The University of Utah
NORA Symposium

UTAHNORA

Abstract
Booklet | 2020

THE UNIVERSITY OF UTAH
DEPARTMENT OF
MECHANICAL ENGINEERING

Rocky Mountain Center for Occupational &
Environmental Health (RMCOEH)

CDC Centers for Disease
Control and Prevention

18th Annual NORA Symposium Schedule
Friday, April 17, 2020

7:45	-	8:00	Sign-in
8:00	-	8:15	*WELCOME* Andrew S. Merryweather, University of Utah

Session 1 – Workplace Injury and Injury Prevention

8:15	**Colleen Brents** *Occupational injuries in the Colorado craft brewing industry: an analysis of workers' compensation claims*
8:30	**Bethany Boggess Alcauter** *Uninvestigated fatal workplace injuries in the U.S*
8:45	**Monika Mioskowska** *Wearable Assistive Device for Active Slip-Induced Fall Prevention during Human Walking*

Session 2 – Workplace Health and Industrial Hygiene

9:00	**Jarom Kuhre, Brent Shepherd, Craig Soelberg, Alex Watts** *Health Hazards Assessment at an X-Ray Tube Manufacturer*
9:15	**Keely Latham, Keller Reeves, Raquel Robello, Lindsay Scholl, & Dallas Shi** *Health Hazard Analysis at a Hospital*
9:30	**Hyrum Bronson, Madison Ellis, Nicholas Gomez, Amy Loftis** *Evaluation of Health Hazards in a Chemical Detergent Manufacturing Facility*
9:45	**Bethany Boggess Alcauter** *Chronic kidney disease among agricultural worker patients of federally-qualified health centers*
10:00	**Josh Fullmer, Bruce Niebergall, Derek Sandberg, Logan Web, Marc Mallari** *Potential Health Hazards in a Copper Refinery*

Session 3 – Ergonomics and MSDs

10:15	**Arippa F** *Analysis of Sitting Postural Strategies During a 2-Hour Shift in Office Workers*
10:30	***Molly Hischke*** *Quantifying trunk posture exposures in vegetable and fruit pickers*
10:45	**Nguyen A** *Cue Engagement, Physical Activity, and Pain Level in Office Workers*
11:00	**Kyle Hancock** *Integration of ergonomics into continuous improvement programs: case studies proposal*

18th Annual NORA Symposium Schedule
Friday, April 17, 2020

11:15	**Bandekar, Anjaneya** *Using Machine Learning (ML) and Artificial Intelligence (AI) to explore associations between multiple risk factors and work-related musculoskeletal disorders (WMSD's)*
11:30	**Yan Y** *Prediction of Occupational Physical Activities using Inertial Measurement Units and Deep Learning Models*

11:45	-	12:30	**BREAK**

Session 4 – Design and Modeling

12:30	**Shiva Nageswaran** *Implications of a lift lever belt buckle on school bus emergency evacuations*
12:45	**Hao Fan** *Anthropometric Analysis of External Acoustic Meatus for Ergonomic Design*
1:00	**Hamidreza Barnamehei** *Synergetic kinematics relationships between elbow and shoulder angle during Taekwondo straight punch (Jirugi) executed by elite athletics*
1:15	**Mengcheng Wang** *Hand Posture and Force Estimation using Surface Electromyography and an Artificial Neural Network*

1:30		1:45	**BREAK**

1:45	-	2:00	**WRAP-UP & AWARDS PRESENTATIONS**

**The full program can be downloaded at https://nora.mech.utah.edu/program/

CONTENTS

OCCUPATIONAL INJURIES IN THE COLORADO CRAFT BREWING INDUSTRY: AN ANALYSIS OF WORKERS' COMPENSATION CLAIMS

Colleen Brents, John Rosecrance

Colorado State University, Fort Collins, Colorado

Introduction: Over the past five years, the number of craft breweries in Colorado grew over 120%. As of 2019, Colorado had the second greatest number of craft breweries in the US. Increased occupational injuries accompanied this overall industry expansion. Per the Colorado Workers' Compensation Act, businesses with more than one employee are legally required to provide workers' compensation insurance to cover the costs of occupational injuries. Information from workers' compensation data can provide insight into common injuries affecting an industry. The purpose of this study was to characterize injuries affecting Colorado craft brewery workers by analysing the accident narratives of workers' compensation claims data.

Methods: A five-year (2013 –2018) history of Colorado craft brewery workers' compensation claims data was analysed. Researchers partnered with Pinnacol Assurance to obtain workers' compensation data. Descriptive analysis of craft brewery injury claims was performed. Accident narratives were coded for specific work activity to further characterize occupational injuries.

Results: Of the 571 claims identified during the study period (July 2013 to June 2018), the majority of injuries by nature were contusions (27%), strains (19%) and lacerations (19%). Specific work activities associated with contusions involved product handling and packaging (37%). Work activities largely associated with lacerations were cleaning and maintenance tasks (49%). Handling product, packaging, and production work activities were associated with the majority (63%) of strain injuries.

Conclusions: The present study identified contusions, lacerations, and strains as the most common nature of injury affecting Colorado craft brewery workers. Practitioners and researchers can use workers' compensation data to help target and develop interventions to reduce occupational injuries. Work activity details extrapolated from accident narratives assist in targeting effective intervention strategies.

UNINVESTIGATED FATAL WORKPLACE INJURIES IN THE U.S.

Bethany Boggess Alcauter[1], Lisa Pompeii[2]

[1] Southwest Center for Occupational and Environmental Health, University of Texas Health Science Center

[2] Baylor College of Medicine

Introduction: While enormous advances in workplace health and safety have occurred in the last century, between 4,000-5,000 men and women still die from injuries at their workplace each year. Approximately 25-30% of these deaths are investigated by a U.S. Occupational Safety and Health Administration (OSHA) office. This research examines regional and demographic disparities in OSHA investigations of fatal workplace injuries.

Methods: This descriptive study used aggregated, publicly available data on fatal workplace injuries from the Census of Fatal Occupational Injuries from 2014-2015 and compared these data with disaggregated data from OSHA obtained via a Freedom of Information Act request for fatal workplace investigations during the same time period. Descriptive statistics for fatalities and investigations were calculated by geographic region, worker age and sex, and industry.

Results: A total of 9,657 fatal injuries occurred during 2014 and 2015, and 27.5% were investigated by OSHA. Nationally, deaths among female workers had significantly lower odds of being investigated by OSHA (OR 0.51, 95% CI 0.41, 0.63) compared to deaths among male workers. Workers under the age of 18 and workers 65 years of age or over had significantly lower odds of being investigated compared to workers 18-65 years of age. Significant geographic disparities were also observed, as both the Midwest and the South had significantly lower odds of an investigation compared to the Western U.S. (Midwest - OR 0.69, 0.61-0.79; South – OR 0.86, 0.77-0.96). Fatalities occurring in a State OSHA Plan state had lower odds of being investigated (OR 0.70, (0.64-0.76) compared to fatalities in states with a Federal OSHA Plan.

Conclusions: Substantial differences in the proportion of investigations by industry, geography, and worker demographics were observed. Some of these differences could be partially explained by jurisdiction restrictions placed on OSHA offices, but not entirely. Policy makers and researchers should consider undertaking a more extensive investigation to determine if low proportions of investigations are having a disparate impact on subgroups of workers, and if these disparities could be reconciled through increased funding and human resources in local OSHA offices.

WEARABLE ASSISTIVE DEVICE FOR ACTIVE SLIP-INDUCED FALL PREVENTION DURING HUMAN WALKING

Monika Mioskowska, Mitja Trkov

Department of Mechanical Engineering, Rowan University, Glassboro, NJ

Introduction: Slips, trips and other types of gait perturbations that lead to falls, pose a significant risk of injury across all populations. Foot slip is one of the major causes for falls especially among adults over 65 years. Preventing slip-induced falls and associated injuries would reduce economic and societal costs and improve life of those experiencing such events.

Previously, we developed a rapid slip detection system and slip-and-fall prevention assistive device (ROKAD). Slip detection algorithms can detect foot slip during human walking shortly after the slip onset (60 msec), which is much faster than the human reaction capabilities. The approach of the ROKAD device was to provide assistive knee torque to the slipping leg, which requires large torque capabilities and heavy, powerful actuators.

The goal of this study was to design a lightweight knee exoskeleton device to assist and prevent falls during slip occurrence of the elderly and occupational worker with high-risk of slip. Compared to the previously reported ROKAD device, the working principle is different, due to providing assistive torque to the knee of the swing leg instead of the stance leg. In this paper, we present the development and characterization of the prototype of knee assistive exoskeleton. The device was designed to assists with knee extension of the trailing leg during slip perturbation. By extending the knee during swing phase, the subject's base of support (BOS) is immediately increased. Rapid increased in BOS results in immediate increase in dynamic stability, due to the position of the projected instantaneous center of mass (COM) being located inside the subject's BOS area. The subject can therefore perform successful balance recovery and prevent falls.

Methods: The wearable device consists of a lightweight knee brace driven by Bowden cable (0.49 kg) and compressed gas actuation electro-mechanical system (2.17 kg). The actuator and electronics are located in a backpack to minimize the effect on walking gait. The brace contains 3D printed top and bottom parts that are connected through two aluminum hinges on each side of the device. The electro-mechanical components of the device include a power bank, piston, 3 port 2-way solenoid, beefcake relay control kit, Arduino UNO and CO_2 pressure regulator with 12g CO_2 cartridge. The device is controlled using an Arduino chip that integrates the IMU-based gait event detection algorithm and activates the device based on the algorithm's output. The cylinder is controlled by a 3-port 2-way solenoid connected to 12g CO_2 cartridge through a pressure regulator that supplies 100 psi pressure. The piston of the cylinder is connected to the brace through a cable in a sheath. By pulling the cable around the 3D printed circular hub that is offset from the axis of rotation, the device exerts a torque on the knee joint. The device is strapped to the knee. We performed experimental benchtop testing to characterize the device and a simplified testing protocol when a subject was wearing the device. The subject was standing with approximately ~60 deg bent knee, while the device provided assistive torque unexpectedly. We simulated the knee extension capabilities as in during walking and measured the required time to extend the knee.

Results: Bench testing of the device showed the device can provide approximately ~10 Nm of assistive torque and can extend 60 deg (~max knee angle during walking) in less than 0.14 sec. The human subject testing results while standing confirmed the device assists with knee extension of more than 30 degrees in less than 0.15 sec. We predict the performance of the device is sufficient to extend the knee and leg during walking and therefore assist human during slip-and-fall recovery.

Conclusions: In this paper, we propose a novel active slip recovery control strategy by using an assistive device to extend the trailing leg during the swing phase of a slip. The device was specifically designed to use small interchangeable energy sources, while still providing rapid actuation, which is the main requirement for slip recovery assistive device. Future work will include improvements of the device design and human subject testing to test various assistive control strategies and validate efficacy of the proposed slip recovery control strategy.

HEALTH HAZARDS ASSESSMENT AT AN X-RAY TUBE MANUFACTURER

Jarom Kuhre, Brent Shepherd, Craig Soelberg, Alex Watts
Faculty: Ken d'Entremont, Leon Pahler, Eric Wood
Rocky Mountain Center for Occupational and Environmental Health, Department of Family and Preventive Medicine, University of Utah

Background: An x-ray tube manufacturer had concerns about respirable levels of beryllium, lead and noise levels that are involved in the manufacture of x-ray tubes. Beryllium is transparent to x-rays and thus serves as an ideal material for X-ray windows, however it can cause acute beryllium disease, chronic beryllium disease and cancer. Lead, in contrast, blocks x-rays and is used in the machine encasing and to protect workers during testing. It, however, is also toxic, affecting the nervous system and causing developmental issues in children. Finally, exposure to loud noise for long durations can damage hearing, causing tinnitus, hearing loss, and deafness.

Methods: Both the beryllium and lead work areas were sampled by using a SKC AirCheck Touch Pump and filter cassette for an 8-hour sample. In addition, personal respirable samples were also sampled using the SKC AirCheck Touch Pump and filter cassette attached to a GS3 cyclone. Metal samples were analyzed using ICP-AES. For the noise, two area samples were monitored, as well as four personal dosimeter samples collected, in work areas of concern. For the noise area samples, a Larson Davis LxT Sound Level Meter was used to monitor 10x10 ft grids. Personal noise dosimeter monitoring was accomplished using four 3M Edge-5 noise dosimeters positioned on workers as per OSHA guidance. All noise dosimeter samples were conducted over an 8-hour work day.

Results: Beryllium concentrations in the manufacturing area were below the analytical detection limit (LOD) for both personal respirable and area samples, <0.0000095 mg/m³ and <0.0000096 mg/m³ respectively. There were detectable levels of lead for area, 2 ug/m³, but not for personal respirable, <0.0010 mg/m³, sampling. However, both of these were well below the OSHA permissible exposure limit (PEL) of 50 mg/m³ . The highest area noise exposure was 68.5 dBA which is below the OSHA PEL of 90 dBA. The highest personal dosimeter level was 80.4 dBA which is below the OSHA action level of 85 dBA.

Conclusion: The employee lead and beryllium respirable concentration results were below the laboratory limit of detection (LOD). As such, the current standards set up by the company to reduce their employees' exposure to these metals are sufficient and no additional abatements are necessary. The beryllium area sample was also below the LOD and no additional abatements are necessary. The lead area sample did register slightly above the LOD; however, the work area concentration was well below the OSHA permissible exposure limit. As such, no abatements are recommended at this time. The noise isopleth mapping in both the chemical and machine rooms showed no areas with noise levels great enough to be of concern to the current employees. As these measurements were taken during a time of decreased production, we recommend additional sampling during days when the machines are running a majority of the time. The personal noise measurements collected from the four employees are also below the OSHA action level and do not necessitate participation in a Hearing Conservation Program. The controls already in place by the company, including use of PPE adherence to warning signs, are sufficient to protect employees from excessive noise levels.

HEALTH HAZARD ANALYSIS AT A HOSPITAL

Keely Latham, Keller Reeves, Raquel Robello, Lindsay Scholl, & Dallas Shi

Faculty: Ken d'Entremont, Leon Pahler, Eric Wood

Rocky Mountain Center for Occupational and Environmental Health, Department of Family and Preventive Medicine, University of Utah

Introduction: A hospital located in the western United States has several processes posing potential occupational exposure risks. The facility has several mechanical rooms, many of which pose a noise exposure risk. Two of such mechanical rooms were assessed for noise; one which was constructed in 2018 and the other built over 20 years ago. The facility also has an oncological division dedicated to treating cancer patients, which contains a radiation oncology alloy molding lab that uses lead and cadmium as a part of the molding process. In order to assess occupational hazards throughout the facility, noise isopleths were created for both mechanical rooms, personal noise dosimeter monitoring was conducted on four randomly-selected mechanical room workers, and wipe sampling was conducted in the alloy molding lab to assess for lead and cadmium levels throughout the lab area.

Methods: Noise sampling was conducted in both mechanical rooms at every 10 foot by 10 foot intercept using a Larson Davis XLT sound level meter to create two noise isopleths using the program NoiseAtWork. Personal noise monitoring was performed on four randomly selected mechanical room workers using 3M 5-Edge noise dosimeters which were attached to employees' lapels for the duration of their 8-hour shifts. Wipe sampling was conducted in the alloy-molding room using wipe sampling kits following the National Institute for Occupational Health and Safety (NIOSH) method 9102 that is capable of analyzing lead and cadmium simultaneously. Wipe samples were collected in five locations: the inside doorknob, the floor near the workstation/hood, light switch, computer keyboard, and inside of the hood. Samples were sent for testing at ALS laboratories where they were analyzed using the NIOSH method 9102.

Results: Noise sampling results from the new mechanical room ranged from 72.1 dBA to 83.2 dBA. While the majority of the noise levels measured in the room were below 80 dBA, the highest noise levels were measured near the water heaters and air handling units. Noise sampling conducted in the old mechanical room revealed much higher noise levels, on average, when compared to the noise levels measured in the new mechanical room, with a range of 69.3 dBA to 88.2 dBA. The highest noise levels were measured in the middle of the room, near heavy machinery. Results of personal dosimeter noise monitoring revealed a range from 75.1 dBA to 79.1 dBA when measured using the Occupational Safety and Health Administration (OSHA) hearing conservation criteria. None of the four measured workers were exposed to high levels of noise levels for any prolonged duration of time. Results from the lead and cadmium wipe sampling were taken using wipe sample kits with an area sample of 100 cm^2 it was found that levels of cadmium and lead were high in the hood splatter area (13,000 μg/100 cm^2) for lead and 5,200 μg/100 cm^2 for cadmium) and on the floor beneath the hood (150 μg/100 cm^2 for lead and 110 μg/ 100 cm^2 for cadmium). However, the samples in the remaining work areas indicated very low levels (< 1.3 μg to 5.3 μg/100 cm^2 for lead and 0.97μg/100 cm^2 to 1.6μg/100 cm2 for cadmium).

Conclusions: Noise mapping revealed that noise levels in the new mechanical room were below the OSHA action level of 85 dBA for workers working an 8-hour shift. However, in the old mechanical room, noise levels exceeded the action level of 85 dBA, indicating that workers should continue using the hearing protection controls associated with their existent hearing conservation program. Additionally, personal noise dosimeter sampling results indicated that current noise levels are below the OSHA action level for workers in regard to personal noise exposure over their respective 8-hour shifts. OSHA recommends the lowest possible exposure with respect to lead and cadmium. The lower levels of lead and cadmium were determined to be 5.0 μg/100 m^2 and 0.5 μg/ 100 m^2, respectively. Areas where the levels of lead and cadmium were exceptionally high were in the hood splatter area and on the floor beneath the hood; the remaining areas yielded samples that were very low and only marginally above the acceptable levels. It is recommended that managerial staff work closely with housekeeping staff to ensure that the alloy molding lab is properly and sufficiently cleaned and maintained to reduce worker exposure to high levels of cadmium. It is also worth checking the hood face velocity to ensure that it is operating correctly, which will reduce worker exposure to lead and cadmium dusts.

EVALUATION OF HEALTH HAZARDS IN A CHEMICAL DETERGENT MANUFACTURING FACILITY

Students: Hyrum Bronson, Madison Ellis, Nicholas Gomez, Amy Loftis
Faculty: Leon Pahler and Eric Wood
Rocky Mountain Center for Occupational and Environmental Health, Department of Family and Preventive Medicine, University of Utah

Introduction: A commercial detergent manufacturing and distribution company recently began internal renovations of their manufacturing lines to optimize workflow and minimize hidden obstructions in the process. These renovations added additional machinery into a room that possibly increased worker noise exposure levels. This room is currently included in the companies' hearing conservation program. High noise levels can cause worker anxiety, irritability, and time away from work, and permanent hearing loss. Additionally, the company has two manufacturing processes within the facility that expose workers to airborne crystalline silica particulates, which can result in silicosis. The equipment used to create the single dose laundry detergent pods also creates large quantities of respirable dust, which can irritate the respiratory tract and aggravate conditions such as pre-existing asthma or lead to work-related asthma, a lung disease caused by workplace exposures. Sampling was requested to determine if a) the hearing conservation program was necessary and would suffice to reduce excessive noise exposures to a safe and healthy level, and b) if silica and respirable dust exposures were within regulatory limits.

Methods: Area noise levels were measured in the production warehouse using a Larson Davis LXT sound level meter. Prior to use, the sound level meter was calibrated using a known, 114dBA calibration tool. A grid with squares 5.03m x 7.32m (16.5ft x 24ft) was applied to the warehouse and the average dBA reading at each intersection point was recorded at a single point in time. The results were analysed using the NoiseAtWork software. To evaluate the silica and dust exposures in the other two rooms, both personal and area samples were obtained. Sampling and analysis followed the National Institute of Occupational Safety and Health (NIOSH) 7500 method. Personal samples were acquired using an Aircheck Sampler (model 224-52) pump with a nylon cyclone and a three-piece open-faced filter-cassette. The same sampling equipment used to acquire area samples; however, the equipment was placed in a static location. Both personal and area samples were collected for an 8-hour period.

Results: Noise levels within the warehouse ranged from 67.8 dBA – 91.5 dBA, with the majority being below 80 dBA. The maximum dBA readings exceeded the Occupational Safety and Health Administration (OSHA) 8-hour time-weight-average (TWA) exposure limit of 85 dBA, as well as the permissible exposure limit (PEL) of 90 dBA. In the first room where air sampling was performed, the respirable dust for not-otherwise-regulated (NOR) was 0.23mg/m^3 and silica was <12μg/m^3 (less than the OSHA PELs of 5mg/m^3 and 50μg/m^3, respectively). In the second room, the NOR respirable dust was 49 mg/m^3, while the silica levels were again <12μg/m^3. The concentration of NOR respirable dust in the second room exceeded the OSHA PEL, thus requiring intervention.

Conclusions: Though the majority of the noise levels measured in the production warehouse were below the 8-hour TWA PEL threshold, the noise levels above 85 dBA indicate that the hearing conservation program should be maintained for all workers entering and working in the facility. For the first room sampled for dust and silica, the concentrations were low and below regulation levels; therefore, no abatements are recommended at this time. However, the second room had higher particulate concentrations and may result in overexposure to NOR respirable dust. The company currently requires workers in this area to wear appropriate respirators and continued use of personal protective equipment (PPE) is recommended. Additionally, the company should consider implementation of engineering controls to reduce the amount of dust generated.

CHRONIC KIDNEY DISEASE AMONG AGRICULTURAL WORKER PATIENTS OF FEDERALLY-QUALIFIED HEALTH CENTERS

Bethany Boggess Alcauter[1], George L. Delclos[1], Edward Hendrikson[2], Sylvia Partida[3]

[1]Southwest Center for Occupational and Environmental Health, University of Texas Health Science Center; Houston, Texas
[2]Salud Family Health Centers; Fort Lupton, Colorado
[3]National Center for Farmworker Health; Buda, Texas

Introduction: Chronic kidney disease (CKD) epidemics have been documented among agricultural workers throughout Latin America in recent years. Primarily affecting working age males, CKD in these populations is usually found in the absence of traditional risk factors, such as diabetes mellitus and hypertension. Given the large population of immigrant workers from Mexico and Central America in the U.S., there is growing concern that this form of CKD exists in the U.S. as well. This research used a large database of electronic medical records from the Community-Based Research Network, a health information exchange of medical records, to examine the prevalence of CKD among migratory and seasonal agricultural worker (MSAW) patients.

Methods: Medical records from 2013-2014 were obtained from five health centers in Washington, California, Colorado, Michigan, and New York for patients between 18 and 49 years of age. Data on patient age, sex, clinic visit location, primary diagnoses from ICD-9 codes, and laboratory testing results were abstracted for all patients. The prevalence of CKD for both MSAW and non-MSAW patients was calculated based on either a primary diagnosis of CKD Stage 3-5 or a laboratory value of serum creatinine indicating an estimated glomerular filtration rate of less than 60 mL/min/1.73m^2 (Stages 3-5). After a master list of patients with CKD was created, descriptive statistics were calculated for both MSAW and non-MSAW patients with CKD.

Results: A total of 23,940 MSAW patients and 112,578 non-MSAW patients were identified. MSAW patients had a prevalence of CKD Stages 3-5 of 0.13% (n = 32) and non-MSAW patients had a prevalence of 0.32% (n = 357). Nationally, the estimated prevalence of CKD Stages 3-5 among people aged 20-39 is 0.3%, and 3.3% among people age 40-59 years.[1] MSAW patients with CKD had significantly higher odds of being Hispanic or Latino (6.36, 95% CI 2.68, 15.12) compared to non-MSAW patients, and of having Spanish listed as their primary language (OR 12.76, 5.31-30.61). The median age of MSAW patients with CKD was significantly younger than non-MSAW patients (41 years versus 44 years, respectively). MSAW patients with CKD were disproportionately male (46.9%) compared to non-MSAW patients with CKD (40.7%), although this finding did not reach statistical significance. MSAW patients with CKD were primarily concentrated in California (34.4%) and Colorado (34.4%), whereas non-MSAW patients were mostly found in Colorado (64.3%) and Michigan (19.7%).

Conclusions: This research provides important insight into a potential "first-stop" of health care for agricultural workers who may have CKD. The prevalence of CKD was lower than expected for both MSAW and non-MSAW patients compared to national figures for people of a similar age, which could indicate that screening for CKD is not conducted as often as needed. The lower prevalence among MSAW patients was unexpected since Latinos in the U.S. typically have a higher prevalence of CKD, but this could plausibly be due to low screening rates or to a healthy worker effect. Further research, such a pilot CKD screening program of MSAW patients at health centers, could potentially provide more accurate information on the prevalence of the disease in this population.

---

[1] United States Renal Data System. (2017). 2017 USRDS Annual Data Report. Retrieved from https://www.usrds.org/2017/download/2017_Volume_1_CKD_in_the_US.pdf

POTENTIAL HEALTH HAZARDS IN A COPPER REFINERY

Students: Josh Fullmer, Bruce Niebergall, Derek Sandberg, Logan Web, Marc Mallari
Faculty: Eric Wood, Leon Pahler, Ken d'Entremont
Rocky Mountain Center for Occupational and Environmental Health, Department of Family and Preventive Medicine, University of Utah

Background: After approval from a copper mining and refinery company, University of Utah Occupational Health and Safety Solutions students were invited to conduct several hazard evaluations at one of their facilities. Refinery workers are regularly exposed to a variety of potential hazards including whole-body vibration (WBV) from the operation of forklifts, exposure to loud noises in a copper operations area, possible lead exposures throughout the unit, and sulfuric acid mist in a tank house processing area. Whole-body vibration can cause discomfort and harm to the body. Several forklift operators have complained about joint aches following work shifts. Loud noises over 85dBA, especially over time, can lead to noise-related hearing loss. Worker exposure to lead can potentially cause anemia, weakness, and more sever health issues including kidney and brain damage and potentially death. Sulfuric acid mist is a significant irritant that affects the eyes, nose, throat, and skin. It may also cause respiratory burning or ailments.

Methods: Identification of forklift vibration sources using vibration instrumentation was the first choice to identify and mitigate whole-body vibration issues, however, due to changes in project goals, International Organization for Standards (ISO) procedure scope, and instrument capabilities, it was concluded that a preliminary observational study would be sufficient to make recommendations. The observational study evaluated existing types of shock absorbers used to reduce vibration transfer to workers from operation of the forklifts. Thirteen noise levels were measured at designated areas using a Larson Davis LXT SLM in a building that has the loudest noise because of the process. Each noise reading was averaged over ten seconds. The resulting noise levels were compared to current noise map levels for this building. Lead wipe samples were taken in a break room as well as in a lunchroom following the NIOSH 9100 method. Using the OSHA method ID-113 for air born sulfuric acid, three personal samples and four area samples were collected using air pumps equipped with 5-μm PVC filter-cassettes. Air borne inhalable sulfuric acid aerosols were collected using a parallel particle impactor for all three personal samples and two area samples. Total air concentrations of sulfuric acid were collected for the other two area samples.

Results: Three of the four main forklifts had outdated chairs or heavily used seats. Three had seat shock absorbers compressing by only 1-2 inches compared to the 4-5 inches compared to a newer seat. All seats had stiffer cushions with reduced shock-absorbing capabilities. The majority of fork lift whole-body vibration is generated by driving over worn, uneven surfaces at relatively high speeds. The range of sound levels were between 78dBA and 99dBA. Each location's sound level reading corresponded to the current noise map. Since all of the noise readings were the same, another noise map was not needed. The break room lead wipe sample result was exactly at the company-wide recommendation value of 3 micrograms per 100 square centimeters or less. The lunchroom area sample lead result was over the recommended value and was 4 micrograms per 100 square centimeters. All personal sulfuric acid sample results were well below the OSHA PEL for sulfuric acid of 1.0 mg/m³ and the ACGIH TLV of 0.2 mg/m³. The personal sulfuric acid sample results as reported by ALS in Salt Lake City are 0.0056 mg/m³, 0.017 mg/m³, and 0.017 mg/m³. Results for the area sulfuric acid samples were all below the PEL, however one area sample value was above the TLV of 0.2 mg/m³. Results for the sulfuric acid area samples are 0.13 mg/m³, 0.25 mg/m³, 0.077 mg/m³, and 0.12 mg/m³.

Conclusion: For the forklift vibration study, we recommend that the company should consider adding a new seat cushion to bolster shock absorbance. New cushions would be more cost-effective but less effective in the long term rather than replacing them with shock-absorbing and vibration-isolating seats. Cost analysis should be performed to determine if updating, patching, or repaving the floor is economical because it would have the most significant positive effect on reducing whole-body vibrations experienced by their forklift drivers. The building with the high noise levels should remain a noise regulated area, and employees should always wear hearing protection while working in it. We recommend that better hygiene practices and enforcement of good housekeeping in the lunchroom should be implemented if the area is to continue as an eating area. Lead concentrations could become unsafe if conditions in the lunch room remain unchanged. The maintenance break room should remain an area that employees do not eat. Continued periodic lead sampling is also recommended for these areas. All the personal samples for sulfuric acid were well below the PEL and TLV, indicating the current controls are adequate. A final recommendation is to continue periodic sulfuric acid sampling to ensure sulfuric acid air concentrations remain low.

ANALYSIS OF SITTING POSTURAL STRATEGIES DURING A 2-HOUR SHIFT IN OFFICE WORKERS

Arippa F[1,2], Nguyen A[2], Pau M[1], Kiok M[2], Ganesh N[2], Xu M I[2], Harris-Adamson[2,3]

[1]Department of Mechanical, Chemical and Materials Engineering, University of Cagliari, Cagliari, Italy
[2]Department of Environmental Health Sciences, University of California Berkeley, Berkeley, California
[3]Department of Medicine, University of California San Francisco, San Francisco, California

Introduction: Office workers adopt constrained sedentary postures for long periods of time on a daily basis, both at work and at home, which has been negatively associated with cardiometabolic and musculoskeletal health outcomes. Movement, whether changing postures between sitting and standing, walking, or fidgeting in one's chair, has been proposed as a way to mitigate MSD and adverse cardiometabolic indicators associated with sedentary behavior. However, the association between these mitigation strategies and described health outcomes are not well understood. This study aimed to evaluate the association between fidgeting (contact pressure and posture sway), posture changes, physical activity and cardiovascular data, within a cohort of office workers during a 2-hour work session at the computer.

Methods: Twenty professional full-time office workers, employed at UC Berkeley, were tested during a regular 2-hour work-shift session while working at the computer continuously sitting. During this period, subjects were asked to not stand up unless physically needed. Body-seat interface pressure data were collected using a pressure sensitive mat (Tekscan 5330E, Boston, MA, USA) and subjective discomfort ratings were evaluated by the mean of a 2-part questionnaire assessing discomfort across body regions. Physical activity (step counts, walking minute, sitting hours, standing hours) was assessed for 48 hours using an inertial measuring unit worn on the thigh (Activpal, Glasgow, Scotland, UK), while cardiovascular data were obtained using an ambulatory blood pressure cuff (Spacelabs ABP, UK) and a wearable heart-rate monitor (Actiheart, CamNtech, Cambridgeshire, UK). Pearson correlation coefficients were calculated to quantify the association between sitting, physical activity and cardiovascular data. Data was then stratified by those who took one or more breaks for at least one minute during the test period (breakers) and those who did not (prolongers).

Results: Results show that, in general, higher daily physical activity was associated with lower heart rate and blood pressure (Table 1). Movements performed while sitting (fidget movements) decrease over time, while mean pressure generally increases during the same time (Figure 1). Comparison between these two groups resulted in different postural strategies, showing that prolongers moved (fidgeted) less over time compared to the breakers (Figure 2). Moreover, differences in posture changes and physical activity were found between the two groups; breakers stood and walked more compared to the prolongers.

Conclusions: Overall, sitting postural strategies significantly changed while continuously sitting for 2 hours with sway decreasing while contact pressure increased. However, this was primarily pronounced in those who did not take any breaks. Participants who took breaks during the work period maintained the same postural strategies for the duration of the test leading to consistent sway and contact pressure. They also tended to spend more time standing and walking over a 48 hour period than their counterparts. Moving more, particularly the number of postural shifts and standing time, were correlated with improved cardiometabolic outcomes.

QUANTIFYING TRUNK POSTURE EXPOSURES IN VEGETABLE AND FRUIT PICKERS

Molly Hischke[1], Giuseppe Todde[2], Maria Caria[2], John Rosecrance[1]

[1] Colorado State University, Fort Collins, Colorado, USA; [2] University of Sassari, Sassari, Italy

Objectives: Throughout the world, fruits and vegetables are grown and harvested through labor-intensive work tasks. The labor-intensive manual work involved with harvesting agricultural produce expose workers to high risk of sustaining musculoskeletal disorders. Row crops, grown close to the ground, are especially task intensive and involve physical tasks that have been associated with high risk of low back injury. The purpose of this study was to investigate novel methods to quantify trunk postures during manual harvesting of fruits and vegetables.

Methods: In the first phase of the study 18 vegetable and fruit pickers were recruited from a farm in Sardinia, Italy. Participants wore an accelerometer based motion logging system (Zephyr[TM] Bioharness) for approximately two hours while harvesting eggplants (9 workers) and strawberries (9 workers). The posture data was processed in a custom MATLAB script. The magnitude, frequency, and time spent in several categories of trunk postures were assessed. The trunk posture categories were divided into four posture categories 1) less than 0° (hyper extension), 0° to 30° of forward flexion, 30° – 60° and greater than 60° of forward flexion.

Results: While harvesting eggplants, pickers had a mean maximum trunk posture of 82°. The eggplant pickers spent the majority of their time between 0° and 30° of trunk flexion. While harvesting strawberries, pickers had a mean maximum trunk posture of 93°. The strawberry pickers spent the majority of their time with trunk flexion postures greater than 60 degrees. The magnitude and frequency of the trunk postures were different between the two products harvested. In addition, there were significant differences in the time spent in the four posture categories (with strawberry picking involving more time spent at greater degrees of trunk flexion).

CUE ENGAGEMENT, PHYSICAL ACTIVITY, AND PAIN LEVEL IN OFFICE WORKERS

Nguyen A,[1] Arippa F,[2] Kiok M, [1,3] Ganesh N,[1] Xu M I,[1] Harris-Adamson C[1,3]

[1]Department of Environmental Health Sciences, University of California Berkeley, Berkeley, California
[2]Department of Mechanical, Chemical and Materials Engineering, University of Cagliari, Cagliari, Italy
[3]Department of Medicine, University of California San Francisco, San Francisco, California

Introduction: Sedentary behavior has been associated with musculoskeletal (MS) pain and cardiometabolic disorders and is especially prevalent in office workers, who are often sitting in sustained postures for long periods of time. Prior studies have shown dose-response relationships between the amount of postural transitions (breakers) and reductions in cardiometabolic risk factors and MS pain. Various approaches have been proposed as ways to mitigate prolonged sitting thereby increasing the amount of postural transitions, including sit-stand desks, walk and talk meetings, and walking snail mails (emails) to colleagues; however, these approaches are typically underutilized. Therefore, the purpose of this cross-sectional analysis was to examine preferred postures of office workers completing common office tasks and to determine whether there were any associations between MSD and posture/activity levels in these sedentary office workers.

Methods: Participants, who worked at least 30 hours per week in an office and had a sit-stand desk, completed baseline questionnaires, reported their task activity throughout a workday, and wore an inertial measuring unit to quantify posture and physical activity (Activpal, Glasgow, Scotland, UK). Nine cues were sent to participants smartphones via SMS text message from 8:30 am to 4:30 pm, the hours of a typical workday. Participants were prompted to respond with the following numbers associated with work tasks: 1 - in meeting; 2 - on call/web conference; 3 - primarily reading text; 4 - primarily typing/writing a paper/emails; 5 - primarily web browsing; 6 - primarily mousing [computer assisted design (CAD) or other design software]; 7 – Other. Time stamped posture/activity data from the inertial measuring unit were matched with time stamped responses from participants to determine posture/activity positions during each response. Task-based postural scores were calculated by summing the posture values for each subject. The relationships among survey data, participants' responses, and posture/activity data were assessed using Pearson correlation coefficients.

Results: There was a total of 146 cues that were sent to seventeen participants with an overall response rate of 95.21%. According to these data, sitting is the preferred position for meetings, having call/web conferences, reading text, typing/writing a paper/emails, and mousing. On the other hand, standing was identified as the preferred posture for web browsing and was second to sitting for primarily typing/writing a paper/emails. There was a moderate positive correlation between pain and measured postural shifts ($r = 0.48$) and a slight negative correlation between pain and task-based posture score ($r = -0.21$). There was also a moderate negative correlation between the composite pain score and time spent standing ($r = -0.37$). There was no relationship between measured steps or time spent walking and MS pain scores.

Conclusions: In this cross-sectional analysis, there was a moderate correlation between musculoskeletal pain and postural shifts indicating that those who have more pain tend to change their posture more. Although weak, there was a negative correlation between hours standing and pain and a positive association between hours sitting and pain. Most office tasks were performed sitting with the exception of web-browsing which may present an opportunity to reduce sitting in other workers. While further investigation is needed to ascertain the relationships between these variables, these data serve as a foundation for understanding preferred postures, activity levels, and MS pain in office workers.

AN ASSESSMENT OF ERGONOMICS CLIMATE AND ITS APPLICATION FOR FUTURE RESEARCH

Kyle Hancock[1], Elham Faez[2], Seyed Abolfazl Zakerian[2], Kamal Azam[2], John Rosecrance[1]

[1]Coloardo State University, [2]Tehran University of Medical Sciences

Introduction: Safety climate is a commonly used tool within the field of occupational health and safety that assesses employees' perception of the value that an organization places on safety. This measure was first introduced in the 1980's and has been implemented in a variety of research. Recently, researchers at Colorado State University adapted safety climate to look at both safety and production metrics. The resulting measure was called ergonomics climate. Ergonomics climate is defined as "the employee's perception of the extent to which the organization emphasizes and supports the design and modification of work such as both operational performance and employee well-being are maximized" (Hoffmeister et al., 2015). Studies using ergonomics climate have demonstrated that a high ergonomics climate (perceptions of high value placed on safety and production) is most beneficial to employee health and organizational performance. The purpose of this study was to assess and compare the ergonomics climate at two Iranian power plants and its association with organizational performance and employee well-being.

Methods: A random sample of 220 workers was selected from two power plants (Besat and Rey) in Tehran, Iran. Three separate questionnaires were administered to collect data. The Hersey & Goldsmith questionnaire (organizational performance), the General Health Questionnaire (employee well-being), and the Ergonomics Climate Survey were utilized for this study. This data was used to test the hypothesis that higher scores on ergonomics climate would be associated with increased employee well-being and operational performance.

Results: The mean ergonomics climate score was statistically different between the two power plants. There was a significant relationship between the overall ergonomics climate and self-reported musculoskeletal pain in the wrist, lower back, hip/thigh, and ankle/foot ($p < 0.05$). Ergonomics climate and all subscales had a positive association with organizational performance ($p < 0.001$). Additionally, the overall ergonomics climate and some subscales had a significant association with employees' general health ($p < 0.001$).

Conclusions: Implementing ergonomic strategies and interventions to design and modify the workplace can improve employee perception in regard to ergonomics climate, which is associated with a reduced number of musculoskeletal pain as well as improved organizational performance and employee well-being. Future research should test interventions that seek to integrate safety and ergonomics into performance initiatives. Based on these results we propose research that looks at the integration of safety and ergonomics into continuous improvement programs. This idea is rooted in ergonomics climate research, work design principles, and the significant overlap described by previous researchers. The ability to improve both safety and production would appeal to many companies and allow them to devote more resources to employee well-being. This approach may also improve employee perceptions for both safety and production which ultimately increases ergonomics climate.

USING MACHINE LEARNING (ML) AND ARTIFICIAL INTELLIGENCE (AI) TO EXPLORE ASSOCIATIONS BETWEEN MULTIPLE RISK FACTORS AND WORK-RELATED MUSCULOSKELETAL DISORDERS (WMSD'S)

Bandekar, Anjaneya[1], Sesek, Richard[1], Drinkaus, Phillip[2], Liu, Jia[1], Gallagher, Sean[1], Harris, Gregory[1]

[1]Department of Industrial & Systems Engineering, Auburn University, Auburn, Alabama
[2]Department of Mechanical Engineering, University of Utah, Salt Lake City, Utah

Introduction: Work-Related Musculoskeletal Disorders (WMSDs) represent a significant proportion of workplace injuries and are the leading cause of health problems resulting in severe long-term pain and lost-work day related disability. The aggregate impact of WMSDs is increasing rapidly from $54 billion in total costs in 1998 to over $250 billion in 2013. There is a high prevalence of WMSDs in automotive related industries which are characterized by assembly-type operations. Moreover, WMSDs occur at a higher rate in the automotive industry. The pathogenesis and WMSD etiology involves a complex combination of physical, individual, and psychosocial risk factors, all of which should be addressed for an effective intervention. Several studies have investigated the role of individual risk factors such as gender, age, BMI, smoking, etc. and psychosocial factors such as monotonous work, lack of job control, time pressure, and poor employee-supervisor relations, to predict WMSDs, but no study has simultaneously considered the complete spectrum of risk factors such as a) Physical/Job-related, b) Individual, c) Psychophysical and d) Psychosocial risk factors across all body segments to develop a holistic, predictive ergonomic model.

Methods: This study considers **(A):** stronger case definitions **(B):** explores associations among physical/job-related risk factors and WMSDs using Machine Learning, and **(C):** explores associations among significant physical/job-related risk factors, individual risk factors, psychophysical risk factors, psychosocial risk factors and WMSD's.

Preliminary analysis of our dataset indicated a logical disconnect between subject symptoms and medical diagnoses. Overly simplified definitions can overstate injuries while highly specific outcomes may understate the true number of injured workers. More robust definitions that incorporate multiple and varied criteria can facilitate a more meaningful and "continuous" health outcome.

This study explores data collected by a team of dozens of researchers across six automotive manufacturing plants and contains hundreds of data points per individual. Adding to the complexity, each job was broken down into as many as seven tasks using a question set with over 230 variables, out of which several are categorical variables containing five or more categories. It is virtually impossible to test associations with each of these job characteristics and WMSDs manually. Therefore, machine learning (ML) was used to identify significant physical risk factors without user biases.

The subjects were initially classified dichotomously as WMSD present/absent (Case-Control). Adjusted Odd's Ratios (ORs) were computed using multiple logistic regression analysis to study the associations of independent variables such as individual risk-factors (e.g., height, weight, etc.), psychosocial risk-factors (e.g., work satisfaction, etc), psychophysical risk-factor (i.e., perceived level of physical exertion), and significant physical/job-related risk-factors (obtained after running an ML algorithm) and WMSDs.

Results: A preliminary study was performed to identify the prevalence of WMSDs by demographic characteristics of the subjects in our dataset. The subjects were classified as *WMSD Present (n=511)* and *WMSD Absent (n=505)*, the overall prevalence of WMSDs was ~50%. An Independent sample *t-test* and χ^2 *test* was used to compare means of continuous and categorical variables univariately. Significant associations were found in demographic variables such as age and height (*p<0.05*), gender (*p<0.001*) and WMSDs. However, WMSDs were not significantly associated with the subject's weight and BMI, which warrants the use of ML techniques that can reveal complex interactions among variables and incorporate meaningful variables that might otherwise be overlooked.

Conclusions: These results are consistent with current literature, however, in-depth analyses of all variables are underway to identify significant associations between multiple risk factors and WMSDs across body regions, which will be incorporated into Mr. Bandekar's dissertation.

PREDICTION OF OCCUPATIONAL PHYSICAL ACTIVITIES USING INERTIAL MEASUREMENT UNITS AND DEEP LEARNING MODELS

Yan Y[1], Fan H[2,5], Li Y[3], Hoeglinger E[4,6], Wiesinger A[4,6], Barr A[5], Harris Adamson C[5,6]

[1]Department of Mechanical Engineering, University of California, Berkeley
[2]Department of Industrial Design, Northwestern Polytechnic, China
[3]Department of Electrical Engineering and Computer Science, University of California, Berkeley
[4]University of Applied Sciences Upper Austria, Linz, Austria
[5]Department of Medicine, University of California, San Francisco
[6]School of Public Health, University of California, Berkeley

Introduction: Many workers engaged in manual material handling (MMH) jobs experience high physical demands that are associated with work-related musculoskeletal disorders (WMSD). Quantifying the physical demands of a job is an important legal requirement in the US that is used by human resources in the job hiring process. Most physical demands analysis (PDA) are performed using observational and semi-quantitative methods. The lack of accuracy and reliability of these methods can create problems when assigning acceptable tasks to an injured worker. Also, the video-based task assessment method is extremely time consuming and thus costly. Although several studies have explored the use of wearable devices combined with direct measurement methods to quantify whole body kinematics, the classification and summarization of physical activities for physical demands analyses and biomechanical risk assessment is still in its initial stage. Therefore, the objective of this study was to apply machine learning models to data from inertial measurement units (IMUs) to predict occupational physical activities (OPA) common to physical demand analyses. Accurate OPA predictions with wearable devices would provide a more reliable, informative and cost-effective approach to quantifying the physical demands of a job and could be used at the individual level for a safer return to work following an injury.

Methods: A lightweight (<1.5lbs) wearable device (SpineTrack, Berkeley, CA) consisting of a vest with eight IMUs was developed. The vest has a shoulder harness, belt, upper arm straps and upper leg straps made of nylon mesh fabric. The IMUs included three-axis accelerometers, gyroscopes and magnetometers; the position and orientation of body segments were logged. Through this device, we were able to track the movement of the trunk, upper arms, lower arms and upper legs. In this study, 26 activities common in MMH jobs were completed and ultimately condensed to 15 categories of OPAs. Three tasks that each included at least three different OPAs (carpentry, bottle packing and drilling) were then performed. Carpentry and bottle packing were performed until the task was complete and drilling was performed for 15 seconds each. The sampling rate of the IMUs is 10 Hz. A convolutional neural network (CNN) was used to predict OPAs. Processed IMU data of activities was converted to tensors for training, validation, and testing respectively. The Resnet-18 structure was used and only the weights were learned during training. Error was defined as the average cross-entropy loss over all samples in one batch. Multimedia video task analysis (MVTA) were applied to the three different tasks and the result was used to verify model accuracy of task data.

Results: Fifteen subjects (6 females and 9 males with age 35.6±14.1, heights: 165.1±18cm and weights: 67.6±15kg) participated in this laboratory study. None of them reported any recent injuries or chronic diseases. The CNN achieved an overall accuracy of 95% in test data but differed by OPA with one handed lifts having the lowest accuracy (83%). The accuracy of activities including overhead, sitting, standing, carrying, reaching and static stoop reached 100%. In most bottle packing task, the accuracy is higher than 70%.

Conclusions: In this study, data from 8 inertial measurement units were applied to a convolutional neural network to predict occupational physical activities with an overall accuracy of 95% in the testing data. The CNN achieved more than 70% accuracy for most bottle packing task. Further analyses are needed to determine its accuracy when applied to carpentry and drilling task that includes a variety of occupational physical activities. This approach may improve the accuracy and reliability of quantifying the physical demands of a job.

IMPLICATIONS OF A LIFT LEVER BELT BUCKLE ON SCHOOL BUS EMERGENCY EVACUATIONS

Shiva Nageswaran[1], Jerry Davis[1], Yousif Abulhasan[2], Richard Sesek[1], Sean Gallagher[1], Mark Schall[1]

[1]Department of Industrial & Systems Engineering, Auburn University, Auburn, AL
[2]Department of Occupational Safety and Health, Murray State University, Murray, KY

Introduction: The first seat belt used in a transportation system was installed in 1885 on a horse drawn carriage. In 1926, seat belts were first required in the cockpit of commercial airplanes. Since 1968 all cars in the United States have been required to have a 3-point restraint system in the driver's seat and cars manufactured after 1996 are required to have that in all seating positions. School buses, an integral part of the education and transportation sector in the United States, are currently only required to have seat belts in eight states. Nearly a half million buses transport approximately 25 million children to and from schools every day. Despite being an incredibly safe mode of transportation, an average of 128 fatalities associated with school buses occurred annually from 2008-2017 and 13 of these fatalities involved occupants.

Much of the conversation regarding the use of safety belts for school buses has focused on their economic impact. Little attention has been focused on the safety, even less so on the ability of young children to operate a seat belt in a post-accident scenario. Federal Motor Vehicle Safety Standards (FMVSS) 208, 209, 210 and 222 regulate seat belt assemblies on school buses, and FMVSS 217 regulates school bus emergency exit systems. However, none of these standards consider the effects of seat belts on egress times during the emergency evacuation of a school bus.

Most vehicles today are equipped with an end-release push-button buckle. Despite differences in the cabin design, school buses also use push-button buckles, but due to the ambiguous nature of the standards, manufactures have the freedom to use any buckle. The majority of commercial aircraft use lift lever buckles because it is easy to locate the buckle, both for the passengers and for the crew, and it makes it easier for rescuers to release the buckle in an emergency.

Research indicates that the unlatching force on a push-button restraint system increases with an increase in belt tension and exceeds the standard requirement of 133N. In a rolled over orientation, unlatching the seat belt appears to be a very difficult task for the majority of school bus riding population. Studies on physical strength capabilities of humans have shown that mean finger push force for children in the age group of 2-15 years old did not reach the permitted 133 N force. Research has primarily studied the effects of seat belts on adults in cars, however, it is essential to design emergency exit systems for the primary occupants of school buses, children. The primary objective of this study is to analyse the ability of young children to unlatch a lift lever seat belt buckle in both normal and rolled-over (suspended on a turned over seat) orientations of a school bus. The study aims to compare the unlatching performance of a custom lift lever belt buckle to a standard end-release push-button belt buckle.

Methods: A custom testing device was built to simulate the seating assembly in a rolled-over school bus. This device consists of a SafeGuard Base school bus seat mounted on a wooden platform that can be rotated 90 degrees. The seat is positioned such that, upon release of the seat belt buckle, the subject will fall into a foam filled pit. We plan to recruit 30 males and 30 females (5-16 years age group) from the Auburn Gymnastics Academy. Gender, age, grade, height and weight of the subjects will be recorded. Maximum push and pull force exerted by fingers for both the hands will be measured in the normal and rolled-over orientations using a custom buckle prototype mounted on a Chatillon CSD 200 push-pull dynamometer. The existing seat belt assembly will be modified with a custom lift-lever belt buckle to evaluate its performance and examine the unlatching capabilities of children in the rolled over orientation. Paired t-Tests will be conducted to compare the results (maximum force exerted, unlatching ability) from this study to a similar study conducted by the authors using a standard push-button seat belt assembly.

Results: We plan to collect data in fall 2020 at the Auburn Gymnastics Academy.

Conclusions: We believe that the physical and cognitive limitations of young children can make the unlatching of a seat belt in a rolled over orientation a very challenging task, particularly in an emergency. It is hypothesized that the customized lift lever seat belt buckle would prove to be a better alternative to the standard end-release push-button buckle in an emergency evacuation.

ANTHROPOMETRIC ANALYSIS OF EXTERNAL ACOUSTIC MEATUS FOR ERGONOMIC DESIGN

Hao Fan[1,2], Mengcheng Wang[1,2], Carisa Harris Adamson [2,3], Yihui Ren[1], Suihuai Yu[1]

[1] Key Laboratory of Industrial Design and Ergonomics, Ministry of Industry and Information Technology,
Northwestern Polytechnical University, Xi'an, Shaanxi, PR China
[2] School of Public Health, University of California, Berkeley, Berkeley, CA
[3] Department of Medicine, University of California, San Francisco, San Francisco, CA

Introduction: Ear-related wearable products have become ubiquitous and have a profound impact on our lives by providing a mechanism of instant communication, entertainment, hearing protection and noise reduction. Numerous studies of the external ear and related products have provided a better understanding of the methods, results and applications for auricular measurements, auricular shape types, related product categorization, and matching relationships of ear measurements and products important for product development. However, there are few studies that have focused on the external acoustic meatus (EAM) which is an important element of the auditory apparatus and should be considered during the ergonomic design of ear-related wearable products. The EAM forms an S-shaped curve with three sections and two bends. The lateral third of EAM is cartilaginous and the medial two-thirds is osseous. Sound waves are collected by the auricle and conducted along the EAM inwards towards the tympanic membrane. Studies have shown that the external ear, specifically the auricle, continues to grow throughout one's life. However, the growth trajectory of the EAM across a person's life span is not well understood. Therefore, the primary purpose of this study was to propose and define EAM measurements and explore how the EAM measurements change with age so they can be incorporated into the ergonomic design of ear-related wearable products.

Methods: 700 Chinese subjects (male:female = 1:1) were recruited between 2016 and 2019, and divided into seven age groups, 50 subjects for each gender of each age group including10s (15-19), 20s (20-29), 30s (30-39), 40s (40-49), 50s (50-59), 60s (60-69) and 70+ (over 70). Both sides of external ear were measured indirectly by a non-contactable method of casting and 3-D scanning from the concha to the EAM. The impression prototype of concha and EAM was casted using ABR impression materials (SOUNDLINK, Inc., China). The point cloud of face, head and the impression prototype were captured using Einscan-Pro+ Handheld HD Scanner (SHINING 3D Inc., China, accuracy 0.01 mm). The point cloud models were hole-filled, smoothed (removed noises) and merged using RapidForm XOR3 (INUS Technology, Inc., Korea). A total of 19 landmarks and 23 measurements were selected, measured by casting and scanning the external ear. Linear, angular and circumference measurements were measured by extracting the 3D parameters of landmarks/points and calculating. Area measurements were extracted and measured using the RapidForm software. Analysis of variance (ANOVA) was used to determine the effects of age group on EAM measurements, while the Tukey's honestly significantly different (Tukey HSD) test was used post-hoc and adjusted for multiple comparisons. The difference of left-right and male-female were examined using the (paired-samples and independent) t-test.

Results: The results showed that all the EAM measurements had correlation with age, with the highest correlation found between EAM entrance length (EEL) and age (0.67, $p < 0.01$). The EAM measurements of Chinese population have significant differences based on age groups. Some age groups showed no significant differences in measurements and this phenomenon appeared mainly in 30s-40s and 60s-70+. From 15 years old to 83, the size of EAM entrance length (EEL) increased 20% (the highest growth rate of linear measurements), and the angle between tragus and medial concha (ATMC) increased by 32% (the highest growth rate of angular measurements). Differences of linear measurements between left- and right-side EAM were less than 0.2 mm, and the values of angular measurements were less than 0.8°. There were significant differences achieved in the measurements of EAM entrance, first and second bends between males and females. The greatest difference of linear measurements were achieved in EEL.

Conclusions: The external acoustic meatus continues to grow throughout the human lifespan; all measurements have a correlation with age. This study provides the anthropometric characteristics of the EAM which could be applied to the ergonomic design of ear-plug and other related products that fit inside the external ear.

SYNERGETIC KINEMATICS RELATIONSHIPS BETWEEN ELBOW AND SHOULDER DURING TAEKWONDO STRAIGHT PUNCH (JIRUGI) EXECUTED BY ELITE ATHLETICS

Hamidreza Barnamehei, Mohammad Ali Safaei, Neda Golfeshan, Mohammad Barnamehei

Gene and Linda Voiland School of Chemical and Bioengineering, Washington State University, Pullman, WA 99164-6515, USA

Introduction: In TaeKwonDo forms are called Poomsae and the practice and development of Poomsae skills is the soul of Taekwondo practice. The Taekwondo poomsaes are so designed to cope collectively with the outside threats in that society has already developed into an organized group, weakening the necessity of solitary individual defence measures. Poomsae is evolving from the traditional core curriculum of Taekwondo into a modern athletic sport. The aim of the current study was to evaluate motor control variables during a Taekwondo straight punch (Jirugi) to finding movement pattern of Taekwondo punch and injury mechanisms.

Methods: Ten elite adult black belt Taekwondo athletics (M ± SD: age 26.0 ± 3.1 years, mass 69.9 ± 8.7 kg, height 173.6 ± 5.8 cm) from the Iran National team performed a Taekwondo straight punch (Jirugi) with their dominant hands. Upper extremity kinematics were recorded using a eight high-speed camera (VICON, Vicon Motion Analysis Systems Ltd., Oxford, UK) with sampling frequency 120 Hz and two force platforms fixed in the floor (Kistler Instrumente AG, Winterthur, Switzerland, sampling rate 1000 Hz).

Results: The figure below shows the relationship between elbow and shoulder kinematics variables. According to this figure elbow and shoulder work with each other to perform the punch effectively. The synergy between elbow and shoulder kinematics is important to make an effective and powerful motion. Results presented a similar pattern between Taekwondo athletes with some considerable variation in some biomechanical variables that pointed out some individualized biomechanical pattern in elite Taekwondo players.

Conclusions: Investigation of upper body joints kinematics examined Taekwondo players performing punch (Jirugi) using the trunk. Biomechanical stretch-shortening pattern evaluated in the Taekwondo straight punch (Jirugi) indicates the potential for increased performance using different types of training. Based on our results, elbow-shoulder synergy is very important in the performance of effective, powerful, and beautiful punches in Taekwondo, especially in the Poomsae competitions.
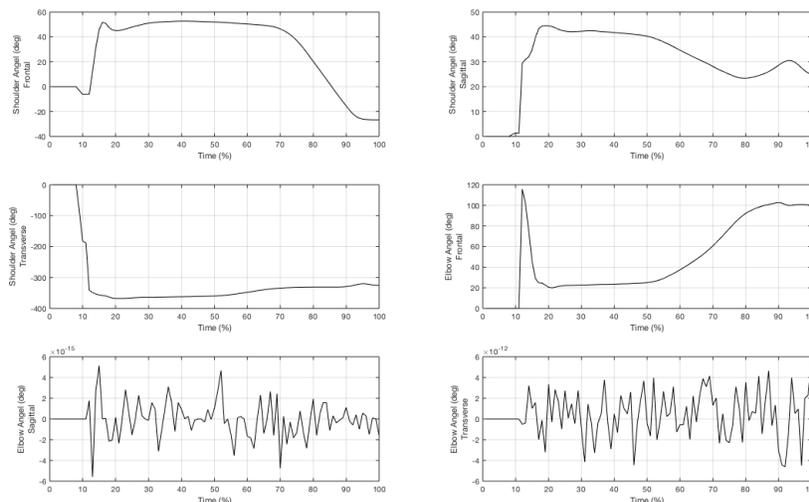

Figure: Relationship between elbow and shoulder kinematics variables during Taekwondo straight punch (Jirugi).

HAND POSTURE AND FORCE ESTIMATION USING SURFACE ELECTROMYOGRAPHY AND AN ARTIFICIAL NEURAL NETWORK

Mengcheng Wang[1,2], Chuan Zhao[2], Alan Barr[3], Jay Kapellusch[4], Carisa Harris Adamson[1,3]

[1]School of Public Health, University of California, Berkeley, Berkeley, CA, US

[2]Key Laboratory of Industrial Design and Ergonomics, Ministry of Industry and Information Technology, Northwestern Polytechnical University, Xi'an, Shaanxi, PR China

[3]Department of Medicine, University of California, San Francisco, San Francisco, CA, US

[4]University of Wisconsin, Milwaukee, US

Introduction: Work-related upper extremity disorders, such as carpal tunnel syndrome (CTS) remain a troubling and costly disease for both employers and workers. Recent prospective studies have identified dose-response relationships between various measures of hand force and carpal tunnel syndrome (Harris-Adamson et al, 2015). However, exposure assessment methods used to quantify hand force are limited in accuracy and ease of measurement. Prior studies have been done to classify the features extracted from the electromyography (EMG) with artificial neural networks (ANN), but relatively few studies have been performed to estimate hand posture and exertion forces at varying levels of force exertion, duty cycle and repetition rate. The primary purpose of this study was to develop a method for estimating hand posture (pinch versus grip) and hand exertion force forearm surface electromyography (sEMG) and neural networks.

Methods: Twelve people participated this experiment. Surface electromyography (sEMG) data was collected (Telemyo 2400 T, Noraxon, Scottsdale, Arizona); four electrodes were equally spaced distal to the elbow with the first sensor over the muscle belly of extensor digitorum and the next 3 forming a ring around the forearm. One additional sensor was placed over the abductor pollicis longus (APL). For calibration, subjects applied 25%, 50% and 75% of their maximum power grip and pinch force (digital dynamometer and pinch meter, Biometrics Ltd, Ladysmith USA) three times holding for 4 seconds per exertion with rest periods between. Next, subjects completed a variety of tasks that varied hand posture (pinch versus power grip), load (grip: 2Kg, 3.5Kg, 5Kg; pinch: 0.5Kg, 1Kg, 2Kg), duty cycle (20%, 80%) and repetition rate (12/min, 20/min). The sEMG data from the calibration were used to train the artificial neural network (ANN) to predict hand posture (pinch or grip) and hand exertion force above previously identified thresholds (1kg pinch; 4.5kg grip). The pre-trained ANN models (posture and hand exertion force) were applied to the task data and validate its accuracy.

Results: Posture prediction overall accuracy is 0.73±0.27, force level prediction accuracy is 0.75±0.19. The predicted posture accuracy of pinch (0.81 ±0.27) was higher than grip (0.65±0.27); prediction of force level at a lower repetition rate of 12/min (0.76±0.19) was better than the prediction of force level at the higher repetition rate (0.73±0.19). Similarly, prediction of force level was higher for lower duty cycle tasks (0.80±0.17) than higher ones (0.70±0.22).

Conclusions: Overall, hand posture and force prediction were possible using sEMG and ANNs, though predictions were better when tasks had lower repetition rates and duty cycle. Applying more sophisticated deep learning models may improve the accuracy of prediction.