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Keynote Speaker

Brett Besser, MPH, CPE-OSHA
Directorate of Technical Support and Emergency

A Fanciful Romp through the History of OSHA Ergonomics Efforts

Biography

Brett is a Senior Scientist with the Occupational Safety and Health Administration. He obtained his BS in Chemistry and Microbiology from Metropolitan State University in Denver and his MPH from the University of Utah with an emphasis in Ergonomics. He obtained his CIH in 1989 and CPE in 2002. He has performed over 400 workplace evaluations since 1990, ranging from office environments to meatpacking facilities to warehousing operations; he is also a technical expert for OSHA regulatory activities in the field of ergonomics. He is a visiting instructor at the OSHA Training Institute and has lectured regularly at the University of Utah. He has consulted with other government agencies and private industries over the last 20 years and has presented at local, national, and international conferences.

Gait Parameters During Obstacle Negotiation in a Virtual Environment

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University of Utah

INTRODUCTION

Virtual Reality (VR) has grown significantly over recent years as a tool for both research and rehabilitation. The use of VR environments as a training tool has led to improvements in gait parameters in high fall risk populations. However, research is limited on obstacle negotiation in VR environments using this technology. Therefore, the purpose of this study was to examine differences in spatiotemporal variables during an obstacle avoidance task in both the VR and non-VR environments.

METHODS

Subjects between the ages of 18 to 35 years were recruited from The University of Utah. Once consented, each participant was randomized to either experience the VR environment first or the non-VR first. Both environments required participants to walk on a treadmill at a fixed velocity of 0.9 m/s. Over a period of 60 seconds, a small box (40 X 18 X 11.5 cm) and a large box (40 X 18 X 11.5 cm) were placed on the treadmill in front of the participant and released onto the belt. Participants were instructed to step over each box without touching it. A trial consisted of each box being released three times in random order and at variable times. Subjects performed five trials in each environment. For both conditions, lower limb spatial and temporal variables were measured while stepping over each box (Tables 1 & 2).

RESULTS

Eight healthy young adults between the ages of 18-35 years old were recruited for this study (4 male and 4 female); however, due to time constraints only 3 subjects have been processed to date and their results follow.

Table 1: Means (SD) of lead leg kinematics during Big Box clearance for both conditions

Condition	Non-VR	95% CI	VR	95% CI
Toe Clearance(m)	0.139 (0.047)	0.128-0.150	0.154 (0.046)	0.140-0.169
Max Hip Flex(°)	75.7 (6.6)	73.6-77.7	76.9 (11.8)	73.2-80.6
Max Knee Flex(°)	110.9 (3.8)	109.7-112.2	102.9 (9.1)	100.1-105.8
Stride Length(m)	0.698 (0.098)	0.667-0.731	0.702 (0.101)	0.670-0.733

Table 2: Means (SD) of lead leg kinematics during Small Box clearance for both conditions

Condition	Non-VR	95% CI	VR	95% CI
Toe Clearance(m)	0.147(0.036)	0.136-0.159	0.178 (0.040)	0.164-0.192
Max Hip Flex(°)	63.7 (12.9)	59.5-68.0	62.9 (12.9)	58.8-66.9
Max Knee Flex(°)	97.7 (3.9)	96.3-98.9	93.2 (10.1)	89.8-96.6
Stride Length(m)	0.718 (0.113)	0.681-0.755	0.681 (0.093)	0.649-0.712

DISCUSSION

The findings of this study indicate an overestimation of the virtual obstacles compared to the non-virtual obstacles identified by an increase in toe clearance. This overestimation was also seen in large obstacle negotiation and may be due to misperception of the boxes due to differing heights and inter-pupillary distances of the participants. Additionally, larger variability in knee and hip flexion in the VR indicate varying strategies between trials.

Real-Time Biofeedback Using Knee Kinetics on Lower Extremity Mechanics During Decline Treadmill Walking Following Total Knee Arthroplasty

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Introduction: Total knee arthroplasty (TKA) is effective at reducing pain and improving patient-reported outcomes, and yet persistent gait deficits exist years after surgery. Compensatory movement strategies between limbs are associated with diminished performance during level walking and sit-to-stand tasks, however, little is known on how these impairments relate to higher demand mobility tasks (i.e. decline walking). Decline walking is an essential functional task, which presents higher demands on the surgical knee and is understudied in this population. Compensatory strategies can become chronic and lead to a lifetime of impaired mobility and may accelerate degenerative changes in the non-surgical limb. Real-time biofeedback (FB_{RT}) has recently been implemented to assist in improving lower limb joint mechanics and improve compensatory strategies during level walking following TKA. However, it is not clear if these compensatory strategies can be mitigated through FB_{RT} using knee moments during decline walking compared to a non-feedback (NFB) condition. We hypothesize that FB_{RT} compared to NFB will show significant improvements in gait parameters in persons 3-months following TKA.

Methods: Lower limb joint mechanics were measured in patients' surgical knee 3-months following TKA during 10° decline instrumented treadmill (Bertec, Columbus, OH) trials at a constrained velocity of 0.8 m s^{-1} during both NFB and FB_{RT} conditions. FB_{RT} using knee joint moments were calculated using Visual3D (C-Motion, Inc., Germantown, MD) and displayed to the patient during the treadmill trials. The kinetic and kinematics variables were collected in Nexus 2.1 (Vicon, Oxford, UK). Using inverse dynamics through rigid body analysis (Visual3D) based on the anthropometrics of the participant and the ground reaction forces (GRF) from the force plates and joint angles of the lower limbs, the individual joint moment contributions were derived within both the NFB and FB_{RT} trials.

Results: Three patients (2 women, mean age 63.7 yrs. $\pm$ 2.5, mean BMI 25.9 kg/m^2 $\pm$ 0.8) who had undergone a primary TKA from a single academic medical center were evaluated. Gait parameters collected were vertical ground reaction force (vGRF), peak knee flexion (PKF) angle at weight acceptance (WA) and lower limb joint moments (hip, knee, ankle) during PKF. Descriptive statistics using t-tests were used comparing differences between conditions at 3-months following surgery (Table 1).

Table 1. Means (SD) of gait parameters during the 10° decline trials.

	Feedback	Non-Feedback	P-Value
vGRF (%BW)	0.84 (0.06)	0.87 (0.04)	0.57
Peak Knee Flexion Angle [at WA (°)]	28.12 (3.38)	19.93 (3.77)	0.04*
Hip Extension Moment [at PKF]	0.18 (0.09)	0.28 (0.14)	0.35
Knee Extension Moment [at PKF]	0.50 (0.04)	0.36 (0.02)	<0.01*
Ankle PF Moment [at PKF]	0.55 (0.26)	0.54 (0.37)	0.97

SUMMARY

Preliminary findings indicate that the FB_{RT} using knee moments has the potential ability to improve faulty lower limb joint mechanics in a chronically impaired population in order to hopefully improve overall mobility and physical outcomes. Early findings appear to show TKA patients compensate with decreased knee flexion angles and ultimately reduced knee extension moments to avoid proper use of the joint. Further research is needed in this area to understand the utility of this method of FB_{RT} in the rehabilitation setting.

Evaluation of 3D Printed Soft Fingertip Grasping Ability for Variable Fingertip Shape, Layer Thickness, and Material Shore Hardness

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ABSTRACT

Early designs of artificial fingertips include only rigid materials, leading to poor performance on grasping tasks, partially due to small rigid contact areas between the fingertips and the objects. Including soft materials provides larger contact area between the fingertips and object, improving grasp stability and ability to manipulate objects. In the literature, various attempts have been made to design soft artificial fingertips that can exhibit grasping ability as close to human fingertips as possible. Previous literature has shown that silicone rubber was considered the best material for grasping performance, but there has been no systematic investigation of how design parameters affect fingertip performance.

In this research, thirty 3-D printed prosthetic fingertip prototypes are created based on three varied parameters: five shapes based on flatness/roundness of the fingertip, three thicknesses of the soft layer which represents fat, and two shore hardness indexes of the silicone rubber. The grasping performance of these thirty prototypes is tested using a custom built three-axial linear actuator experiment device and a force plate. The objective of this research is to identify what combination of the three parameter values results in the best fingertip grasping performance.

The experiments are still ongoing and results will be summarized as soon as the experiments are completed. Findings will of this study will be presented at the NORA conference 2016.

Quantifying Hand Activity Level (HAL) from Frequency and Duty Cycle: A Comparison of Using All Exertions versus Forceful Exertions

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ABSTRACT

Hand Activity Level (HAL) uses frequency and duty cycle of hand exertions to measure repetition and is used to predict injuries of the hand in the workplace. HAL is commonly quantified using verbal anchor scale or tabular lookup. Recently, Radwin et al. developed an equation to quantify HAL using frequency and duty cycle of exertions[1]. It is common for varying levels of force to be used when performing exertions and there is little guidance for which exertions should be included and which should be ignored when calculating HAL. The objective of this study—which used data from a prospective study—is to see if there are marked differences in calculated HAL ratings when using total versus forceful exertions.

Frequency of exertion and duty cycle ratings from 10,244 tasks performed by 1,784 predominantly manufacturing workers were evaluated. Data were obtained for left and right hands separately, and force (Borg CR-10 rating) frequency and duty cycle of exertion were provided for all exertions. HAL ratings were computed using forceful exertions, defined as exertions having a Borg rating greater than or equal to 2, and total exertions, defined as all exertions regardless of force level.

HAL ratings were highly correlated with frequency for both forceful exertions and total exertions ($R^2 = 0.93$, and $R^2 = 0.88$, respectively). HAL ratings were more poorly correlated with duty cycle ($R^2 = 0.68$, and $R^2 = 0.22$ for forceful and total exertions, respectively). Forceful exertion HAL ratings and total exertions HAL ratings were poorly correlated ($R^2 <= 0.47$).

The Radwin et al. equation for computing HAL ratings appears to be biased towards frequency. HAL ratings for a given task are markedly different depending on whether forceful or total exertions are used in the calculations. Further testing is needed to determine whether HAL for forceful exertions or HAL for total exertions should be used to determine risk of distal upper limb musculoskeletal disorders.

1. Radwin, R.G., Azari, D.P., Linstrom, M.J., Ulin, S.S., Armstrong, T.J., Rempel, D. (2015). A frequency-duty cycle equation for the ACGIH hand activity level. *Ergonomics* 58(2): 173-183.

The Effect of Rounding Techniques on Agreement between Verbal-anchor Rated and Mathematically Computed Hand Activity Level (HAL)

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ABSTRACT

Hand activity level (HAL) measures hand repetition on the basis of frequency, duty cycle, and speed of hand exertions, and is used to predict distal upper limb musculoskeletal injuries in the workplace. HAL is most commonly quantified using a verbal anchor scale or tabular lookup. Recently, Radwin et al. developed an equation to quantify HAL based on measured frequency and duty cycle. [1] The objective of this study is to determine the agreement between verbal HAL and Radwin et al. calculated HAL using data from a prospective cohort study.

Frequency of exertion and duty cycle ratings from 10,244 tasks performed by 1,784 predominantly manufacturing workers were evaluated. Data were obtained for left and right hands separately, and frequency and duty cycle of exertion were provided for all exertions. HAL ratings were computed using the Radwin et al. equation[1] and rounded to integers using five different methods: rounding 1) to the nearest integer, 2) up to the next integer, 3) down to the integer, 4) to the nearest half integer, and 5) to the nearest $1/10^{th}$ integer.

Agreement levels range from 35% to 56% depending on the rounding method used. Regardless of the rounding method, verbal HAL ratings are consistently higher than calculated HAL ratings. Rounding up showed the most agreement between verbal HAL and calculated HAL (56% agreement).

Rounding technique has an effect on HAL ratings. Rounding up to the next integer yields the greatest agreement with verbal anchor HAL ratings, and should be considered as standard practice when using the Radwin et al. equation[1]. Computed HAL and verbal HAL have large disagreement regardless of which rounding technique is used. This suggests that analysts are considering more than just frequency and duty cycle when providing their HAL ratings.

1. Radwin, R.G., Azari, D.P., Linstrom, M.J., Ulin, S.S., Armstrong, T.J., Rempel, D. (2015). A frequency-duty cycle equation for the ACGIH hand activity level. *Ergonomics* 58(2): 173-183.

Dairy Tool Box Talks: An Educational Pilot Project

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Background: The dairy industry has seen substantial reorganization since the 1940s, with small family farms increasingly being absorbed into large, industrial operations. Between 1992 and 2012, cow populations shifted from 49% small herd (<100) and 10% large herd (>999) to 17% and 49%, respectively. This trend has encouraged reliance on immigrant labor for herdsmen and milking parlor operation, resulting in lapses in comprehensive training—a situation aggravated by language barriers. This *Tool Box Talks* training series was designed to address training gaps for dairy owners and employees via a 10-week topical curriculum. Sessions were conducted in Spanish at three large-herd dairies with feedback at week 10.

Objectives: (a) Educational training and (b) One Health worker and animal health promotion

Methods: 75 workers from three dairies took part in the voluntary *Tool Box Talks* training program. Weekly educational content consisted of 30 minute sessions in Spanish with complementing educational handouts. Content focused on diverse educational topics in an engaging and informal atmosphere.

Week 1: Basic cow knowledge
Week 2: Cow housing
Week 3: Animal health and cow signals
Week 4: Mastitis and somatic cell count
Week 5: Milking routine standards
Week 6: Safe hands-on cow handling
Week 7: Workplace cultural differences
Week 8: Animal welfare and organization
Week 9: Zoonoses and ergonomics
Week 10: TurningPoint® assessment and presentation of Certificates of Completion from South Dakota State University (SDSU) Extension and High Plains Intermountain Center for Agricultural Health and Safety (HICAHS)

Results: The final assessment administered via a TurningPoint® interactive response system indicated high employee satisfaction, learning achievement, and enthusiasm for the training program. Post-training, employers noted changes in employee behavior, performance, and hygiene awareness. Surveys showed increased understanding of mastitis and milk quality, milking procedures and hygiene, zoonoses awareness, cultural differences, animal welfare and handling, and ergonomics. Future work will continue education via similar dynamic training sessions with topics elected by the participants such as artificial insemination and bovine maternity.

Conclusions: Educational programs for immigrant-based industries such as agriculture must be designed with cultural and lingual sensitivity for true effectiveness. Dairy *Tool Box Talks* was a novel and effective approach to training in the agricultural sector. Further development of similar programs will aid the industry in adapting to increasing immigrant labor trends while still meeting production goals.

Promoting Psychosocial Health and Empowerment among Female Commercial Sex Workers in Nepal: A Peer Education Approach

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Introduction

Female commercial sex workers (FCSWs) in Nepal are exposed to many occupational hazards, including unsafe and unstable working conditions, sexual and reproductive health risks, and various forms of violence, harassment, and exploitation. They are also susceptible to excessive poverty, lack of education and alternative job opportunities, and discrimination stemming from pervasive gender inequalities and the stigma surrounding sex work. All of these stressors place FCSWs in a highly vulnerable condition; one which negatively impacts their psychosocial health and, in turn, their ability to protect themselves from future harms. The aim of this study was to pilot test a brief peer education intervention to promote the psychosocial health and empowerment of FCSWs in Kathmandu, Nepal. In line with the Integrated Empowerment Theory, the program was specifically designed to promote three types of empowerment: power *within*, power *with others*, and power *over resources*. It was hypothesized that exposure to peer educators would be associated with improved psychosocial and occupational health and empowerment outcomes.

Method

In collaboration with a Kathmandu-based non-governmental organization, ten FCSWs from an existing community empowerment network were trained as peer educators and, through formal and informal teaching opportunities, reached over 140 FCSWs with psychosocial health promotion messages. A quasi-experimental pre- and post-evaluation, in which FCSWs who were (n = 99) and were not (n = 94) exposed to the peer educators, was conducted to assess the impact of the program on psychosocial and occupational health and empowerment outcomes.

Results

According to multilevel multiple regression analyses, FCSWs who were exposed to the peer educators reported significantly higher post-intervention scores on psychosocial health knowledge, the efficacy component of power *within*, power *over resources*, happiness, and job control when compared to FCSWs in the control comparison group. Contrary to the hypothesis, exposure to peer educators was associated with higher scores on the personal dimension of workplace incivility.

Conclusions

Overall, these findings suggest that peer education is a promising way to enhance the psychosocial and occupational health and empowerment of FCSWs. The increase in perceived incivility may have been due to increased awareness of experienced incivility as opposed to an actual change in the amount of incivility. Nonetheless, future research should examine ways to mitigate the potentially adverse effects on workplace incivility. These results can be used to inform future programs aiming to promote the well-being of FCSWs and other vulnerable and hard-to-reach working populations.

Occupational Physical Activity in the Workplace

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Objectives
Occupational physical activity in the workplace is important to ergonomics, as well as total worker health. Determining an ideal level of occupational physical activity in the workplace will improve workplace interventions and designs. The purpose of this preliminary study was to assess the feasibility of using activity monitors, like the Fitbit, to measure physical activity in the work environment. This is a small, preliminary study for a more comprehensive pilot project that will be conducted in a large manufacturing facility this summer.

Methods
Occupational physical activity of 20 workers was monitored during three office and three manufacturing work shifts using Fitbit Charge HR activity monitoring devices. Data collected from the Fitbit Charge HR monitors were matched with self-reported daily work activity logs that workers used every hour to track their physical activities. The data collected from the monitors included heart rate, step counts and Metabolic Equivalence of Task (METs). Intraday data were analyzed using a third-party software program in one-second and one-minute intervals. Using these data, we will determine the feasibility of using activity monitors like the Fitbit.

Results
Respondents included 10 office and 10 manufacturing workers. The results of this preliminary study indicate that office workers do not receive adequate levels of physical activity while at work. Manufacturing workers appeared to receive a more appropriate amount of occupational physical activity, though further sampling will need to be conducted in order to better assess occupational physical activity.

Conclusion
Workers with limited occupational physical activity levels may need increased physical activity throughout their workday, and workers with extensive physical activity may need adequate rest. This research will help optimize occupational physical activity through an ergonomics systems approach in the redesign of traditional work practices.

Lifting Motions During Patient Repositioning in Novice and Experienced Nurses: A Pilot Study

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ABSTRACT

Introduction: According to the Bureau of Labor Statistics, in 2014, nursing and residential care facilities had the highest incidence rate of total nonfatal occupational injury cases in the U.S. Manual patient handling tasks result in high lumbar load and most work-related back disorders in nurses are related to patient transfers. The present pilot study seeks to determine if there are significant differences in the motion of experienced nurses and novice nurses while performing the same patient repositioning tasks.

Methods: A motion capture experiment was conducted in a laboratory setting on 15 female nurses performing two patient repositioning tasks (moving patient toward the head of the bed; transferring patient from bed to a wheelchair). Of the nurses selected, 8 were experienced nurses (greater than 5 years of nursing experience), and 7 were novice nurses (between 0 and 2 years of nursing experience). The motion capture data were post-processed using Cortex and Visual3D software. Average and maximum joint angles for the spine, knees, elbows, and shoulders for each task were compared between the novice and experienced nurses using a t-test to determine whether there were significant differences in motion for the same patient repositioning tasks.

Results: Although significant differences were not found between the novice and experienced groups for average or maximum joint angles, there was a significant difference in variances between the novice and experienced groups for some angles for the wheelchair task. Several factors potentially influenced these results including: sample size, the nurses' units, variations in the SP performance, and this study's imprecise definition of experience level. However, the significant difference in the variances suggests that the novice nurses had less consistency in their approach to the tasks. This supports the hypothesis that there is a difference in motion between novice and experienced nurses while performing the same patient repositioning tasks. Future work will attempt to address possible sources of variability and provide a more thorough definition of experience.

Conclusion: These findings will be used to develop and validate a generic optimization and reliability-based method to predict optimal body dynamic motions for individual nurses and other workers in order to prevent injuries under uncertainty during load handling.

Same-Level Fall Injury Incidence Rates in US Workplaces by Age and Industry During 2010 Using the Survey of Occupational Injuries and Illnesses

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Background: Fall injuries on the same level are a common type of occupational injury. As the workforce ages, occupational fall injuries on the same level will likely become even more common. Increasing age is independently associated with elevated fall injury risk both at work and away from work. Same-level fall injuries, like other occupational injuries, result from the interaction between individual-level risk factors (e.g., vision, balance, etc.) and environmental hazards (e.g., slippery flooring material). Individual-level risk factors that account for the age-related increase in falls are well documented. Fall hazards in the work environment have been well characterized and prevention interventions have been tested. However, same-level fall injuries persist. Industries differ in terms of the age distribution of the workforce, the prevalence of fall hazards and the rate of same-level fall injuries. The relationship between age and the frequency of same-level falls has not been compared across US industrial sectors.

Hypothesis: The relationship between age and the incidence of same-level fall injuries requiring time away from work varies by industry.

Methods: Using a cross-sectional study design, the following descriptive statistics are presented by age group and industry using 2-digit NAICS codes: injury counts, at-risk experience and incidence rates. Data are presented in graphical and tabular forms. Additionally, in order to test for effect modification by industry, rate ratios and rate differences are calculated by age and industry for three large sectors: manufacturing, retail and healthcare and social assistance. Injury data were provided by the Bureau of Labor Statistics Survey of Occupational Injuries and Illnesses. At-risk experience was estimated using the Current Population Survey.
Results: Several, though not all, industries exhibit a positive monotonic increase in same-level fall injury incidence with age. The relationship between same-level fall injury incidence and age varies across sectors. The highest estimated age- and industry-specific incidence rate was among workers 65+ in the retail sector (45.0 injuries/1,000 FTE, 95% CI: 43.2, 46.8).

Conclusions: Incidence rates of same-level falls, a preventable occupational injury, vary by age group and industry. The variation in observed rates across industries is likely due to a combination of demographic factors, working conditions and information bias. Epidemiology theory may help researchers develop and test hypotheses to explain these differences.

Ability of WBGT Indices to Discriminate Between Sustainable and Unsustainable Heat Stress Exposures

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Objectives

Heat stress assessment through wet bulb globe temperature (WBGT) was designed to limit exposures to those that could be sustained for an 8-h day. The exposure limit was based on limited data from Lind in the 1960s. The results from two progressive heat stress studies provided the opportunity to determine the ability of the current WBGT-based occupational exposure limits (OELs) to discriminate between Sustainable and Unsustainable heat exposures.

Methods

The progressive heat stress studies included 176 matched pairs of Sustainable and Unsustainable exposures over a range of relative humidities and metabolic rates using about 29 participants. To assess the ability of an existing WBGT-based OEL, the exposure metric was the difference between the observed WBGT and the OEL's WBGT limit adjusted for metabolic rate. Because there were matched cases and controls, conditional logistic regression models were used to fit the binary outcome with a continuous predictor. The ability of the current WBGT-based OEL to accurately discriminate Sustainable vs Unsustainable was assessed using a receiver operating characteristic (ROC). The ROC curve graphically displays the predictive accuracy of the logistic regression model and the area under the curve (AUC) is a measure of the overall ability to discriminate between Sustainable and Unsustainable.

Results

The current WBGT-based OEL has a sensitivity of 1.00 and a specificity of 0.07. The conditional logistic regression model found that the odds of being Unsustainable increased 4 times per 1 ℃-WBGT of difference above the OEL (C.I. 2.75 – 5.54). The ROC curve had an AUC of 0.95 (C.I. 0.92 – 0.97). By increasing the threshold to a point where the probability of an Unsustainable exposure was 5% (p=0.05), the threshold increase was 2.7 °C-WBGT, and sensitivity was 0.98 (C.I. 0.95 – 1.00) and specificity was 0.42 (C.I. 0.34 – 0.49).

Conclusion

Current TLV has a high sensitivity, meaning that the exposed working population is protected. Nevertheless, its specificity is very low, which is translated in a high percentage of false positive cases. The specificity can be increased substantially with little loss of sensitivity by increasing the exposure threshold by 2.7 °C-WBGT.

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Evaluation of Physiological Strain in Hot Work Areas using Thermal Imagery

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Objective: This study utilized thermal imaging and heart rate monitoring to calculate Physiological Strain Index (PSI) from predicted core temperature of human subjects wearing thermal protective garments during recovery from hot work.

Methods: Ten male subjects employed as copper furnace tappers were evaluated for physiological strain while wearing thermal protective clothing and participating in hot work. Thermal images of the head and neck were captured with a high-resolution thermal imaging camera concomitant with measures of gastrointestinal and skin temperature. Lin's concordance correlation coefficient (rho_c), Pearson's coefficient (r) and bias correction factor (C-b) were calculated to compare thermal imaging based temperatures to gastrointestinal temperatures. Calculations of PSI based upon thermal imaging recorded temperatures were compared to gastrointestinal temperatures were also performed.

Results: Participants reached a peak PSI of 5.2 on a scale of 10, indicating moderate heat strain. Sagittal measurements showed low correlation (rho_c = 0.133), moderate precision (r = 0.496) and low accuracy (C_b = 0.269) with gastrointestinal temperature. Bland-Altman plots of imaging measurements showed increasing agreement as gastrointestinal temperature rose, with higher levels of agreement in the sagittal views; however, the limits of agreement fell outside the ±0.25C range of clinical significance. Bland-Altman plots of PSI calculated from imaging measurements showed increasing agreement as PSI calculated from gastrointestinal temperature rose; however, the limits of agreement fell outside the ±0.5 range of clinical significance.

Conclusions: This study confirmed previous research showing thermal imagery is not highly correlated to body core temperature during recovery from moderate heat strain in mild ambient conditions. Measurements display a trend toward increasing correlation at higher body core temperatures, which may enable use of thermal imagery as a screening tool for high heat strain. Accuracy was not sufficient at mild to moderate heat strain to allow calculation of individual physiological stress.

A pilot study predicting core temperatures of smelter workers with thermal imagery and infrared thermometry

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Objective: This study investigated whether infrared temperatures of the face and head measured with a thermal camera and infrared thermometer, or a predicted gastrointestinal temperature (P_{GI}) calculated with a correction factor developed from these infrared temperature measurements, could be used interchangeably with gastrointestinal temperatures (T_{GI}) to estimate core body temperature (T_C). Temperature monitoring was performed in the workplace to explore the practicality of these two instruments in occupational conditions.

Methods: This cross-sectional study monitored temperatures and heart rates (H_{RATE}) of nine smelter tappers during normal work activities. T_{GI} were compared to four infrared temperatures of the face and head. Multivariate linear regression and a bootstrap technique were used to develop an equation that calculated P_{GI}. Concordance analysis and Bland-Altman plots assessed the degree of agreement between T_{GI} and each infrared temperature, and between T_{GI} and P_{GI}.

Results: The best model included Frontal (T_{FRN}) and Sagittal (T_{SAG}) camera temperatures and H_{RATE}. R-squared and standard error of the estimate (SEE) for the model were 0.24 and 0.3. Comparisons of P_{GI} to T_{GI} produced a mean bias, 95% limits of agreement (LoA), concordance correlation coefficient (CCC), and Student t-statistic of -0.034; -0.619–0.550; 0.656; and 1.259 (p=0.211).

Conclusion: The results of this study agree with prior research suggesting a convergence of T_{GI} and infrared facial temperatures with increasing heat stress. The correction factor developed in this study accurately predicted T_{GI}. However, due to occupational conditions and study limitations, the P_{GI} calculated with the correction factor lacked the desired precision to correctly identify elevated T_{GI} (>38.0˚C) with sufficient specificity to avoid having a negative impact on work productivity.

Comparison of a New Low-Cost Inhalable Sampler and IOM Sampler for Field Testing of Metal Refinery Workers

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BACKGROUND: Metal refinery workers are exposed to heavy metals through inhalation of particulates. The Institute of Occupational Medicine (IOM) sampler is one of the most common samplers used to sample inhalable particulates to assess work exposure. Although popular, the IOM sampler is difficult to operate, prone to contamination, and has been found to inadequately capture the inhalable fraction of particulates in low-wind conditions. In addition, it is relatively expensive, making the sampler cost-prohibitive for industrial hygienists. A Prototype inhalable sampler has been designed to address the deficiencies in the currently used IOM sampler.

METHODS: The IOM sampler and Prototype sampler were tested side-by-side on a group of 11 smelter workers at a copper smelter. The workers were fitted with a vest containing the samplers attached to personal sampling air pumps. Sampling periods ranged from 2 to 8 hours. Tasks included tappers, measures, and workers on the boiler. Samples were taken to an AIHA accredited laboratory for analysis. Samples were analyzed using a metals panel A. Samples were also pre- and post-weighed for total particulates.

RESULTS: Four metals (arsenic, cadmium, copper, and lead) and total weight of particulates collected by the samples were statistically analyzed. Tests for skewness to assess the distribution of the data revealed all data collected to be non-parametric. Traditional non-parametric statistical analysis included Spearman's rank coefficient and Wilcoxon signed-rank test. The Bland-Altman test, which is a novel approach in statistical analysis of samplers, was also used.

Analysis revealed a significant difference in the total amount of particulates collected by IOM sampler and Prototype sampler. However, while the amounts of *total* particulates differed between the two samplers, three of the four metals analyzed showed statistically similar concentrations were collected.

CONCLUSION: When comparing metals, the prototype sampler seems like a close surrogate to the IOM sampler. The difference between *total* particulate collected by the samplers may be attributed to differences in the inlet design and should be investigated further. An increase in sample size to 50 total paired samples is suggested to demonstrate a power of <90%. Increasing the power would validate the findings discussed herein and conclusively determine any statistically difference in the samplers' collection efficiency of particulates.

Special Presentation

13th Annual Paul S. Richards, MD, Endowed Distinguished Visiting Lectureship in Occupational Medicine

David M. Rempel, MD, MPH
Professor Emeritus of Medicine (UCSF)
Professor in Bioengineering (UCB)
School of Medicine
Division of Occupational and Environmental Medicine
University of California

"New findings from prospective studies on musculoskeletal disorders and practical implications for ergonomic interventions in the workplace"

Biography

David M. Rempel is Director of the Ergonomics Laboratory and Professor of Bioengineering at the University of California at Berkeley, and Professor of Medicine at the UC San Francisco in the Division of Occupational and Environmental Medicine. His research focuses on hand biomechanics and the design of tools and tasks in order to improve productivity and the quality of work while preventing hand and arm fatigue and injury. The lab has developed and evaluated new keyboards, mice, tablets, pipettors, and agricultural and construction tools. His team conducted 6 randomized controlled trials in the workplace to evaluate interventions for preventing musculoskeletal disorders. Recently, Rempel directed a national multicenter prospective study of 4321 workers to identify risks factors for carpal tunnel and tendonitis. He also treats patients at UC Berkeley. Publications and descriptions of research projects are available at http://ergo.berkeley.edu/

Impact of School Bus Post-accident Orientation on Egress through the Rear Emergency Exit

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Introduction: The rear emergency door on many school buses is mostly used for loading sporting equipment and other non-emergency activities. However, the rear emergency door is a primary exit route for school bus passengers after a rollover accident due to its relatively large size and location. Emergency windows are often inaccessible due to their location on a rolled-over school bus, and passengers may not be familiar with the operation of roof hatches. The size and operating requirements of school bus emergency exits are regulated by Federal Motor Vehicle Safety Standard (FMVSS) No. 217. The purpose of this study was to determine if children in kindergarten are able to unlatch the rear emergency door and self-extricate in both upright and rolled-over orientations. This population was selected because many school districts transport this age group on routes exclusively used for school buses where the only adult is the school bus driver.

Methods: A total of 39 kindergarten students (22 males, 17 females) were recruited from Oak Mountain Elementary School (Birmingham, AL). Anthropometry, force exertions on a school bus door handle, and self-extrication rate through the door were measured using a school bus rear emergency door mock-up. Force exertions were measured using a door handle representing the emergency door in the upright and rolled-over orientations. A school bus mock-up with the capability to be assembled to represent a school bus in the upright or rolled-over orientation was built from the rear section of a 2013 Blue Bird Vision School bus. Subjects performed self-extrication trials with the original seat configuration adjacent to the rear emergency door, and without the seat.

Results: Force exertions on the door handle in the upright orientation (14.9 lbf, SD = 6.7) were significantly greater than force exertions on the door handle in the rolled-over orientation (13.4 lbf, SD = 6.7) ($p < 0.05$). The majority of students tested were able to unlatch the door, however, they were unable to exert the minimum force specified by FMVSS No. 217 (40 pounds) ($p < 0.05$). The mean self-extrication time through the rear emergency door opening with the rear seat obstruction was 6.4 seconds, whereas self-extrication time without the seat adjacent to the door opening was 3.5 seconds.

Conclusions: Based on the strength capabilities of the students tested, the force requirements specified by FMVSS No. 217 to operate a rear emergency door are not representative of the strength capabilities of children. Physical capabilities of children appear to have a significant impact on emergency evacuations. Additionally, evacuation flow rate is approximately doubled with the removal of the seat which partially obstructs the door opening when the school bus is rolled-over on its side.

One Size Does Not Fit All
Measuring Fit and Personal Attenuation of Hearing Protective Devices in a Military Organization

Benjamin J. Heaton MD, Spencer C. Checketts MD, MPH

Intro: Exposure to hazardous noise levels is more common in certain career fields of active duty Air Force personnel than others. At Hill AFB Tactical Aircraft Maintainers (Crew Chiefs) are especially prone to hearing loss due to the noise exposure. Proper use of hearing protection should provide sufficient attenuation to ensure that noise induced hearing loss is avoided; however, hearing loss continues to be observed among Crew Chiefs enrolled in the Air Force's Hearing Conservation Program. Therefore it was necessary to evaluate the Hearing Conservation Program – one portion being the fit and personal noise reduction rating (PNRR) of the hearing protective devices (HPDs) issued to Crew Chiefs at Hill AFB.

Methods: Visits to the work area found that earplugs (manufacturer NRR 29) and various ear muffs (NRRs ranging 21-34) are the HPDs used by Crew Chiefs. Noise levels at Hill AFB have been measured at 107 dBA 8hr TWA for Crew Chiefs. A commercially available validation system was used as the testing platform to determine PNRR and fit among Crew Chiefs. For those that did not achieve an acceptable PNRR of at least 22dBA education was given concerning proper placement and testing repeated. Additional testing with different type and/or size of earplug was performed for those who failed after receiving education.

Results: 47% (29/61) initially failed to achieve adequate hearing protection with the device issued in the work place. Five of the 61 participants were able to pass with additional education. 22 of the 61 participants passed only after being fit with an alternate device while two participants were unable to achieve an adequate fit with any of the HPDs. These results show the current practice of providing a single type of earplug leaves (24/61) active duty members at an increased risk for loud noise exposure and noise induced hearing loss.

Conclusion: At Hill AFB only one type of disposable earplug is available for Crew Chiefs in the workplace. This data shows that one size does not fit all. Inadequate fit of HPDs leave these individuals (39% in this study after education) susceptible to noise exposure and increased likelihood of future noise induced hearing loss. Although these findings and conclusions are only applicable to Crew Chiefs at Hill AFB, similar results have been obtained at other bases. However, it should be noted that any future results may vary significantly in accordance with the specific mission each base is tasked to support. Noise exposure, education, and compliance with use of HPD's may also differ among bases.

Industrial Hygiene & Ergonomic Assessment of an Aluminum Foundry

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OBJECTIVE

Foundries have several occupational hazards that contribute to increased risk of injury and development of adverse health effects in workers. The aim of this assessment was to quantify exposures to noise, airborne particulate matter, and ergonomic hazards present in the facility. Results of this assessment were then used to develop recommendations for appropriate hazard abatement strategies to reduce the targeted exposures.

METHODS

Individual noise exposures were measured for three foundry workers using 3M dosimeters. Personal measurements were collected over 8 hours of a typical work shift. Sound levels were measured in three work areas, the Machine Room, the Foundry, and the Finishing Room, using a Larson-Davis Sound Level Octave Band Meter. These readings were then overlaid on a floor plan to visualize areas of high and low sound levels. The dominant octave band frequency for each room was also determined using measurements from the sound level meter.

Levels of particulate matter in air were measured in the Foundry area using a GRIMM optical dust measurement system. Particulate matter (PM) concentrations were measured as counts per volume by particle diameter. This information was then used to calculate the mass concentrations for respirable particulate (diameter ≤ 5 µm) and the total particulate (diameter < 32 µm). The respirable and total particulate levels were also overlaid on a floor plan to visualize areas of high and low concentration.

A specific work task involving transfer and pouring of molten aluminum was analyzed for ergonomic hazards. The 3D Static Strength Prediction Program (3DSSPP), the Rapid Upper Limb Assessment (RULA), Moore-Garg Strain Index (SI), and Rodger's Muscle Fatigue Indices were used to assess the risk strain or injury associated with this task.

RESULTS

Personal noise dosimetry measurements were all below the OSHA standard of 90 dBA as an 8 hour Time Weighted Average (TWA) for exposure to occupational noise. However, two of the three employees were overexposed to noise based on the Hearing Conservation Program monitoring criteria. The Foundry work area tended to have the highest noise levels. The Machine Room had the lowest, with a majority of the noise appearing to originate from the Foundry. The dominant octave band frequency differed by area.

Over 99% of the particulate matter counted was considered respirable, with particle diameters less than 5 µm. The approximated PM mass concentrations were less than 1 $\mu g/m^3$, which is well below both the OSHA standard and ACGIH threshold level. For both respirable and total particulate, the PM levels were highest in the area where casting was taking place and molds were being preheated using open flame jets.

Ergonomic analytical tools identified the combined ladle and aluminum load weight as the most significant contributor to developing upper extremity strain or injury. The RULA assessment yielded the maximum score, indicating a need for immediate risk abatement.

CONCLUSION

Exposure to occupational noise and upper extremity strain places workers at an increased risk for adverse events which could negatively impact not only their health, but also the productivity and profitability of the company as well. It was concluded that implementation of minimal, cost-effective abatements would mitigate most of these hazards. Further monitoring of particulate air concentrations is also recommended to more accurately assess risk.

Unloading Coke from Railcars at a Cast Iron Pipe Manufacturer

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BACKGROUND: A cast iron pipe manufacturer presented concerns for ergonomic issues and potential musculoskeletal injury and disorders (MSDs) associated with unloading coke, a high carbon coal derivative, from railcars. Four days per week for about two hours per day, two workers utilize sledgehammers and a steel poker rod to dislodge the large, irregularly shaped coke from a railcar on an elevated platform. During winter months unloading the coke is often complicated by the coke freezing together. The process exposes workers to upper extremity and whole body biomechanical stresses and vibration.

METHODS: The process of unloading coke from a railcar was observed and filmed. Measurements and parameters of the worksite were taken. The company's management provided information on workers' duties, tools, and cost of materials involved with the process. Peer facilities and the American Foundry Society were identified and contacted for information regarding industry practices. Available market tools were researched using an online search engine and by contacting the product manufacturers. Five main tasks were analyzed: (1) high-, (2) mid-, (3) low-sledgehammer swing, and (4) through hopper- and (5) through railcar-use of steel poker. Video and still photos of the tasks were analyzed with the following tools: University of Michigan 3D Static Strength Prediction Program (3DSSPP™), Rapid Upper Limb Assessment (RULA), and the Moore-Garg Strain Index (SI).

RESULTS: The results from the RULA indicate that all tasks have a "very high risk" for causing injury to the worker. Results of the SI support these findings for all sledgehammering tasks, with the low-swing sledgehammering task being extremely hazardous with a score three times the level considered "hazardous." Results from the SI for the prodding coke tasks were inconclusive. The 3DSSPP™ for all five tasks does not indicate a major strain on the body, with the exception of the mid-swing sledgehammering task. However, the 3DSSPP™ cannot accurately assess dynamic exertions, repetition, and vibration transmitted through the sledge to the user.

CONCLUSION: The analytical tools (RULA, SI, and 3DSSPP™) indicate that all five tasks associated with unloading coke pose some ergonomic risk to the worker. While efforts should be made to abate the risks associated with all five tasks, two tasks pose the most risk to the worker and should be addressed first: mid- and low-sledgehammering. Possible abatements were investigated in accordance with the hierarchy of controls. Substitution of coke to a smaller size would likely decrease ergonomic risk, but is not possible secondary to production specifications. Accounting for platform dimensions, railcar model and design, and coke size, the most feasible abatements at this time include worker rotation and the use of personal protective equipment.

Ergonomic Assessment of Patient-Driven Unscheduled Ambulations in a Medical Surgical Unit

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Objective: Musculoskeletal stresses on floor nurses and certified nursing assistants performing patient-driven unscheduled ambulations, typically sit-to-stand lifts, were analyzed in a major medical center surgical unit due to management concerns with musculoskeletal disorder and injury rates. The projected outcome is a reduction in biomechanical stress.

Methods: Nursing staff provided simulated patient ambulations and comparative measurements of force for the evaluation team. In all calculations the individual observation or measurement yielding the highest estimate of stresses was used. The recreated postures were screened using Rapid Entire Body Assessment (REBA). Tasks professionally judged as hazardous or with a REBA score ≥ 4 were then examined using University of Michigan's 3D Static Strength Prediction Program 3DSSPP. Available interventions were researched and examined using REBA and 3DSSPP to yield quantitative reductions in biomechanical stresses.

Results: Nursing staff indicated the primary manual patient lift utilized during unscheduled ambulations is a one-person side lift. The REBA assessment score was 7 for the unassisted side lift, indicating a medium level of risk. The lift was then modeled with 3DSSPP using 5th percentile female anthropometry. Analysis showed the load during the lift to be acceptable, however, the lift balance is marginally acceptable as center of gravity falls near the edge of the acceptable range. Since a significant percentage of lifts will result in slips or falls due to the vulnerable nature of the patient population, the lines of force were redirected to 45° from perpendicular, thereby recreating a moderate slip or imbalance. Joint stresses were raised, particularly on the shoulder, which resulted in a moderate risk acceptable to only 50% of the 5th percentile female population. Significantly, the balance diagram indicates the lift balance to be unacceptable with the center of gravity falling well outside of the acceptable range. These results indicate the side lift is unacceptable due to inherent instability in the case of a patient slip or fall and an increased risk of shoulder injuries due to horizontal forces on the hand inducing lateral torque on the upper arm.

Conclusions: Results of this study indicate current practices place providers and patients at risk due to the inherently unstable nature of the lift, which requires a vulnerable population to maintain stability in order to prevent injury. Adoption of the Banner Mobility Assessment Tool and use of a Mobility Level 3 manual sit-stand aid such as the RoMedic ReTurn is recommended.

Poster Abstract

"Cardiovascular Disease Risk and Glenohumeral Joint Pain: A Cross-Sectional Study"

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Background: According to the CDC, cardiovascular disease (CVD) is prevalent and increasing in the United States. CVD is caused by a multitude of risk factors, including: age, gender, diabetes mellitus, dyslipidemia, hypertension, obesity, and tobacco use. An adjusted algorithm from the Framingham Heart Study was used in this study to more accurately categorize patients according to their cardiovascular health.

Epidemiological studies have reported that physical demands of certain jobs are related to neck and shoulder pain. During occupational tasks, continuous muscle activity requires significant amounts of local energy, subsequently increasing the burden on surrounding muscle fibers. The glenohumeral joint requires significant perfusion to continually replenish its tissue.

This study explored the possible link between glenohumeral joint pain and a variety of cardiovascular disease risk factors measured by the Framingham Heart Study. Using the specific outcome of glenohumeral joint pain allows for a more accurate quantification of relationships between joint pain and CVD.

Question: Among the working population surveyed at the beginning of the WISTAH study, is there a correlation between the prevalence of glenohumeral joint pain and an increasing risk of cardiovascular disease?

Methods: Workers for the study were recruited from 15 employers with 17 diverse production facilities located in Wisconsin, Utah, and Illinois. The Health Outcomes Assessment Team administered a questionnaire at baseline, which included past medical history, confounders, and psychosocial factors. A structured interview was administered by a standardized clinician and included a survey of symptoms required for diagnostic purposes. Workers then underwent standardized physical examinations. Blood pressures were measured at the end of the survey using an Omron HEM-780 automated cuff. Height and weight were measured in metric units and used to calculate BMI. Each cardiovascular disease variable was scaled in accordance with the Framingham Heart Study, and a CVD risk score was calculated for every participant with complete data. Glenohumeral joint pain was reported in each glenohumeral area (Figure 1) for pain in the past month (1-month period prevalence). "Shoulder pain" was defined as right, left, or bilateral glenohumeral joint pain. Logistic regression using SAS 9.4 software was performed to assess the risk between CVD risk factors and glenohumeral joint pain.

Results: The results showed a strong increasing relationship between CVD risk and glenohumeral joint pain. Higher CVD scores generally demonstrated higher magnitude odds ratios. These odds ratios ranged from 2.06 – 4.55. The substantial relationship between CVD risk and joint pain persisted even after adjusting for other factors related to shoulder pain. This is the first study of its kind that uses a validated risk algorithm to capture the correlation between CVD and joint pain.

Conclusions: Modifying CVD risk factors can meaningfully impact morbidity among workers and reduce healthcare costs. Among the study population, the data sets demonstrate a robust relationship between CVD factors and 1-month period prevalent glenohumeral joint pain. Dose response demonstrated an increasing CVD score related to higher prevalence of glenohumeral pain, even after adjustment for confounders. Although causality cannot be proven, these results warrant additional research to evaluate the potential causal relationship between CVD scores and glenohumeral pain.

"A Review of Best Practice Recommendations for Training Immigrant, Latino/a Dairy Workers in the U.S."

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Introduction

Industrialized dairy production in the U.S. relies on an immigrant, primarily Latino/a, workforce to meet increasing production demands. There are many factors that pose challenges to the provision of effective health and safety training for this growing workforce, including limited formal education and dairy experience, cultural and linguistic differences, and the overall marginalization of immigrant workers. Given the high rates of illnesses and injuries on U.S. dairies, there is a pressing need to develop culturally congruent training programs to reduce occupational hazards and promote safer practices among immigrant dairy workers. To date, there are scant published research articles or guidelines specific to developing effective health and safety training for immigrant, Latino/a workers in the dairy industry.

Method

Relevant literature was examined to identify promising approaches and best practice recommendations for researchers and practitioners involved in the design and implementation of health and safety training programs for immigrant, Latino/a workers in the dairy industry. The search was restricted to English language peer-reviewed journals and guidelines published by extension programs and universities between 1980 and 2015 that were related to safety and health training among immigrant, Latino/a workers within agriculture and other high-risk industries. Recommendations to promote the transfer of training were also included from literature in the field of industrial-organizational psychology.

Results

The review revealed a number of promising strategies on how to best tailor health and safety training for immigrant, Latino/a dairy workers, that fall under five main themes: 1) understanding and involving workers; 2) training content and materials; 3) training methods, 4) maximizing worker engagement; and 5) program evaluation.

Conclusion

These best practice recommendations can be used to inform the development of more culturally congruent and impactful health and safety training for immigrant, Latino/a workers in the U.S. dairy industry.

"*Innovative Engineering to Improve the Quality of Life for Individuals with High Level Spinal Cord Injury"*

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University of Utah

INTRODUCTION: It is well known and documented that individuals with traumatic spinal cord injuries (SCI) experience a decline in their quality of life. An increase in depression, anxiety, and irritability is common among the majority of individuals with SCI. One reason for these changes is the loss of independence in both day-to-day and extracurricular activities.

Research suggests that patients with SCI who become involved in recreational activities experience a positive change in attitude. Studies show recreational rehabilitation improves mood, combats depression, and increases the feeling of a higher quality of life. Therapists recommend recreation rehabilitation begin as soon as possible to combat changes in mood.

While recreational equipment is widely available for individuals with low-level SCI, high-level SCI (HL-SCI) patient recreation equipment is limited. The majority of outdoor recreation equipment available to HL-SCI patients consists of passive equipment such as running pushchairs, rather than user-controlled equipment. There is significant need for adaptive equipment that allows greater independence to individuals with HL-SCI.

METHODS: Researchers in the Department of Mechanical Engineering have collaborated with the Therapeutic Recreation and Independent Lifestyles (TRAILS) Program of the Rehabilitation Center at the University of Utah Health Care center to answer the call for creation of an adaptive control framework to interface with recreational therapy equipment already in use.

Using a modeling-prototype-feedback approach between patients, therapists, and SCI specialists, the research team has developed a system to bridge the gap between patients and devices to allow patients with SCI the ability to control recreational equipment. The system consists of a microcontroller and hardware interface that provides patients with a customizable solution with quasi-independent control. These improvements stem from a newly created sip and puff system, which allows recreational equipment limitless input and customization for each user, depending on his/her abilities. Other features include compatibility with existing technology, such as wheelchair joystick controls, and wireless therapist override to allow safe equipment operation in the event of a patient emergency.

DISCUSSION: As medical advances increase survivability of HL-SCI, it is imperative that HL-SCI patients have the opportunity to participate in activities similar to those enjoyed before their injuries. Providing a system that enables independence and customization to interface with recreational equipment significantly improves participation. With the new sip and puff technology, HL-SCI patients can enjoy the same activities as friends and family in a recreational setting, which improves sociability and quality of life. Beyond recreation equipment, advances in this field can be adapted to control devices used for day-to-day situations, such as using a computer, watching TV, opening doors, and using other household appliances.

"Person Specific Control System for Adaptive Equipment in Recreational Therapy"

Nicolas Brown, Paige DaBell, Matt Koplin, Keith Schendel, Andrew Merryweather PhD,
Ross Imburgia, Jeffrey Rosenbluth M.D.

INTRODUCTION: The involvement of persons with high-level spinal cord injury (HL-SCI) in recreational therapy is limited by a lack of properly engineered equipment. Adapted recreational equipment for HL-SCI patients often requires appropriate control systems that are easily tailored to an individual's injury level and function. For example, it is not appropriate to use a sip and puff control system when a patient has complete or partial upper body control.

SCIs do not present the same between individuals. Function is largely influenced by location and completeness of the injury. This presents a major challenge in designing adaptable recreational equipment for individuals with HL-SCI. One of the greatest challenges in adapting recreational equipment for individuals with HL-SCI is the level of customization required for each design. Historically, this has resulted in equipment that is prohibitively expensive. In an effort to address these challenges, researchers in the Department of Mechanical Engineering have collaborated with the Therapeutic Recreation and Independent Lifestyles (TRAILS) Program of the Rehabilitation Center at the University of Utah Health Care center.

METHODS: A downhill all-terrain wheelchair (Mountain Chair) was created and evaluated for users with an injury at the 6th cervical vertebrae (C6). Functional limitations include partial/complete paralysis in the hands, legs, and trunk, and degraded wrist flexion, and paralysis in the triceps. Wrist extension and bicep function is only partially affected.

The C6 control system design takes advantage of wrist extension by evaluating user function and setting range of motion values as end-points. Next, wrist position information is fed back to a central control system to manage the proportional Smart Brake System (SBS). Directional control is accomplished using only biceps. A head-switch engages a drive motor when necessary to maneuver obstacles or travel up hill. A Bluetooth based remote control provides a companion with full override of the smart brake system in case of emergency.

DISCUSSION: The modifications and control strategy developed through this work enables individuals with HL-SCI full control over recreational equipment. A Sit-Ski, Sailing Kayak, and Recumbent Bike are all undergoing transformation to accept derivations of this common control system. Research shows that recreational therapy increases independence and quality of life and includes benefits during transition from injury recovery to injury adaptation. Giving control at the injury level improves natural reflexes and enables the patient to feel independent again.

"TEN-PIN BOWLING ASSISTIVE DEVICE FOR THE VISUALLY IMPAIRED"

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Abstract

Visual Disability is a factor that can hamper day to day activities. It is estimated that over 7 million people are having some form of visual disability in the United States according to a survey conducted by American foundation for the blind in 2013. Blind people also have difficulty with respect to various sporting activities. One such activity is bowling.
Bowling is a popular sport, and it is done by a wide variety of people, even people who are visually impaired. In fact, blind bowling is quite popular with leagues all over the world. Bowling has been adapted to enable visually impaired and sighted friends and family to engage in together and have fun. Blind bowling has proven to be very popular and requires very little modifications. The existing system enables the blind and visually impaired people to bowl through the method of guidance from another normal person with good eyesight and a guide rail. Our device aims to eliminate the need for sighted assistance so as to make the bowling experience more independent and enjoyable for the visually impaired.

The working model of the bowling system was designed and constructed which contained our assistive device. The real time data about the number & position of pins which had fallen and the number & position of pins which remain after the first shot of bowling round using a camera with optimum resolution located above the pins. The data was processed using the concept of image processing which used the data from the images shot to the micro-controllers to synchronize the real time system with the tactile display. A solenoid actuator was used to generate output of the information thereby enabling the blind bowler to sense which pins have fallen and which will remain after the first trial.