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Investigation of musculoskeletal discomfort, work postures, and muscle activation among practicing tattoo artists

Dana L. Keester, Carolyn M. Sommerich*

Department of Integrated Systems Engineering, The Ohio State University, USA

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ABSTRACT

Tattoo artists are an understudied worker population with respect to investigation of work-related musculoskeletal (MSK) discomfort and associated risk factors. Results from one discomfort survey has been published; no analysis of worker biomechanics has been published. As such, a study was conducted to begin exposure assessment of tattoo artists to work factors that could result in MSK discomfort. Consistent with the prior survey, the current study showed an elevated prevalence of MSK discomfort. Twelve month discomfort prevalence exceeded 50% in the neck, shoulders, hands/wrists, and upper and lower back (range: 53–94%). Seventy-one percent of postures evaluated during 16 h of observation had total RULA scores of 5, 6, or 7 (investigation and changes are required soon or immediately). Static muscle activity levels in the left, right, or both upper trapezius muscles in each study participant exceeded the 2–5% MVE limit recommended in the literature. Intervention concepts are also discussed.

1. Introduction

According to polls conducted in the United States, about 40% of millennials (people reaching adulthood around the year 2000) have one or more tattoos, while percentages of tattooed adults in other age groups range from 5 to 30% (Harris Interactive: Harris Polls, 2012; Pew Research Center, 2010). The growth in popularity and acceptability of tattooing has led to increasing numbers of people working in the body modification industry in general and specifically as tattoo artists. There were estimated to be about 55,000 people employed in the tattoo industry in the US in 2015, and that number is expected to increase to about 77,500 by 2020 (IBISWorld, 2015). As reported by Grieshaber et al. (2012) it is difficult to ascertain the exact number of tattoo artists in the US because there is no centralized licensing body and each state handles its own regulation of the industry. State regulation of tattoo facilities is focused primarily on blood borne pathogens as both a risk to clients and as an occupational risk to the tattoo artists. While it is important to continue to enforce training and regulations relating to blood borne pathogens, as tattooing grows in popularity and the population employed in the industry continues to grow and age, it is important to consider other occupational hazards to which tattoo artists are exposed, including risk factors for musculoskeletal disorders (MSD). As discussed by Grieshaber et al. (2012), from casual observation it would appear that tattoo artists may be exposed to MSD risk factors that are similar to dentists and dental hygienists. Both dental professionals and tattoo artists appear to sit for prolonged periods of time in awkward postures while grasping small vibrating tools that they use to perform fine, detailed visually-guided work on a client who is often in a recumbent position (Fig. 1).

The length of time that it takes to apply a tattoo can vary widely depending on the size, location, and complexity of the design. A small piece can take half an hour or less to complete, whereas a larger tattoo, such as a sleeve (a tattoo that covers the arm) or back piece, can take many hours over multiple sessions. Grieshaber et al. (2012) reported prevalence of MSK discomfort exceeding 50% in several regions of the body, including low back, neck, shoulder, and hand-wrist, based on their survey results from 79 tattoo artists attending a tattoo convention in Toronto. This survey appears to still be the only published, formal ergonomics-related assessment made in this population of workers prior to the current study described herein. By contrast, work-related MSD risks associated with dentistry have been extensively studied (Akesson et al., 2012; Books and Klemm, 2012; Droeze and Jonsson, 2005; Finsen et al., 1998; Hayes et al., 2009; Rafeemanesh et al., 2013; Sakzewski and Naser-Ud-Din, 2014; Thornton et al., 2004; Valachi and Valachi,

* Corresponding author. Department of Integrated Systems Engineering, The Ohio State University, 1971 Neil Ave., Columbus, OH, 43210, USA.
E-mail address: sommerich.1@osu.edu (C.M. Sommerich).

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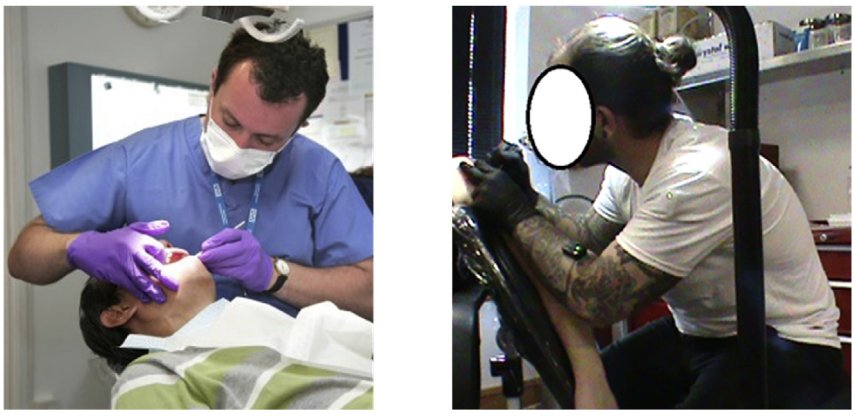


Fig. 1. Examples of similar working postures of dental professional (left) and tattoo artist (right). Source of dental image: http://www.wales.nhs.uk/sitesplus/863/page/42151.

2003). This is appropriate given the high prevalence of MSK discomfort in dental professionals, with as many as 85% of participating dentists experiencing discomfort in the neck or neck/shoulder region and 60% in the low back, as reported in various studies (Finsen et al., 1998; Hayes et al., 2009; Rafeemanesh et al., 2013).

Given the limited attention to date to tattoo artists as a worker population that appears to be at some risk of exposure to MSD-related risk factors and subsequent development of MSDs, a study was conducted with the following specific aims: 1) conduct a survey similar to that of Grieshaber et al. (2012) to determine if tattoo artists in another geographical region experience a similar or different prevalence of MSK discomfort, 2) gather objective data to begin to characterize the biomechanics of tattooing, 3) provide initial recommendations for intervention to reduce problematic exposures.

2. Methods

The study was observational in design, and consisted of the administration of a questionnaire followed by collection of postural and muscle activity data from a subset of questionnaire respondents. Both parts of the research protocol were approved by The Ohio State University's Institutional Review Board. Participants provided informed consent prior to involvement in each part of the study.

2.1. Materials and methods

2.1.1. Questionnaire

The questionnaire was self-administered and took 10–20 min to complete. It consisted of five sections: work history (including time employed in tattooing industry, hours worked per day and week, break patterns, job satisfaction), musculoskeletal health (modified Nordic Questionnaire (Kuorinka et al., 1987)), hand health (hand diagram, specific symptoms, frequency and intensity of symptoms), other health issues (including eye health, headaches, arthritis), and demographic information (including age, height, weight, gender, handedness, exercise participation).

2.1.2. Electromyography (EMG)

A Trigno™ Lab Wireless EMG System (Delsys, Inc., Boston MA) was used with eight wireless electrodes to sample muscle activity throughout the tattoo session. This system has a fixed sampling rate of 2000 Hz and an internal DAC filter bandwidth DC-500 Hz, 160 dB/Dec. The system was coupled with the Motion Monitor Data acquisition software (Innovative Sports Training, Inc. Chicago IL). A 10 Hz high pass filter and notch filters at multiples of 60 Hz were applied prior to exporting the data for analysis. Electrodes were placed over the bellies of the extrinsic finger extensor muscle group of the left forearm, the extrinsic finger flexor muscle group of the right forearm, right and left mid-deltoid, right and left upper trapezius, and right and left erector spinae muscles. All areas were shaved and cleaned with alcohol prior to application of electrodes.

For purposes of normalization, muscle-specific maximum voluntary exertions (MVEs) were obtained for all muscles except for the right and left erector spinae, for which reference contractions (RVCs) were obtained. Each exertion was performed twice, with 2 min of rest between repetitions. EMG data were collected for 15 s every 3 min throughout the tattoo session; recording sessions lasted from 1 to 3 h depending on the stage of the particular tattoo. For each EMG data sample, the researcher marked whether the tattoo artist was currently in the process of lining or shading and took notes. Depending on the stage of the tattoo, some sessions did not include both lining and shading.

The median frequency of the erector epinae muscle activity was compared over time through a series of reference posture trials, with subjects in a static flexed torso posture similar to those seen while tattooing, to inspect for evidence of muscle fatigue. For the upper extremity and shoulder muscles, means and standard deviations were calculated overall and per participant for 10th and 50th percentile EMG data. The number of participants whose muscle activity exceeded recommended static and mean muscle activity level recommendations according to Jonsson (1978) was calculated for each muscle.

2.1.3. Postural observation

Postural observations were carried out concurrently with EMG collection, though the timing was not coordinated. One observation was carried out every 5 min during the course of each tattoo session and posture was recorded using a Rapid Upper Limb Assessment worksheet (McAtamney and Corlett, 1993). Just prior to recording the posture, a photograph was taken that could be referenced in case of lost data or to confirm joint angles during later analysis. The observations were made from both the right and left sides of the participant. Observations were not made during breaks.

2.2. Participants

Study participants were recruited in one of two ways, both involving convenience sampling. Some participants were recruited from a tattoo convention held in Spring 2014 in Ohio. In addition to

the participants recruited from the convention, local participants were recruited from tattoo shops in the Central Ohio area. Permission to recruit was granted by the shop owners prior to making contact with individual tattoo artists. A subset of local questionnaire participants was asked to participate in the observational portion of the study, based on shop owner willingness and sufficient space in the shop to accommodate the researchers and data collection equipment.

In total, 34 questionnaires were collected from all recruiting efforts. A total of 20 questionnaires were returned either during the convention or later by mail of 37 that had been handed out (54% response rate). Of the 15 local tattoo artists who were approached, 14 questionnaires were returned. Twelve of the local artists were subsequently asked to participate in the observational portion of the study, 11 agreed, but only 10 were able to participate due to one participant being injured in the interim.

Twenty-eight male and six female tattoo artists participated in the questionnaire phase of the study, ranging in age from 26 to 54 years (avg. = 36 yrs). Height and weight means were 177.8 cm (sd = 9.7) and 84.0 kg (sd = 18.6), respectively. Three of the women and seven of the men also participated in the observational phase of the study.

3. Results

3.1. Questionnaire

3.1.1. Work history and practices

The 34 participants had been in the body modification industry for between 2 and 22 years (mean = 11.4, sd = 5.2) and had been tattooing for between 1 and 22 years (mean = 11.0, sd = 5.3). They worked as tattoo artists between 2 and 7 days per week (mean = 4.9, sd = 1.2) and between 3 and 14 h per day (mean 8.5, sd = 2.0). Most participants reported that tattooing was their sole source of income (91%; 31 of 34). Additional relevant information on work patterns includes the distribution of time on various tasks during the workday (Fig. 2), length of average tattoo session with a given client (Fig. 3), and time spent tattooing without a break (Fig. 3). Information in Fig. 2 indicates that tattoo artists are performing close work and holding a drawing instrument (tattoo gun or pencil/pen) for 80% of the workday, on average. Information in Fig. 3 indicates that tattoo artists tend to complete shorter sessions without interruption, while they tend to take a break during longer sessions.

3.1.2. Musculoskeletal health and discomfort

Twelve-month prevalence of musculoskeletal discomfort (ache, pain, discomfort, burning, numbness, tingling, or other trouble) in the eight major regions of the body (neck, shoulders, elbows, hands/wrists, upper back, lower back, legs/feet, and eyes) included in the questionnaire ranged from 38% for the legs/feet to 94% for the lower back; prevalence exceeded 50% for six of the eight regions (Fig. 4). Sixty-eight percent of respondents reported experiencing some type of hand discomfort (12-month prevalence). Reported discomfort in specific regions of the right hand ranged from 24% in the palm to 44% in the thenar eminence, and in the left hand from 9% in both the thumb and palm regions to 24% in the thenar eminence. Seven-day prevalence in the eight major regions of the body ranged from 9% for the elbow to 50% for the lower back; 7-day prevalence exceeded 20% in six of the eight regions. Those with previous injuries accounted for between 3% and 26% of the total 12-month prevalence, and between 0% and 15% of the total 7-day prevalence. Forty-one percent of the participants reported having seen a health care provider in the last 12 months due to discomfort in at least one of the eight major regions of the body. Seventy-nine percent reported that work activities related to tattooing made their discomfort worse in one or more regions (Fig. 4); 31% reported losing time from work due to MSK discomfort. Eye discomfort was remarkable in the group, with 12-month and 7-day prevalence of 74% and 47%, respectively.

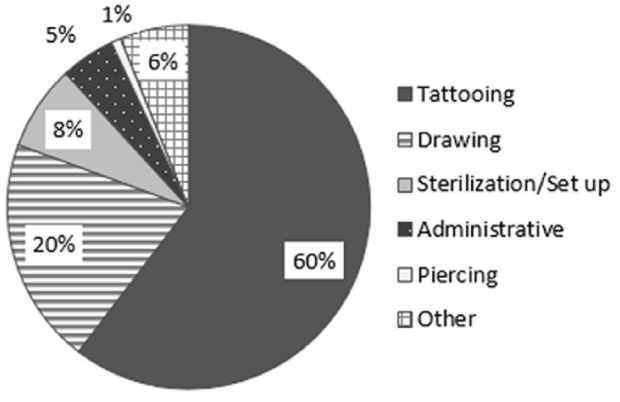


Fig. 2. Survey results from participating tattoo artists for time spent on various work tasks as a percentage of workday.

3.2. Posture assessment

The Rapid Upper Limb Assessment (McAtamney and Corlett, 1993) can produce overall scores that range from 1 to 7, where scores of 1–2 are acceptable (action level 1: 'posture acceptable if not maintained or repeated for long periods') and 7 is associated with the highest action level (action level 4: 'investigation and changes required immediately'). In the current study, seventy-one percent of the overall scores were at action levels 3 or 4, where changes are required soon or immediately, respectively. In total, 23% of the overall scores were 7 (action level 4) and another 48% were 5 or 6 (action level 3). Only one reading was at action level 1, and the remaining 28% were at action level 2 ('further investigation is needed and changes may be required'). Fig. 5 shows the distribution of the overall scores and the two final intermediate scores (Score C, the overall upper limb score, and Score D, the overall neck, trunk, and leg score). As an example, Fig. 6 illustrates the postural patterns displayed by one participant over the course of a session, for each scored body element that contributes to the C and D scores. This level of examination, for this participant, shows different patterns of use for the two hands and protracted periods of consistent position scores for the neck and trunk.

3.3. Muscle activity

All ten Phase 2 participants displayed 10th percentile muscle activity levels that exceeded the 2–5% MVE limit recommended by Jonsson (1978) in at least one muscle or muscle group. This was primarily seen in the left upper trapezius (n = 9, from 5.9 to 16% MVE) and the right upper trapezius (n = 6, from 7.9 to 13.1% MVE). All three female participants and two male participants (S24 and S28) showed elevated activity bilaterally, four of the other males showed unilaterally elevated activity in the left trapezius and one male only in the right trapezius muscle. Tenth percentile muscle activity levels in the upper trapezius muscles, averaged across all subjects, were 9.1% and 8.0% for left and right sides, respectively. The three female participants and two of the male participants (S24 and S26) had 50th percentile muscle activity levels that exceeded the 10–14% MVE limit recommended by Jonsson (1978) in at least one muscle or muscle group. This was primarily seen in the left upper trapezius (n = 3, from 14.2 to 24.9% MVE) and right upper

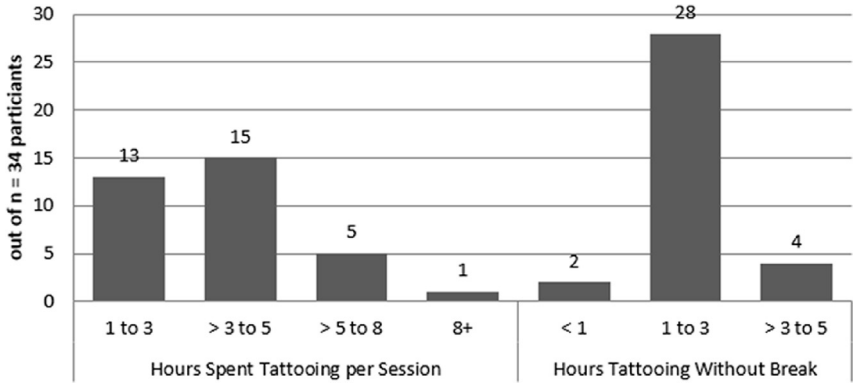


Fig. 3. Length of time survey respondents reported that they spend tattooing per session and without taking a break.

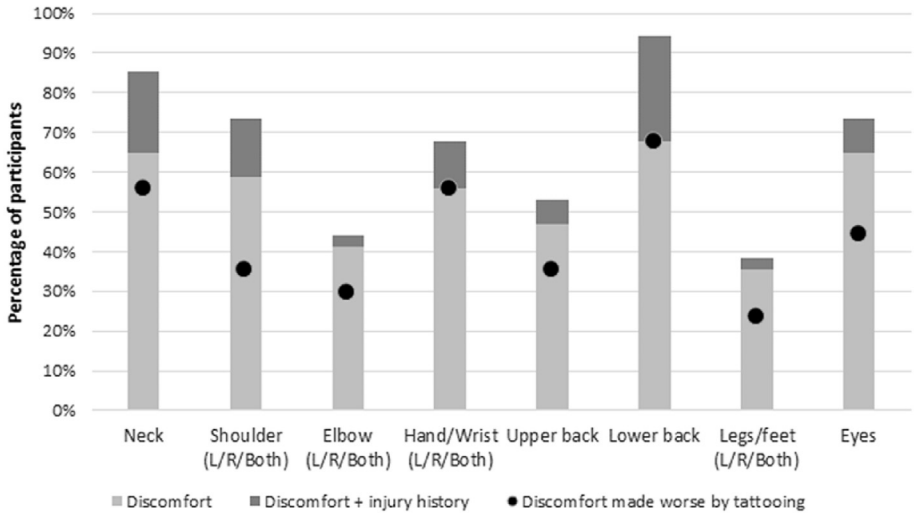
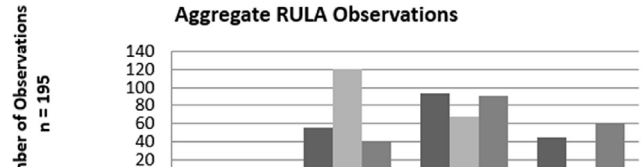


Fig. 4. Bars show twelve month prevalence of musculoskeletal discomfort in survey participants. Individuals who reported any prior traumatic (acute) injury to the body part are noted separately. Dots indicate the percentage of respondents who reported their discomfort was made worse by work activities related to tattooing.



	1 to 2	3 to 4	5 to 6	7+
Level of MSD Risk Range: 1-7	1	55	94	45
Upper Extremities	5	121	67	2
Neck, Trunk, Legs	4	40	90	61

Fig. 5. Frequency of RULA scores (1 to >7) across participants in the observation phase of the study. Total RULA score is presented in the top row. Upper extremity scores (Score C) are in the second row and Neck, trunk, leg scores (Score D) are in the third row.

trapezius (n = 5, from 16.4 to 23.6% MVE). Two of the female participants and one male participant showed elevated 50th percentile trapezius m. activity bilaterally. Fiftieth percentile muscle activity levels in the upper trapezius muscles, averaged across all subjects, were 13.5% and 13.9% for left and right sides, respectively. Evidence of fatigue was not see in the erector spinae m., based on examination of the median frequency and amplitude of the test contractions.

4. Discussion

The results from this study support the initial concern for an elevated prevalence of MSK discomfort in tattoo artists. This is the first study that has assessed the muscle activity and posture of the trunk and upper extremities of tattoo artists during real or simulated work, and results from that part of the study demonstrate patterns of exposure to awkward postures and elevated muscle activity levels over prolonged periods of time during typical tattooing sessions.

4.1. Discomfort and posture

The results from this study concerning musculoskeletal discomfort in tattoo artists are consistent with the work of Grieshaber et al. (2012). Both studies support the conclusion that musculoskeletal discomfort is highly prevalent in several regions of the body in these workers. Twelve-month discomfort prevalence in the current study exceeded the levels for all body parts reported for tattoo artists by Grieshaber et al. (2012), but are comparable to prevalence reported for the neck, shoulders, and upper back in dental hygienists by Akesson et al. (2012). However, if tattoo artists who experience MSK discomfort were more likely to participate in the current study than those who did not experience MSK discomfort, then these results could overestimate the prevalence of

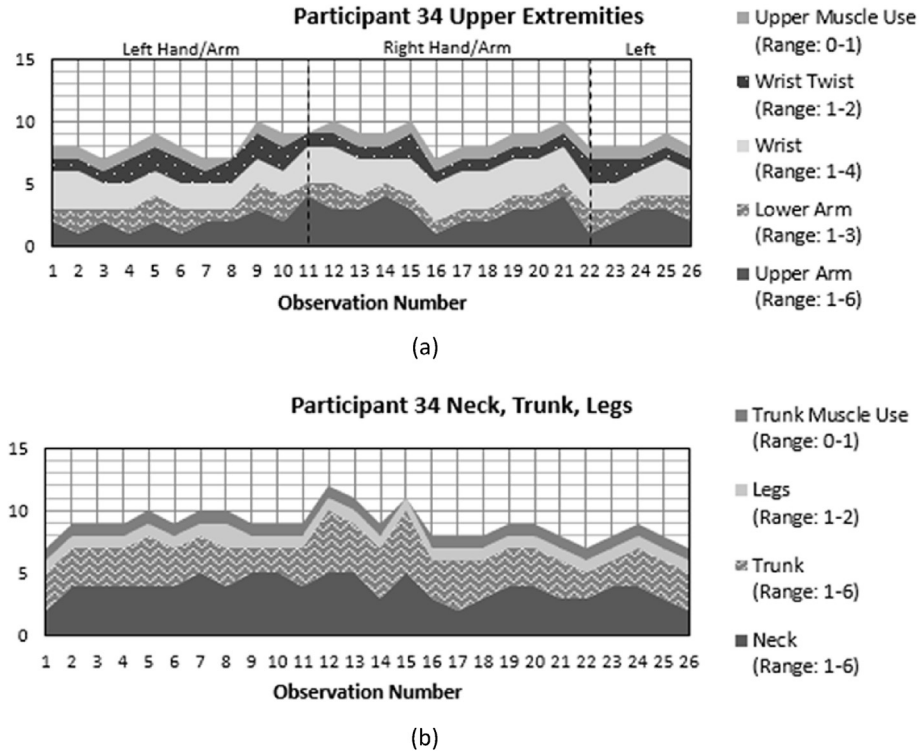


Fig. 6. Example of postural pattern displayed by one study participant during 2 h of tattooing, based on RULA scores for each body element that make up the upper extremity (a) and neck, trunk, and leg (b) scores, Scores C and D, respectively. Interpretation example, Upper Extremities - Observation 1: Upper Arm score = 2, Lower Arm score = 1, Wrist score = 3, Wrist Twist score = 1, Upper Muscle Use score = 1.

MSK discomfort in tattoo artists. Conversely, a healthy worker effect could contribute to an underestimation of MSK discomfort in tattoo artists.

The difference in discomfort prevalence between the present study and Grieshaber et al. (2012) may be due, in part, to differences in the reported proportion of work time spent tattooing between the two samples. Participants in the current study averaged 60% of their time tattooing and 20% drawing, while the same activities were performed 38% and 21% of the time, respectively, by Grieshaber's participants.

The Rapid Upper Limb Assessment showed that the prolonged awkward postures held by tattoo artists during work suggest that they have an elevated risk for developing musculoskeletal problems. Elevated, unsupported arms, pronounced neck flexion, forward head posture, and an unsupported flexed trunk were commonly observed among participants of this study and are also known risk factors in the dental community (Morse et al., 2010).

4.2. Muscle activity

As with dentists, the postures held by tattoo artists during their work contribute to high levels of static (10th percentile) and mean (50th percentile) muscle activity. According to Pope-Ford and Jiang (2015), "Seated postures, preferred by dentists as a way to relieve back stress, may contribute to the development of shoulder or neck MSDs due to elevated upper trapezius exertions." That study found mean (50th percentile) activity levels in the upper trapezius muscles during simulated dental work to be as high as 15–20% MVE while standing and 30–35% MVE in seated postures. In the current study, only two of the ten tattoo artists were observed to stand while tattooing and this was for only brief periods of time and only when working on clients who were lying down. Pronounced trunk flexion was observed when they stood because the table height was set for seated work. Two other artists were also observed to work on clients who were lying down and neither artist was observed to stand during those sessions. Awkward postures, particularly pronounced neck flexion, twisting, and lateral bending, and elevated and abducted or elevated and adducted shoulder postures were observed when artists were seated or standing.

In the current study, 10th and 50th percentile muscle activity levels for the trapezius muscles exceeded general recommendations by Jonsson (1978). In fact, mean 10th and 50th percentile trapezius muscle activity levels in the current study were comparable to 50th and 90th percentile values, respectively, reported by Akesson et al. (1997) in their study of female dentists and by Akesson et al. (2012) in their study of female dental hygienists whose prevalence of neck and shoulder discomfort was comparable to the tattoo artists in the current study.

Activity levels in the right and left erector spinae muscles did not appear to be particularly high in any of the participants in the current study, suggesting that back discomfort is likely related to the duration of sustained postures rather than particularly high levels of exertion. Lack of change in median frequency or amplitude may reflect a lack of repeatability of the test exertion method. Future studies should consider employing more reliable methods for eliciting a reliable reference exertion for these muscles in a work setting, given the high prevalence of discomfort experienced in this region of the body by tattoo artists and the prolonged trunk flexion observed in the current study.

4.3. Influence of workstation

Heightened upper extremity muscle activity levels and awkward postures are influenced in large part by the workstations at which tattoo artists spend a significant amount of their work days. The two largest influences of the overall working position of

the tattoo artists in this study seem to be the location of tools (i.e. inks, water, ointment, machines) and the location of the client. Tools were located directly to the right or behind the artist and often required spinal twisting and full reach with pronounced shoulder abduction to access. Clients were seated in chairs or laying on either massage-style tables or more adjustable dental-style chairs. No powered, height-adjustable tables were observed. In some instances adjusting the height of the target body part is either impossible or cumbersome, resulting in the tattoo artist making compensating adjustments to his/her body, that result in working at an inappropriate height and hunching or bending over to get close enough to see the target area. As is also the case with dentists, tattoo artists who use dental-style chairs sometimes positioned patients too high, allowing the artist to straighten their spines but resulting in elevated, unsupported arms (Valachi and Valachi, 2003).

The quality of the chair or stool used by the artists varied, but the presence or absence of a backrest seemed to be largely irrelevant, because there were no tattoo artists in the present study who were positioned such that they were able to use a back rest. Each artist sat with trunk flexed forward between 0 ° and 60 °, with many artists spending extended periods of time between 20 ° and 60 ° in order to be in close visual proximity to their work.

4.4. Recommendations and interventions

Locating tools such as inks, water, ointment, and tattoo machines closer to the artist will allow for easier access and less repetitive reaching and twisting. Increased use of dental-style chairs or powered, height-adjustable physical therapy-style tables would allow for more adjustability in positioning of the client, but as the present study and those of dentists have shown, this is not enough to eliminate awkward work postures. Tattoo artists might also benefit from positioning strategies recommended for dentists that include avoiding static postures, alternating between sitting and standing, repositioning the feet, and avoiding twisting, in addition to positioning patients at the proper height (Valachi and Valachi, 2003). Particularly in the case of appropriate patient/client positioning, dentists are assisted greatly by the proper use of magnification which allows for healthier postures and has been associated with decreased neck and low back pain (Chang, 2002). Alternative viewing aids for dental work were investigated by Smith et al. (2002) and something similar may also prove useful in tattooing.

Since tattoo artists are unable to effectively use back supports on chairs, providing support from the front may be a viable alternative. Combined chest and arm supports have been found to be effective at reducing muscle activity levels in the trapezius muscle of dentists during seated work (Haddad et al., 2012), while a prototype chest support reduced the activity levels in the erector spinae muscles of (standing) surgeons by 44% (Albayrak et al., 2007). An ergonomic sitting device of this type was developed with tattoo artists in mind by an industrial designer who first trained as a tattoo artist; it warrants further investigation (Hardie, 2014).

Research into possible interventions for tattoo artists should be conducted within a partnership between researchers, tattoo artists, and shop owners, because this field has many unique requirements and challenges. It is important to understand that many tattoo artists in the US work as independent contractors. As such they may have little control over the environment in which they work and the tools with which they work. Tattoo artists often own their own tattoo machines, but depending on the shop in which they work, they may have little to no control over the furnishings such as client chairs, arm rest stands, chairs available for the artist to use, or their workstations. These items can vary widely in their comfort and adjustability and it is up to the shop owner to make decisions about whether or not to provide ergonomically sound furnishings and equipment, making it important to engage shop owners in the intervention development process. Further complicating the issue of environmental effects on posture and muscle activity, some tattoo artists travel to multiple tattoo conventions/festivals each year. At a convention the artists must use only what they can bring or what is provided which often equates to a folding chair with little to no padding or support for the tattoo artist and a folding massage table for the client. As such, some intervention concepts should include requirements for portability.

5. Conclusion

The present study found that tattoo artists experience MSK discomfort in the neck, shoulders, elbows, hands/wrists, upper back, lower back, and legs/feet, and in many cases report that their discomfort is made worse by work activities. Eye discomfort also appears to be prevalent in this worker population. Prolonged awkward postures were found to be common during tattooing and may place tattoo artists at an elevated risk for musculoskeletal problems. Muscle activity levels in the trapezius m. were found to exceed recommended static and dynamic limits and are consistent with the high prevalence of self-reported discomfort in the neck and shoulder regions. Intervention is needed to reduce the exposure to risk factors for MSK discomfort and disorder in this population of workers.

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