm postures than office workers, with greater arm usage at both slow and fast velocities. This latter finding suggests that dental hygienists are exposed to greater repetitive motion than office workers. We found no significant difference between occupations, in terms of current arm disability, though the dental hygienists reported having experienced five-fold more work related shoulder injuries (52%) than computer workers (10%). The greater arm elevation exposure observed among dental hygienists may be related to this difference in injury, a difference that is consistent with earlier reports.[17,38]

Specific Aim 2 Establish the biomechanical response to compromised rotator cuff function. Our hypothesis was that changes in shoulder kinematics due to a nerve block model would be related to the level of impairment of the rotator cuff.

Methodology

Nerve block

Kinematic and EMG data were collected before and after a suprascapular nerve block performed by a board certified anesthesiologist. Subjects were asked to sit, with their head flexed forward, throughout the nerve blocking procedure. One inch above the junction of the middle and outer third of the scapular spine, the suprascapular nerve was targeted at the scapular notch through a skin wheel of 0.2 ml of 1% lidocaine. A total of 40-100 mg of lidocaine was injected to the subject's nerve. Moreover, eight subjects had epinephrine (1:400,000) combined with the lidocaine in order to increase the effects of the nerve block. A time stamp was recorded, and a countdown timer was initiated, the moment the needle was withdrawn. Ten minutes following initial injection, subjects were asked to stand, and the post block trials were collected.

Kinematics

A GE (OEC) 9800 fluoroscopy unit was utilized for collecting two-dimensional in-vivo kinematics of the glenohumeral joint. The sampling rate was set at 8 Hz, which is the highest rate for this system. The fluoroscopy was set at a normal standard mode (59-72 kvp and 0.52-1.5 mA) and the average subject radiation exposure was 659 mR. A standardized protocol was utilized when taking fluoroscopic images in order to regulate each data collection across subject and condition. The protocol was able to control focal point, magnification, and abduction velocity of the arm. During data collection, the subjects were asked to stand in between the c-arm.

Muscle activation

Electromyography (EMG) data were collected to verify minimal muscle activation post suprascapular nerve block. In addition, muscle activation patterns pre and post nerve block were analyzed. Kinematic measurements were synchronized with the EMG activity using an external trigger. The Myopac Jr. (Run Technologies, Mission Viejo, CA) was used to collect raw surface and fine-wire EMG data. This unit provided signal amplification, band pass filtering (10-1000Hz), and a common mode rejection ratio of 110 dB. Output from the Myopac was linked to an analog to digital board in a laptop computer and data were collected at a frequency of 1200 Hz. Disposable Blue Sensor surface electrodes (Ambu Inc, Linthicum, MD) were placed over the anterior deltoid, middle deltoid, posterior deltoid and latissimus dorsi muscles along their primary muscle fiber directions. Sterilized fine-wire electrodes (Chalgren Enterprise, Inc, Gilroy, CA) were inserted intramuscularly in the supraspinatus and infraspinatus muscles. To allow for normalization of EMG measures, EMG data were collected during a standard Maximum Voluntary Contraction (MVC) for each muscle.

Results

At 60 degrees of humeral elevation, the humeral head was significantly more superiorly located after the nerve block. There was a significant increase in scapular upward rotation after the nerve block, for humeral elevation angles of 30, 60, and 90 degrees. The supraspinatus, infraspinatus, and middle deltoid demonstrated statistically significant differences from 30 – 120 degrees of humeral elevation angles. The supraspinatus and infraspinatus had decreased muscle activation after the nerve block, while the anterior deltoid, middle deltoid and posterior deltoid showed significant increases at higher humeral elevation angles. In addition, the deltoid muscle group had increased muscle activation during higher humeral elevation. The latissimus dorsi did not show any significant differences across all humeral elevation angles.

Discussion

The current study supports our hypothesis that a suprascapular nerve block results in a compensatory increase in superior translation of the humeral head and greater scapular upward rotation. The observed superior translations at 60 degrees of humeral elevation in the current study are similar to the findings in patients with impingement and rotator cuff tears [39-43]. This provides evidence that there is a compensatory increase in humeral head translation during the mid-range of motion after paralysis of supraspinatus and infraspinatus. In a similar study performed by Werner et al [44], they did not find any significant differences in measured humeral head translation after suprascapular nerve block. There are two possible reasons for the differences seen in measured translation. First, the reference point utilized by the current study was different. The current study used the corresponding humeral elevation angle of the pre nerve block condition to compare translation of the humeral head while the latter study used the humeral head location in the neutral position as the reference. Second, the subjects were seated during arm elevation trials compared to the current study were the subjects were standing. Lastly, they tested 10 subjects while the current study collected and analyzed 20 subjects.

The present study had similar results seen in a related research design that was previously completed in our laboratory. That study also found a more upwardly rotated scapula at mid-ranges of motion after the block.[45] Additionally, our results are similar to other studies that have examined scapular kinematics in rotator cuff patients compared to healthy individuals.[41,43,46] It is interesting to note the increase in scapular upward rotation after paralysis of the supraspinatus

and infraspinatus, since contraction of these muscles are not directly responsible for scapular motion. This result may be due to the fact that some of the subjects reported experiencing difficulty elevating their arm after the suprascapular nerve block. Therefore, the subjects may have compensated for the loss of function of the supraspinatus by hiking theirs shoulder and inducing greater upward rotation of the scapula.

In addition, an increase in muscle activation was observed in all the deltoid muscles after 90° of humeral elevation. The middle deltoid showed increase muscle activation starting at 30° of elevation. This result is in accordance with Thompson et al,[47] who showed a significant increase in the middle deltoid force required to initiate abduction force after paralysis of supraspinatus in a cadaver. This might be due to the fact that it is compensating for the loss of abductor effect of the supraspinatus during the early stages of elevation. One of the main actions of the supraspinatus is to aid the deltoid in elevating the glenohumeral joint.[48] Moreover, McCully et al in their study showed increases in the deltoid muscle group after suprascapular nerve block.[49]

The main goal of the present study was to mimic rotator cuff dysfunction and not rotator cuff tears. The authors used suprascapular nerve block to paralyze the supraspinatus and infraspinatus. The result of the current study showed a more superiorly located humeral head after nerve block at 60 degrees of humeral elevation with a mean value of 1.3 mm. This value is comparable to studies that measured humeral head translation and found significant differences. Chen et al. [50] using a muscle fatigue model observed increased superior humeral head translation of 2.5 mm after the deltoid and rotator cuff were fatigued. Deutsch et al. [40] reported superior translation of the humeral head equivalent to 1.2 mm with rotator cuff patients during humeral elevation. In a more recent study, Bey et al. [51] reported observing superior translation ranging from approximately 2.6 mm during shoulder elevation in subjects that had a surgically repaired supraspinatus tendon tear.

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Inclusion Enrollment Table

Program Director/Principal Investigator (Last, First, Middle): Karduna, Andrew Robert

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Dental Hygienists

Total Enrollment: 71 **Protocol Number:**

Grant Number: 5R01OH008288

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race					
Ethnic Category	**Females**	**Males**	**Sex/Gender Unknown or Not Reported**	**Total**	
Hispanic or Latino	3	0	0	3	**
Not Hispanic or Latino	62	0	0	62	
Unknown (individuals not reporting ethnicity)	6	0	0	6	
Ethnic Category: Total of All Subjects*	71	0	0	71	*
Racial Categories					
American Indian/Alaska Native	1	0	0	1	
Asian	1	0	0	1	
Native Hawaiian or Other Pacific Islander	0	0	0	0	
Black or African American	0	0	0	0	
White	62	0	0	62	
More Than One Race	4	0	0	4	
Unknown or Not Reported	3	0	0	3	
Racial Categories: Total of All Subjects*	71	0	0	71	*

PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)					
Racial Categories	**Females**	**Males**	**Sex/Gender Unknown or Not Reported**	**Total**	
American Indian or Alaska Native	0	0	0	0	
Asian	0	0	0	0	
Native Hawaiian or Other Pacific Islander	0	0	0	0	
Black or African American	0	0	0	0	
White	1	0	0	1	
More Than One Race	1	0	0	1	
Unknown or Not Reported	1	0	0	1	
Racial Categories: Total of Hispanics or Latinos**	3	0	0	3	**

* These totals must agree.
** These totals must agree.

Program Director/Principal Investigator (Last, First, Middle): Karduna, Andrew Robert

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Suprascapular Nerve Block

Total Enrollment: 17 **Protocol Number:**

Grant Number: 5R01OH008288

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race

Ethnic Category	Females	Males	Sex/Gender Unknown or Not Reported	Total
Hispanic or Latino	0	0	0	0 **
Not Hispanic or Latino	10	7	0	17
Unknown (individuals not reporting ethnicity)	0	0	0	0
Ethnic Category: Total of All Subjects*	10	7	0	17 *
Racial Categories				
American Indian/Alaska Native	0	0	0	0
Asian	0	1	0	1
Native Hawaiian or Other Pacific Islander	0	0	0	0
Black or African American	0	0	0	0
White	8	5	0	13
More Than One Race	1	0	0	1
Unknown or Not Reported	1	1	0	2
Racial Categories: Total of All Subjects*	10	7	0	17 *

PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)

Racial Categories	Females	Males	Sex/Gender Unknown or Not Reported	Total
American Indian or Alaska Native	0	0	0	0
Asian	0	0	0	0
Native Hawaiian or Other Pacific Islander	0	0	0	0
Black or African American	0	0	0	0
White	0	0	0	0
More Than One Race	0	0	0	0
Unknown or Not Reported	0	0	0	0
Racial Categories: Total of Hispanics or Latinos**	0	0	0	0 **

* These totals must agree.
** These totals must agree.

Publications

Journal Articles

Amasay T, Zodrow K, Kincl L, Hess J, Karduna A: [2009] Validation of tri-axial accelerometer for the calculation of elevation angles. International Journal of Industrial Ergonomics 39(5):783-799.

Amasay T, Latteri M, Karduna A: [2010] In vivo measurement of humeral elevation angles and exposure using a triaxial accelerometer. Human Factors 52(6):616-26.

Acuna M, Amasay T, Karduna A: [2010] The reliability of side to side measurements of upper extremity activity levels in healthy subjects. BMC Musculoskeletal Disorders 11:168.

San Juan JG, Karduna AR: [2010] Measuring humeral head translation using fluoroscopy: a validation study. Journal of Biomechanics 43(4):771-4.

Ettinger L, McClure P, Kincl L, Karduna A: [2012] Exposure to a workday environment results in an increase in anterior tilting of the scapula in dental hygienists with greater employment experience. Clinical Biomechanics 27(4): 341-345.

Acuna M, Karduna A: [2012] Wrist activity monitor counts are correlated with dynamic, but not static assessments of arm elevation exposure made with a triaxial accelerometer. Ergonomics 55(8): 963-70.

San Juan J, Kosek P, Karduna A. [2013] Humeral head translation after a suprascapular nerve block. Journal of Applied Biomechanics 29(4): 371-9.

Ettinger L, Kincl L, Johnson P, Carter C, Garfinkel S, Karduna A: [2013] Workday Arm Elevation Exposure, a Comparison between Professions, IIE Transactions on Occupational Ergonomics and Human Factors 1(2): 119-127.

Amasay T, Karduna A: [2013] Patient's body size influence dental hygienist shoulder kinematics, IIE Transactions on Occupational Ergonomics and Human Factors 1(3): 153-165.

Conference Abstracts

Amasay T, Zodrow K, Kincl L, Karduna A: [2007] Validation of tri-axial accelerometer for the calculation of elevation angles. American Society of Biomechanics, Stanford, CA, August, 2007.

San Juan JG, Karduna A: [2008] Measuring in-vivo humeral head translation using fluoroscopy: A comparison of static and dynamic positioning. International Shoulder Group, Bologna, Italy, July 2008.

Amasay T, Karduna A: [2008] Quantifying and predicting elevation angle error using tri-axial accelerometer during dynamic motion. North American Congress on Biomechanics, Ann Arbor, Michigan. August 2008.

San Juan, JG., Karduna, A: [2008] Measuring in-vivo humeral head translation using fluoroscopy: A comparison of static and dynamic positioning." North American Congress on Biomechanics, Ann Arbor, Michigan, August 2008.

San Juan JG, Kopek P, Karduna A: [2009] Humeral head translation after a suprascapular nerve block. Northwest Biomechanics Symposium, Pullman, Washington, May 2009.

San Juan, JG, Kosek P, Karduna A: [2009] The effects of suprascapular nerve block on humeral head translation. American Society of Biomechanics, University Park, Pennsylvania, August 2009.

Ettinger L, Kincl L, Karduna A: [2009] Changes in scapular kinematics pre and post workday. American Society of Biomechanics, University Park, Pennsylvania, August 2009.

Amasay T, Karduna A: [2010] The Use of the virtual corset, triaxial accelerometer, to quantify humeral elevation angles and exposure in dental hygienists. 3rd International Conference on Applied Human Factors and Ergonomics, Miami, Florida, July 2010.

Ettinger L, Kincl L, Karduna A: [2010] Alterations in shoulder joint perception pre and post workday. American Society of Biomechanics, Providence, Rhode Island, August 2010.

Ettinger L, Kincl L, Karduna A: [2011] Workday arm elevation exposure, a comparison between two professions. American Society of Biomechanics, Long Beach, California, August 2011.

Amasay T and Karduna A: [2012] The influence of patient's body size on dental hygienist shoulder kinematics. American College of Sports Medicine, San Francisco, CA, June 2012.