

ORIGINAL RESEARCH

Patient's Body Size Influences Dental Hygienist Shoulder Kinematics

Tal Amasay^{1,*}
and Andrew Karduna²

¹Department of Sport and
Exercise Sciences, School of
Human Performance and
Leisure Sciences Barry
University, 11300 NE 2nd Ave.,
Miami Shores, FL 33161, USA

²Department of Human
Physiology, University of
Oregon, Eugene, OR 97405,
USA

OCCUPATIONAL APPLICATIONS This study found that dental hygienists are exposed to higher shoulder elevation angles when treating a simulated big-girth patient versus a simulated average-girth patient. These differences in motion patterns may increase dental hygienists' susceptibility to shoulder musculoskeletal disorders. Ergonomic interventions may be needed to facilitate solutions to problems associated with treating patients who are overweight or obese. Ergonomics and human factors practitioners should educate dental hygienists to be more aware of their body posture, specifically shoulder position, while working on patients with big chest girth.

TECHNICAL ABSTRACT *Background:* Dental hygienists suffer from musculoskeletal disorders of the upper extremities, and the prevalence of these disorders increases with years of occupation. Furthermore, the prevalence of overweight and obese individuals in the United States has been rapidly increasing for both adults and children in recent years. This may increase the involvement of dental hygienists with obese patients, which may result in an increased prevalence of shoulder musculoskeletal disorders. The effect of patient's body size on the three-dimensional humeral and scapular kinematics of dental hygienists, however, is currently unknown. *Purpose:* The aim of the current study was to measure the influence of patient girth on the shoulder kinematics of dental hygienists during teeth instrumentation in a simulated work environment. *Method:* Sixteen female dental hygienists participated in a lab-based study that simulated a dental hygienist workplace. Three-dimensional kinematic data were collected for the right and left scapula and humerus using the Polhemus Liberty magnetic tracking system (Colchester, VT, USA). To quantify differences in humeral and scapular kinematics and exposure variables, two independent variables with two levels were chosen: handedness and body type size. Separate two-way ANOVAs with repeated measures were conducted. *Results:* Dental hygienists sustained significant higher mean humeral elevation angles and higher mean scapular upward rotation angles for the dominant and non-dominant hands while instrumenting a simulated patient with big girth chest. Furthermore, dental hygienists spent significantly more time above 30° and 60° of humeral elevation for the dominant and non-dominant hands while

Received July 2012

Accepted March 2013

*Corresponding author. E-mail:
tamasay@mail.barry.edu

instrumenting this simulated patient. **Conclusion:** This study provided evidence that dental hygienists alter their shoulder kinematics while instrumenting patients having a larger girth. Consequently, working with patients who are obese, or with a larger body size, may increase dental hygienist susceptibility to shoulder musculoskeletal disorders.

KEYWORDS Obesity, scapular kinematics, shoulder exposure, biomechanics, teeth instrumentation

INTRODUCTION

Proper arm elevation is the result of the interaction between the glenohumeral and scapulothoracic joints. Abnormal position and/or orientation of the scapula and humerus may interfere with optimal shoulder coordination. Abnormal scapulothoracic joint motion has been found to be associated with such pathologies as idiopathic loss of shoulder range of motion (Rundquist & Ludewig, 2005), shoulder instability (Matias & Pascoal, 2006), shoulder impingement (Lukasiewicz et al., 1999), frozen shoulder (Rundquist et al., 2003), and rotator cuff tears (Poppen & Walker, 1976; Mell et al., 2005). However, there is currently no scientific evidence that abnormal scapulothoracic joint motion or exposure to arm elevation is the cause or result of shoulder pathology.

Shoulder pathologies are included under the broad term of musculoskeletal disorders. The U.S. Department of Labor reported that in 2011, there were a total of 1.2 million injuries and illnesses requiring days away from work in the private industry. Of those, 30% were due to musculoskeletal injuries. The event that resulted in the longest absences from work was repetitive motion. The injuries that resulted in the longest absences from work involved the shoulder (Bureau of Labor Statistics, 2011).

Studies have shown that dental hygienists suffer from high incidences of musculoskeletal disorders of the neck (37%–72%; Liss et al., 1995; Morse et al., 2007), upper extremity (11%–68%; Liss et al., 1995; Akesson et al., 1999; Werner et al., 2002, 2005; Morse et al., 2007), and back (15%–65%; Liss et al., 1995; Rising et al., 2005). These pathologies include carpal tunnel syndrome, elbow tendinitis, shoulder impingement, and rotator cuff tears. Werner et al. (2002) found that 13% of the dental hygienists they studied suffered from shoulder tendinitis. Liss et al. (1995) found that for a given 12-month period, dental hygienists are 2.8 times more likely to report shoulder problems than dental

assistants. The prevalence of these disorders increases with years of occupation (Liss et al., 1995; Akesson et al., 1999; Rising et al., 2005; Morse et al., 2007). Akesson et al. (1999) and Morse et al. (2007) found that the prevalence of shoulder musculoskeletal disorders in this population was as high as 35% to 68%. However, research in this area has been limited to the use of questionnaires and physician evaluations to determine the physical risk factors for musculoskeletal disorders. These two methods are subjective measurement tools. Direct measurements tools are objective and more precise, although they involve higher cost, equipment setting, proper calibration, and limited recording time.

To the best knowledge of the authors, there has been only one published study that measured dental hygienist shoulder kinematics. Data were collected at the work place using a video recorder (Marklin & Cherney, 2005). Marklin et al. (2005) found that dental hygienists' non-dominant hand was abducted 45% of the time, while the dominant hand was abducted 34% of the time. Shoulders were abducted over 30° of elevation more than 50% of the time, and posture was predominantly static (Marklin & Cherney, 2005). This study did not use reference markers and was a 2D estimation of back and neck flexion and humeral abduction. The use of a single video camera may have introduced projection errors related to the camera and dental hygienist positions, which further added to the limitations of this study. To the best of the authors' knowledge, there are no reports in the literature on 3D humeral and scapular kinematics of dental hygienists.

During a typical work day, dental hygienists work with a wide range of patients, children to elderly and lean to obese body types. This variety may introduce different difficulties to the dental hygienist. Since the mid-1970s, the prevalence of overweight and obese individuals has increased sharply for both adults and children in the United States. Data from the Centers for Disease Control and Prevention (CDC) show that among adults aged 20–74 years, the prevalence of

obesity increased from 15% in the late 1970s to 33% in 2007–2008 (Ogden & Carrol, 2010b). There was also an increase in children and teens that were overweight (Ogden & Carrol, 2010a). The increase in population obesity may introduce a more pronounced problem in the near future for dental hygienists as a result of patient's girth and limitations in dental equipment (such as dental chairs and stools) as well as the size of the dental hygienist's working environment.

This study measures the effects of patient body type (average chest girth and big chest girth) on humeral and scapular kinematics of dental hygienist during typical dental cleaning work in a simulated workplace environment. This is a novel model to measure the influence of body type on dental hygienist scapular and humeral kinematics. The research hypothesis was that working on simulated patients with big chest girth will result in higher humeral elevation and scapular upward rotation angles and exposure in comparison to simulate patients with average chest girth for both dominant and non-dominant shoulders.

MATERIALS AND METHODS

Participants

Sixteen female dental hygienists (14 right handed, 2 left handed) with a mean age of 49.6 years (28–64 years), height of 166.8 cm (157–175 cm) and body mass of 71.1 kg (56.2–83.9 kg) participated in the study. Inclusion criteria required that dental hygienists had at least 1 year of current work experience (actual experience range was 1.5–32 years). Exclusion criteria were impairments in arm elevation range of motion (less than 120° of humeral elevation), present injuries to the shoulder or back, any surgery on these body parts in the past 2 years, and any diagnosed neurological disorders. Prior to data collection, all participants signed an informed consent form approved by the university's institutional review board (IRB).

Prior to recruiting participants for the present study, a pilot study consisting of a questionnaire was conducted on 24 dental hygienists. At the time of the study, these dental hygienists had a mean work experience of 19 years (2–37 years). Their mean frequency of work schedule was of 48 weeks/year (36–52 weeks/year), 3 days/week (1–5 days/week), and 8 hours/day (7–10 hours/day). The dental hygienists had a mean of 5 (range, 1–15) patients per week with a big chest girth. All participants answered yes when

asked if their working positions differ while working on patients with big chest girth relative to patients with average chest girth. They reported having to adjust their body position and their working environment to accommodate for patients with big chest girth. Moreover, 96% of the dental hygienists indicated that their body felt more stressed after treating these patients relative to patients with an average chest girth, specifically at the neck (83%), dominant shoulder (78%), and low back (48%).

Instrumentation

Three-dimensional kinematic data from the scapula, humerus, and thorax were collected with a Polhemus Liberty magnetic tracking system (Colchester, VT, USA), which consisted of an electronics unit, a transmitter, five sensors, and one digitizer. This system was interfaced with the MotionMonitor software program (Innovative Sports Training, Chicago, IL, USA). Data were sampled rate of 120 Hz per sensor. The relative orientation and position of the sensors in space were determined by the system's electronic unit. Data analysis and interpolation were executed using LabView software (National Instruments, Austin, TX, USA).

A simulated work station consisting of a hydraulic dental chair, dental light, and dental hygienist stool was set up in a laboratory setting. Two dental hygienist training manikins were used. Each included just the head connected to a metal rod that simulates head and neck motion. Two custom-made body types, big chest girth (big manikin) and average chest girth (average manikin), were formed and connected to the manikins to simulate different body types. Each manikin was fitted with dentures (Model M-YNR-1560, Colombia Dentoform Corp., NY, USA). The manikins were secured to the dental chair using a strap. The two manikins were identical except for the padding (which limited the neck range of motion) to simulate the two different body types. The big manikin represented the 99th percentile of the American male, with a chest circumference of 138 cm, arm circumference of 46 cm, shoulder width of 66 cm, and chest thickness of 35 cm (Tilley & Henry Dreyfuss Associates., 2002; Wells et al., 2008). The average manikin represented the 50th percentile male, a chest circumference of 96 cm, arm circumference of 32 cm, shoulder width of 49 cm, and chest thickness of 25 cm (Woodson et al., 1992). The neck ranges of motion for the average manikin were

extension of 18° , flexion of 30° , and axial rotation of 50° based on the model limitation. The neck ranges of motion for the big manikin were extension of 10° , flexion of 6° , and axial rotation of 12° . The neck range of motion of the big manikin was decided based on the recommendations of a dental hygienist focus group. Mouth opening from lip to lip was 6 cm for the average manikin and 4 cm for the big manikin (Brodsky et al., 2002). These measurements were taken while the manikins were strapped to the dental chair.

Five sensors were placed on each participant. A thoracic sensor was attached to the manubrium just below the jugular notch with tape. Left and right scapular trackers, previously validated in our lab, were used to quantify scapular kinematics (Karduna et al., 2001). Plastic screws secured a sensor to the scapular tracker jig. The jig was attached atop the spine of the scapula and acromial process using adhesive Velcro strips. The humeral sensors were placed on the right and left humeri just above the medial and lateral epicondyles using a customized molded cuff attached by hook-and-loop strips. A global coordinate system was established by mounting the transmitter on a rigid plastic base. The transmitter was located behind the tested participant at the scapular sensor height at a horizontal distance of 30 cm from the trunk.

Study Design

The simulated work station was modified to reduce the error of the magnetic tracking device by replacing the dental chair's metal head support with wood; also, the manikins were made out of fiberglass. Prior to beginning the study, the errors of the magnetic tracking device due to the simulated dental hygienist work station were assessed. It was found that the highest root mean square (RMS) angle error for the magnetic tracking system at this simulated work station was 1.4° .

During digitization, participants were in their natural standing position. Anatomical landmarks were digitized for the coordinate systems of the thorax (T8, xiphoid process, C7, and jugular notch), scapula (root of spine of the scapula, acromial angle, and inferior angle), and humerus (medial and lateral epicondyles and ulnar styloid process). The arbitrary axes defined by the magnetic tracking system were converted to anatomically appropriate embedded axes derived from the digitized bony landmarks, based on the ISB recommendation for the upper extremity (Wu et al., 2005). Surface

landmarks were located directly by palpating the area, except for the center of the humeral head. The point on the humerus that moved the least with respect to the scapula while moving the humerus through short arcs ($<45^\circ$) of mid-range glenohumeral motion was defined as the center of the humeral head, calculated using a least-squares algorithm (Veeger, 2000). The raw data from the sensors were converted into anatomically defined rotations using the digitized anatomical landmarks using the MotionMonitor software.

Standard matrix transformation methods were used to determine the rotational matrix of the humerus and scapula with respect to the thorax. For the humerus, the ISB second recommendation was used, taking the ulnar styloid process as the third point for the plane, with the elbow in 90° of flexion (Wu et al., 2005). Humeral rotations were represented using a standard Euler angle sequence ($YX'Y''$) in which the first rotation defined the plane of elevation, the second rotation described the amount of elevation, and the last rotation represented the amount of internal/external rotation. Clinically, abduction is humeral elevation in 0° and flexion is humeral elevation in a 90° plane. Scapular rotations were represented using a Euler angle sequence ($YZ'X''$) of external/internal rotation, upward/downward rotation, and anterior/posterior tilting (Fig. 1; Wu et al., 2005).

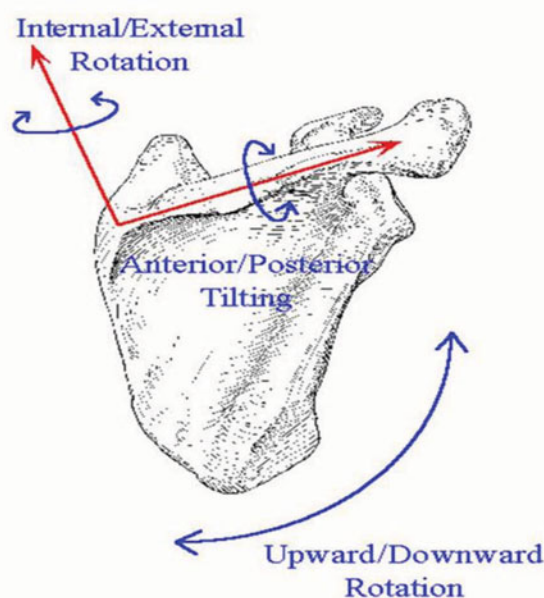


FIGURE 1 Scapular rotations (color figure available online).

Data Collection

All data collection was concluded in a single session. Participants started the experiment with a shoulder standardized warm-up procedure including Codman's pendulums and stretches for the rotator cuff muscles for both arms (Suprak et al. 2006). Following the warm-up procedure, participants were instructed to remove any object that may interfere with the magnetic tracking system data collection, such as belts and necklaces.

The simulated work experience for the dental hygienists consisted of instrumenting teeth using a universal curette and a mouth mirror (Hu-Friedy, Chicago, IL, USA). The three teeth were numbers 3, 19, and 24 (Fig. 2) for right-handed and numbers 14, 30, and 24 for left-handed dental hygienists, which correspond to the same teeth positions on the opposite side. These specific teeth were based on the simplified oral hygiene index (OHI-S), in which teeth 3, 8, 14, 19, 24, and 30 are examined to assess oral cleanliness (Greene & Vermillion, 1964).

Prior to data collection for each tooth, the participants practiced instrumenting the tooth until they felt comfortable performing the procedure in approximately 30 seconds. The reason for limiting the teeth instrumentation to 30 seconds related to the limitation of the interfacing program, MotionMonitor, to collect and process data for a longer period of time. Participants starting position was seated with their arms on the manikin's chest. Participants were instructed to instrument the teeth as they do in their actual workplace with similar patient's body size. The dental hygienist was instructed to instrument each tooth for 30 seconds (Fig. 3). At the end of each trial, if the participants reported that they were unable to finish instrumenting the tooth, the trial was repeated. The reason to repeat a trial was based on the need to capture the shoulder kinematics while instrumenting all the tooth surfaces. The order of the average and big manikins and the order of the three teeth were randomized. Rest periods of 2 minutes were given to the participants between all trials. Each tooth was instrumented twice. The dental

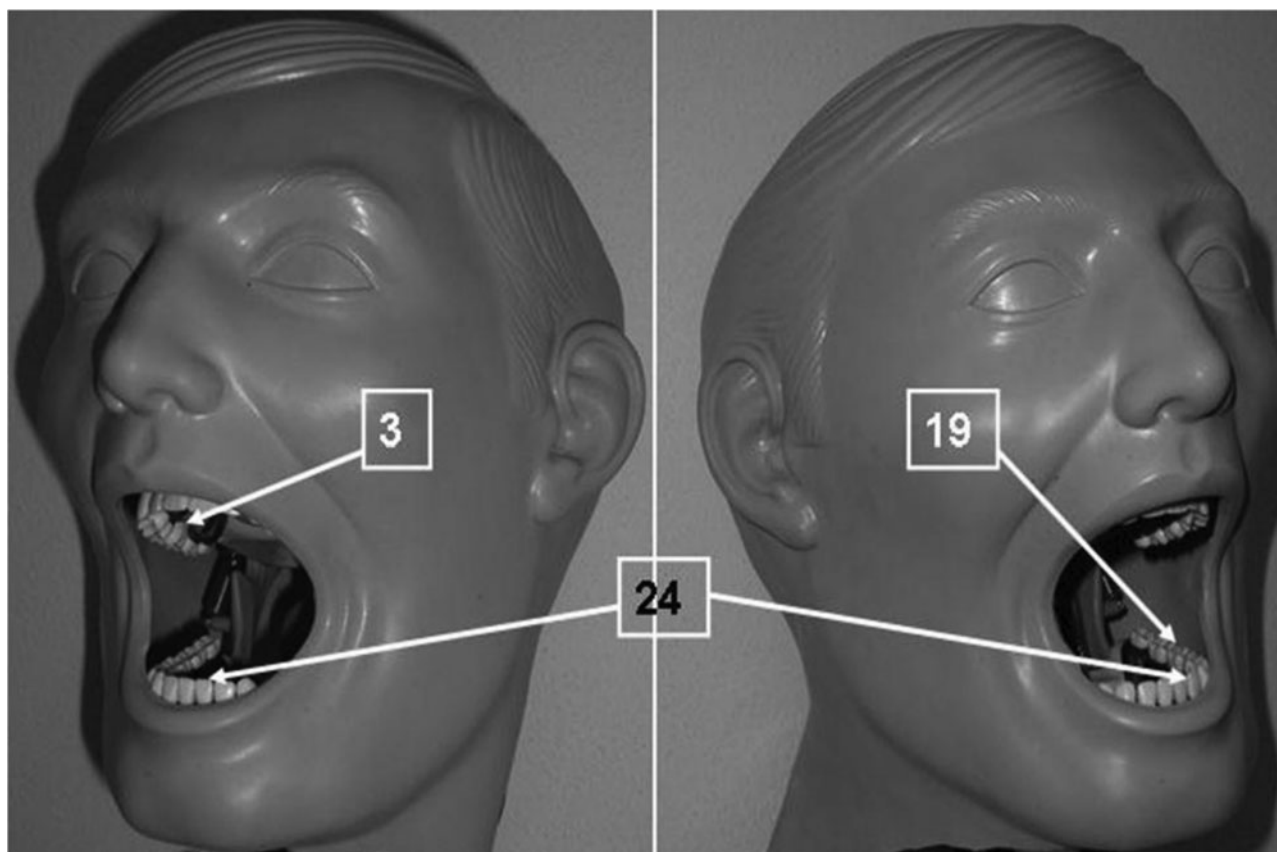


FIGURE 2 Location of the instrumented teeth for a right-handed dental hygienist.



FIGURE 3 Instrumenting the manikins: (a) average size and (b) big size.

hygienists were allowed to adjust the dental stool, dental chair, and manikin head position to their preferred position prior to the instrumentation of each tooth. Throughout the entire duration of the study, the dental hygienists wore gloves.

Statistical Analysis

To quantify differences in humeral and scapular kinematics, two independent variables with two levels were chosen: hand dominance (dominant and non-dominant) and body type (average and big manikins). The dependent variables were humeral plane of elevation, humeral elevation, scapular external rotation, upward rotation, and posterior tilt angles. The mean of two trials of each tooth and of the three teeth was calculated. For each angle, a two-way repeated measures ANOVA ($\alpha = 0.05$) was performed, with hand dominance and body type as the independent variables.

Exposure parameters were used to quantify the differences in humeral elevation between the two independent variables (body type and hand dominance) using separate two-way repeated measures ANOVAs ($\alpha = 0.05$). The chosen exposure parameters were percent of time above 30° and 60° (Bernard, 1997) and jerk analysis. The jerk is a parameter describing the repetitiveness of a task and was defined as the percentage of the cycle time spent in time sequences shorter than 1 second within the same exposure bin or 10° . A larger jerk value indicates a more dynamic exposure pattern (Mathiassen et al., 2003; Moller et al., 2004). As with the angle data, the mean of the two trials and of the three teeth were calculated for each dependent variable. If significant interaction was found, a post hoc Bonferroni correction procedure was used. Intra-subject reliability for all the dependent variables was quantified by intraclass correlation coefficient (ICC; 3, 1) and standard error of measurement (SEM).

RESULTS

Intra-subject ICC values for the dependent variables ranged from 0.32 to 0.99, indicating low to high reliability (Table 1). For the kinematic data, the ICC values for all humeral and scapular angles were high, and the same was observed for the exposure parameters of percent of time above 30° and 60°. For the exposure parameter of jerk, the ICC values range from low to moderate.

For average humeral elevation angle, a significant interaction between body type and hand dominance was found ($p = 0.006$). No interaction was found for humeral plane of elevation and scapular angles ($p > 0.12$). A significant main effect of body type ($p = 0.001$) was evident for the humeral plane of elevation angles, with higher angles observed during average manikin instrumentation. For scapular upward rotation angle, a significant body type main effect was observed ($p < 0.001$), with higher angles during the big manikin instrumentation. Post hoc paired t -tests demonstrated a significantly higher humeral elevation angle while instrumenting the big manikins for both hands ($p < 0.004$; Figs. 4 and 5).

No significant interactions were found between body type and hand dominance for all exposure parameters ($p > 0.068$). There was a significant main effect of body type for the dependant variables jerk and percent of time above 60° of humeral elevation ($p < 0.013$). The dental hygienists were more dynamic and spent a longer time above 60° of humeral elevation while instrumenting the big manikin. The main effect of body type was significant ($p < 0.001$) for percent of time above 30° of humeral elevation. While instrumenting the big

manikin, dental hygienists spent more time above 30° of humeral elevation (Fig. 6).

DISCUSSION

Three main risk factors were identified in the literature that contributed to musculoskeletal disorders in the workplace: force (intensity and duration), repetition, and posture (awkward and constrained). Repeated shoulder motion or static shoulder posture above 60° of shoulder flexion or abduction has been associated with shoulder musculoskeletal disorders. The strongest evidence for this relation is the combination of these shoulder postures, with physical factors such as manipulating a tool while working overhead (Bernard, 1997).

Pilot data collected with the questionnaire indicated that working on patients with big chest girth in comparison to patients with average chest girth was felt to be more challenging and stressful to a dental hygienist's body. Therefore, there was an attempt to identify a specific posture risk factor that would alter scapular and humeral kinematics and exposure parameters in dental hygienists. Eight dependent variables were investigated. The kinematic variables were mean angle for humeral and scapular angles, and the exposure variables were jerk and percent of time above 30° and 60° of humeral elevation. The ICC values for the dependent variables (mean angle, percent of time above 30°, and percent of time above 60°) were found to be good to high, and the SEM values were low. For the jerk analysis, the ICC values were between low to good and the SEM values were low. These demonstrated a good repeatability for the study dependent variables. One explanation for the

TABLE 1 Intra-subject reliability of kinematic and exposure dependent variables for different orientations of scapular external rotation (SER), scapular upward rotation (SUR), scapular posterior tilt (SPT), humeral plane of elevation (HPE), and humeral elevation (HE) for the dominant and non-dominant hand and for average and big manikins

	Average				Big			
	Non-dominant		Dominant		Non-dominant		Dominant	
	ICC	SEM	ICC	SEM	ICC	SEM	ICC	SEM
Mean SER angle	0.99	1.0°	0.93	2.3°	0.99	0.9°	0.99	0.8°
Mean SUR angle	0.98	1.4°	0.99	0.8°	0.99	1.0°	0.98	0.9°
Mean SPT angle	0.99	1.0°	0.99	1.0°	0.99	1.2°	0.99	0.9°
Mean HPE angle	0.89	5.1°	0.95	4.0°	0.95	3.0°	0.98	2.4°
Mean HE angle	0.96	1.9°	0.98	1.1°	0.96	2.3°	0.97	1.8°
HE jerk	0.56	1.8%	0.70	2.0%	0.63	2.0%	0.32	2.1%
HE above 30°	0.95	7.4%	0.91	5.9%	0.96	6.9%	0.93	6.4%
HE above 60°	0.81	3.5%	0.97	2.1%	0.89	4.7%	0.95	3.7%

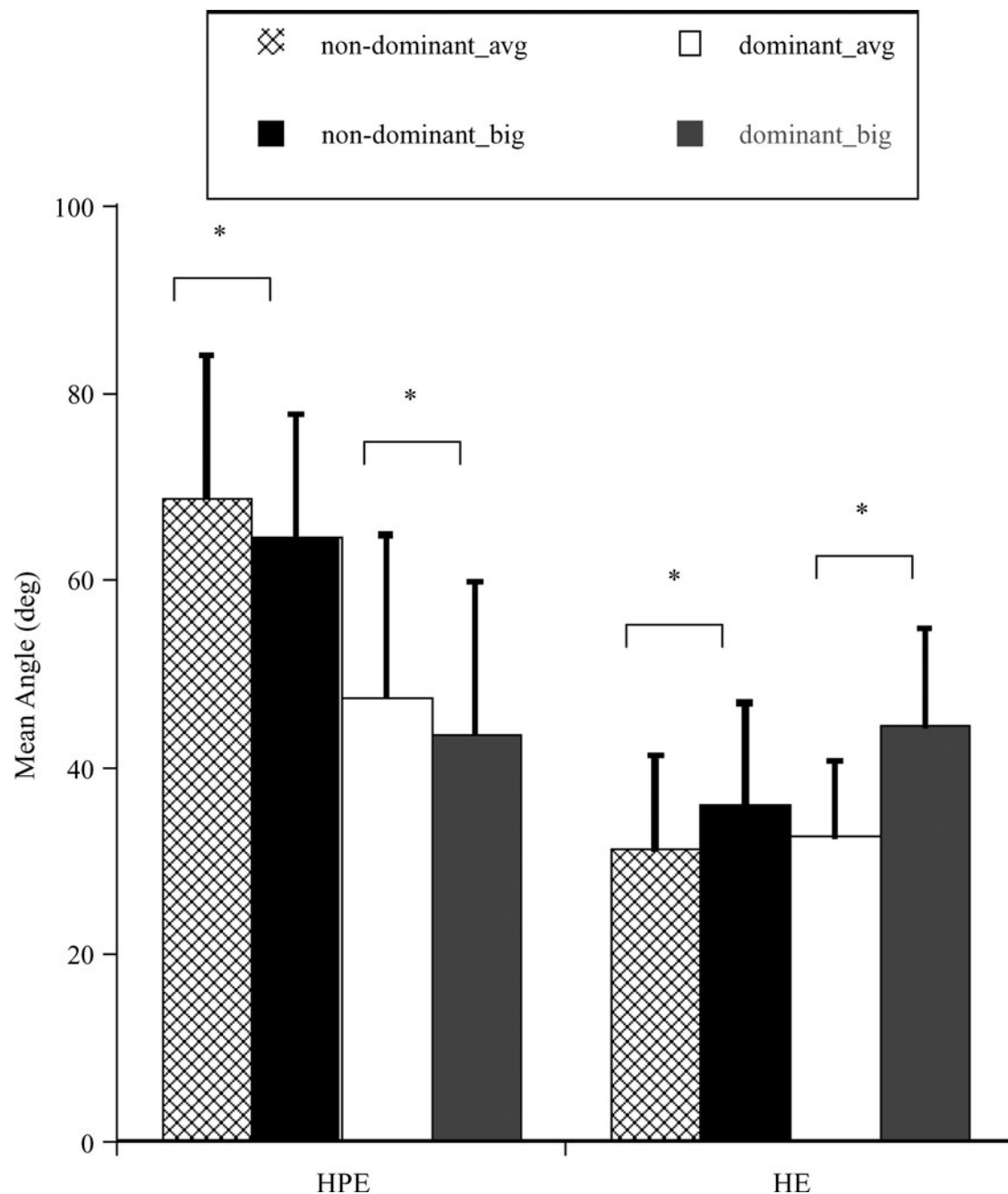


FIGURE 4 Mean and standard deviation of humeral plane of elevation (HPE) and humeral elevation (HE) angles for the non-dominant and dominant hand while working on the two body type manikins (average and big); * $p < 0.05$.

low reliability values of the jerk may be related to the short duration of data collection time, as each task was performed for 30 seconds. In a typical dental hygienist's work day, teeth scaling duration can take 30 minutes or more per patient, and this pattern is repeated during the work day. The more data collected, the smaller the influence of outliers on this parameter.

The present study examined the influence of a patient's body type on the mean humeral and scapular

angles. There was a significant interaction between the body type and hand dominance variables for mean humeral elevation angle, meaning that the effect of body type on mean humeral elevation angle was different for different levels of hand dominance. The post hoc paired t -test found significant differences between the big and average manikins for the dominant and non-dominant hands. In both cases, the mean humeral elevation angles were significantly larger while

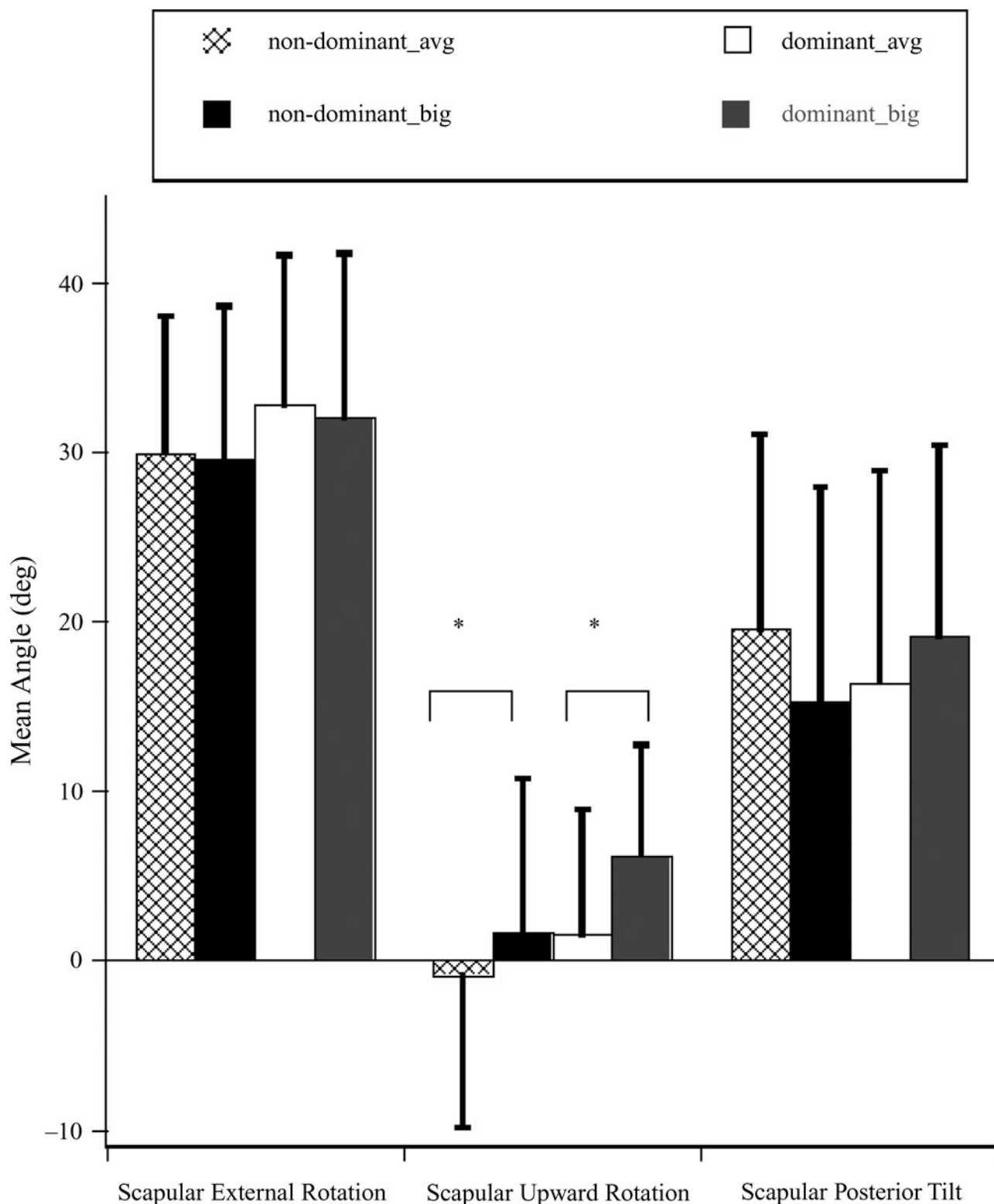


FIGURE 5 Mean and standard deviation of the scapular angles for the non-dominant and dominant hand while working on the two body type manikins (average and big); * $p < 0.05$.

working on the big manikin. For the dominant hand, the mean angle difference was 12° , and for the non-dominant hand, it was 5° . These differences, below 90° of humeral elevation, contribute to an average in-

crease in arm torque for the dominant hand of 21% and non-dominant hand of 9%, which might increase shoulder muscle fatigue as a result of sustained posture. It has been previously shown, in animals studies,

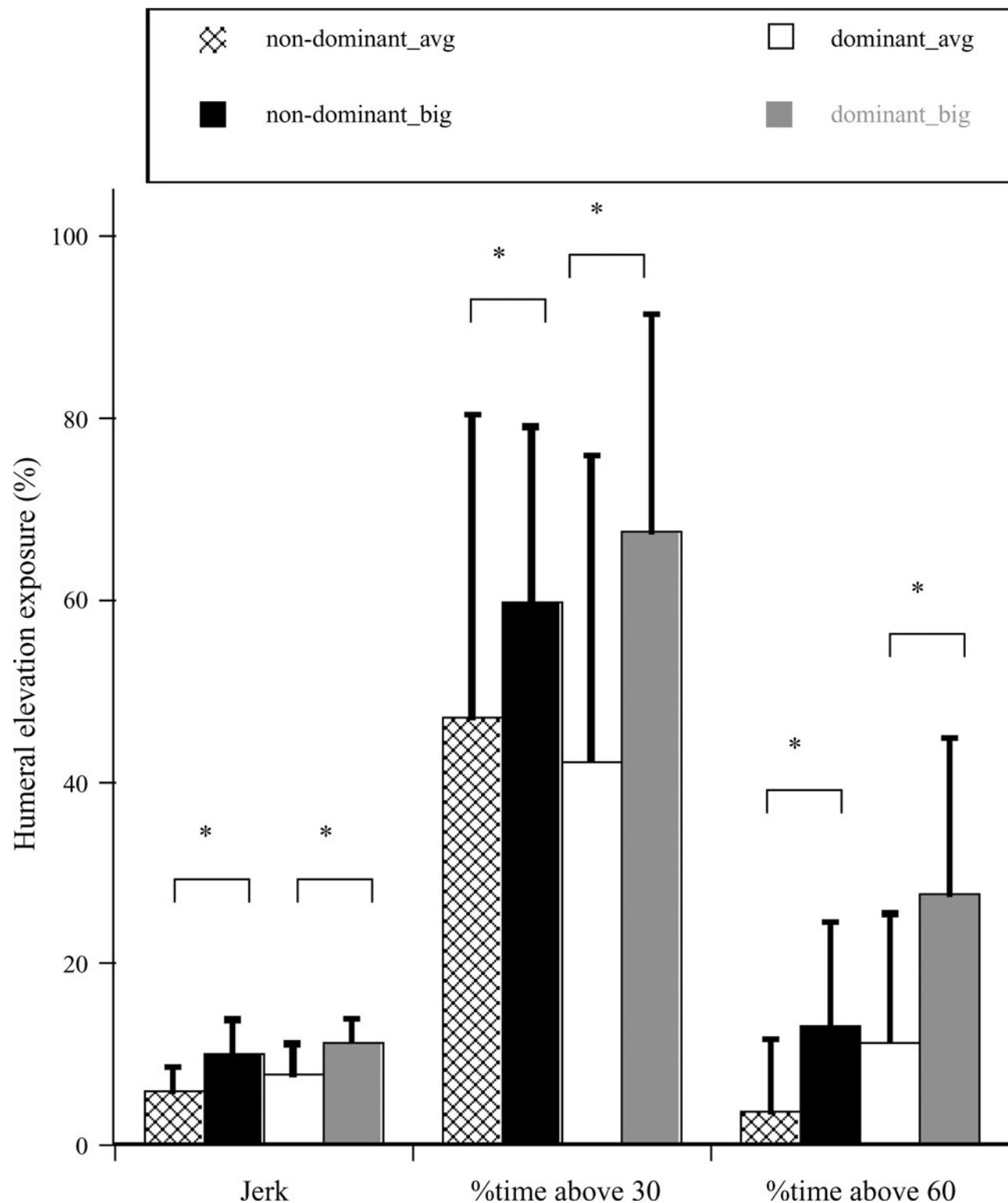


FIGURE 6 Mean and standard deviation of the humeral elevation angles exposure parameters for the non-dominant and dominant hand while working on the two body type manikins (average and big); * $p < 0.05$.

that low intensity loading of a muscle in static position for prolonged periods of time causes muscle damage (Visser & van Dieen, 2006). Sustained static arm position, even with low intensity, was found to be a risk

factor for musculoskeletal disorder in workers (Mani & Gerr, 2000; Visser & van Dieen, 2006).

No significant interactions were found for the humeral plane of elevation and for all three scapular

rotations. The main effects were observed in body type for humeral plane of elevation and for scapular upward rotation. The significant differences between the average and big manikins were approximately 11° in both sides for humeral plane of elevation. For scapular upward rotation, differences were found between the patients' body type for both the dominant (5°) and non-dominant (3°) hands with a higher mean upward rotation angles while working on the big manikin. These differences describe the adjustments in shoulder position dental hygienists use to accommodate different patient body types. While working on the big manikin dental hygienists, plane of elevation angle was always smaller than when working on the average manikin. In order for a dental hygienist to reach their patient's mouth, they have to reach over their patient's chest, causing them to elevate their humerus. Consequentially, humeral elevation and scapular upward rotation are adjusted when working on patients with big chest girth.

The mean scapular rotations at neutral position were 27° for internal rotation, 4° for downward rotation, and 14° for anterior tilt. Neutral position data from a previous study of healthy participants in the laboratory found a mean of 30° of internal rotation, 1° of downward rotation, and 12° of anterior tilt (Amasay & Karduna, 2009). Upward rotation elevates the acromion process of the scapula during arm elevation for better clearance of the humeral head to prevent impingement at the lateral edge of the acromial process. Posterior tilt clears the anterior edge of the scapula to prevent impingement at the anterior edge of acromial process, which is a more common site for impingement (Flatow et al., 1994). The small upward rotation and large anterior tilting might put the dental hygienist at a greater risk for shoulder impingement.

The second part of the study investigated the influence of patient's body type on humeral elevation angle exposure parameters. No significant interactions were found for all exposure parameters. In the jerk analysis, a significant main effect was found in the body type variables. Differences in body type were 1%–2% of time. The closer the jerk parameter values were to 0% of time, the more static was the motion. Static and/or high repetitious motions are identified as risk factors for musculoskeletal disorders. The mean dental hygienists' posture was found to be more static during teeth instrumentation on the average manikin. However, this small difference may not be clinically relevant for this

specific task. The jerk analysis on the instrumentation of teeth 3, 19, and 24 revealed that dental hygienist shoulders were in static posture 90% of the time. The sustained static position might increase shoulder susceptibility to musculoskeletal disorders (Mani & Gerr, 2000; Visser & van Dieen, 2006).

A main effect was observed for the exposure parameter percent of time above 30° of humeral elevation in body type variable. The observed differences were 25% of time for the dominant hand and 13% of time for the non-dominant hand. The dental hygienists spent more time above 30° of humeral elevation while instrumenting the big manikin. For percent of time above 60° of humeral elevation, a significant main effect was evident in the body type variable. The dental hygienists spent more time above 60° of arm elevation while instrumenting the big manikin than the average manikin. The observed differences were 15% and 7% of the time in the dominant and non-dominant hands, respectively. During humeral elevation, the subacromial space decreases, leading to mechanical pressure on the subacromial space soft tissues, which is the largest between 60° and 120° of humeral elevation (Flatow et al., 1994). Bernard (1997) defined awkward posture for shoulder musculoskeletal disorders as shoulder elevation above 60° , although the exposure severity is increasing from 30° of humeral elevation to maximal humeral elevation (Bernard, 1997). With respect to the present study, working on patients with big chest girth might increase dental hygienists' susceptibility to musculoskeletal disorders as a result of higher humeral elevation angles.

When collecting data in a simulated environment, there is always the need to balance between a controlled and more precise measurement; a field study, which better represents the task, still suffers from lack of control. For instance, using manikins instead of actual patients gave better control of teeth instrumentation, patients chest girth, and neck range of motion between all participants. However, the manikins did not have all anatomical and physiological variances that one would expect when working on live patients (such as those due to saliva and a tongue). One of the repeated comments of the participating dental hygienists in the present study was the fact that obese patients have thicker tongues and cheeks than the average-sized patients. In the present study, it was not practical to modify the obese manikin to display accurate anatomical variances due to a lack of anthropometric data in

the literature regarding the obese population's tongue and cheek thicknesses.

In the current study, each tooth was instrumented in 30 seconds to quantify the differences between body type and hand dominance. The reasoning for that was based on the magnetic tracking device and the interfacing MotionMonitor software data collection duration ability. Another limiting factor was the wide range of dental hygienist work experience and age variations. The large varieties in dental hygienist height and weight also have influenced the way the dental hygienist approached the two manikins. It is possible that a tall dental hygienist may have less difficulty when working with obese patients while still seated than shorter dental hygienists. Another limitation observed was that each dental hygienist had a unique way to approach and instrument each manikin. Furthermore, the dental hygienists altered their working patterns based on their need and the patient's need (treating the manikin like a traditional patient). For example, while working on the big manikin, two dental hygienists stood during instrumentation in order to reduce their humeral elevation angles. No dental hygienists rested their arms on the manikins while instrumenting the teeth.

It was found that dental hygienists sustained higher humeral elevation angles while instrumenting the big manikin. Patients of greater girth may increase dental hygienist susceptibility to shoulder musculoskeletal disorders. Although in the present study, the dental hygienist instrumented only three teeth, it is believed that these teeth covered a representative range of shoulder motion of the dental hygienist during a typical work day. A similar shoulder motion pattern would likely be seen during instrumentation of other teeth.

Based on the present study, dental hygienists should be more aware of their body posture, specifically shoulder position, while working on patients with big chest girth. Ergonomic interventions may be needed to facilitate solutions to problems associated with treating these patients. Finally, it has been shown that shoulder stretching and strengthening exercises can effectively reduce shoulder pain and impingement symptoms and improve shoulder function (Ludewig & Borstad, 2003). Fitness programs designed to strengthen and stretch scapular stabilizing muscles may be beneficial to the dental hygienist who has shoulder pain and impingement symptoms. In addition, this intervention may be beneficial in alleviating shoulder stress in dental hy-

gienists that work with patients with big chest girth and may lead to a decrease in the prevalence of shoulder musculoskeletal disorders in this occupation.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGMENTS

This research was supported by National Institute of Occupational Safety and Health (grant 5R01OH008288). The authors would like to thank M. Latteri and L. Ettinger for their assistance with data collection.

REFERENCES

- Akesson, I., Johnsson, B., Rylander, L., Moritz, U., & Skerfving, S. (1999). Musculoskeletal disorders among female dental personnel—clinical examination and a 5-year follow-up study of symptoms. *International Archives of Occupational and Environmental Health*, 72(6), 395–403.
- Amasay, T., & Karduna, A. R. (2009). Scapular kinematics in constrained and functional upper extremity movements. *Journal of Orthopaedic and Sports Physical Therapy*, 39(8), 618–627.
- Bernard, B. (1997). Musculoskeletal disorders (MSDs) and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. (Report). National Institute for Occupational Safety and Health (NIOSH), pp. 122–341.
- Brodsky, J. B., Lemmens, H. J., Brock-Utne, J. G., Vierra, M., & Saidman, L. J. (2002). Morbid obesity and tracheal intubation. *Anesthesia and Analgesia*, 94(3), 732–736.
- Bureau of Labor Statistics. (2011). Nonfatal occupational injuries and illnesses requiring days away from work, 2010. USDL-11-1612. Washington, DC: United States Department of Labor.
- Flatow, E. L., Soslowsky, L. J., Ticker, J. B., Pawluk, R. J., Hepler, M., Ark, ... Bigliani, L. U. (1994). Excursion of the rotator cuff under the acromion. Patterns of subacromial contact. *American Journal of Sports Medicine*, 22(6), 779–788.
- Greene, J. C., & Vermillion, J. R. (1964). The simplified oral hygiene index. *Journal of the American Dental Association*, 68, 7–13.
- Karduna, A. R., McClure, P. W., Michener, L. A., & Sennett, B. (2001). Dynamic measurements of three-dimensional scapular kinematics: A validation study. *Journal of Biomechanical Engineering*, 123(2), 184–190.
- Liss, G. M., Jesin, E., Kusiak, R. A., & White, P. (1995). Musculoskeletal problems among Ontario dental hygienists. *American Journal of Industrial Medicine*, 28(4), 521–540.
- Ludewig, P. M., & Borstad, J. D. (2003). Effects of a home exercise programme on shoulder pain and functional status in construction workers. *Occupational and Environmental Medicine*, 60(11), 841–849.
- Lukasiewicz, A. C., McClure, P., Michener, L., Pratt, N., & Sennett, B. (1999). Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *Journal of Orthopaedic and Sports Physical Therapy*, 29(10), 574–583, 584–576.
- Mani, L., & Gerr, F. (2000). Work-related upper extremity musculoskeletal disorders. *Primary Care*, 27(4), 845–864.

- Marklin, R. W., & Cherney, K. (2005). Working postures of dentists and dental hygienists. *Journal of the California Dental Association*, 33(2), 133–136.
- Mathiassen, S. E., Burdorf, A., van der Beek, A. J., & Hansson, G. A. (2003). Efficient one-day sampling of mechanical job exposure data—a study based on upper trapezius activity in cleaners and office workers. *AIHA Journal*, 64(2), 196–211.
- Matias, R., & Pascoal, A. G. (2006). The unstable shoulder in arm elevation: a three-dimensional and electromyographic study in subjects with glenohumeral instability. *Clinical Biomechanics (Bristol, Avon)*, 21(Suppl. 1), S52–S58.
- Mell, A. G., LaScalza, S., Guffey, P., Ray, J., Maciejewski, M., Carpenter, J. E., & Hughes, R. E. (2005). Effect of rotator cuff pathology on shoulder rhythm. *Journal of Shoulder and Elbow Surgery*, 14(1 Suppl. S), S85–S85.
- Moller, T., Mathiassen, S. E., Franzon, H., & Kihlberg, S. (2004). Job enlargement and mechanical exposure variability in cyclic assembly work. *Ergonomics*, 47(1), 19–40.
- Morse, T., Bruneau, H., Michalak-Turcotte, C., Sanders, M., Warren, N., Dussetschleger, J., ... Cherniack, M. (2007). Musculoskeletal disorders of the neck and shoulder in dental hygienists and dental hygiene students. *Journal of Dental Hygiene*, 81(1), 10.
- Ogden, C., & Carroll, M. (2010a). *Prevalence of Obesity among Children and Adolescents: United States, Trends 1963–1965 Through 2007–2008*. Washington, DC: National Center for Health Statistics.
- Ogden, C., & Carroll, M. (2010b). *Prevalence of Overweight, Obesity, and Extreme Obesity among Adults: United States, Trends 1960–1962 Through 2007–2008*. Washington, DC: National Center for Health Statistics.
- Poppen, N. K., & Walker, P. S. (1976). Normal and abnormal motion of the shoulder. *Journal of Bone and Joint Surgery. American Volume*, 58(2), 195–201.
- Rising, D. W., Bennett, B. C., Hursh, K., & Plesh, O. (2005). Reports of body pain in a dental student population. *Journal of the American Dental Association*, 136(1), 81–86.
- Rundquist, P. J., Anderson, D. D., Guanche, C. A., & Ludewig, P. M. (2003). Shoulder kinematics in subjects with frozen shoulder. *Archives of Physical Medicine and Rehabilitation*, 84(10), 1473–1479.
- Rundquist, P. J., & Ludewig, P. M. (2005). Correlation of 3-dimensional shoulder kinematics to function in subjects with idiopathic loss of shoulder range of motion. *Physical Therapy*, 85(7), 636–647.
- Suprak, D. N., Osternig, L. R., van Donkelaar, P., & Karduna, A. R. (2006). Shoulder joint position sense improves with elevation angle in a novel, unconstrained task. *Journal of Orthopaedic Research*, 24(3), 559–568.
- Tilley, A. R., & Henry Dreyfuss Associates. (2002). *The measure of man and woman: Human factors in design* (rev. ed.). New York: Wiley.
- Veeger, H. E. (2000). The position of the rotation center of the glenohumeral joint. *Journal of Biomechanics*, 33(12), 1711–1715.
- Visser, B., & van Dieën, J. H. (2006). Pathophysiology of upper extremity muscle disorders. *Journal of Electromyography and Kinesiology*, 16(1), 1–16.
- Wells, J. C., Cole, T. J., Bruner, D., & Treleaven, P. (2008). Body shape in American and British adults: Between-country and inter-ethnic comparisons. *International Journal of Obesity (London)*, 32(1), 152–159.
- Werner, R. A., Franzblau, A., Gell, N., Hamann, C., Rodgers, P. A., Caruso, T. J., ... Klausner, C. P. (2005). Prevalence of upper extremity symptoms and disorders among dental and dental hygiene students. *Journal of the California Dental Association*, 33(2), 123–131.
- Werner, R. A., Hamann, C., Franzblau, A., & Rodgers, P. A. (2002). Prevalence of carpal tunnel syndrome and upper extremity tendinitis among dental hygienists. *Journal of Dental Hygiene*, 76(2), 126–132.
- Woodson, W. E., Tillman, B., & Tillman, P. (1992). *Human factors design handbook : information and guidelines for the design of systems, facilities, equipment, and products for human use* (2nd ed.). New York: McGraw-Hill.
- Wu, G., van der Helm, F. C., Veeger, H. E., Makhsous, M., Van Roy, P., Anglin, C., ... Buchholz, B. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: Shoulder, elbow, wrist and hand. *Journal of Biomechanics*, 38(5), 981–992.