17th Annual Regional National Occupational Research Agenda (NORA) Young/New Investigators Symposium

University of Utah's Rocky Mountain Center for Occupational and Environmental Health (RMCOEH)
and
The Department of Mechanical Engineering

April 18-19, 2019

Welcome Address

We are delighted by your attendance this year at our Annual NORA Young and New Investigators Symposium. This year commemorates our 17th Annual NORA Symposium and is attended by students, researchers, and professionals from around the country. We want to thank each of you for attending our symposium and bringing your expertise, knowledge, and vision to our group. We invite you to ask questions of the speakers, network with one another and develop new friendships and collaborations.

We would also like to thank Drs. Ken d'Entremont and Don Bloswick for reviewing abstract submissions, and Liz Reiser for her efforts in taking care of everything else. Please contact Liz.Reiser@mech.utah.edu if you need any- thing during the symposium.

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Expanded Focus of Occupational Safety and Health

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CDC/NIOSH: Associate Director for Research Integration

Profound changes in the nature of work, the workforce, and the workplace in the United States today challenge old paradigms of worker safety and health and require new approaches. Injury focused reporting systems of the past have largely underestimated the full extent of occupational burden, which in turn affects the way decision makers view investment in research and worker protections. A transition is needed from the more narrow view of occupational burden to a more comprehensive view that considers multiple domains of burden, a broader view of the work-relatedness of disease and injury, the assessment of the burden over the entire working-life continuum, and applying the concept of "well-being" as a more comprehensive burden indicator. This transition will have implications for future occupational safety and health practitioners, researchers, policy makers, and professionals. This presentation will introduce an approach that researchers at NIOSH have developed that could be useful in improving burden estimates. This approach is designed to encompass the many dimensions of burden on people and organizations, the resultant burden from different aspects of work and workplace hazards, and the changes that affect burden over a working lifetime. Accounting for all aspects of occupational burden individually and comprehensively is the contribution of this approach.

Effect of Wearing Insoles on Human Normal Pattern During Non-steady State Activities of Daily Living

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Introduction: Ground reaction forces (GRF) provide insights into human balance [1], gait pattern/abnormality [2] and rehabilitation effectiveness [3]. Wearable instruments for gait analysis offer new opportunities to study human motion during activities of daily living (ADL). Force plates have been used to measure human GRF and shear forces during different ADL. However these are limited to a laboratory environment. Instrumented insoles are an emerging wearable technology that can be readily worn inside footwear and have shown promise. Several studies report the reliability of insoles used to measure GRF_z in steady state gait like walking and running. However, previous works have overlooked the effect of wearing wearables on the subject's normal kinematic pattern during activities of daily living. The purpose of this study is to understand the role of wearable sensors, specifically instrumented pressure insoles (MoticonScience, Germany), on the subjects' kinematic behavior during some of the most common non-steady state activities.
In this pilot study, a participant was asked to perform defined non-steady state tasks on force plates (AMTI, MA, USA). The participants performed the tasks in two sets of experiments, wearing insoles inside their footwear, and without the insoles inside their footwear.
The force results obtained from the force plates are then compared to assess the effect of wearing insoles on the subjects' kinematic data during those non-steady state tasks.
Methods: One participant performed two sets of experiments: wearing pressure insoles (WS) and not wearing the sensors (NS). The participant was asked to wear standard hospital socks in both WS and NS experiments. During WS set of tastings, the pressure insoles were placed inside the subject's socks, touching their feet. In NS experiments, the participant repeated the same set of tasks wearing the same socks without the insoles. In both sets of experiments, the participant was asked to perform three trials of each of the following six tasks: sit-to-stand (ST2SD), stand-to-sit (SD2ST), gait initiation (GI), gait termination (GT), turning (TN) to left (L) and right (R). For ST2SD and SD2ST tasks, a standard height chair was used. In GI/GT tasks, the participants walked with their normal cadence toward one of the force plates and stopped, then they initiated gait by stepping onto the second force plate and walked away from it. Finally, in TN tasks, the participants were asked to step on the first force plate with the foot agreeing with the direction of turn (L/R), then step on the second plate with the foot opposite to the direction of the turn (R/L) and step out from the force plate to their L/R. The data were recorded at 50 Hz. The statistical post hoc analysis was performed to assess the similarity of the recorded data from the force plates signals during the two sets of experiments.
Results and Discussion: For each task of each experiment, the force plates data (f_x, $f_y$and f_z) were resampled and normalized to have the same number of sample data during different trials regardless of the time window of the task. Then, the mean value of all the trials in one task was calculated, Figure 1. The sliding inner product or cross-correlation (CC) was used to assess the similarity of the mean value of the force data of the same task, during WS and NS experiments. The 99% correlation between two sets of experiments during turning task indicate the high similarity of the corresponding force signals. This result is promising in the sense that wearing insoles has minimal effect on the subjects kinematic pattern and can be used to drive conclusions on the subjects general kinematic pattern.

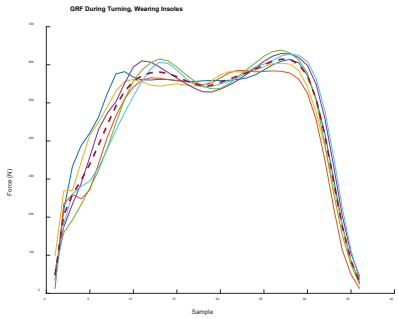

Figure 1, Forces in z-axis during turning, wearing pressure insoles, and their mean value

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The effect of transitioning surfaces on gait with persons with Parkinson's disease

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Introduction: Each year, millions of older people (65 and older) fall. Less than half report falls to their doctor. More than one in four older people fall each year. Some research has shown that one in three adults over the age of 65 fall each year and this number doubles after age 80. One out of five falls causes serious injury. Annual costs for falls is $31 billion. Falls are the leading cause of injury-related death for older adults. Falls are a major determinant of poor quality of life, reduced mobility, and reduced life expectancy. Among elderly persons, 55% of fall injuries occurred inside the home, 23% occurred outside, near the home. Of indoor and outdoor injuries 43% occurred at ground level. With the definition of a recurrent fall being defined as more than one fall in a year, about 15% of the older population have had a recurring fall. One study reported that recurrent falls among people with PD are above 50%. A better understanding of transitioning between surfaces is needed to further educate and inform at risk populations and therapist to help reduce some of these falls. There are three aims to this study. What transitions present the most risk to participants with Parkinson's disease (PD)? What transitions present the most risk to healthy age matched control (HC) participants? The gait of PD participants will be different from HC on different surfaces and the transitions between them.

Methods: Common indoor and outdoor surfaces were used in this study. Carpet, laminate, and tile were used for the indoor surfaces. Cobble, concrete, and artificial turf were used for outdoor surfaces. A 9.75 m gait track was designed to give participants the best chance to consecutively strike six force plates that were to be embedded in the track. Oriented strand board (OSB) was used as the subflooring of the track, this represented the control surface. The track had 2.9 m for participants to reach steady state before reaching the force plates. There were 10 people in the PD group and 5 people in the HC. Motion capture was used to assess the gait of the participants. Spatiotemporal/kinematic parameters included, step length (SL), step width (SW), center of mass velocity (COMvel), ankle range of motion (AnkROM), knee range of motion (KneROM), and hip range of motion (HipROM). Fall risk parameters include required coefficient of friction (RCOF), minimum toe clearance (MTC), margin of stability (MOS), and the maximum margin of stability (MOSmax).

Results: Laminate to carpet was the transition with the highest risk to both groups on indoor surfaces. The PD group increased their MTC on this transition by 1.45 cm compared to the control surface. The HC group increase their MTC by 1.14 cm. The tile to carpet transition had the second greatest increase in MTC for both groups and was likely posed the second highest risk.
The turf to cobble transitions had the highest risk for both group on outdoor surfaces. The PD group slowed down by 0.22 m/s, and the HC group slowed down by 0.16 m/s on this transition. SL decreased by 4.72 cm and 2.87 cm for PD and HC groups respectively. MOSmax increased by 0.72 cm and 1.21 cm for PD and HC respectively. The concrete to cobble transition had the highest difference in MTC for both groups and likely posed the second highest risk.

Conclusions: Transitions are important. Many of the differences in gait observed were on the transitions. PD overcompensated on nearly all surfaces and transitions, especially with MTC. MTC in this study seemed to be the most indicative of a fall due to a trip. PD participants adopted a proximal strategy using their hip and knee. HC participants have a more balanced strategy where they use their hip, knee, and ankle. Outdoor surfaces and transitions posed a greater risk than indoor surfaces. The transitions that had the most differences were similar between the PD and HC groups. Compliant surfaces, such as carpet and turf used in this study have interesting effects on gait. The increase in HipROM and KneROM indicate that
participants should have an increase in MTC, but there is actually a decrease because the participants have to overcome the compliance of those surfaces. The HC participants actually had a negative MTC, indicating they brush their feet through the turf. This study adds important information to the base of knowledge on falls. This knowledge can inform home builders, at risk populations (and family members/caretakers), physical therapists, and doctors to help prevent falls.

Acknowledgement: This research was supported by NSF (#1162617)

Fall Impact Force Attenuation using Compliant Flooring Surfaces

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Introduction: Falls and injuries related to falls are a prevalent safety concern in high fall risk sites such as hospitals and nursing homes. Individuals are more prone to falling when flooring transitions exist and on slippery surfaces. Different medical conditions, surgery, medications, procedures or diagnostic testing can leave any patient weakened or confused. This can magnify a dangerous situation when it comes to fall risk. Whether there is an obstacle on the floor to maneuver around, a slippery surface, or someone simply trips, all can lead to a fall. Injuries occurring from a fall can lead to complications including increased length of hospital stay, increased cost, and even death. This study aims to investigate how a compliant flooring system reduces the risk of an injury occurring from a fall. We tested complaint floorings and propose a new flooring design using Sorbothane as an underlayment for popular vinyl sheet flooring.

Methods: Existing literature related to flooring design, hospital falls, fall prevention devices, finite element analyses and experimental analyses of compliant flooring and hip injury prevention was studied. ANSYS Workbench and SolidWorks were used to model and simulate a fall using an explicit dynamic model. Explicit dynamics analysis was conducted with the model to understand how the forces are distributed across different surface configurations. The stress values were used to estimate the peak impact force and duration of impact for the simulations. Experimental testing was performed using an Instron Dynatup Impact tester which provides consistent values in a highly controlled environment. Seven different flooring compositions consisting of VCT, Ecore, rubber tile, three thickness of Sorbothane (0.1",0.125", 0.2") with vinyl sheet flooring on top, and lastly 0.2" thick Sorbothane all at two different velocities were tested. The two velocities were chosen from literature studies that found the average impact velocities of falls with contact occurring at the hip and wrist. Experimental data were processed using a multiple regression linear mixed model with random effects (R-studio).

Results: Results of the experimental testing indicate that each of the complaint floorings tested showed statistically significant lower impact force when compared to the control flooring of VCT. This was true for both the lower velocity impacts and the higher velocity impacts. The worst performing complaint flooring was the rubber tile. The best performing flooring for attenuation of impact force was the proposed flooring consisting of 0.2" thick Sorbothane. The full list of reduction percentages can be found in Table 1 below. The results also indicated that there was no interaction effect between velocity and flooring types.

Force Reduction from Control (VCT)						
Flooring	Ecore	Rubber tile	Sorbothane (0.1") with Vinyl	Sorbothane (0.125") with Vinyl	Sorbothane (0.2") with Vinyl	Sorbothane (0.2")
Reduction (%)	36.7	26.8	28.5	34.5	54.5	55.3

Table 2: Reduction in impact force of compliant floorings compared to standard VCT tile.

Conclusion: This study found that any of the tested floors are superior to standard VCT when it comes to the peak impact force observed. The best flooring option found in the experiment is the flooring using a thicker Sorbothane underlayment with a vinyl surface layer. However, future testing will be required in order to determine if Sorbothane could be used as a commercial compliant flooring. More durability testing to ensure it could hold up under use and gait analysis including balance studies should be performed to see what effects Sorbothane could have on patient stability.

Anthropometric Characteristics Analysis and Classification of Chinese Auricles

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Introduction: With the increase demand of auricular measurement for application in ergonomics, clinical diagnosis and identity recognition, the need of comprehensive auricular measurements is rising. The design of various wearable products requires auricular measurements including headphone, earphone, headsets, ear-related wearable products with health monitoring functions, and medical robots worn in on or behind the ear. However, despite the large need, anthropometric characteristics of the Chinese population is lacking. Thus, most ear-related product manufacturers in China make their products following European standards, which can lead to poor fit, discomfort and poor performance of ear related products. Further, currently, there are more than 10 auricular anthropometric measurements that are consistently used for design which can be difficult and time consuming to measure. Therefore, the purpose of this study was to summarise anthropometric characteristics of auricle in the Chinese population and to determine the fewest number of auricle measurements that are required to describe key characteristics of auricles required for design.

Methods: 1120 Chinese volunteers (560 males, 560 females) were recruited in 8 cities of in mainland China. 18 anthropometric measurements of both ears were taken directly on the auricles. In addition, the angle between tragus and medial concha (ATMC) was measured by casting and scanning the concha and external acoustic meatus parts using Z-scores to normalise measurements. Bivariate correlation analysis was performed using the Pearson correlation coefficient. Bilateral difference analysis was performed using a paired t-test to examine the difference between left and right in ear dimensions, and a t-test was used to examine the difference between male and female ear dimensions. Principal Component Analysis (PCA) with varimax orthogonal rotation was performed to categorize the variables and determine the variation of ear shape.

Results: Differences of linear measurements between left- and right-side ears were less than 0.4 mm, and the values of angular measurements were less than 0.5°. Except for auricular inclination angle, tragal height (TH) and conchal depth (CD), the results showed that the dependent variables had a correlation with age, with the highest correlation found between auricular length (AL) and age (0.753, $p < 0.01$). There were no significant differences between left- and right-side in ear measurements, except for TH of males. Differences in linear measurements between males and females were less than 2 mm and differences in angular measurements between were less than 5°. The PCA resulted in 6 principal components (PCs), and the first 6 PCs explained 72.24% variations of auricular shape. Three to 6 types of auricular shapes observed in the dendrogram were considered to be practically useful and suitable for the ergonomic design applications of ear-related products.

Conclusions: Ear shape changes with age and gender; thus, providing anthropometric measurements specific to populations and by age and gender are important to optimizing design for these groups. There is a decrease in ear protrusion, concho-mastoid angle, tragal height (TH) and conchal depth (CD) of higher age groups, respectively. Most ear measurements of males were larger than females', however, some of the differences were not significant. The overall growth rates of females are higher than those of males in most linear measurements. A new measurement (angle between tragus and medial concha) was found to be useful and should be considered when measuring auricular characteristics or using them in design. These findings provide a fundamental reference for the future study and application of auricular dimensions to optimise of ear comfort and usability or devices work on, in or around the ear.

Health hazards and analysis in a chemical and consumer goods company

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Introduction: A chemical and consumer goods company in Salt Lake City, Utah has implemented new procedures and work processes as a result of their single-dose detergent product. Since the implementation of the new manufacturing process, the noise levels have not been analyzed, the talc used in the process has not been resampled, and the volatile organic compounds have not been reassessed. These new procedures to the process can cause the potential for silica exposure, noise exposure, and VOC exposure, which can result in silicosis, hearing loss, damage to the respiratory system and other negative health outcomes. The purpose of this study was to sample these areas of concern for any evidence of health risk to help ensure safety of workers at the facility.

Methods: The study team sampled for noise using a sound level meter and noise dosimeters. A Larson Davis XLT sound level meter was used to measure sound levels and create a noise map (NoiseAtWork) of the production floor. The production floor was marked into 10 foot by 10 foot squares and the meter recorded sound levels for an average of 10 seconds. Additionally, five 3M noise dosimeters attached to employees throughout the production floor collected noise levels for their entire 8-hour work day. An area sample was collected to determine whether silica was present in the talc. This was done using a SKC cyclone, calibrated with an AirChek air pump, and placed near the powdering process. In addition, a bulk sample of talc was collected for analysis. Both samples were sent to ALS labs for analysis for quartz/silica in the talc. Lastly, a ToxiRae photoionization detector was used to detect for the potential of volatile organic compounds (VOCs) in the workplace. Three separate areas were observed: the breakroom, the production floor, and the detergent vats.

Results: ALS environmental analytical results for silica, reported under the NIOSH 7500 method and did not detect the presence of silica within the provided bulk sample of talc-powder. Additionally, the company's safety data sheets indicated that their detergent contained benzene (C-10-13-alkyl derivatives) and ethyl alcohol. The measured components, however, of these VOCs are so low in their final product, about 0.1-5%, that the ppm values recorded by the PID was insignificant and considered to not be a concern to its employees. The production floor noise map showed several points where the local noise levels were above the OSHA PEL of 90 dBA. Specifically, the vibrating table on the catwalk was 95.8 dBA and the area around the scrap-cord collector was 97.3 dBA. Additionally, the four workers who wore the noise dosimeters had an 8-hour average exposure level of 88.8 dBA, 88.6 dBA, 84.3 dBA and 82.3 dBA with a group average of 86.0 dBA, which is above the OSHA action level of 85 dBA. The two workers at the palletizing area had an 8-hour average had 78.4 dBA and 73.4 dBA for an average of 75.9 dBA.

Conclusions: The analysis for talc, VOCs, and noise levels in the palletizing area presented no concern to the employees. However, noise mapping revealed areas above the PEL of 90 dBA and the personal noise dosimeters had an 8-hour exposure above the OSHA action level of 85 dBA. As a result of these concerns, it is recommended that there is a continued implementation of the Hearing Conservation program and consideration of abatement strategies to reduce the noise levels. These abatements may include isolating the strap-cord and vibrating table areas and implementation of sound stones throughout the ceiling of the production floor. With a Noise Reduction Coefficient (NRC) of 0.65, it will reduce 9.12 dBA from the initial noise measurement. It is recommended to cover 15-20% of the room's square footage in order to achieve this result. In addition, strategically placed sound absorbing panels is another possibility to reduce noise to a safe level for employees.

Potential Inhalation Concerns in Manufacturing Company

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Introduction: A manufacturing company has several processes which have potential occupational health exposures. The manufacturing process involves using two different compounds in a vapor deposition chamber, soldering electrical components, and using degreasers to clean the components. These operations have potential inhalation exposures to volatile organic compounds (VOCs), soldering particulates, and particulates from the vapor deposition chamber. VOCs are irritants to the eyes, skin, and respiratory tract, and exposures to these compounds are associated with central nervous system effects including headache, drowsiness, and impaired coordination. Exposures to soldering particulates have been associated with the development of occupational asthma. Finally, exposures to particulates from the vapor deposition chamber can cause skin, eye, and respiratory irritation along with more severe health effects.

Methods: Sampling was performed throughout the facility for VOCs, soldering particulates, and other particulates. In addition, the face velocity of a downdraft hood was measured in order to determine if the hood was functioning properly during grinding tasks which could generate particulates. A photoionization detector (PID) was used to measure VOC concentrations throughout the facility. Two Summa canisters were used to collect a 1-hour whole air sample in order to determine the composition of VOCs in two areas in the facility. A personal air sample was collected for the compounds used in the vapor deposition chamber. The sample was collected over a 3.5-hour period using an SKC aluminum cyclone and cassette attached to a workers lapel during the duration of the cleaning of the vapor deposition chamber. The Summa canisters and personal air sample were sent to ALS Laboratory for analysis. The Grimm Portable Aerosol Spectrometer was used to collect particulate counts and mass during soldering operations and during operations involving the vapor deposition chamber. Results stored on the Grimm memory card were exported to Excel for analysis.

Results: The PID showed levels of up to 600 ppm in open trash receptacles indicating the accumulation of VOC vapors. The results from both Summa canisters showed that the VOC analytes were well below the OSHA PELs and ACGIH TLVs. One compound, trans-1,2-dichloroethene was detected in a room where it was not being used, however, this compound was being used in an adjacent room. The measurements for the downdraft hood revealed that the hood was functioning at 1432 cfm, which is below the manufacturer recommended at 1500 cfm. Particulate analysis of the personal air sample revealed relatively low levels of the two compounds used in the vapor deposition chamber which were 0.00063 mg/m^3 and 0.00099 mg/m^3 respectively. The area exposures from the Grimm did not reveal concerning particulate levels for the soldering tasks and vapor deposition tasks.

Conclusion: The results of our sampling revealed that for the tasks we analyzed, the controls are working properly and there was a minimal risk of occupational health exposure. The laminar hood, however, was functioning below the manufacturer's recommendations. The company's health and safety employees are currently investigating the reason for the inadequate flow rate. We are also in discussion with the company regarding the trans-1,2-dichloroethene and we are investigating possible reasons for the presence of this compound.

Using IMUs to Predict and Quantify the Physical Demands of a Job

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Introduction: In the United States, the physical demands of a job must be quantified for use in the employment process. When jobs are posted, the physical demands of the job are provided to applicants. Additionally, when an injury occurs, the physical demands of a job are referred to during the return to work process to ensure that workers regain the physical capacity required to perform their jobs. However, currently, the physical demands of a job are primarily quantified using observational techniques which lack accuracy and reliability. Thus, improved quantification methods are warranted and can be further used to improve our understanding of the relationship between job demand and work-related musculoskeletal disorders (WMSDs), a problem that costs the US nearly $60 billion per year (Liberty Mutual Insurance, 2018).
In response to this need, the UC Ergonomics Research & Graduate Training Program has developed a light (<1.5lbs), low cost wearable device called SpineTrack which quantifies the kinematics of the trunk and the upper extremities using inertial measurement units (IMUs) and predicts common physical activities summarised in a physical demand job analysis. Therefore, the purpose of this study was to optimise then quantify the accuracy of the device when compared to the gold standard approach of video analysis.

Methods: A laboratory validation study was performed on a sample of convenience. Potential subjects were included in the study if they were between the ages of 18-65, were familiar with tools used in manual materials handling (MMH) jobs and had no chronic disorders (i.e. back pain). This study was approved by the University of California at Berkeley.
First, a series of activities (i.e. lifting/lowering, carrying, etc.) were performed sequentially for a set duration or frequency. Next, subjects performed three occupational tasks that included a variety of physical activities typically performed in MMH-jobs (i.e. drilling, painting). Tasks were video-taped and analysed at 30 frames per second. The predicted activity using IMU data was compared to the actual activity from video analysis.
Seventy percent of the generated IMU data collected was used to train a deep learning model (training data) to predict physical activities of the other 30% of the data (test data), producing a confusion matrix for each person that summarised the percentage of time each activity was correctly predicted versus incorrectly identified as another activity.

Results: There were 17 subjects (10 males) with an average age of 31±13.61 years. The average height and weight of individuals were 169.47±14.88cm and 68.52±15.66kg, respectively. For predicting correct activities in the test data an overall accuracy of 96.66% was achieved. Walking was correctly classified 90.06% of the time and was mostly mistaken with crouching (1.6%) and crawling (3.2%). Static overhead activity was correctly classified 94.76% of the time and was mostly mistaken with dynamic overhead activity (4.0%). Reaching for a nearby object was correctly classified 93.15% of the time and was mostly mistaken with dynamic overhead activity (1.6%), reaching for an object on shoulder height (0.9%), crawling (1.8%) and crouching (1.8%).

Conclusions: The results of this small pilot validation study showed a high overall accuracy. However, the model still confuses dynamic activities which are similar to each other.
Despite the benefits of identifying the percent time spent performing different physical activities, the magnitude of loads handled and load moments are not addressed with this technology. Further work should include additional technology that can be used to quantify load and/or load moment. The opportunity to classify physical demands in different job sectors using objective methods such as IMUs will allow better quantification of the physical requirements of a job that can be used for effective surveillance and return to work programs.

Using machine learning approach to classify lifting tasks from instrumented insole measurements

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Introduction: Low back pain (LPB) and low back injuries (LBI) represent the majority of work-related musculoskeletal disorders (WMSDs). Improper lifting technique, pushing or pulling, have been shown to lead to WMSDs. Back pain can occur as a result of a single high load event or cumulative trauma. Therefore, it is important to monitor both individual high load and cumulative exposures of workers performing lifting tasks. Enhanced "in-the-field, real-time" monitoring and quantification techniques could provide greater insight to improve our understanding of the most influential parameters causing low back pain. The approach of using instrumented insole and machine learning classification algorithms to classify lifting activities and estimate exposure offers a great promise, due to being non-invasive and non-obtrusive to the worker. The simplicity of such sensory system and comfort of the workers are important considerations for successful transfer of this technology into workplaces

Methods: We performed experiments simulating lifting tasks commonly observed at workplace as shown. These tasks included lifting and lowering of a box of various mass (5.7 kg and 12.5 kg), lifting heights (ground, knuckle height and shoulder height) and lifting behaviour (overreaching or fast/jerky). The instrumented insoles were inserted in subject's shoes to measure the normal ground reaction forces from each foot (fzL and fzR), total ground reaction force (Fz), three-axis accelerations from each insole Acc_{ij} , i = {x, y, z}, j = {L, R}, and centre of pressure (COP) of the individual foot. We computed statistical features (mean, standard deviation, autocorrelation, peak spectral density and power spectral density) for the time series of the signal measurements that were used as input to the machine learning algorithm (k-Nearest Neighbor). We chose an epoch size of 2 sec with 90% overlap.

Results: Results show that using only instrumented insoles it is possible to detect the lifting tasks with varying weight and lifting behaviour with the average accuracy of 87%. The classifier has successfully detected and distinguished between lifting events when lifting two different loads in two different postures: lifting 5.7 kg in a stoop posture (80% accuracy), lifting 12.5 kg in a stoop posture (79 % accuracy), lifting 5.7 kg in a squat posture (80% accuracy), and lifting 12.5 kg in a squat posture (90 % accuracy). The hazardous overreaching lifting was detected with 91% accuracy.

Conclusions: In this study, we developed an algorithm to detect and classify lifting events based on measurements from the instrumented insoles. The measurement system is non-invasive and enables potential longitudinal monitoring of workers at workplace. The use of instrumented insoles to identify lifting tasks of a worker represent a significant step toward estimating the exposure of a worker. Accurate identification of lifting events including various lifting weight allows identification of some of the most important injury risk parameters, such as lifting load and frequency. In addition, instantaneous detection of proper or hazardous behaviour further enables providing direct feedback to the worker to improve lifting posture and behaviour and therefore reduce the risk of injury. Implementation of our system in real occupational settings will be the aim of our future studies.

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Evaluation of a Trunk Supporting Exoskeleton for reducing Muscle Fatigue

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Background: Back injury can occur when the applied load on the tissue exceeds the failure stress in that tissue or through cyclical loading of the muscle tissue until failure [1], [2]. Local muscle fatigue occurs during cyclical loading of muscle tissue, is defined as the progressive loss of force generating capacity of the muscle, and has been associated with increased risk of musculoskeletal injury [2], [3]. The objective of this study was to evaluate the effect of wearing a back-support exoskeleton (BSE) on muscle fatigue during cyclical lifting and lowering to determine whether wearing a BSE increases endurance time to fatigue. Additionally, a common industry concern is whether workers will incur a higher metabolic cost while wearing the exoskeleton [4]; thus, a secondary objective is to evaluate how wearing a BSE affects oxygen demand during repetitive lifting tasks.

Methods: Twelve male subjects with an average age of 31.1 years (SD = 10.2) participated in this within-subjects laboratory study. After providing informed consent, participants completed a baseline survey and the BSE was fitted to them. Subjects were asked to perform three maximum voluntary contractions (MVC) for the right and left lumbar erector spinae (RLES, LLES), thoracic erector spinae (RTES, LTES), and biceps femoris (RBF, LBF). Then, subjects performed an endurance test where each subject was in a prone position on a Roman chair with their feet secured then held his upper body at a 45° angle while holding a 5 kg weight until exhaustion (test posture). The duration that the subject could hold the test posture prior to performing any work was measured before (pre-work endurance time) and after (post-work endurance time) each work session. The work session consisted of lifting and lowering an 18 kg load at 7 lifts/minute for 4 minutes. This endurance tests and work session were repeated for each subject with and without the BSE in a randomized order. Electromyographic (EMG) data (Noraxon, Scottsdale, Arizona) was collected at 1500 Hz continuously during work and endurance tests and normalized to the subject's MVC. Summary measures of EMG amplitude probability distribution functions for 50 (APDF50) and 90 (APDF90) percent of the work session were normalized against MVC for each muscle group to assess median and peak muscle activation levels. Metabolic changes were quantified by oxygen consumption (Metamax, Leipzig, Germany). Data is presented as means (standard deviation), unless otherwise noted.

Results: Compared to the unassisted condition, use of the BSE during the repetitive lifting task reduced peak thoracic and lumbar erector spinae muscle activity. RLES and LLES EMG activation when wearing the BSE were at or below 62.6% (2.1%) and 57.4% (1.9%) MVC for 90% of the work session, respectively, compared to 75.0% (2.2%) and 73.4% (3.1%) MVC when not wearing BSE. For 50% of the work session, RLES and LLES activation was at or below 24.3% (1.5%) and 23.3% (1.2%) of MVC when wearing BSE, compared to 29.2% (1.7%) and 27.3% (1.4%) of MVC while not wearing BSE. Additionally, endurance test data suggests that the work session was less fatiguing when performed wearing the BSE. Post-work endurance time was 74% (14%) of the pre-work endurance time after wearing BSE, but only 50% (16%) of the pre-work endurance time after not using the BSE during the work session.

Conclusions: *Muscle Activity.* The results of this study indicate that wearing a BSE during a lifting task reduces muscular activation of the erector spinae. Reduction in peak and median muscle activation for RLES, LLES, RTES, and LTES is consistent with various studies showing reduction of back muscle activation while wearing a BSE to perform a lifting task [5]–[8].
Fatigue. Increased post-work endurance time relative to pre-work endurance time, as well as reduced muscle activation, is congruent with reduced muscle fatigue during the work session [8]–[10]. The increase in post-work endurance time is likely attributed to the reduction in erector spinae muscle activity when using the BSE. Reducing muscle activity by using the BSE while holding lifting rate and load constant increases post-work endurance time [11] and would result in higher post-work endurance time after working wearing the BSE versus not wearing the BSE during the work session.

Comparison of Contact Pressure in the Perineal Region and Subjective Comfort among Various Bicycle Saddles

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Introduction: Bicycle saddles play an important role in a cyclist's performance because the saddle is the major interface between the rider and bicycle. Saddles can also greatly affect the rider's comfort level and energy consumption, which could be of critical importance in a racing scenario. Unfortunately for male cyclists, prolonged stress in the perineal region can lead to a myriad of issues, including erectile dysfunction, impotence, and numbness. While there are saddles on the market designed to be more comfortable for male cyclists, few studies have quantitatively compared the biomechanical difference among various cyclist's saddles. The purpose of this project is to better understand the relationship between the cyclist's saddle structure and the contact pressure distribution in the perineal region during riding. In this work, we compare the contact pressure in the perineal region and subjective participant comfort levels across three saddle styles.

Methods: Three saddle styles were used for testing: a typical narrow nose racing saddle, a split nose saddle commonly used for triathlons, and a unique saddle design with a lower elevation nose and adjustable air pressure in the perineal region. The testing procedure involved 3 trials of each saddle in a randomized order, where a pressure mat was placed over the trial saddle with the saddle attached to a stationary bicycle, and the participant was instructed to ride for approximately 8 minutes while the pressure on the perineal region was recorded. In addition to the pressure mat data collection, qualitative data was obtained by asking the participant to rate the comfort of the saddle used in each trial from a scale of one to ten, one being least comfortable and ten being most comfortable.

Results: This project will rely on both physical contact pressure analysis and subjective comfort levels to determine which of the three saddles is best. Specifically, the average contact pressure recorded for each saddle will be identified and a ranking of the saddles will be conducted based on feedback from the participants. Conclusive results have not yet been obtained, but we expect that the saddle with the lowest average stress possesses the most ergonomic design, which should be corroborated by participant opinion. Current progress on the study indicates greater stress reduction and comfort in the saddle with the low elevation nose. In addition, surveys thus far have shown qualitative preference for both the low elevation nose and standard long nose saddles.

Conclusions: Results from this study could help in distinguishing the most comfortable saddles currently available on the market. It could also lead to an improved design of bicycle saddles, which would result in increased consumer happiness. We also expect a reduction in issues concerning reproductive health in male cyclists as a result of our findings, allowing for a significantly safer and more enjoyable cycling experience.

Human Posture Estimation and Ergonomics Analysis Solely from the Robot in Physical Human-Robot Interaction

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Introduction: Ergonomic analysis of human posture plays a vital role in long-term, work-related injury prevention. As physical human-robot interaction (HRI) such as telesurgery and telemanipulation becomes more prevalent, we must consider the important problem of ensuring operator comfort and ergonomics to minimize the risk of musculoskeletal disorders, improve efficiency, and reduce error over long periods of work. Motivated by this problem, we envision an autonomous solution to improve ergonomics and worker safety in telemanipulation that includes three main steps: (1) estimating the human operator's posture, (2) analysing the ergonomics and injury risk of the estimated posture, and (3) providing feedback from the robot to the operator to encourage moving toward a better posture.
Current methods for human posture estimation in the literature, including marker-based and markerless posture estimations, are limited in many ways. Both of these approaches rely on vision systems which might be infeasible to set up in real workplaces. In this presentation, we focus on the first two problems and suggest a new approach to estimate upper body posture and associated risk using only data observed from the robot.

Methods: The main feature of telemanipulation that distinguishes it from other applications of posture estimation is the physical attachment of the human body to the master robot in one or more points. We believe that we can use this feature to estimate human posture without needing additional sensors other than the robot. We model the human upper body using a redundant, partially observable dynamic system. This allows us to naturally formulate the estimation problem as probabilistic inference and solve the inference problem using a standard particle filter. We formalize this as a probabilistic inference problem where, we measure the robot's stylus trajectory (including pose and velocity) as the observation and infer the unobserved human posture (joint angles and angular velocities). We encode human factors and biomechanics knowledge into our partially observable dynamics model. We use anthropometry models to estimate the segment lengths of the human body and impose limits on joint angles. We incorporate multiple observations over time enabling us to perform inference using a standard particle filter. We evaluate our approach using simulation and human-subject experiments and compare it with the human posture estimations from a commercial motion capture system and an off-the-shelf depth-based markerless posture-estimation algorithm. We use the Rapid Upper Limb Assessment (RULA) to analyse the ergonomics of the task based on the estimated posture.

Results: In simulation, as expected, the model with full measurement has the lowest RMS error across all the experiment tasks. As the complexity of task increases, the effect of measurements becomes more pronounced. However, the highest RMS error achieved using the "no-measurement model" remains less than 10 deg. We see that the estimated joint angles track the ground truth posture relatively well. However, due to the redundancy of the human model, we can see noticeable errors in some joints, even though the hand estimate tracks the stylus well. In human subject testing, it is obvious that markerless posture estimation using Kinect V2 had poor performance in comparison with motion capture and the particle filter algorithm. Although the markerless algorithm could successfully track a human standing in open areas, it was unable to track the human well while sitting behind the desk and working with the robot. The results from the motion capture system were also sometimes wrong or inconsistent in some tasks, especially for the wrist joint. Overall, the posture estimated from our approach and from motion capture system generally agree and the RULA score we provide also agrees with the score given by ergonomists.

Conclusions: In this presentation, we addressed a new problem in physical HRI: human posture estimation from the robot without any additional sensors and automatic ergonomic analysis of the estimated posture. We define the problem as a partially observable dynamical system and use a particle filter to estimate posture of a 10-DOF model of the human upper body. The proposed approach can fit different populations of users with different body segment lengths and can be easily implemented in different applications.

Design and Preliminary Validation of a Powered Knee Exoskeleton with Self-Aligning Mechanism

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Introduction: Powered exoskeletons promise to improve the movement ability of their human users by augmenting their strength and endurance with artificial actuators. Numerous upper and lower limb powered exoskeletons have been recently proposed for rehabilitation therapy, movement assistance, strength amplification, and productivity enhancement. To accomplish these goals, powered exoskeletons must transmit a controlled amount of torque to the wearer at the joint level in a way that is safe, comfortable, and effective. This task is particularly challenging due to the high variability of human anatomy. The shape and volume of the limb change significantly depending on the muscle activation and the stress produced by the physical interaction with the exoskeleton. As powered exoskeletons become more common, it is fundamental to understand how the physical human-robot interface affects comfort and usability. Passive degrees of freedom have been proposed to self-align the axis of rotation of the exoskeleton and user's joint, thereby reducing spurious forces and torques reflected to the user's articulating joint. Unfortunately, quantifying the usefulness of these additional degrees of freedom is difficult. Consequently, evidence correlating the effectiveness of passive degrees of freedom on the spurious forces and torques, as well as their effect on the user's comfort is largely unknown. To further explore this relationship, we measure the relative displacement of our exoskeleton's (Utah ExoKnee) passive degrees of freedom during three tasks.

Methods: The Utah ExoKnee is designed to maximize comfort and ergonomics while transferring high torque to the user's leg. To assess the self-aligning capabilities of the Utah ExoKnee, we measured the displacement of its passive DOFs during ambulatory and non-ambulatory activities involving flexion and extension movements of the knee joint. During these tests, the motion of the passive DOFs was measured using a motion tracking system. Preliminary validation of the Utah ExoKnee was provided by a healthy volunteer subject performing ambulatory and non-ambulatory activities with the exoskeleton under different experimental conditions. In the first experiment, the subject donned the exoskeleton without the actuator being connected to it and performed knee flexion and extension while sitting on a chair. The subject repeated the protocol with the exoskeleton mounted on the leg with intentionally introduced misalignments. In the second test, the subject performed sit to stand transition (STS) while powering through the exoskeleton's viscous resistance. For the third experiment, the subject was asked to walk on a treadmill.

Results: Preliminary experiments with a healthy subject show a significant displacement of the passive DOFs in all tested conditions. Interestingly, significant displacement was observed even when the experimenter visually aligned the exoskeleton and the anatomical knee axes. This result may be due to both the natural movement of the anatomical rotational knee axis during flexion and extension movements and the error of the visual alignment performed by the experimenter. From results, the displacement of the passive DOF was approximately 40% larger when a misalignment was intentionally introduced by the experimenter. Comparison of the STS task with the unpowered knee flexion-extension suggests that torque being transferred at the human-robot interface does not significantly affect the joint alignment as similar displacements of passive DOFs were observed. On the other hand, out of all tasks, treadmill walking has shown the largest passive DOF displacements. Experimental results show that highly dynamic activities, such as walking, produce a large displacement of the passive DOFs. In contrast, slower movements such as STS produce smaller displacements.

Conclusions: For the first time, we quantified the effectiveness of a self-aligning mechanism for powered exoskeletons under imposed joint misalignments. Our results suggest that the mass of the exoskeleton combined with the flexibility of the physical human-robot interface can lead to significant misalignments even when the exoskeleton joint is visually aligned to the anatomical axis by the experimenter. Cumulatively, our preliminary results support the feasibility of the proposed self-aligning mechanism to cope with misalignments without adding significant weight and complexity to the exoskeleton. Further experiments with a larger number of subjects are needed to statistically confirm these preliminary results.

Decreasing fall-injury accidents among roof-top workers through a fall-arrest anchor system

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Introduction: Of the 4,693 U.S. worker fatalities in 2016, 991 (22.1%) were in the construction industry [1]. Of these construction-industry fatalities, 384 (38.7%) were the result of falls from elevation. In fact, falls are the largest single cause of construction-worker fatalities. The primary objects from which workers fall and sustain fatal injuries are rooftops, ladders, scaffolding, and vehicles. Falls from heights of ten feet (3 m) or less accounted for 16.9% of fatal falls in 2015 [2], showing that even a small fall can result in injury or death. These statistics also show that construction workers at small companies (10 or fewer employees) and of Hispanic descent are at higher risk than the average worker. The anticipated increase in solar-panel installations on residences is likely to only increase the number of workers exposed to rooftop fall hazards in the near future.

There are already fall-protection requirements in place through OSHA [3] that include personal fall-arrest systems (PFAS), guard rails, and safety nets. Despite this, many construction workers do not have access to PFAS or choose not to use them. One common reason is that PFAS take too long to set up. This is especially true with residential construction work. Therefore, the goal of the work presented here is to design, build, and test a practical, affordable PFAS anchor system adaptable to many residential roof configurations. Another goal of this work is to eliminate the need for the first worker onto a rooftop to "free climb" without fall protection. This system can provide fall protection for the very first worker onto a rooftop.

Methods: The design team took on this task as part of their Capstone-Design project during their senior year as undergraduates. This project was based on a need in the construction industry raised by concerned industry members. The design team studied, researched, and met with various parties including construction workers, construction supervisors, a manufacturer of fall-protection devices, and industry experts to best understand needs and constraints before undertaking the engineering-design portion of the project.

Once the concept selection for solving the problem had been identified, the team engineered a solution through analysis, computer simulation, and even the testing of scale mock-ups of the proposed system-and-roof combination. Several samples of the final proposed "hook" fundamental to the system were fabricated by the team. The team also fabricated a transportable, three-dimensional residential roof mock-up for full-scale drop-testing of the system to meet industry requirements.

Results: The laboratory testing of the structure to simulate real-world operating conditions will commence in the next three weeks and should show that the system meets or exceeds industry requirements. In addition, the steel from which the hook was fabricated is to be tested to confirm material properties and be compared with values used in the finite-element (FE) model.

Conclusions: The laboratory testing will confirm that a system has been scoped, designed, analyzed, fabricated, and tested and has the potential for occupational-injury prevention for residential rooftop workers. In addition to the hook anchor used at the roof's edge, a method for attaching and securing the hook to the roof from ground level is part of the system and should also lead to increased worker safety. Further work will be necessary to refine this design including the fabrication and testing of the hook assembly using aluminum, rather than steel, in order to achieve weight reduction for ease of use.

Using Predicted Heat Strain to Demonstrate Sustainable Exposures

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Introduction: The most commonly used exposure assessment for heat stress is based on Wet Bulb Globe Temperature (WBGT), and the exposure limits are based on empirical relationships. The ISO 7933 (2017) describes the Predicted Heat Strain (PHS), which is a rational model for heat stress assessment that is used to assess time-limited exposures. Investigators have examined PHS validity under a variety of time-limited conditions. The purpose of this paper is to demonstrate that PHS can predict a sustainable exposure.

Methods: The data used for this study were from two previous heat stress studies using a progressive heat stress protocol. The studies included 29 participants wearing four different ensembles (woven clothing, particle barrier, water barrier, and vapor barrier coveralls) at three levels of metabolic rate and relative humidity. Each trial provided data for a fully compensable (sustainable) exposure and an uncompensable (time-limited) exposure. The heat stress data for each condition were used to see if PHS demonstrated a steady-state response indicating a sustainable exposure.

Results: From the analysis, the sensitivity and specificity respectively for the ensemble types were: 0.65 and 0.94 for all ensembles, 0.80 and 0.91 for woven clothing, 0.83 and 0.91 for particle barrier, 0.60 and 0.95 for water barrier, 0.18 and 1.00 for vapor barrier.

Conclusions: The data show that while the specificity of PHS (correctly identifying unsustainable conditions) is good for the different ensembles, PHS sensitivity (correctly identifying sustainable exposures) was weak. From an occupational health and safety perspective, using PHS to identify sustainable exposures leads to protective decisions.

Transfer Sheet Study: Experimental vs. Standard Transfer Sheet

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Introduction: Emergency responders, which include emergency medical services (EMS), firefighters, and law enforcement, put their health and safety at risk each time they are called to medical or man-made emergencies (1). In addition, patient handling can be a very a physically demanding job requirement and can cause muscular skeletal disorders (MSD)(3). According to the study done by Fredericks et al (2009), the Bureau of Labor Statistics (BLS) reported an incident rate of 13.9 per thousand recordable cases of nonfatal occupational injuries and illnesses for ambulance personnel in 2007. MSDs account for approximately 2.2 per thousand of the injuries and resulted in a median of 6 days away from work (2). Although emergency responders are a diverse group, this study focuses on first responders' perception and preference to the standard method or experimental method of patient transfer. First responders are tasked with extracting and transferring the patient to a gurney for ambulance transport. The standard method of transporting patients uses a common bedsheet. Studies have suggested that EMS workers are at high risk for occupational injuries from patient transfers (3). The study objective was to assess if there was a difference between standard transfer sheets versus the experimental sheet.

Methods: Four different first responder crews (N=24) performed two separate patient transfers (Ground-to-Gurney and Gurney-to-Bed), using first their established transfer method and then the experimental sheet. After performing each type of transfer, participants and simulated patients were given a questionnaire that rated but was not limited to variables of 1) overall rating, 2) comfortability, and 3) safety. Additionally qualitative data (1, How safe the transfer sheet felt; 2, if there were any concerns when using either the experimental or standard transfer sheets) was collected and then compiled into themes. Using SAS 9.4, a logistic regression model was created to predict which transfer sheet would be most preferred by first responders. In addition, these variables were used to create a logistic regression model to establish the relationship between each variable and what transfer sheet they preferred.

Results: Of the 15 participants that acted as simulated patients, responses had two themes: Integrity of the Transfer sheet (3) and the safety of the sheet (1) (Missing or N/A = 11). Results showed a statistical significance between the standard and experimental transfer sheets when measured in comfort level, safety level, and overall rating [comfort level mm (Floor to gurney N = 45, Mean = 38.81; Bed to gurney N = 45, Mean = 54.19; P = 0.0022) safety level of transfer sheet mm (Floor to gurney N = 45, Mean = 38.20; Bed to gurney N = 45, Mean = 52.80; P = 0.0095), overall rating mm (Floor to gurney N = 45, Mean = 32.04,CI (24.34-39.73); Bed to gurney N = 45, Mean = 48.37, CI (39.95-56.79); P = 0.0049)]. According to the results from this sample size, participants were 17.54 times more likely to choose the experimental sheet when the overall rating of the sheet was "comfortable" compared to "Indifferent" overall rating. Similarly, participants that preferred a specific sheet (experimental or standard) "A Lot More" were 4.405 times more likely to choose the experimental sheet when compared to "Nearly Equal" preference. The best model had a pseudo R squared value that accounted for 27 percent of variance in the model, or when using the Max-rescaled R-squared it accounted for 36% of variance in the model.

Conclusion: Based from the results of the logistic regression, there is a significant difference between which transfer sheet is preferred among first responders when taking into account overall rating, comfortability, and safety. Overall First responders preferred the experimental transfer sheet over the standard sheet, but further analysis is needed to confirm.

Characterization of environmental contaminants in a frontier community in Western Utah

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Introduction: Frontier communities may suffer from higher exposures to environmental contaminants due to their location near waste sites, mines, and agricultural sites where inhabitants may have higher exposures to pesticides, dust emissions, and soil contaminants. Two primary health-related concerns are exposures to particulate matter and heavy metal soil contamination. Exposures to particulates with a diameter of 10 μm (PM_{10}) or less have been associated with increased risks for cardiovascular disease. Heavy metals in the soil can cause numerous health effects including damage to cellular components. There is limited environmental research on frontier communities, so the goal of this study was to determine the presence of environmental contaminants in a frontier community in Western Utah.

Methods: PM_{10} samples were collected at twelve locations in the community with a Haz-Scanner Environmental Portable Air Station (EPAS). Eighteen site locations were chosen for collection of soil samples. At each location three soil samples were collected and composited. The eighteen samples were analyzed in the laboratory with a portable x-ray fluorescence (XRF) field analyzer. The soil samples were analyzed for 24 different heavy metals and compared to previous Western Utah measurements taken by the United States Geological Survey (USGS).

Results: Several samples contained elevated levels of heavy metals as compared to USGS measurements. The highest heavy metal soil concentrations were for lead, zinc, and titanium. PM_{10} concentrations in this frontier community were also elevated as compared to PM_{10} concentrations in Salt Lake City, UT.

Conclusions: The concentrations of lead were particularly concerning in samples taken from a nearby community center as this center was near a playground. Based on discussions with the community it was determined that the source of this lead was an industrial site that was no longer operational. Community members are currently taking action to mitigate potential lead exposures at this site.

Improved Ergonomic Risk Factor Assessment Using OpenSim and Inertial Measurement Units

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Introduction: Exposure to repetitive work and awkward postures, often with a forceful exertion continues despite years of progress in ergonomics. Understanding how these risk factors contribute to work related musculoskeletal disorders (WMSDs) is still imprecise and has only been modestly successful using traditional methods. Rapid Upper Limb Assessment (RULA) is one common method used to assess risk and is considered an observational method. RULA has many benefits, one of which is ease of use. RULA achieves this by categorizing posture into ranges of motion of human joints to generate ergonomic risk scores. Traditionally, this method is applied to a snap shot of an extreme posture, or the typical posture observed. This approach limits our understanding of how postures and forces combine to generate risk, including the biomechanical explanation of how WMSDs occur with repeated exposure over time. Assessment methods like RULA often require substantial effort to complete and suffer from interrater reliability. The majority of methods like RULA are designed for observational analyses and rely on the determination of posture from observation or image analyses. This limitation affects measurement resolution and our knowledge about the effects of posture and loading on ergonomic risk. Direct measurement instruments, specifically inertial measurement units (IMU) have been shown to be reliable for measuring posture in the workplace. Combining these methods with a more robust and comprehensive musculoskeletal model such as OpenSim provides additional insights. Our work proposes a software-based method designed to maintain RULAs ease of use, but includes expanded risk metrics from an OpenSim model and greater resolution. Our long-term goal is to improve our ability to predict and prevent WMSDs.
OpenSim is a musculoskeletal modelling platform to investigate muscle forces and joint loads. The dynamic simulations provide insight that posture analyses alone cannot, including the effect of active muscles on joint loads. The Computed Muscle Control (CMC) algorithm determines muscle activations for a given motion. It may be possible to determine ergonomic risk factors with better accuracy than RULA alone by modelling various postures and applied loads in OpenSim. To test this hypothesis, we compared muscle activations and joint loads predicted in OpenSim with RULA risk scores.

Methods: We modified an existing OpenSim model of the upper limb to use more computationally efficient muscles. We simulated various postural and loading conditions. We performed CMC to gather biomechanical data for every combination of five shoulder postures, three elbow postures, four wrist postures, and two hand loads. Excluding posture, Tukey Tests were used to predict RULA scores from the biomechanical data. We then added grip function from another OpenSim model. Due to the computational cost associated with this model, SO was used to simulate biomechanical data from a subset of the above combinations and Tukey Tests were again performed. This method allowed us to identify which OpenSim metrics best predict RULA, and demonstrate that additional biomechanical data from OpenSim model simulations are available for WMSD risk prediction.

Results: CMC generated data, predicted RULA scores with joint loading. We found that without grip motions, no OpenSim metric could explain RULA scores for wrist postures. Once grip motion was included, joint loading predicted RULA scores well. SO generated data required other joints to be neutral to effectively predict RULA scores. Neither muscle activation nor muscle fiber length were predictive of RULA scores.

Conclusions: We have demonstrated that joint loading can be easily simulated in OpenSim and is predictive of RULA scores. Other metrics thought to influence WMSDs were unable to reproduce RULA scores, suggesting that RULA over simplifies risk. OpenSim does not report risk in large categories, so greater resolution of risk may be obtained. Future studies should use injury data to study how using OpenS the information OpenSim needs for complete exposure assessment and risk prediction. Such a tool could transform how ergonomics theory is applied to job design, and result in reduction of the prevalence and severity of WMSDs.

The Thermodynamics of Indoor Air Pollution – A Pilot Study Emulating Traditional Kenyan Cooking Techniques

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This study examines the efficacy of additional natural ventilation (i.e., windows) in traditional Kenyan homesteads and other similar dwellings in developing countries. There is a particular need for the reduction of indoor air pollution in Kenya and other countries where traditional cooking relies on unrefined biomass fuels. For the purposes of this study, a cardboard tower equipped with thermocouples and an 80-watt heat source was constructed. As the recreation of smoke was deemed unfeasible, the study measured temperature differentials within the tower to examine how varying temperature conditions might contribute to or lessen the accumulation of smoke indoors. Two scenarios were tested, windows-open and windows-closed. In the windows-open scenarios, decreased temperature differentials were consistently observed throughout the sampling process with an average of 4.8 ◦C less than the windows-closed ($p=<0.0001$). As existing research on smoke movement and temperature demonstrates, a decreased temperature differential will contribute to smoke stratification and an increase in exposure to indoor air pollution. This study suggests that additional natural ventilation in isolation does not necessarily improve indoor air quality among households that use traditional cooking practices similar to Kenya's. Rather, alternative interventions should be designed, including the placement of an exterior stove that is shielded from the elements but accessible to those indoors.

Pre- and Post-Calibration Equations of Low-Cost Sensors Using a Calibration Chamber and Reference Instrument

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Introduction: Low-cost sensors are becoming a popular option to analyze $PM_{2.5}$. At the University of Utah, the AirU sensor is deployed in multiple projects and into various Utah homes. However, it is unclear as to how robust the sensors are when it comes to either hardware or environmental issues that may occur over time as a result of them being in a variety of settings. However, questions remain about sensor performance and life expectancy. The purpose of this study was to compare the AirU sensors' pre-deployment and post-deployment calibration equations in order to evaluate particulate data gathering performance over various times and environments.

Methods: A pre-calibration equation was produced on the sensor using a calibration chamber, ammonium nitrate, and a reference instrument (Dust Trak). The calibration chamber evenly distributed the particulate to all low-cost sensors being calibrated. After they were deployed, a post-calibration equation using the same methods was also produced. Wilcoxon signed-rank tests were used to determine the statistical difference between the two equations. There are pre-and post-equations for twenty-four AirU sensors that were in the field for a time period ranging from 1-5 months.

Results: The results demonstrate that the difference between pre-and post-calibration equations for twenty-four sensors was statistically significant for the R2 and Y-intercept, but the slope was not statistically different.

Discussion: Over time, low-cost sensors remain accurate, but the precision of measurements begin to decrease. Given the results of this project, it is logical to assume that the AirU sensors have not drifted far from their initial capability. These results suggest that in a real-world application, the low-cost sensors will likely remain accurate in its data logging quality and not deteriorate due to environmental or hardware issues.

Quantifying the Relationship between Job Task and Depression

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Introduction: Depression, a mental illness that causes negative emotional responses, loss of interest in activities, decreased energy, or suicidal thoughts, affected approximately 16 million Americans in 2017 compared to 300 people that were diagnosed worldwide. There has been a study that looked at risk of depression in commercial truck drivers and concluded that truckers have a higher risk of depression than the general population. Meanwhile, another study found that office workers have a higher level of depression than those in manufacturing jobs. However, there are few studies that compare the risk of feeling depressed in the population of truckers towards manual material handlers (MMH), assemblers, and administrators. These job tasks are commonly employed in the U.S., with 16% of U.S. employments are office and administrative support jobs (in 2013), 3.5 million professional truck drivers (in 2015), 1.82 million people employed as assemblers (in 2016), and 12,822 people with manufacturing jobs (as of 2019). The aim of this study is to determine if there is a relationship between those job types and depressive symptoms.

Methods: This is a cross sectional study with pooled data collected from three different studies (Distal Upper Extremity, Lower Back Pain, and Commercial Truck Drivers) targeting a population mainly of commercial truck drivers, manual material handlers, assemblers, and administration employees. Depression data were collected via self-report questionnaires. We considered if participants felt depressed if they answered "Seldom," "Often," or "Always" to the question of "how often do you feel down, blue, or depressed?" Job types were categorized into one of the four categories based on job title and place of employment. A logistic regression was done for job task and confounders (tobacco use, alcohol use, diabetes, gender, body mass index (BMI), and age) for risk of depression. A multivariate analysis was done afterwards to adjust for the cofounders.

Results: Of the 2,753 participants, 1,814 were considered depressed. After adjusting for tobacco use, alcohol use, age, gender, BMI, and diabetes, administrative employees were 2.35 times more likely than truckers to feel depressed (OR=2.35, 95% CI 1.30-4.23, P=0.0045). Assemblers were 1.79 times more likely than truckers to feel depressed (OR=1.79, 95% CI 1.42-2.26, P<0.0001). Manual Material Handlers were 1.05 times more likely than truckers to feel depressed (OR=1.05, 95% CI 0.84-1.32, P=0.6468).

Conclusions: This study concluded that administrators, assemblers, and manual material handlers were more likely to be depressed than truckers. Depression in the workplace could cost businesses billions of dollars every year due to lost productivity and health care expenses. As a result, the cost for depression in the United States is about $26.1 billion for medical expenses, $5.4 billion for costs related to suicide, and $44-51.5 billion for lost in productivity. Further research needs to be done to determine the primary cause of depression in administrators, assemblers, and manual material handlers that puts them more at risk for depression than truckers.

The Effect of Posture and WBV on Neck Muscle Activation Requirements

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Introduction: Commercial truck drivers have a high incidence of neck pain, approximately 51%.[1] While lower back pain of commercial truck drivers has received significant attention in the literature, our understanding of the factors that lead to neck pain remains limited. Whole body vibration (WBV) has been identified as a potential contributor to neck pain.[2] This work aims to investigate the relationship between posture, WBV, and musculoskeletal stress.
OpenSim is an open source musculoskeletal modeling platform that has the ability to investigate the effects of posture and WBV by predicting muscle activation and joint loading[3]. OpenSim is used to simulate gait,[4] tendon transfer surgeries,[5] and sports movements.[6] Recently an OpenSim model of the head and neck, known as the HYOID model, was developed which is the first OpenSim model to deliver realistic strength in each principal direction of movement in the neck.[7]
The long term goal of our work is to understand the effects of driving time, posture, and WBV on commercial truck driver neck pain and neck fatigue. With observational studies planned in the future to determine the effects of drive time on posture and how WBV is transmitted to the head, this study is focused on using the HYOID model to define a relationship between posture, WBV, and muscle activation requirements.

Methods: The HYOID model includes 72 muscle actuators, passive elements, realistic inertial properties, and kinematic constraints which lower the degrees of freedom in the model to six.[7] The HYOID model has been shown to be able to reproduce experimentally observed functional movements of the neck more effectively than previous models. [7] One of the strengths of using OpenSim is the ability to interface directly with MATLAB. We created a custom MATLAB script which enables a parametric simulation study in which we altered posture and WBV characteristics. We simulated every combination of three upper cervical spine postures, 3 lower cervical spine postures, 3 torso postures, 2 WBV frequencies, and 3 WBV amplitudes for a total of 162 simulations. After each simulation, our script recorded the average of the sum of all muscle activation in the model. With this data, we performed a TukeyHSD analysis in RStudio to determine which factors have a significant effect on muscle activation. We also developed a linear model to predict muscle activation based on posture and WBV characteristics.

Results: The TukeyHSD results indicate that the amplitude and frequency of WBV have significant effects on required muscle activation. While the TukeyHSD results indicate no significant effects of posture on required muscle activation, the linear model reveals complex interactions between posture degrees of freedom and WBV characteristics. The linear model has an adjusted R^2 value of 0.85 and indicates significant effects from WBV amplitude, the interaction between WBV amplitude and frequency, and several interactions between cervical spine posture, torso posture, and WBV characteristics.

Conclusions: The results indicate that there is a meaningful relationship between the characteristics of WBV, posture, and muscle activation requirements. The three degrees of freedom for posture in this analysis can interact to either amplify or dampen the effect of posture in this relationship. For example, the neck can be in flexion while the torso is rotated anteriorly allowing more of the loads from WBV to travel through the spine. Future work includes determining the relationship between driving time and posture. If truck drivers fail to alter their neck posture in response to altering torso posture increased neck activation, fatigue, and loading may occur and lead to increased pain.

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Development of a New Full-body Musculoskeletal Model in OpenSim

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Introduction: Musculoskeletal modeling is a very powerful tool that allows users to analyze the dynamics of human motion and the activation of muscles during that motion. A wide range of models such as full-body, lower-extremity, upper-extremity, and spine models can be found in literature. Extremity-specific models tend to incorporate highly detailed musculature and joint configuration. The major difficulty in creating a more physiologically accurate full body-model is that too much detail can lead to a huge computational cost. In turn, while full-body models are described in literature, many of them incorporate a simplified torso, simplified muscle configuration, and/or minimal degrees of freedom (DoFs) to lessen the required computation time. Therefore, it is critical to be cautious of the level of detail that is contained within a full-body model. However, we believe that increased physiological accuracy within a model will lead to more accurate simulation results. This project focuses on the early development of a new full-body model that incorporates more detailed joints and musculature than is currently available by integrating previously validated OpenSim models. In this work, we chose to use OpenSim because it is an open-source musculoskeletal modeling software that allows researchers to share their work with others and it also has a repository of shared models.

Methods: At this time, we have created a new full body musculoskeletal model by integrating two previously validated OpenSim models that were available for download in the OpenSim repository: the full body lumbar spine (FBLS) model and the musculoskeletal model for the analysis of spinal injuries (MASI). Each model was scaled so that their masses and stature matched before their joints and muscles were combined. During the scaling process, the mass properties and inertial properties were automatically scaled via OpenSim, and these new values were taken as true. The FBLS model was used as our base because it contained detailed musculature in the lower extremities and the lower/mid back. It has a detailed lumbar spine but defines the torso as a lumped rigid body that contains the skull, vertebrae C1 – T12, scapulae, and clavicles. Next, the MASI model was combined with the FBLS model by adding detailed musculature and 6 joints. This established more degrees of freedom within the spine and shoulder and more musculature in the cervical region. In the process of integrating these two models, we ensured that the muscle locations were mapped appropriately on the FBLS model, otherwise this could lead to errors in muscle force calculation. Currently, our model contains 36 body segments, 402 muscles, and 37 DoFs. We will begin the model verification and validation process as suggested by the OpenSim documentation, as well as the procedures performed by the authors of their respective models.

Results: We expect that our model will align with previously established experimental results that were used to validate the original models. We also intend to compare our simulations with previous simulations described within the papers of the original models. If our results are not sufficient, we can investigate the misalignments between the combinations of the models to ensure that our new model is appropriate for future simulations.

Conclusions: It is expected that we will have a new full-body musculoskeletal model that has been verified and validated. By accomplishing this, this model will be used to predict and evaluate the effects of various tasks such as walking, running, or lifting. We fully intend to share our new model with other OpenSim researchers so that further improvements can be made.

Relationships between the Duration and Intensity of Physical Activity and Sleep

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Introduction: In the United States, only 50% of adults participate in the daily health-enhancing physical activity needed to reduce health problems and disease. In addition to healthy habits, adults require 7 or more hours of sleep in a 24-hour period for maximal health benefits. Nearly 1 out of 3 Americans sleep fewer than 6 hours per night. Commercial motor vehicle (CMV) drivers account for about 2.2% of the 160 million individuals in the U.S. working population. Studies suggest that CMV drivers have poor overall health with higher risk factors of cardiovascular disease, obesity, obstructive sleep apnea, and hypertension when compared to the general population. Due to the demands of the job, CMV drivers sit for a long duration of time with limited physical activity, as well as an increase in psychological stress, fatigue, and other physical and social elements. The goal of this investigation is to analyze whether an increase in physical activity or intensity improves sleep in CMV drivers.

Methods: This cross-sectional study assessed baseline data through a large prospective cohort study. The population consisted of 797 drivers (Mean age=47.2±SD years). Each worker completed a computerized questionnaire and reported factors of demographics, physical activity, medical history, psychosocial factors, etc. There were six activities that were categorized as moderately intensive exercise (n=797) including: walking, bowling, gardening, hunting, swimming, and lifting weights. Restless sleep defined by a response of "Never", "Seldom", "Often", or "Always" were reclassified into binary variables of no ("Never"; n=178) and yes ("Seldom, Often, or Always"; n=615). Potential confounders that were analyzed against the exposure and outcome in this current model were age, gender, body mass index (BMI), tobacco usage, alcohol usage, and low back pain (LBP) prevalence. SAS 9.4 was used to create a logistic regression model to analyze the relationship of between sleep moderate physical activity minutes.

Results: Data showed that individuals who do not participate in moderate activity are 2.25 times more likely to have restless sleep (95% CI=1.27-3.97, p=0.0055) compared to individuals who participate in up to 1,278 minute of moderate activity each week. Individuals that participated in 30 minutes of moderate activity per week were decreased to 1.75 times more likely to have restless sleep (95% CI=1.02-3.00, p=0.0432). Similarly, the probability of restless sleep decreased to 1.05 times when individuals participated in 105 minutes of moderate activity per week (95% CI=0.63-1.77, p=0.8454). Individuals probability of restless sleep was decreased 1.24 times if they participated in 270 minutes (95% CI=0.74-2.07, p=0.4189) compared to the maximum minutes of activity.

Conclusions: The results demonstrate that longer durations of moderate physical activity per week lowers the chances of having restless sleep. Other factors such as age, gender, BMI, LBP prevalence, tobacco usage, and alcohol usage can play a role in restless sleep. Restless sleep can affect situational alertness, cause a decrease in health, and add additional psychosocial stress, all of which can negatively affect the performance of truckers. Further analyses of sleep elements are warranted in order to create a greater understanding and solution to this problem.

Relationship between Diabetes and Sleep in Commercial Motor Vehicle Drivers

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Introduction: According to the Journal of Clinical Sleep Medicine, the average healthy adult requires seven or more hours of sleep per night [1]. Sleep is a vital process for the body to reach homeostasis and deprivation could lead to an increased risk of developing multiple health problems including: diabetes, hypertension, obesity, other heart disease, etc. [1, 2]. In the United States, the amount of people who average less than six hours of sleep a night continues to increase [3]. Studies have suggested that some metabolic diseases, such as diabetes are greatly affected by lack of sleep [2, 4]. In 2010, there were 25.8 million people in the United States diagnosed with diabetes-compared to 2015, which was increased to 30.3 million diagnosed with diabetes. Similarly, approximately 84.1 million people diagnosed prediabetes indicating a greater prevalence of diabetes growing rapidly [5, 6]. The purpose of this paper is to determine if there is a relationship between diabetes and sleep.

Methods: This case-control study was performed with data collected from a larger prospective cohort study. Diabetes was defined as participants that answered "yes" to a previous diagnosis of diabetes and a Hemoglobin A1C value >5.6%. Restless sleep was reported as "Never, Seldom, Often, or Always". Participants who reported "Often and Always" were categorized into Yes (n=197) and participants that answered "Never" were categorized into the No group (n=178). Both groups were compared to individuals who reported "Seldom" experience of restless sleep (n=418). Quality of sleep was defined as participants that reported sleeping "Very Poorly" (n=7), "Poorly" (n=36), "Fair" (n=219), "Well" (n=362), or "Very Well" (n=169) at night. A logistic regression analysis was performed using SAS 9.4 to evaluate the relationship between restless sleep and diabetes. In addition, the relationship between quality of sleep at night and diabetes was evaluated. We controlled for the following confounders: body mass index (BMI), age, gender, total physical activity, and haul type.

Results: The sample consisted of 480 truck drivers with a mean age of 47.2 ± 10.5 years. The results showed that individuals who experienced restless sleep were 2.11 times more likely to have diabetes (95% CI 1.05-4.33, p=0.037) compared to those who had seldom restless sleep. Individuals who did not experience restless sleep were 0.62 times less likely to have diabetes indicating an inverse relationship (95% CI 0.39-2.24, p=0.885). Due to the small number of participants in the "Very Poorly" group (n=7), logistic regression analysis could not be performed. Individuals that responded slept "Poorly" were 5.73 times more likely to have diabetes (95% CI 1.46-22.40, p=0.012) compared to individuals that slept "Very Well". Participants that responded "Fair" sleep quality were 1.56 times more likely to have diabetes (95% CI 0.58-4.24, p=0.380). Similarly, participants that responded "Well" sleep quality were 1.32 times more likely to have diabetes (95% CI 0.51-3.34, p=0.565).

Conclusions: The data suggests that individuals who experienced restless sleep or slept poorly during the night are more likely to have diabetes. Based on these results, sleep appears to play a role in the outcome of diabetes. Further analysis using larger case numbers is required to gain a better understanding of its role. In the workplace, specifically for truck drivers, workers and employers would benefit from increased breaks or sleep time to prevent any adverse health effects.

Friday, April 19 - Annual Dr. Paul S. Richards Endowed Distinguished Visiting Lectureship in Occupational Medicine

The Role of the Epidemiological and Exposure Sciences in the Resolution of Medicolegal Disputes

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Medicolegal disputes necessarily involve the principles of science. Evidence-based resolution of medicolegal disputes matters not just to the individual litigants, but also to our technologically complex society, which the law must serve. Despite popular notions about "evidence-based medicine, critical analysis of causation remains lacking in American courtrooms.

Adopting a case report format predicated on a recently-litigated toxic tort lawsuit, this section will explore the conscientious, methodical application of state-of-the-art knowledge of the clinical, epidemiological, technical, and psychological sciences for the determination of causation – a multidisciplinary approach that promotes the equitable and unbiased resolution of medicolegal disputes.

Depression and Drug Use: A Comorbidity in Commercial Truck Drivers

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Introduction: Drug abuse, defined as excessive indulgence or dependence of addictive substance(s), is a major health issue in the United States. There were 63,632 deaths in the United States caused by either prescription or illicit drug overdoses in 2016, which was a 21% increase from 2015. In 2007, illegal drug abuse in the United States totaled $193 billion dollars in medical care, crime, and loss of work productivity, a number that has increased substantially in the last decade. Another major health concern in the US, depression, is a leading cause of disability for people ages 15-44 years, depression leads to approximately 400 million disability days per year in the United States. A common comorbidity among people with depression is substance abuse, affecting 18% of individuals with the disorder. Among commercial truck drivers rates of drug abuse and depression are high, ranging from 3.4%-44% for drug abuse and 13.6%-26.9% for depression. The purpose of this study was to determine if there was an association between feeling depressed and habit forming drug use among a long-distance truck drivers.

Methods: This is a cross-sectional study of commercial truck drivers. A computerized questionnaire was taken by 797 commercial truck drivers. The questionnaire included information on the following: demographics, psychosocial factors including depressive symptoms, use of narcotic or habit forming drugs, crashes, and chronic illness risk factors. Depressive symptoms were measured using a question of "How often do you feel down, blue or depressed?" with the choices of "always" felt depressed (N=13), "often" felt depressed (N=73), "seldom" felt depressed (N=370), and "never" felt depressed (N=341). Drug abuse was assessed by asking about using narcotics or habit-forming drugs (N=17) or not using narcotic or habit-forming drugs (N=780). A multivariate logistic regression analysis was conducted to evaluate the association between depression scores and the use of narcotic or habit-forming drugs. Odds ratios (OR) and 95% Confidence Intervals (95% CI) were calculated)

Results: In this analysis, 797 commercial truck drivers with a mean age of 47.22 years were included. After adjusting for age, BMI, and gender, and other variables, truck drivers reporting "always" feeling depressed were 20.485 times more likely than those reporting never feeling depressed to have used narcotic or habit-forming drugs (95% CI=3.103-135.228). Drivers who reported often feeling depressed were 4.829 times more likely than those reporting never feeling depressed to have used narcotic or habit forming drugs (95% CI=0.955-24.420). Drivers who reported seldom feeling depressed were 2.809 times more likely than nose reporting never feeling depressed to have used narcotic or habit forming drugs (95% CI=0.754-10.463).

Conclusions: The data suggests that feeling depressed may play a role in narcotic or habit-forming drug use. Because of the small number of cases (N=17) of narcotic or habit-forming drug use in this population, there may be a decrease in the accuracy of this analysis. This being said, it shows a significant relationship between feeling depressed and narcotic or habit-forming drug use. Further analysis with a large number of instances of narcotic or habit-forming drug use is necessary to get a better idea of the relationship between depression and drug abuse. Depression symptoms are treatable and targeted work place interventions or counseling services aimed at reducing the risk of depression could have a lasting beneficial impact on commercial truck drivers.

The impact of mouse weight and connection type on muscle activity and performance while gaming

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Introduction: E-sports are popular around the world and playing games has become a profession for an increasing number of players. Specialized keyboards, mice, headphones and gaming workstations have been developed to improve performance and reduce physical discomfort associated with prolonged gaming. Games have special requirements of operation requiring faster and larger movement, greater mouse sensitivity and higher input efficiency of pointing devices like the computer mouse. The rapid and precise movements of the mouse impact performance and may pose challenges to musculoskeletal health. Therefore, different mice are designed to optimise performance and reduce the physical workload associated with gaming. The purpose of this study was to compare the muscle activity and performance while gaming with mice that vary in connection type (wired versus wireless) and weight (light versus heavy).

Methods: This was a within-subjects laboratory study of crossover design with 3 conditions. Professional gamers 18 years and older (paid to play) were recruited to participate. This study was approved by the committee for protection of human subjects at the University of California, Berkeley. The independent variables were weight and connection type of the mouse and included 3 conditions (light wireless, heavy wireless and heavy wired) with mouse weights of 80 grams, 87 grams, and 86 grams respectively. The dependent variables included neck and upper limb muscle activity and performance as measured by the Fitts' Law (Fitts, 1954) test. Dominant side muscle activity was collected on 4 muscles (Upper Trap, Middle Deltoid, Extensor Digitorum Communis, Extensor Pollicis Brevis) using electromyography (EMG) (Noraxon, USA). Performance was assessed using the Fitts' Law test with 16 sessions, which provided variation of radius and position of circles or targets that subjects were asked to click as quickly and accurately as possible. Subjects were provided a baseline survey to provide demographic and gaming experience data. Next, the Fitts' test was performed followed by ten minutes of game play (Overwatch) for each of the three conditions, the order of which was randomized. Muscle activity was collected during game play and normalized to each muscle's maximum voluntary contraction (MVC). The 10th and 50th Amplitude Probability Distribution Function (APDF) EMG values were calculated to quantify static and mean muscle activity and averaged across individuals (Jonsson, 1982). A repeated measure MANOVA was performed using the Turkey post hoc test to identify statistically significant differences across conditions.

Results: Thirteen male professional Overwatch players with an average age of 20yrs (SD=0.95) participated. Mean muscle activity was high in the Extensor Digitorum across conditions, yet lower in the light wireless mouse (Fig.1 (a)). There were no statistically different changes in performance across mice (Fig.1 (b)).

	Mouse 1 # heavy Wired	Mouse 2 # Light wireless	Mouse 3 # heavy Wireless	P_Value
APDF 10				
Upper Trap	4.05(4.47)	2.92(2.60)	3.35(3.11)	0.2826
Middle Deltoid	2.87(2.38)	2.14(2.13)	2.54(2.35)	0.1751
Extensor Digitorum Commnunis	7.63(3.97)	7.00(3.98)	7.75(3.93)	0.2424
Extensor Pollicis Brevis	3.60(2.20)	3.27(1.98)	3.45(2.09)	0.1303
APDF 50				
Upper Trap	6.17(5.64)	5.09(4.09)	5.53(4.66)	0.2424
Middle Deltoid	6.11(5.99)	5.24(4.95)	5.88(5.96)	0.0911
Extensor Digitorum Commnunis	13.10(6.14)	12.06(6.29)	13.63(6.43)	0.1949
Extensor Pollicis Brevis	7.34(4.71)	7.09(4.47)	7.52(4.98)	0.2332

(a)

condition	mean time(ms)	Error rate(%)	Throughput(bits/s)
heavy wired	518.84(164.41)	6.57(6.46)	6.70(1.05)
light wireless	520.03(166.24)	6.12(5.95)	6.64(1.05)
heavy wireless	529.83(169.63)	6.79(6.22)	6.60(1.14)

(b)

Fig.1 (a) Static and mean muscle activity, (b) Performance metrics generated from the Fitts' law test.

Conclusions: There were no statistically significant differences between muscle activities across conditions; however, average static and mean muscle activity was consistently lower in the light wireless mouse. Across all conditions, the mean activity for the Extensor Digitorum exceeded 10%, which may increase the risk of musculoskeletal symptoms and/or disorders.

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Health Hazards in an Aircraft Part Assembly Operation

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Introduction: Three problems have been identified at an aircraft part assembly operation including worker exposures to 1) carbon dust particulate matter, 2) high noise levels, and 3) ergonomic risk factors during loading and unloading processes. Extensive carbon dust sampling was previously conducted in the trim area due to concern for the potential development of adverse health effects among employees. Concern for current particulate exposures and involvement of nanoparticles in the future have contributed to continued interest in this process. The trim area has also previously been identified as an area with higher noise levels. These increased noise levels have been associated with the operation of waterjets and adjacent machinery. Evaluations through personal noise monitoring, as well as isopleth mapping, was identified as beneficial to further evaluation of noise exposures in this area. The loading and unloading area was identified as most concerning for worker exposures to ergonomic risk factors for the development of upper extremity musculoskeletal disorders and back injuries. An ergonomic assessment of the processes was requested.

Methods: A particulate survey of the trimming area using both GRIMM 1.109 and Enmont instruments was conducted at two locations designated as location 1 and location 2 (see schematic diagram). Noise exposure levels were evaluated using 3M personal noise dosimeters worn by employees. Additionally, sound level samples were taken around the facility using a Larson Davis XLT sound level meter. The specific area sampled was adjacent to waterjets and machinery identified as contributors to elevated noise levels, using a 10 foot by 10 foot grid pattern (see schematic diagram). The resulting values were used to generate an isopleth map using Noise at Work software that illustrates the noise levels in different areas of the facility. Ergonomic evaluation tools applied to the observed work processes included: Strain Index, Rodgers Muscle Fatigue Analysis, Metabolic Analysis, and 3D Static Strength Prediction Program.

Results: Particulate survey with the Grimm instrument in the trimming area revealed averages at location 1 of 2.77 [ug/m^3] inhalable, 2.74 [ug/m^3] thoracic and 2.4 [ug/m^3] alveolar particulate sizes. The averages recorded at location 2 were 3.09 [ug/m^3] inhalable, 3.05 [ug/m^3] thoracic, and 2.17 [ug/m^3] alveolar particulate sizes. The Enmont recorded an average concentration of 11,900 particulates/cm^3 at location 1 and an average concentration of 9,200 particulates/cm^3 at location 2. The personal noise dosimetry readings did not exceed the OSHA Permissible Exposure Limit (PEL) of 90 dBA or the action level of 85 dBA. Noise levels did not exceed 84 dBA. Personal noise dosimetry showed levels within the acceptable range with an average TWA result of 64.5 dB. Dose percentages were all 5% or lower. The creation of an isopleth noise map also revealed no immediate areas of concern. The Rodgers Muscle Fatigue Analysis indicate that all body parts assessed by this tool should be high priority for change due to the prolonged duration of each task. This finding was primarily driven by the continuous effort duration. The Moore-Garg Strain Index was calculated at 21.9 exceeding the hazardous threshold limit of 7. The Metabolic Analysis indicated the total metabolic expenditure of work in the area of interest is 14.94 kcal/min, resulting in a percent rest cycle required of approximately 59%.

Conclusions: Our particulate matter survey using both Grimm and Enmont instruments to sample two separate one-hour intervals presented descriptive data to determine if further sampling was needed. Eight-hour time-weighted averages are recommended at this time to compare against OSHA regulations. Personal noise dosimetry as well as isopleth noise mapping indicate that current noise levels do not exceed the OSHA 8-hour PEL or action level. However, some machines were not in operation during this assessment, so further evaluation at full operation is recommended. Continued periodic monitoring as well as prompt re-evaluation in response to any process changes which may alter noise levels in the area is recommended. Our application of multiple ergonomic analytical tools to loading and unloading work tasks indicate significant hazardous worker exposures to known ergonomic risk factors for the development of lower back and upper extremity musculoskeletal disorders. The results of the strain index tool were primarily driven by the near maximal force required to get the cart moving, the Rodgers analysis was driven by the duration of the task and the metabolic analysis was the result of repeatedly pushing a cart long distances. Further automation of worker tasks, more frequent maintenance of work surfaces, worker rotation, and increased rest times from these arduous tasks are recommended potential abatements to these identified health hazards.

Ergonomic solutions for healthcare employees

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Introduction: Ergonomic problems are one of the major hazards and inducers of work-related musculoskeletal disorders (WRMSDs) in the clinical, diagnostic, and pharmacy settings in a healthcare system. While a pharmacy warehouse work environment exposes workers to strenuous and frequent lifting tasks, the stressors for the workforce in a sterile compound facility are more complex, and less amenable due to the nature of a sterile workplace. The high physical job demands of utilizing awkward postures increase the risk of WRMSDs in this population. These tasks include hanging IV bags, utilizing a pinch grip while manipulating those bags, shaking vials, standing for long periods of time and manipulating a variety of syringes. The most affected areas are the lower back, neck, shoulder and the knees when doing specific tasks at work. For ultrasound (US) technicians, there is a plethora of ergonomic risks those specialized workers are exposed to. The most affected areas were identified to be the shoulder, neck, back, and distal upper extremities. Some underlying causes to these WRMSDs are use of the poor "pinch" grip, sustained shoulder abduction while applying sustained transducer pressure, and postures sustained while scanning bariatric patients. The purpose of this study was to investigate and analyze the single tasks at different worksite locations, develop a hierarchical abatement strategy, and recommend work safety and work cultural changes.

Methods: The research team conducted multiple site visits to various healthcare facilities to collect physical measurements, record video and administer a survey to the employees. A job hazard analysis (JHA) identified potential job hazards for specific tasks in the warehouse and sterile compounding facility. The survey was used to get a personal understanding from the workers of where the greatest issue may lay. University of Michigan 3D Static Strength Prediction Program (3D SSPP) was used for determining shoulder and back loads during tasks in the sterile compounding facility. The Moore-Garg Strain Index was used to evaluate repetitive tasks in the sterile compounding facility. The Revised NIOSH Lifting Equation was used to evaluate lifting tasks in the warehouse.

Results: The following job tasks were identified to be most stressful based on the survey and JHA results: 1) reaching and placing bags on hooks during the Total Parenteral Nutrition bag filling task, 2) pulling the syringe back with one hand, and 3) the pass-through window to main counter material handling task (SI = 4.5). The 3D SSPP revealed that even in the observed extreme postures, loads on the shoulders and lower back were within acceptable limits in the sterile compounding facility. The Moore-Strain Index and the Revised NIOSH Lifting Equation indicated the following jobs require abatement: Placing Bags on hooks (SI = 3) and pulling the syringe back (SI = 10.125). For the US-tasks, after completion of a literature review and video assessments based on the previously published joint-angle table by Harrison and Harris, the suggested Sonography abatements include: 1) providing each technician with their own set-up, or possible area to perform work, 2) providing easy access to PT, massage therapy, and Occupational Medicine Consultation, including education about mindfulness, and 3) teaching of ergonomic principles of patient positioning, and posture modifications when sitting in front of the US device. In addition, the number of patients scanned per day should be decreased based on BMI, and one should allow for micro-breaks during exams and stretches for the sonographer in between patients.

Conclusions: In all observed cases, employees' daily job tasks were fast-paced and frequently repeated, causing ergonomic issues to be replete. Employees in the sterile compounding warehouse are under-utilizing the resources at their disposal (i.e. carts) because they feel they do not allow them to keep up with the workload and pace. A safety culture, complete with posture training, must be emphasized over "getting the job done." In the clean room portion of the sterile compounding facility, workers are reaching overhead to lift 3-kg bags because the equipment heights are non-adjustable. We recommend the implementation of height-adjustable racks. In the ultrasonography suites we detected the aforementioned hazards and administrative limitations, which we would abate by recommended action items (see above) and training to improve posture and minimize required exerted force.

Starting up a high-school safety-outreach program: The Utah Ergonomics & Safety Program experience

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Introduction: One duty of a NIOSH Education and Research Center (ERC) is to reach out to the community. A possible outreach form is educating local high-school students on workplace safety. Discussed will be the experiences of the Ergonomics & Safety (E&S) Program in starting up such an effort in late 2018.

The E&S Program's outreach began with the goal of speaking to students at local high schools who worked typical youth jobs when not at school. The intent was to use the NIOSH *Youth @ Work: Talking Safety* curriculum[1]. The material covers workplace rights and accident avoidance for young workers employed at typical youth jobs.

For various reasons, it was not possible to establish interest at traditional local high schools. The E&S Program was, however, able to find a need for and an interest in construction-safety material at a local vocational high-school. There, students receive vocational training in many areas including construction. The construction-trades division of the school, taught by licensed contractors, instructs students to become carpenters, plumbers, and electricians. Students tackle real-life construction projects and earn high-school credit while learning a trade that can be used throughout their lifetimes.

Methods: The E&S Program wanted to reach as many working students as possible with general workplace-safety content. Candidate high-schools had been identified based on socio-economic demographics along with submissions made to an essay competition sponsored by *Utah Workplace Safety Week*, an annual event sponsored by the state legislature. Repeated communication efforts were made to these high schools without reciprocity. Once interest was demonstrated by the vocational high school, that school became the outreach priority.

The occupational-safety curriculum was delivered in person by the E&S Program. A presentation was given during class and was entitled *Construction Safety: Falls*. The entire process, including questions and answers, took one hour and reached approximately twenty students. The presenter followed up with the high-school instructors afterwards about the content and student reception.

Results: The E&S Program curriculum was successfully delivered to a group of students with a specific need and has been invited back to the school to present the same curriculum to another section of the same course.

Conclusions: Although the E&S Program has not yet reached the high-school students it initially identified, it has reached a different group of students with an equal, if not greater need, for safety instruction.

The E&S Program will continue its efforts to break through to area high schools and reach working high-school students with a general curriculum. The Program will also look to expand the existing construction-safety offering to address other aspects of construction safety and worker health.

[1] https://www.cdc.gov/niosh/talkingsafety/