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Conference Proceedings

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6th Conference of the Centre for Research in Occupational Safety and Health (CROSH)

Sudbury, ON
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Human factors for the future workforce

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Introduction

The UK-based Chartered Institute of Ergonomics and Human Factors will celebrate its 70th year in 2019. Through those 7 decades the organization has rebranded itself (The Ergonomics Research Society, to Ergonomics Society, to Institute) and been at the forefront of developing the discipline of Ergonomics and Human Factors. Despite the long-established legacy, there is no indication that the work of ergonomists is finished.

The Association of Canadian Ergonomists (1) defines ergonomics as:
'*…the scientific discipline concerned with the interactions between humans and other elements of a system (environment, people and objects) with the goal of optimizing human well being and overall system performance.'*
This means that in order to achieve the goal of optimization, an understanding of the environment, the people and the objects are required. One of the reasons why there will remain an ongoing need for professional ergonomists is that environments develop, people change, and new objects are invented relentlessly. These characteristics are at the very core of modern society.

Projecting forwards there is a need to consider future users of future products. There is an increasing demand for consideration of product consequences far further into the future that once was the case. For example, many countries are faced with legacy costs of decommissioning nuclear plants that exceed initial build costs, have durations longer than the service life, are not designed for deconstruction and have naturally deteriorated over the years (2). These issues are not unique to nuclear (3), and are becoming increasingly challenged at the concept phase. Could such legacy issues occur for products, large and small, being conceived today?

Legacy of Historical Technologies

Throughout history new technologies have been driven by user needs, user desires, and new possibilities. Behind these were people generating ideas and with the drive and knowledge to take them to market. One example is in the pocket watch of the 16th century (4). The earliest known depiction of the pocket watch appears in a portrait of Cosimo I de Medici, Duke of Florence, c.1560. The object was developed on the user need for a timepiece, but the desirability was such that the influential Duke chose to be depicted with it in a significant portrait. It could only be manufactured due to new technologies in materials, miniaturization, and a demand from the market for the development of complex engineering. The inaccuracy was such that it did not need a minute hand.

Watchmakers were an early example of ergonomic adaptation for the workplace, providing magnifying lenses, adjustable workstations, precision tools and support for wrists and hands (Figure 1). These represented some of the highest levels of complexity and precision of their day and required new workplace concepts in order to achieve the required levels of performance.

Figure 1 Watchmaker using traditional tools (image: 1949, Elgin National Watch Company, GFDL license)

Modern 'smart' watches have been driven by user needs (e.g. information connection), user desires (e.g. fashion and self-identification as a 'smart' person), and new possibilities (e.g. battery, screen, electronics). However, like the 16th century pocket watch, some elements are not particularly accurate. Heart rate and energy expenditure features in particular can prove unreliable, particularly for short high-intensity bouts of exercise (5). There is an acceptance that the feature is a 'work in progress' but is useful nonetheless.

Common systems can allow users to develop a stereotype which can often be useful. For example, modern accepted iconography for digital systems refer to extinct or rare objects ranging from folders and floppy discs, through to telephone handsets or clipboards. However, the processes represented are still relevant and the icons tap into the core user needs and user desires, but exploit new technological possibilities.

Industry 4.0 / Cyber-Physical Systems

There is a current move towards industrial digitization, where digital systems will become ubiquitous across all industrial applications. This has been expressed in terms of the '4th Industrial Revolution', or Industry 4.0. Industrial development has been classified thus:

- 1st Industrial Revolution Mechanization, water power, steam power
- 2nd Industrial Revolution Mass production, assembly lines, electricity
- 3rd Industrial Revolution Computer control and automation
- 4th Industrial Revolution Cyber-physical systems, AI, Internet of Industrial Things

The move towards cyber-physical systems in the workplace means that robots will become more intelligent and potentially adaptable using AI / deep learning. They will be more capable of carrying out more complex tasks for smaller volume processes thereby increasing their versatility. By being cloud networked, data streams can be accessed from anywhere and production control manipulated remotely. Maier (CEO, Siemens UK) stated: *Emerging technology breakthroughs in fields such as AI, robotics, and the Internet of Things are significant in their own right. However, it is the convergence of these Industrial Digital Technologies that really turbo-charges their impact* (6). Hence, Industry 4.0 is about the integration of other technologies including the internet, computing, robotics, big data, neural networks, and ergonomics / human factors.

The fear that jobs will be 'taken away' from the future industrial worker is naïve, although it is true that some existing manual tasks will, in future, be completed by machines and individual cases of human redundancy will inevitably prove controversial. Future jobs will continue to evolve, as they have throughout the centuries. Future workers will be employed in an environment where all businesses will become increasingly digitized. Cobotics will become the norm whereby humans will work alongside robots. Cobots have already been introduced in some warehouses to assist with picking and transport (e.g. Next clothing; Arla milk) and there is a move towards including robots in manufacturing. This presents a challenge of situation awareness both for the human and for the AI of the robot.

Situation Awareness concerns the ability of the human to have a coherent cognitive model of the world around them now, and project that model into the future (7). Under normal operation the behaviors of robots are usually easy to predict for an experienced observer, but this will become increasingly difficult as AI makes the machines more adaptable and responsive (8). Experimental cobots, such as the 'Baxter' (Figure 2) have methods of providing cues to a user, such as a screen showing 'eyes' that can track to the next target, and safety systems to ensure that it can feed back obstacle (i.e. human) collision. With AI and deep learning, it is possible for individual robots to develop their own behavioral personality traits in response to the individual behaviors of those interacting with them. In future, not only will the humans need to be trained to work with the robots but the robot AI will need to be trained to work with the humans.

Figure 2 The author with a 'Baxter' robot designed to work closely with humans.

Wearables are becoming more accepted in the workplace. Although location and basic physiological monitoring are growing in popularity, the longer term could see a normalization of 'bodyhacking' where implants are placed in the body or under the skin for convenience, rather than medical uses. This opens up new possibilities in interface design as well as trust and security.

Future society, values and needs

Ergonomists have been adapting workspaces to accommodate a workforce that is getting older and having to adapt design tools to be appropriate for this changing population (9). There is an increasing need for through-life training in order to keep up with technological advances and to build the skills base. The shape of education and CPD will need to adapt to meet this skills crisis (10). Taking extremes of age and experience stereotypes / personae, a 'digital native' service engineer could be adept at operating a tablet-type interface but with little understanding of underlying mechanics, whereas an experienced service engineer approaching retirement could have a far clearer understanding of the item being serviced but less adept with the interface. Human Factors principles will be vital in ensuring that 'Digital Twin' models and augmented reality systems are usable by those with the valuable field experience.

For major projects with long design / implementation / reuse / removal cycles present a significant challenge to human factors. There are infrastructure projects with a legacy that will extend beyond the life of those who design them and may run into hundreds or thousands of years. Do designers have a responsibility to consider the workers using the object in 1, 10, 100, 1000, 10000 years' time? There are immediate issues relating to re-use of components in a washing machine, but issues increase in complexity in considering design for deconstruction through mobile phones, aircraft carriers, power stations, dams, cathedrals, and nuclear waste stores.

Whilst it is speculation to predict the details of future technologies and the shape of future societies 1000 years into the future, it is possible to project some aspects of future value and future needs. The oldest institutions in the world include educational and religious establishments, and these

continue to have relevance as judged by number of members. Prehistoric art depicts humans striving for meaning and survival, and living in communities. The oldest texts refer to family and community groups. Today's social networking, founded on human interaction, attracts a significant minority of the world population with 2.2, 1.5, and 1.0 billion monthly users of Facebook, WhatsApp, and WeChat respectively. Social values, relationships, dealing with birth and death, and the drive for knowledge and novelty are therefore likely to remain a priority for humans. Human physiology will adapt slowly, although differences in nutrition and healthcare could alter how that physiology is manifested.

Ways to communicate 10,000 years into the future have been considered in the context of signage for buried hazardous waste that could be forgotten, lost and then rediscovered by a future society (11). How could this future culture be warned of hazards? Amongst suggestions were the creation of a myth or a religion that could portray the risk over the generations, as these can have more longevity than culture, language or political frameworks (12). The human factors of signage for workers from unknown cultures is a fascinating challenge.

Conclusion

Human factors experts and ergonomists have a responsibility to consider the breadth of population for whom they design. They need to consider changes in the workplace and the working population that are predictable; there is a debate to be had over how many generations into the future they should be designing for.

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Prévention équitable de l'incapacité de travail auprès des adolescentes et adolescents faiblement qualifiées par la conception *d'environnements capacitants* d'apprentissage

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Il est plus difficile pour les adolescentes et les adolescents qui éprouvent des difficultés d'apprentissage de terminer leurs études avec un diplôme (Rousseau et Bergeron, 2017). Il est également reconnu que les jeunes adultes sans diplôme se retrouvent plus souvent sans emploi que leurs pairs diplômés (EPA, 2015). Cet écart du taux d'emploi entre les diplômés et les non diplômés est plus élevé pour les femmes (taux d'emploi 2,6 fois supérieur pour les hommes diplômés et 4 fois supérieur pour les femmes). Or la possibilité de travailler à l'âge adulte est une mesure importante de réduction des écarts de pauvreté et d'inclusion sociale (Carcillo et al., 2017). Par ailleurs, les jeunes faiblement qualifiés sont plus à risque de subir une lésion professionnelle, ce qui ajoute un facteur de comorbidité quant aux possibilités d'insertion professionnelle durable pour cette population (Saunders et al., 2017; Lay et al., 2017, Breslin et al., 2017). La nature de l'emploi et les conditions de travail dans les métiers peu spécialisés expliquent les risques accrus de se blesser (emploi manuel, cumul de contraintes physiques et organisationnelles). Le type de lésions professionnelles auxquelles ces jeunes sont exposés est différente entre les jeunes hommes et femmes (Laberge et al., 2010; Laberge et al., 2012).

Dans la province de Québec, un Parcours de Formation Axée sur l'Emploi (PFAE) a été mis sur pied en 2008 pour aider les élèves handicapés ou qui éprouvent des difficultés d'apprentissage et d'adaptation (HDAA) à développer leur employabilité. Ce parcours s'adresse aux élèves de 15 à 21 ans qui sont en échec scolaire et qui ne peuvent poursuivre leur cheminement régulier au deuxième cycle du secondaire (MELS, programme de formation à l'école québécoise, 2008). L'offre du PFAE répond à une demande de diversification des parcours pour soutenir la réussite des élèves HDAA (Québec, politique de l'adaptation scolaire, 1999), en permettant à ces élèves de réussir autrement et de développer des compétences qui leur permettra d'accéder au marché du travail. Dans ce parcours, les modalités pédagogiques privilégiées sont basées sur l'alternance études – travail et sur la différenciation pédagogique (plan de formation adapté aux besoins individualisés de chaque personne). À ce sujet, il existe une littérature abondante recensée par Mlynaryk et al. (2017) qui démontre que, pour les personnes avec incapacité, la possibilité de réaliser des stages de pré-emploi est une mesure favorisant l'intégration au marché du travail. Le ministère propose un plan de formation aux jeunes qui empruntent le PFAE pour plus de 130 métiers semi-spécialisés. Entre 10,000 et 15,000 jeunes sont inscrits chaque année dans le PFAE. La population est majoritairement masculine, avec environ les deux tiers d'élèves inscrits qui sont des hommes. Toutefois, le programme propose une approche de différenciation et dans cette optique, il nous apparaît opportun de favoriser des interventions sensibles au genre.

L'objectif de la conférence est de présenter quelques résultats découlant d'une programmation de recherche qui se déploie depuis 10 ans qui porte sur la prévention de l'incapacité de travail auprès des élèves du PFAE. La programmation tient compte du sexe et du genre des élèves et des acteurs du système de formation. Elle s'est amorcée au moment de la mise en place du PFAE en 2007. Elle s'est centrée dès le départ sur la conduite de recherches-intervention visant la conception d'environnements capacitants adaptés à cette clientèle, selon deux grands volets : 1) la prévention des lésions professionnelles et 2) le développement des compétences professionnelles en vue d'accroitre les possibilités d'emploi. Les interventions développées visent les jeunes, tout autant

que les acteurs qui les accompagnent dans leur démarche d'insertion professionnelle, soit les enseignants responsables des stages et les milieux de travail qui les accueillent. Les thématiques de recherche et le développement d'interventions s'est fait en collaboration avec des acteurs clés, réunis en comité de suivi depuis le démarrage de la programmation (ministère de l'Éducation, Fédération des commissions scolaires du Québec, Fédération des syndicats de l'enseignement, Institut des troubles d'apprentissage).

La démarche mise de l'avant s'inspire de l'ergonomie constructive. Il s'agit d'une filière de l'ergonomie qui s'intéresse au développement des personnes et des organisations par la conception d'environnements capacitants (Falzon, 2013). Cette discipline s'appuie sur le concept de « capabilité » proposé par Amartya Sen (2001) qui soutient que pour qu'une personne réussisse, il ne suffit pas qu'elle ait appris une tâche, mais que l'activité mise en œuvre dans cette tâche lui permettent de développer son potentiel et de préserver sa santé. Un environnement capacitant permet aussi aux organisations de se développer et d'être performante. Dans ce courant, l'ergonome ne s'intéresse donc pas seulement aux situations de travail actuelles, mais au cheminement des personnes et aux parcours professionnels, tout autant qu'aux prospections de l'état de santé qui évoluera en fonction de ces parcours. Pour qu'un environnement soit capacitant, il doit 1) prendre en compte les différences entre les personnes, hommes et femmes et 2) compenser pour les déficiences individuelles (par exemple liées aux incapacités).

Les méthodes de recherche qui ont été mises de l'avant pour réaliser la programmation de recherche sont issues du domaine de l'ergonomie de l'activité. Elles misent sur la collecte de données de sources multiples visant à caractériser l'activité de travail et ses déterminants. Elles sont de nature tant qualitative que quantitative, avec une préférence pour les données de terrain (observations du travail en situation réelle, mesures des paramètres de l'activité, verbalisations sur le travail, entretiens d'autoconfrontation).

La conférence abordera les différents défis qui ont été soulevés au cours des 10 dernières années de recherche, en mettant en lumière les préoccupations des partenaires, les recherches réalisées, ainsi que les recommandations qui en ont découlé. Parmi les résultats présentés, des exemples d'outils pédagogiques qui permettent la différenciation pédagogique en milieu de travail seront présentés. Ces outils ont été développés en prenant en considération un cadre conceptuel d'analyse de l'activité de travail utilisé en ergonomie : le modèle de régulation d'une personne en activité (Vézina, 2001; St-Vincent et al., 2011). Lors de la conférence, trois cibles d'action pour mieux tenir compte des parcours d'insertion des hommes et des femmes au PFAE seront discutés. En effet, malgré qu'elles soient moins nombreuses au PFAE, des défis d'insertion professionnelle spécifiques se posent pour les jeunes femmes.

Défaire les préconceptions liées aux facteurs de risque de lésion selon le genre

Au PFAE, la majorité des métiers proposés par le ministère sont plutôt associés à des intérêts typiques masculins (ex : installateur de pneus, ouvrier dans un atelier de bois, manutentionnaire, etc.) (Laberge et al., 2010, ERA, 2015). En outre, les différentes personnes impliquées dans la supervision de stages entretiennent des préjugés quant aux mécanismes de lésion préférentiellement attribués aux hommes, comme les caractéristiques comportementales liées à la témérité ou la prise de risque volontaire (Laberge et al. 2012). Cela se manifeste par des demandes répétées de la part des partenaires de prioriser la prévention des accidents imminents qui pourraient survenir en stage, avec des exemples tirés d'emplois masculins, et un intérêt pour le développement d'interventions de sensibilisation visant surtout les attitudes des jeunes hommes. Pour montrer l'importance de considérer aussi les risques associés aux métiers plus féminins, nous

avons réalisé des analyses différenciées selon le genre et montré l'existence de certaines exigences et conditions de travail propres aux femmes. Ces analyses ont permis de faire évoluer la perception des risques pour les métiers choisis par les jeunes femmes et d'offrir des activités d'apprentissage et de prévention équitables.

Différencier les activités d'apprentissage selon le genre des élèves

Des enjeux différenciés d'exposition aux facteurs de risque de lésion se posent entre les métiers choisis par les hommes (ex. accidents liés à la manipulation d'outils et machinerie) et les métiers choisis par les femmes (ex. troubles musculosquelettiques et risques psychosociaux associés au travail statique ou répétitif et travail avec la clientèle) (Laberge et al., 2012). En montrant que les jeunes hommes étaient majoritairement exposés à des risques d'accident à court terme et que les jeunes femmes étaient plutôt exposées à des risques de troubles musculosquelettiques (TMS) à plus long terme, notre équipe de recherche a proposé une démarche de prévention comprenant le développement d'une culture durable de prévention. Des idées de situations d'apprentissage liés à des catégories variées de métier et de facteurs de risque ont été intégrées à aux recommandations et outils développés.

Tenir compte des rôles et rapports sociaux liés à la supervision de stage : Genres croisés des enseignant.es superviseurs de stage et des interlocuteur.trices en milieu de stage

Dans une étude portant sur la prise en charge de la SST par les enseignantes et enseignants du PFAE, il a été montré que les rôles sociaux de genre se manifestaient aussi lors de la relation triangulaire de supervision au PFAE (élève, enseignant.e, superviseur en entreprise). En effet, les dynamiques sociales de supervision sont modulées par le fait que la majorité des interlocuteurs en entreprise est un homme, alors que la majorité du personnel enseignant affecté à la supervision des stages est une femme. En outre, le domaine de la prévention en SST a été traditionnellement plus souvent porté par des hommes. Par conséquent, il est fréquent que la crédibilité des enseignantes à ce sujet soit remise en question par les entreprises (Laberge et al., 2017). Plusieurs aspects liés au genre ont pu être décrits dans la dynamique de supervision, dont le fait que les femmes enseignantes ont souvent l'impression d'être imposteur lorsqu'elles abordent le sujet de la SST avec les superviseurs masculins auxquels elles se réfèrent en entreprise. Ces résultats ont mené à des recommandations pour favoriser le pouvoir d'agir et le sentiment de compétence des enseignantes superviseur de stage lorsqu'elles souhaitent établir un dialogue sur la SST avec les entreprises de stage.

En résumé, la conférence sera l'occasion de discuter des apports de l'ergonomie au développement d'environnements capacitants pour favoriser une meilleure intégration professionnelle en santé des jeunes faiblement qualifiés, avec un souci pour l'équité entre les hommes et les femmes. Les problématiques de recherche et les résultats obtenus pourront trouver écho dans d'autres types de situation qui concernent la prévention des lésions professionnelles chez les jeunes, les relations triangulaires d'emploi (ex. agences de placement), le développement de l'employabilité auprès des personnes présentant des incapacités et même, le développement vocationnel lors de situations de réadaptation professionnelle complexe avec perte de lien d'emploi.

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What is Situational Awareness and why does it matter?

Richard Gasaway, PhD, EFO, CFO

Most workers know, intuitively, that strong situational awareness is an important aspect of worksite safety. However, many do not understand what situational awareness is, how it is developed and how it can erode while working in a high risk, high consequence environment. This talk will discuss situational awareness and explain how it is developed. Specific examples of barriers that can erode awareness will be shared.

Reaping what we sow: Engaging workers and stakeholders in agricultural health research

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Introduction

Musculoskeletal disorders in agriculture: Scope of the issue

According to the ILO's Programme on Occupational Safety and Health, agriculture "…is one of the most hazardous occupations worldwide"(1). According to the Canadian Agricultural census, there are over 230,000 farms in Canada and 44,329 of these reside in Saskatchewan, producing commodities like grain, oil seeds, and pulses, as well as poultry, dairy, beef, and pork (2). Operating these farms requires a variety of work tasks: animal care; operation of planting and harvesting machinery; equipment and building maintenance. The physical exposures of farm work combine with a unique employment context that can deliver a large cumulative lifetime dose. Farm work often starts at a very young age and continues beyond typical retirement age (3, 4); more than half of Canadian farm operators work more than 40 hours per week on their farm, and 48% also work off the farm (2).

Unsurprisingly, these work exposures are associated with elevated rates of musculoskeletal disorders (MSD). A systematic review found prevalence MSD is consistently higher in farmers than non-farmer populations, with 12 month prevalence as high as 90%. The majority of surveillance studies have focused on low back disorders (LBD), which, as in other industries, represent the bulk of MSD in farming (3, 5, 6). Across studies of many types of farming, the average lifetime prevalence of low back pain was 75% (95% CI = 67-82) and average one-year prevalence was 48% (95%CI = 42-55) (3). A more recent publication shows Saskatchewan has slightly higher estimates back pain: 57% for 12-month prevalence (7). The result can be measured not only in human suffering and health care costs, but also in economic productivity; in a study of workers on intensive Canadian swine farms, 58% of respondents reported having their activities interrupted by MSD symptoms (8). MSD are the most common cause of work absence in self-employed farmers, (9) and farm income has been shown to be lower when operators have MSD-related disability (10). A survey of Iowa farmers showed they were 8 times more likely to make major changes in their work activities as a result of low back pain than the general working population (11).

Challenges in agricultural health research

Despite the demonstrated need for effective intervention, research in agriculture remains challenging, with the greatest challenges likely aligning with the most understudied populations (12). The need for prevention research in agriculture has been widely acknowledged (13, 14), but few ergonomic interventions have been systematically evaluated in agricultural contexts relative to other industries. Part of the challenge is that there is a broad variety of commodities, farm practices, topography, climate, tools, machinery, and work environments (12) that defies generalizing findings at the industry or even occupation level.

In Canada, most small-scale 'family' farms do not reach the employment threshold to require workers compensation board insurance, and so they elect not to purchase it. This leads to a lack of industry-level administrative data on injury rate and limits research surveillance. Efforts to address this have resulted in the Canadian Agricultural Injury Report (CAIR) (15), as well as cohort studies using postal surveys to investigate farm injury rates {McMillan, 2015 #1445}.

Despite these efforts, the additional challenge of geographically dispersed farms makes on-farm ergonomic assessment rare. The average farm size is 1135 acres in Manitoba and 1784 acres in Saskatchewan, which translates into many kilometers of travel between farms. These farms also typically have few employees, so targeting typical research sample sizes involves communication, trust-building, and recruitment with multiple worksites, followed by extensive travel. This is in contrast to the more typical occupational research sampling frame achieved by approaching a single employer or union and accessing a large group of potential participants.

Lastly, there can be considerable challenges for researchers to gain credibility with an occupational group who identifies strongly with the history and culture of their vocation. Farmers often refer to their work as 'more than a job' and 'way of life' that permeates all aspects of family and work life, often in an inter-generational way (16). If farmers consider expertise to be acquired through experience, the 'outsider' status of researchers may not be seen to offer much in the way of understanding the work context or developing realistic solutions.

Philosophy and Approach

Clearly there are multiple diverse challenges in addressing health and safety in agriculture, and overcoming these challenges requires a unique set of approaches. Engaging partners in ergonomics research can take many forms, and these 'collaboration' strategies come by many names: participatory action research, community-engaged research, and participatory ergonomics. The projects undertaken by the University of Saskatchewan Ergonomics Lab have used CIHR's integrated knowledge translation (iKT) approach (17). As with the other approaches above, iKT characterized by engaging stakeholders throughout the research process/project; there is collaboration of researchers and knowledge users to shape the research process starting with research questions and methodology through to interpreting and disseminating results. Forming successful partnerships with key stakeholders to conduct this research produces results that are more relevant and more likely to be put into practice – an important outcome in ergonomics research or professional consulting.

The main mechanism for iKTE at the University of Saskatchewan Ergonomics Lab is the Stakeholder Advisory Group (SAG). Each industry area or research topic has its own SAG comprised of members who will help direct the research and interpret findings: inter-disciplinary researchers (usually co-investigators on the project); OSH professionals and NGOs such as WorkSafe Saskatchewan and the Prairie Agricultural Machinery Institute (a non-profit applied research institute whose mandate to determine and promote best practices in agriculture); policy makers such as Ministries of Agriculture and Department of Labour Relations and Workplace Safety; and industry stakeholders including representatives from the University of Saskatchewan Research Farms and producers from the surrounding community. While many of these stakeholders participate in the course of their usual work, for farm owners, agricultural workers, and other producers the SAG involves travel, reading, and meeting activities outside of their regular work. Cultivating relationships with producers requires building trust and making the research relevant and responsive to their needs so that the demands of participation are outweighed by the benefits. It also requires consideration of some of the potential barriers to producers' participation: avoiding scheduling during busy growing season, travel and parking costs, and the less tangible aspect of feeling comfortable, welcomed, valued, and included in research discussions.

The SAGs are engaged at key stages in the research process. In addition to soliciting specific input from specific members during development of research questions and grant proposals, we typically plan at least two in-person meetings with a SAG: 1) a preliminary meeting to discuss and refine data collection protocols and specific research questions, 2) an interpretation meeting once data has

been collected, processed, and summarized to discuss the findings and brainstorm how best to disseminate it. Throughout this process, workers and producers shift from 'subjects/participants' to 'research partners'; this can involve intellectual contributions that substantially impact the goals and methodology of the study and result in co-authorship.

Results and Discussion

This section describes some examples of ergonomics and occupational health projects that have used an integrated knowledge translation approach to conduct research.

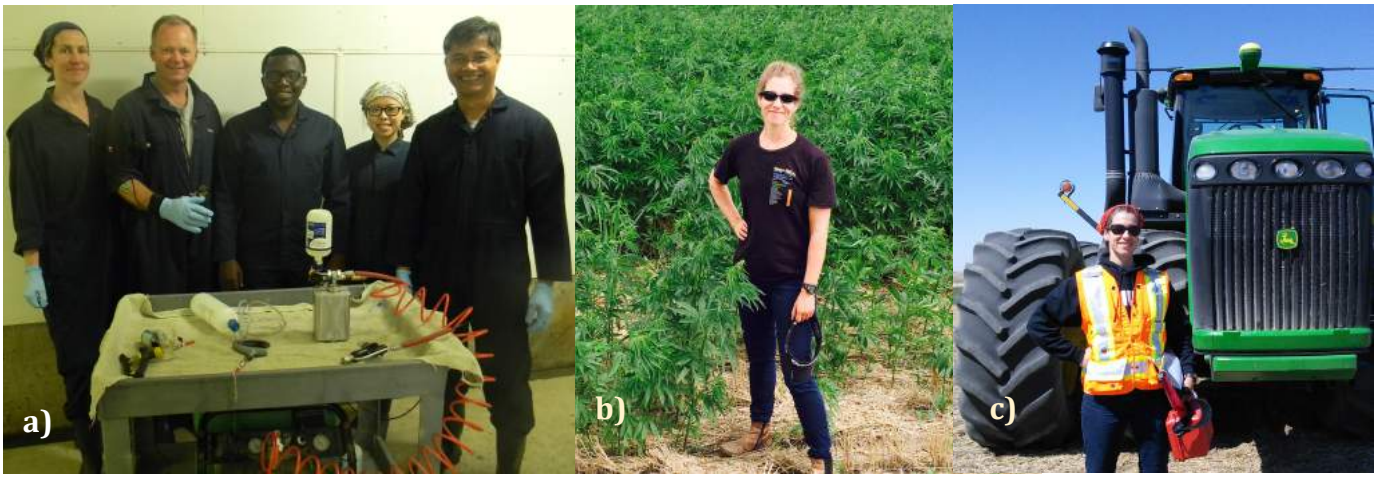

Figure 3: The author conducting research at agricultural workplaces: a) intensive swine production with measurement team (L to R) Catherine Trask, Lee Whittington, Olugbenga Adebayo, Xiaoke Zeng, and Bernardo Predicala; b) outdoor hemp production at a family farm; c) whole body vibration assessment on heavy agricultural machinery

Farmers Back Study

Lower back disorders are an important public health issue among farmers, and this study aimed to measure exposure to back pain risk factors on Saskatchewan farms. This involved visiting 54 farmers on 22 farms throughout the growing season to measure machinery vibration, manual handling, and trunk posture during regular work days. On the advice of the SAG, we also conducted interviews with farmers to learn about the impact of the pain and disability that lower back disorders have, as well as examining the preventative measures and solutions that farmers implement to prevent lower back pain. The SAG was also instrumental in shaping the dissemination plans, resulting in summaries of the information being sent out to 27,000 Saskatchewan farms and presented at agricultural events like the Farm Progress Show and Agribition.

Comprehensive evaluation of needle-less injection in swine barns

Over the past several years, the Canadian pork industry has rapidly developed from small family farms into large-scale, modernized production systems that required major process changes and technological advancements. These technology and process changes may impact worker health and safety, but these effects can be difficult to quantify especially when needed to make business decisions on mitigation strategies. In order to evaluate workplace health and safety relative to improvements in productivity, this project conducted a comprehensive evaluation of needle-less injection devices; the needle-less devices were evaluated in terms of injury rates pre- and post-implementation, worker preference, productivity and upper extremity biomechanics compared to traditional needles, and overall cost. On the advice of the SAG, the project goals were expanded to develop a suite of performance measures that can be generalized to any new workplace technology.

The result is an online tool that estimates cost-benefit based on user inputs regarding the main considerations for adopting a new tool: equipment purchase, productivity, risk for injury, maintenance needs, and labour force considerations like turnover and training.

Occupational health and safety for indoor marijuana production

Changing regulatory environment means marijuana production will move from an illegally-grown crop to a potentially common indoor crop. Because it has historically been illegal, there is very little research on the occupational hazards or effective prevention strategies for this industry. As a result, occupational health and safety professionals are unlikely to be familiar with industry needs. There is a need to better understand the OSH knowledge of marijuana production workers and their perceptions of OSH regulations, OSH controls, and sources of OSH information. The goals of this study were to conduct interviews and facility tours with marijuana producers to 1) describe production tasks and identify potential hazards related to these tasks; and 2) determine production workers' perceptions of, and information sources for, OSH hazards and controls in their sector.

Many workers in this sector have historically been secretive and reluctant to share details about their work and occupational health and safety practices. Therefore, building trusting relationships with stakeholders was vital and in this case involved cultivating existing contacts in the industry, working with them on the study proposal, and enlisting them to help with additional recruitment. To recognize contributions to the study design and findings, one of these initial contacts and study participants is also a co-author on a journal manuscript.

Relevance to Practitioners

This paper posits that ergonomics projects (and all occupational health research) are more relevant and applicable when related stakeholders are engaged throughout the process, and gives several examples from the challenging context of the agricultural industry. Here is a summary of considerations for incorporating this strategy in an ergonomics project:

1) Do not under-estimate the time or budget required to do this well. Stakeholders will take time to get up to speed, and if that takes time away from their work an honorarium may be appropriate.
2) It's helpful to cultivate relationships with stakeholders, and not just when you need something from them. Prioritize frequent communication to stakeholders by report back on findings, providing updates on funding applications and project progress, and check-in just to say hi and touch base on what their current issues are.
3) Consider formalizing partnerships and involvement with stakeholders. This may involve including stakeholders as co-authors or co-presenters, delivering findings in formats they select and that serve their constituency.
4) Go to the group you trust for ideas and direction; they will tell you what is important to them, and when the project is meaningful they will want to be involved in the work.

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WORKSHOPS

Day 1 – Oct 15th	
09:00-16:30	Facilitators: Dr. Judy Village and Dr. Patrick Neumann How to Integrate Ergonomics into the Engineering Design Process
Day 2 – Oct 16th	
14:45-16:15	Facilitator: Tanya Morose Applying for certification with CCCPE and maintaining certification
Day 3 – Oct 17	
10:15-12:00	Facilitator: Vance McPherson Applying adult learning principles: ensuring success to your health and safety education and training sessions
15:15-16:45	Facilitator: Lucy Hart Office ergonomics 2018: unpacking the new CSAz412 standard
Day 4 – Oct 18th	
10:30-12:00 13:00-14:30	Facilitator: Richard Wells Development of a new MSD Prevention Guide for Ontario
13:00-14:30	Facilitator: Allison Stephens Moving from Lab to Industry : How to measure force and assess it for acceptability
13:00-14:30	Facilitator: Trevor Schell Can ergonomists do more harm than good? How to avoid costly mistakes for your clients.

How to integrate ergonomics into the engineering design process

Dr. Judy Village[1], Dr. Patrick Neumann[2]

[1]School of Population and Public Health UBC, Vancouver, BC, Canada
[2]Department of Mechanical and Industrial Engineering, Ryerson University, Toronto, Ontario

Workshop Overview

In this one-day workshop, participants will learn about how human factors/ergonomics can be effectively integrated into the engineering design process to improve not only worker health, but business performance. Participants will learn about HF and the industrialization process and various production design issues and strategies. They will also learn how to link HF to corporate strategies to gain support from senior management for HF. Ergonomists will be challenged to think about gaps in their understanding of engineering design language, tools and techniques and strategize to find ways to gain this information in order to work more effectively on a team with engineers. Common business improvement strategies such as "Lean" and "Six Sigma" will be discussed highlighting ways that HF can enhance these strategies. Several engineering design tools that have been adapted for HF will be presented (such as the failure mode effects analysis, and design for assembly). Participants will learn ways to work with engineering groups to adapt other engineering design tools and techniques to include HF.

Objectives of the Workshop:

At the end of this workshop, participants will be able to:

- Explain why ergonomics is typically left out of the engineering design process
- Describe typical design processes for how work is organized
- Describe ways to integrate ergonomics into the engineering design process based on the design for human factors (HF) theory
- Explain key principles of lean manufacturing and how HF can be integrated into lean
- Use tools to navigate the corporate strategy (cognitive mapping) and the design process (process mapping)
- Show how other engineering tools can be adapted to include ergonomics (such as failure mode effects analysis, and design for assembly)
- Provide ergonomic design guidelines and other information to engineers in a format that is most effective for their use

Duration of the Workshop:

Full Day

Brief Biography of the Facilitator:

Judy Village is an Adjunct Professor in the School of Population and Public Health at the University of British Columbia and a Certified Professional Ergonomist in Canada and the US. She has more than 25 years of experience conducting research, consulting and teaching in musculoskeletal injury

prevention. She earned her Ph.D. in the Department of Mechanical and Industrial Engineering at Ryerson University. The goal of her research, working with a large electronics company, was to work with engineers and human factors specialists to find ways to integrate human factors into design of their assembly production systems. Her publication in the Ergonomics Journal describing the three-year action research collaboration recently won the 2015 Liberty Mutual Award for the paper most advancing the field of ergonomics..

Patrick Neumann is an Associate Professor in the Department of Mechanical and Industrial Engineering of Ryerson University. He holds a limited engineering license in Ontario, the European Ergonomist designation and a doctoral degree in design science from Lund University in Sweden. His research focuses on integrating human factors into the design and management of operations for sustainable competitive advantage through improvements in productivity, quality and employee competence development.

Applying for Certification with CCCPE and Maintaining Certification

Tanya Morose, MSc, CCPE, CRSP[1,2]
[1]Public Services Health and Safety Association, Toronto, Ontario, Canada
[2]Canadian College for the Certification of Professional Ergonomists, Renfrew, Ontario, Canada

Workshop Overview

In this interactive workshop, representatives of the Board of the Canadian College for the Certification of Professional Ergonomists (CCCPE) will provide an overview of the application requirements and the application process for Associate Ergonomist (AE) and Canadian Certified Professional Ergonomist (CCPE) designations. Tips to improve the chances of a successful application will be provided.

Once the CCPE designation is awarded it is the responsibility of the certificant to participate in continuing education and maintain an active professional practice as an ergonomist in order to maintain their certification. The Continuance of Certification requirements and process will be reviewed. Tips to maximize accumulation of points during the CCPE's 5 year CoC period and track progress for successful CoC submissions will be proved.

Participants are encouraged to review the Continuance of Certification and/or CCCPE Application kit prior to attending the session in order to engage in a discussion and question/answer period with board members.

Objectives of the Workshop:

- Participants will gain an understanding of the application requirements for the AE and CCPE designations
- Participants will gain an understanding of the application process, important deadlines and timelines for the CCCPE Board's decision on the application status.
- Receive tips from seasoned board members to increase the chances of a successful AE, CCPE or CoC submission

Duration of the Workshop: 90 minutes

Brief Biography of the Facilitator:

Tanya is a Canadian Certified Professional Ergonomist (CCPE) and Canadian Registered Safety Professional (CRSP). She has worked in a wide range of industries and brings over 18 years of consulting experience to PSHSA. Prior to joining PSHSA, Tanya was involved in clients' ergonomics programs including reviews of new production lines in the design phase, workstation assessments, and job suitability evaluations for return-to-work. In her current role as the Police Services Specialist at PSHSA, Tanya provides support to police services in their injury and illness prevention efforts.

Tanya earned her Masters of Science in Kinesiology from the University of Waterloo and Occupational Health and Safety certificate from Ryerson University. She is on the Executive of the Golden Triangle Canadian Society of Safety Engineers (CSSE) chapter and is a current board member and past president of the Canadian College for the Certification of Professional Ergonomists (CCCPE).

Applying Adult learning Principles: Ensuring success to your H&S education and training sessions

Natalie Carscadden, BSC, CCPE, CRSP[1], Vance McPherson, MEd[1]
[1]Vance McPherson MEd, HSN, Sudbury Ontario Canada

Workshop Overview

What are the most effective, efficient ways to teach health and safety topics to adults? How can training go beyond knowledge transfer and help create a culture of safety? What techniques will move you past compliance towards *lasting change?* This workshop will provide you with some basic principles and tools to facilitate successful training sessions for adult learners. Participants will walk away from this half-day workshop with a variety of ready-to-use tools and templates, and design documents for a training program that they can implement immediately.

Objectives of the Workshop:

By the end of this workshop, participants will:	Section Focus Question
1) Assess the need for *effective* health and safety training	Do you want compliance, or culture?
2) Distinguish outcomes, objectives, and competencies	Outcomes/objectives… who cares?
3) Develop an operational definition of *learning*	Can learning last?
4) Review techniques that promote memory retention in adults	What can be done to promote learning and retention?
5) Distinguish cognitive, affective, and psychomotor (knowledge/attitude/skill) outcomes	What about hard skills and soft skills?
6) Review psychomotor domain (hands-on) techniques	What can be done to promote specific *actions*?
7) Recognize affective domain techniques as the key to culture change	How can you ingrain new *attitudes*?
8) Assess the efficacy of online learning for a variety of workplace training scenarios	What can / should go online?
9) Perform an outcome analysis for a training problem	Putting it together: Establishing an effective training plan in 30 minutes
10) Design an authentic evaluation for a training problem	
11) Blueprint a training plan for a training problem	

Duration of the Workshop: 1hour 45minutes

Brief Biography of the Facilitators:

Natalie Carscadden is the Manager of Occupational Health and Safety at Health Sciences North. She has over 25 years of work experience related to health and safety management, ergonomics and auditing.

Vance McPherson is Coordinator of Leadership and Learning at Health Sciences North. He has been designing and coordinating learning experiences for adult learners in a variety of contexts for eight years.

Office Ergonomics 2018: Unpacking the New CSA Z412 Standard

Lucy Hart, MSc, CCPE
[1] Global Furniture Group, Toronto, Ontario, Canada

Workshop Overview

CSA Z412-17 Office Ergonomics – An application standard for workplace ergonomics has undergone a major overhaul since the last edition was published in 2000. Z412-17 is the application part of Z1004-12 as it applies to offices. As a standard (previously a guideline), it is intended to be suitable for adoption into jurisdictional regulations. CSA Z412-17 contains high level requirements as well as detailed requirements for the application of ergonomics in office work systems including furniture, accessories, equipment, layout and use, environmental conditions, manual materials handling, psychosocial workplace factors and psychological health. The standard applies to all office users in office workspaces in new and existing buildings. CSA Z412-17 is a new staple for corporate due diligence with respect to enhancing occupant health, safety and well-being and optimizing system performance.

Objectives of the Workshop:

1. Recognize the positioning of Z412-17 within CSA OHS Management System standards
2. Describe Z412-17 highlights
3. Summarize key high level and detailed requirements for the office workspace
4. Recognize the usefulness of Z412-17 in the design and redesign of office workspaces

Duration of the Workshop:
1 hour

Brief Biography of the Facilitator:
Lucy Hart is a certified ergonomist with over 25 years' experience guiding public and private organizations in the application of ergonomics to enhance employee health, well-being and productivity. She actively contributes to the development and maintenance of standards and guidelines including the Canadian Standards Association (CSA) application standard for office ergonomics and the Business and Institutional Furniture Manufacturer's Association (BIFMA) Ergonomics Guideline. She is the Chair of CSA Technical Committee on Z412 Office Ergonomics, Chair of BIFMA Ergonomics Subcommittee and member of the LEED Pilot Credit 44 Ergonomics Work Group. Lucy is a peer- elected Educationally Influential Ergonomist as recognized by the Institute for Work and Health.

Development of a new MSD Prevention Guide for Ontario

Richard Wells, PhD[1.2]
[1] Professor Emeritus, Department of Kinesiology, University of Waterloo
[2] Director, Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD)

Development of a new MSD Prevention Guide for Ontario: A multi-stakeholder initiative led by the Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD) Building on previous work by the Ontario Health and Safety system, the Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD) has been leading a two-year project to develop a new Ontario MSD Prevention Guide. We have used a collaborative approach to engage and work with a wide range of workplace stakeholders. The new Guidelines are being released during Global ergonomics month in October 2018. The half-day workshop will lead the participants through the process of creating the Guidelines and the rationale for the content and structure.

Duration of the workshop: 3 hours

Brief Biography of the Facilitator: Dr. Richard Wells is a professor in the Department of Kinesiology, Faculty of Applied Health Sciences, University of Waterloo. He was educated as a Mechanical engineer at the University of Manchester, England and McMaster University, where he specialized in Applied Mechanics with application to human function and injury; head injury in boxing and description of human gait using assistive devices. He is the associate director, stakeholder relations for the Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD), a multi-university Centre hosted at the University of Waterloo. He is also an adjunct scientist at the Institute for Work & Health (IWH). He is a past member of the Board of Directors of Occupational Health Clinics for Ontario Workers (OHCOW). He has been involved in ergonomics standards and regulations with ACGIH and the Occupational Safety and Health Administration (OSHA) in the USA and in the Ontario Strategy for the Prevention of MSD and the Canadian Standards Association (CSA). He also acts as a consultant and speaker on ergonomic issues.

Moving from Lab to Industry : How to measure force and assess it for acceptability

Allison Stephens, MSc,CCPE,CPE[1]
[1]Fanshawe College, London Ontario, Canada

Learning objectives include:

- Critical thinking to determine approach to force measurement
- Measure forces to demonstrate part variation.
- Review and demonstrate external influences on Force measurement
- Analysis of acceptability relative to strength capability

The workshop would be using the Mark 10 force gauge. Workshop will include many hands on measurements, of lego, jars, clips, and triggers. Topics of discussion would include a brief review of force gauges, tips and trick, variability of parts and how to deal with this statistically. From the measurements taken, participants will evaluate the acceptability of the effort using the Handpak software, Dreyfus and Peebles & Norris references.

To conclude the workshop there will be a demonstration of a new technology, the Force Puck. An introduction to why it was developed, it's reliability and repeatability will be discussed. Participants can perform hands on measurement with the Force Puck, and review the force profiles.
This will be a hands-on workshop for both beginners and practitioners to review, discuss and demonstrate force measurement in the field of ergonomics.

Duration of workshop: 90 minutes

Can ergonomists do more harm than good? - How to avoid costly mistakes for your clients

Trevor Schell BSc. MSc, CCPE[1]

[1] Occupational Health Clinics for Ontario Workers (OHCOW), Sudbury, ON, Canada

Workshop Overview

While office ergonomics can be the most common area of investigation for an Ergonomist, the process of evaluation and structuring of recommendations can often become very confusing and costly for workplaces without sufficient knowledge. Nothing can be more frustrating for a company than purchasing new equipment only to find out it is not compatible with the workers. This in turn, can have many workplaces reject the notion of ergonomics as a benefit to them.

Ergonomists need to be conscious of equipment they are recommending to their clients to ensure the product they are suggesting will perform as promised and not place the worker at an increased risk of injury. How recommendations are presented is important to workplace parties to ensure they are purchasing the correct equipment. For example, is saying "purchase a height adjustable keyboard tray" the correct approach?

By utilizing case studies and tools learn how to avoid costly mistakes and improve employee well-being.

Objectives of the Workshop:

- To increase awareness of the importance of knowing the product you are recommending
- Implications of recommending equipment with little to no research behind it
- The costs to workplaces based on unsound recommendations
- Recognition of the importance of knowing the product being suggested
- Is a product truly ergonomic or beneficial to the worker

Duration of the Workshop:

90 minutes

Brief Biography of the Facilitator:

Trevor Schell graduated from the University of Guelph in 1994 with an Honors Bachelor of Science degree in Human Kinetics with specialization in the field of Biomechanics and Ergonomics. In 1997, Trevor graduated from the University of Massachusetts-Lowell with a Master's degree in the field of Ergonomics and a minor in Epidemiology. Trevor is also recognized as a Canadian Certified Professional Ergonomist (CCPE) and a full member of the Association of Canadian Ergonomists (ACE).

Trevor has been an Ergonomist with the Occupational Health Clinics for Ontario Workers for 20 years working with joint health and safety committees on a variety of ergonomic issues over a wide range of industries. He is also the coordinator of the annual International RSI Day webinar series. Trevor has also presented at conferences, testified before a US Senate Commission on the need for ergonomic regulations and has been featured in interviews with CNN, Associated Press, CTV and CBC Radio.

PAPER SESSION 1: PHYSIOLOGY

Day 2- Oct 16th	
10:30-11:30	**Paper Session 1** Physiology <u>Igor Zovilé</u> Évaluation des contraintes physiologiques associées au port d'un appareil de protection respiratoire de type P100 dans différentes conditions d'humidité relative <u>Samuel Charbonneau</u> Contraintes physiologiques et physiques associées au port d'un appareil de protection respiratoire de type P100 selon l'intensité physique et la température ambiante <u>Alexie Dennie</u> The Relationship Between the Physical Working Environment and Self-Reports of Sleep Quality and Quantity in the Mining Industry

Évaluation des contraintes physiologiques associées au port d'un appareil de protection respiratoire de type P100 dans différentes conditions d'humidité relative.

Zovilé, I.[1*], Charbonneau, S.[1], Marchand, D.[1], Gauvin, C.[2], Tuduri, L.[2]
[1]UQAM, Montréal, Québec, Canada
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Introduction

Le port des appareils de protection respiratoires (APR) de type P100 cause un inconfort qui incite les travailleurs à ne pas se protéger adéquatement et à s'exposer à des contaminants qui peuvent favoriser le développement de plusieurs maladies professionnelles (1). Parmi les facteurs environnementaux susceptibles d'influencer leur confort, l'humidité relative interfère avec les mécanismes de thermorégulation, augmenterait la résistance respiratoire (2), et inciterait les travailleurs à ne pas porter leur APR.
Ce projet à comme objectif d'identifier les conditions environnementales les plus inconfortables et quantifier l'effet de ces conditions sur plusieurs paramètres physiologiques.

Methods

Huit hommes entre 20 et 30 ans ont marché pendant 30 minutes à une inclinaison augmentant progressivement de 30% à 80% du cout cardiaque relatif. Les tests ont été réalisés dans 3 conditions d'humidité relative différentes (30%, 50%, 80%) à une température de 29°C. Chaque condition a été effectuée avec et sans le port d'un APR. Les variables suivantes ont été mesurées : saturation en oxyhémoglobine, fréquence cardiaque, température interne, température dans l'APR, %O2, %CO2, fréquence respiratoire, perception de l'effort, temps de réaction, temps de mouvement.

Findings

Dans les conditions d'humidité relative plus élevées on observe des fréquences cardiaques (Figure 1), l'$EtCO_2$, la fréquence respiratoire et une perception subjective de l'effort significativement plus élevés pour un même effort pour les conditions effectuées avec le port d'un APR. Ces différences sont plus apparentes lors des efforts physiques les plus intenses.

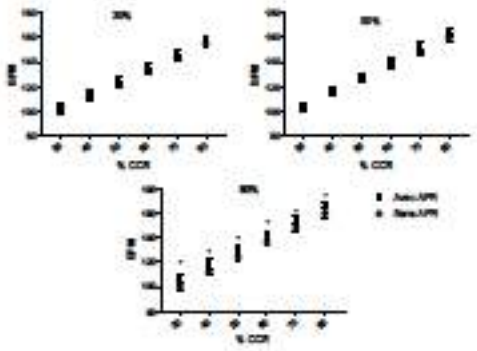

Figure 1 Fréquence cardiaque selon l'intensité de l'effort

Relevance to Practitioners

Les résultats de ce projet devraient permettre d'émettre de nouvelles recommandations pour limiter les périodes de travail trop longues chez les travailleurs portant un APR dans certaines conditions environnementales.

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Contraintes physiologiques et physiques associées au port d'un appareil de protection respiratoire de type P100 selon l'intensité physique et la température ambiante

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Introduction

Dans le secteur de la construction, l'exposition professionnelle à divers contaminants tels que l'amiante, la silice cristalline et les moisissures, est fréquente dans plusieurs métiers. Le port d'un appareil de protection respiratoire (APR) est reconnu comme un outil essentiel pour réduire les risques d'exposition par voie respiratoire dans les milieux où le contrôle à la source s'avère insuffisant. Une des raisons les plus fréquemment citées pour l'intolérance et l'inutilisation des APR de type filtrant serait l'inconfort lié à l'accumulation de chaleur au niveau du visage (Radonovich et coll., 2009; Baig et coll., 2010). Selon Roberge et coll. (2010), d'autres facteurs tels que l'augmentation de la température de l'air respirable et de la concentration de dioxyde de carbone (CO2) à l'intérieur de l'APR, ou des contraintes physiologiques tels que la fréquence cardiaque et la saturation en oxygène peuvent aussi expliquer le manque de motivation à porter ce type de protection respiratoire. L'objectif de ce projet de recherche consiste à mesurer l'impact du port d'un APR à épuration d'air sur différentes variables physiologiques selon l'importance de l'effort physique et de la température ambiante. Le type d'APR sélectionné pour l'étude est celui le plus fréquemment utilisé par les travailleurs du milieu de la construction et suggéré par l'ASP construction, soit un demi-masque à filtre P100 réutilisable (3M série 6000 avec filtre particules 2091).

Méthodologie

Des conditions avec et sans APR ont été évaluées lors d'un test d'effort progressif (30 % à 80 % du coût cardiaque relatif) sur un tapis roulant dans une chambre à environnement contrôlé. Différentes conditions de température ambiante (23°, 29° et 35°C dans un environnement où l'Humidité relative HR est constante à 50%) ont été évaluées afin de mesurer l'importance des contraintes physiologiques associées au port de l'APR selon l'effort demandé et la température ambiante. Lors des évaluations, des tâches perceptivo-motrices ont été réalisées avant, pendant et après les tests sur le tapis roulant. Plusieurs variables physiologiques ont été mesurées: la capacité cardio-respiratoire maximale (VO_2 max), la concentration de CO_2 à l'intérieur de l'APR, la saturation en oxygène cérébrale, ainsi que la fréquence cardiaque et respiratoire. Des échelles de perception psychophysique (Borg) ont été utilisées pour évaluer la perception de l'effort.

Résultats

La figure 1 présente la fréquence respiratoire des sujets selon les différentes conditions évaluées et l'intensité de l'effort. L'analyse statistique Anova à deux facteurs à mesures répétées a permis de déceler une différence significative seulement pour le facteur APR (p=0,0028) et une interaction entre les facteurs APR*intensité (p=0,0003). L'analyse par comparaison multiple pour le facteur APR semble indiquer que la condition avec APR engendre une fréquence respiratoire supérieure par rapport à la condition sans APR pour les intensités de 70 et 80 % du coût cardiaque relatif. La figure 2 présente la perception de l'effort des sujets selon les différentes conditions évaluées et l'intensité de l'effort. L'analyse Anova à deux facteurs à mesures répétées a permis de déceler une différence significative pour les facteurs APR (p=0,0001), intensité (p<0,0001) et une interaction entre les facteurs APR*intensité (p=0,0054). L'analyse par comparaison multiple pour le facteur

APR semble indiquer que la condition avec APR engendre une perception de l'effort supérieure par rapport à la condition sans APR pour les intensités de 70 et 80 % du coût cardiaque relatif.

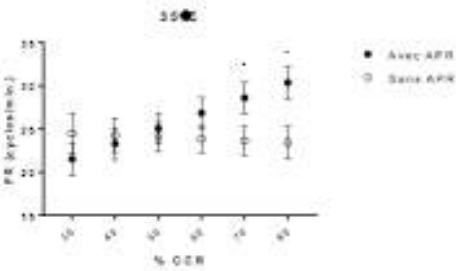

Figure 1 : La fréquence respiratoire (FR) pour les conditions avec et sans APR à 35°C.

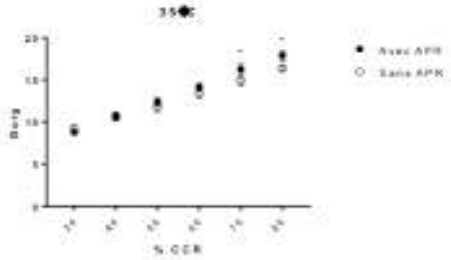

Figure 2: La perception de l'effort pour les conditions avec et sans APR à 35°C.

Le port d'un APR a également eu des effets significatifs sur les concentrations en O_2 et en CO_2 respirées ($p<0,0001$). Les concentrations en O_2 à l'intérieur de l'APR et dans l'air ambiant étaient respectivement de 17,51 et 20,52 %, alors que les concentrations en CO_2 étaient de 2,82 et 0,11 %.

Discussion

La variable physiologique la plus affectée par le port d'un APR semble être la fréquence respiratoire. Comme les concentrations en O_2 et en CO_2 à l'intérieur de l'APR sont respectivement inférieures et supérieures aux concentrations que l'on retrouve dans l'air ambiant, une augmentation de la fréquence respiratoire permet d'augmenter la ventilation afin de renouveler l'air à l'intérieur de l'APR. Nos résultats sont en accord avec l'étude de Louhevaara et coll. (1984) qui avait également observé une augmentation de la fréquence respiratoire avec le port d'un masque de protection à l'effort. Les recommandations de l'OSHA (Occupational Safety and Health Administration) envers les concentrations en O_2 dans l'air ambiant sont fixées à 19,5 % et plus. Pour les concentrations en CO_2, on recommande des valeurs <0,5% pour un quart de travail de 8h, alors que des concentrations >3 % sont associées à des maux de tête, de l'anxiété et de la confusion. Les résultats obtenus lors de cette étude ne respectent pas ces recommandations. L'augmentation de la fréquence respiratoire semble également expliquer l'augmentation de la perception de l'effort lors de l'utilisation d'un APR.

Pertinence de la recherche pour les praticiens

Les résultats obtenus permettront d'émettre des recommandations lorsque les APR de type P100 sont utilisés dans des conditions ambiantes contraignantes et lors d'efforts physiques important. Des recommandations seront proposées pour identifier le début des situations à risque pour la santé des utilisateurs d'APR.

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The Relationship Between the Physical Working Environment and Self-Reports of Sleep Quality and Quantity in the Mining Industry

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Introduction

Poor sleep quality can alter a worker's attention, vigilance and alertness[1]. These can be further impacted in occupations characterized by challenging working environments thereby increasing a worker's vulnerability to an occupational injury[2]. Work in the mining industry can be a physically demanding occupation conducted in suboptimal working environments. Although evolutions in technology, including equipment modernization, have improved working conditions, the mining industry remains an occupation characterized by extremes of temperatures and humidity, suboptimal lighting, poor air quality, elevated noise and physically demanding work, all of which can impact a worker's wellbeing. In the current study, the link between the physical working environment, the working conditions and sleep quality in the mining industry were investigated as their associations are not fully understood.

Methods

Data were collected from 2,224 workers from a Canadian mining company using a comprehensive questionnaire that included various validated questionnaires. For the purpose of this study, a modified version of the Pittsburgh Sleep Quality Index (PSQI) was used to collect information on self-reports of overall sleep quality over the past month. The PSQI generates an overall Global Component Score that ranges from 0 to 18. Scores between 0 and 4 are deemed as good sleep quality, and individuals scoring between >4 are classified as having poor sleep quality. Furthermore, data were collected from the National Institute of Occupational Safety and Health (NIOSH) Generic Job Stress Questionnaire. Using an independent sample t-test, the means of the Global PSQI Scores from the participants that completed the NIOSH Generic Jobs Stress Questionnaire, more specifically the physical environment component (i.e. noise, lighting, temperature , humidity air circulation, air quality, dangerous substances, and overall physical environment,) were compared.

Findings

The average Global PSQI Score for individuals that are classified as having good sleep quality (N=345, 16% of sample) was 2.34 (± 0.79). As for the individuals that had a Global PSQI score above 4 (N=1781, 84% of sample), the average score was 7.22 (± 2.69). The overall average of the Global PSQI Score for the entire sample was 6.43 (± 3.07), which qualifies as poor sleep quality. The PSQI scores for each of the physical environment subcomponents of the NIOSH Generic Job Stress Questionnaire are displayed in Table 1.

Discussion

While poor sleep quality is known to impact workers on the job, less is known about how the working environment in the mining sector can contribute to sleep quality[3]. Results from the current study suggest that over 80% of the workers self-reported poor sleep quality defined as scores greater than 4 on the PQSI. The t-tests revealed significant differences between the means of the Global PSQI Scores according to the subcomponents of the physical environment. In particular, sleep quality was worst for individuals that reported working in noisy conditions, poorly lit areas,

in uncomfortable summer temperatures, in comfortable winter temperatures, in comfortable humidity, in environments with poor air circulation and air quality, feeling unprotected from dangerous substances, and working in crowded work areas. It is worth noting that the physical working environment is considered a component of psychosocial work stress, which in turn is a key determinant of sleep quality[4]. Although there is a relationship between the physical working environment and sleep quality, these physical components may impact overall sleep quality indirectly via psychosocial work stress. Accordingly, regression models will be developed to identify the key determinants of sleep quality, including the physical working environment components that can explain the greatest variance of overall sleep quality scores.

Relevance to Practitioners

The workplace physical environment is linked to overall sleep quality in the sample of workers in the current study. Physical factors may influence sleep quality via their impacts on psychosocial wellbeing, which is known to affect sleep quality.

Table 1. *T-test analysis for Global PSQI Scores and subcomponents from the NIOSH Generic Job Stress Questionnaire*

Variable	Condition	N	M	SD	*df*	p value
Noise	Too high	1412	6.64	3.11	1465	0.000
	Fine	699	6.00	2.94		
Lighting	Poor	983	6.67	3.15	2102	0.001
	Fine	1121	6.21	2.98		
Temp. Summer	Comfortable	904	6.05	3.00	2109	0.000
	Uncomfortable	1207	6.71	3.09		
Temp. Winter	Comfortable	827	6.69	3.08	2106	0.001
	Uncomfortable	1281	6.26	3.04		
Humidity	Too high or too low	873	6.07	2.89	1973	0.000
	Fine	1231	6.68	3.17		
Air Circulation	Good	1123	6.05	2.85	1969	0.000
	Poor	982	6.88	3.23		
Air Quality	Good	672	5.95	2.95	2096	0.000
	Poor	1426	6.65	3.10		
Dangerous Substances	Protected	1201	6.09	2.96	1858	0.000
	Unprotected	894	6.91	3.15		
Overall Physical Environment	Good	911	6.80	2.95	1878	0.000
	Poor	1189	6.14	3.18		
Crowded Work Area	Crowded	331	7.04	3.38	432	0.000
	Not Crowded	1768	6.32	2.99		

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INTERACTIVE PANEL SESSION

The evolution of wearable assessment devices in ergonomics

Panel Facilitator: Michele Oliver, Ph.D., P.Eng.
[1]School of Engineering, University of Guelph, Guelph, Ontario, Canada

Panel Overview

Wearables are a recent addition to our everyday vocabulary but in reality they've been available for use in ergonomics for the better part of the last three decades. The purpose of this panel will be to highlight where we've been, where we are right now and where we see the future going in terms of wearables available for use in ergonomic assessments. Along the way we'll talk about product development using a recent University of Guelph engineering capstone design project.

Panelists

Panelist 1 Michele Oliver, Ph.D., P.Eng.
School of Engineering
University of Guelph, Guelph, Ontario, Canada

What is a wearable?
The Past - A brief history of wearables in ergonomics.

Panelist 2 Karen Gordon, Ph.D., P.Eng.
The Present
What products are currently available?
Are the measurements provided valid (i.e., do they measure what they say to measure) and reliable (and how would you know if they weren't)

Panelist 3 Erika Ziraldo, B.Eng.
School of Engineering
University of Guelph, Guelph, Ontario, Canada

Brief discussion of why and how a recent wearable ergonomic assessment device was developed.

Panelist 4 Andrew Hamilton-Wright, Ph.D., P.Eng.
School of Computer Science
University of Guelph, Guelph, Ontario, Canada

The Future
Artificial Intelligence – The Good, the Bad and the Ugly
While data loggers and other wearable collection devices have been in use for decades, short-range broadcast devices such as the Fitbit™ have recently become popular as a local area remote sensor broadcasting to computers and cell phones. By using the available computational power on a cellphone or similar device, machine learning algorithms, reasoning systems and other technologies

identified as Artificial Intelligence (AI) come into play. The positive as well as the negative aspects of AI will be discussed as well as some insights into what the future may hold.

Concluding Remarks from All Panelists - Do wearables have the potential to ultimately replace ergonomists and other safety professionals?

PAPER SESSION 2: MANUAL MATERIALS HANDLING

Day 2 – Oct 16th	
10:30-11:30	**Paper Session 2** Manual Materials Handling <u>Harrison Kloke</u> Balanced joint loading – a new recommended lifting strategy <u>Alison McDonald</u> The effects of task and ladder on shoulder and low back demands during common ladder handling tasks <u>Tianna Beharriell</u> Physiological responses to acute lifting tasks of varied frequency and magnitude

Balanced joint loading – a new recommended lifting strategy

Harrison Kloke[1], Guler Arasan[1], Eric Poon[1], Andrew Tao-An Wong[1], Mohammad Abdoli-Eramaki[1]
[1]Ryerson University, Toronto, Ontario, Canada

Introduction

Training for safe lifting techniques is used by employers to lower exposure to risk of workplace musculoskeletal injuries. In our previous studies, 266 attendees at two professional conferences were asked to identify and demonstrate their preferred lift technique with demonstration being an ideal floor-to-waist height lift of a 10-kg weighted crate (1). The results showed that the trained group experience less loading at L5/S1, but higher loading at the knees and ankles (1).

Objective

The objective of this study was to compare the kinematics (joint) of postures of symmetrical and asymmetrical lifting techniques in order to determine the optimal lifting method with an equivalent loading distribution on all the involved joints.

Methodology

3D Static Strength Posture Prediction software [3DSSPP] was used to model 6912 symmetrical conditions representing all the possible lifting postures from the floor with different positions for the upper extremities, trunk and the lower extremities (4 leg angles x 6 thigh angles x 2 reaching distances x 4 trunk angles x 3 foot positions x 2 foot angles x 3 loads x 2: 95th %ile male and 5th %ile female). The force increments to both hands were 0, 11.5, and 23 Kg respectively. Female 5th and male 95th percentile were chosen for the analysis. 3DSSPP is a widely used tool that is known for simulation of static postures for kinematic evaluation (2).

Results

Joint moments, spinal compression forces, and population strength capabilities were analyzed from the data collected. The primary evaluations showed that lowest average joint moments for the knee and hip were observed in the 150-60 (Figure 1.), and 30-80 (Figure 2.) postures. Lowest ankle joint moments varied by population. These were seen in the 80-60 posture for Male 95th percentile population and the 80-50 posture for Female 5th percentile population. When average ankle joint moments were examined, the 80-60 posture produced the lowest moment (Figure 3.). All populations showed the lowest L5/S1 compression forces in the 30-80 posture (Figure 4.). Hip and ankle population strength capabilities were within safe ranges with more than 80% of all populations capable of reproducing the required joint angles (Figure 5.). Knee population strength capabilities showed some areas of concern though with only 29.97% of the Male 50th percentile population and 55.93% of the Female 5th percentile population having the strength required to reproduce the 30-80 posture. Postures with knee angles

of 80 and 150 degrees were observed to have the greatest proportion of the population able to reproduce the posture (Figure 5.).

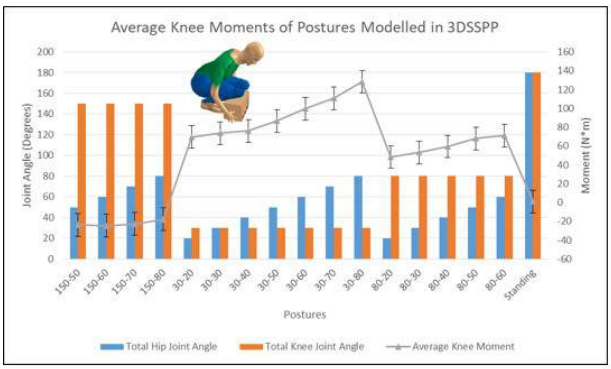

Figure 2. Average knee moments of all population percentiles with standard error bars of postures modelled in 3DSSPP.

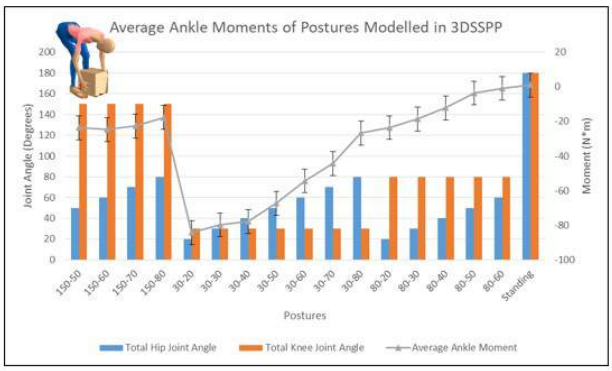

Figure 4. Average ankle moments of all population percentiles with standard error bars of postures modelled in 3DSSPP.

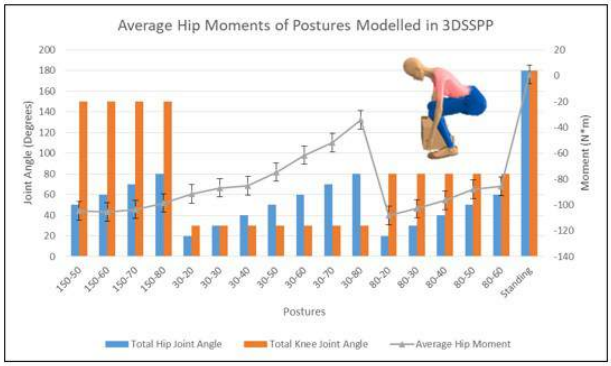

Figure 3. Average hip moments of all population percentiles with standard error bars of postures modelled in 3DSSPP.

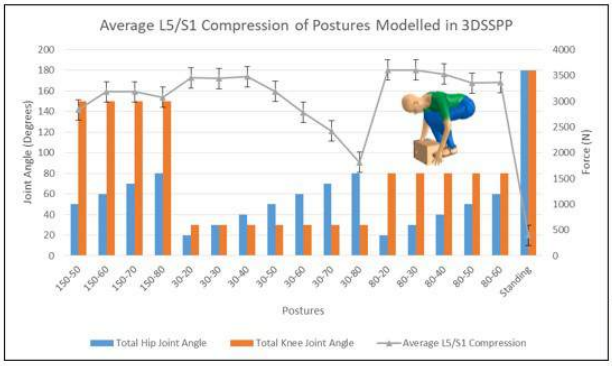

Figure 5. Average spinal compression force of all population percentiles with standard error bars of postures modelled in 3DSSPP.

Conclusion

Optimal lifting postures are often thought of as a squat lift similar to the 30 degree knee angle postures modelled while spine is the main focus of training. However, this analysis presents findings that show some populations may not have the strength capable to produce these postures, and have higher total joint moments when the load is lifted symmetrically in front of the body.

Based on the postures modelled, 150 degree knee angle are optimal for this task when the feet are parallel and kept symmetrical close to one another. This is supported by lower total joint moments compared to all other postures and the greater proportion of the populations capable of producing it.

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The effects of task and ladder on shoulder and low back demands during common ladder handling tasks

Alison C. McDonald*, Alan C. Cudlip, Emma Tung, Jack P. Callaghan, Clark R. Dickerson
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Introduction

Workplace upper extremity back and shoulder musculoskeletal injuries are very common in Ontario[1]. Awkward postures, constrained workplaces, repetitive exertions and high loads are risk factors for developing these injuries in the workplace[2]. The purpose of this investigation was to evaluate task demands during common tasks performed by telecommunication pole workers while using 3 different ladders and provide recommendations for which ladder should be used to minimize awkward postures and high shoulder and low back loading.

Methods

Twenty-three young, healthy, novice participants were included in this study (23 males, 2 females; 27 ± 4 years old, 1.8 ± 0.2 m tall, 87.2 ± 14.3 kg body weight). Participants were instrumented with reflective motion capture markers (20 individual markers, 7 marker clusters) and 10 VICON MX20 cameras (VICON, Oxford, UK). They were provided with personal protective equipment (fall arrest harness, a hard hat, steel toe boots) and hands-on training on how to perform the ladder tasks. Participants were asked to complete 4 ladder handling tasks ([1] Removing ladder from simulated vehicle; [2] Lifting ladder from ground to carry position; [3] Carry ladder to raise location; [4a] Raise ladder supported against wall, [4b] free raise ladder), each with 3 different ladders ([1] 2-piece wood ladder (8.5m, 29.6kg), 2P-W; [2] 2-piece fiberglass ladder (8.5m, 29.6kg), 2P-F; [3] 3-piece wood ladder (9.2m, 30.1kg), 3P-W. Each task/ladder combination was completed 3 times. The order that the tasks/ladder combinations were performed were block randomized between participants to mitigate order effects. Following each task, participants rated their perceived exertion (RPE) and perceived hand, shoulder and back discomfort (RPD). At the end of the data collection participants completed a survey expressing their favorite and least favorite ladder and task.
Inclusive humeral elevation angles relative to the trunk were calculated using algebraic dot products between the upper arm and trunk vectors. Torso angles relative to the global axis system were calculated with an XYZ Euler sequence. To calculate joint loading, external hand forces were estimated with a hand held dynamometer placed between the ladder and one of the researchers during the tasks and used in a kinetic model that was created in Matlab with individual participant segment masses and postures. The raise tasks were evaluated at the top and bottom of the raise. Resultant joint moments were calculated and comparisons were made to population strength estimates for a 50th percentile male from 3DSSPP (v 6.0.1, University of Michigan). The analysis portion of this investigation is ongoing, therefore only the results for the carry and raise tasks are included. Repeated measures analysis of variance examined the influences of task (5) and ladder (3) for joint angles, forces, moments, and perceptual variables (RPE, RPD) (IBM SPSS Statistic v. 23 IBM, NY, USA). Least Squared Differences (LSD) tests with Sidak corrections were used to evaluate post hoc significant main effects.

Findings

The biomechanical variables (posture, joint forces, joint moments) were affected by the both ladder used and the task completed. Arm and trunk posture were influenced by task ($p<0.05$) and were the same across ladders. Dominant arm elevation was greatest at the tops of the raises tasks than the carry and the bottom of the raises ($p<0.05$) and was lower at the bottom of the raises than the carry

task ($p<0.05$). Shoulder and low back joint forces were influenced by both task and ladder ($p<0.05$). In the dominant shoulder and the low back, joint forces were lowest when tasks were performed with the 3-piece wood ladder. Across the tasks, dominant shoulder and the low back joint forces were greatest during the carry task.

Joint moments in the dominant and non-dominant shoulder and trunk were influence by ladder used and task ($p<0.05$). When compared to estimates of population joint strengths for 50th percentile males, resultant dominant shoulder joint moments were 27-81% of strength (Figure 1) and resultant trunk moments were 61-123% of strength. In the survey, 52% of respondents indicated a preference for the 2-piece fiberglass ladder, compared to 24% for both the 2-piece and 3-piece wood ladders.

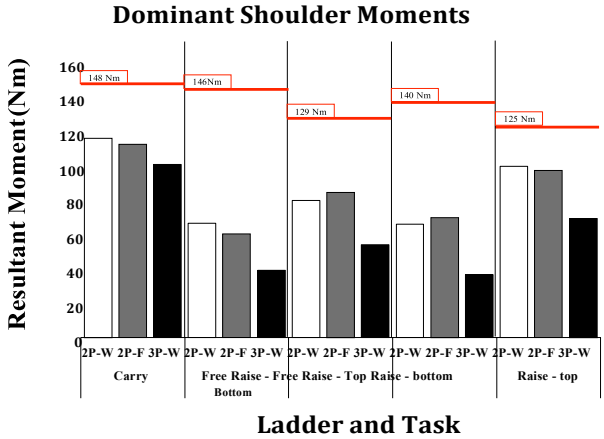

Figure 1: Resultant shoulder moments (Nm) for the 5 tasks and 3 ladders plotted in bars. Resultant population strength values, for a 50th percentile male, calculated with 3DSSPP (v 6.0.1) are plotted with red lines for each task.

Discussion

There was no precise ladder choice that universally mitigated the physical demands while also lowering perceptual difficulty. However, trends emerged that favored the 3-piece wood ladder for minimizing the biomechanical variables. The 3-piece wooden ladder was associated with the lowest joint loads at both the shoulders and low back, while the survey suggests that the 2-piece fiberglass ladder generally led to preferred body posture. Several task and ladder combinations required close to or even greater resultant trunk moments than the strength estimates. In a large study of occupational low back pain development, low back pain cases were exposed to greater peak trunk moments and hand forces[3], suggesting that caution should be taken when performing these tasks.

Relevance to Practitioners

Although this investigation was specifically focused and designed for the evaluation of ladder handling tasks performed by telecommunication pole workers, these tasks and similar ones are common across many industries. Space constraints make laboratory based evaluations of ladder handling tasks challenging. The findings from this investigation show the importance of equipment evaluation and selection and can be applied across industries that use ladders.

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Physiological responses to acute lifting tasks of varied frequency and magnitude

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Introduction

Currently, musculoskeletal disorder research focuses primarily on mechanical variables to assess whether acute or cumulative task demands exceed the capacity of the tissue; however, it is important to assess how other non-mechanical variables affect tissue capacity in a time-dependent manner[1,2]. The current research sought to answer the question of whether lifting a heavier load in a low frequency manner induced comparable systemic inflammatory responses to lifting a lighter load in a high frequency manner. Placed in an occupational context, if a worker has to move 10 boxes weighing 50 kg in total from the floor to a shelf at waist height, theoretically they could choose to lift 50 kg at once, or perform 5 lifts of 10 kg, 10 lifts of 5 kg, and so on.

Purpose

To supplement the traditional mechanical approach to MSD research by considering systemic inflammatory responses and related factors (i.e. body composition and psychology) under differential magnitudes and frequencies during a lifting task to identify their impact on injury risk while controlling for external biomechanical work.

Methods

In initial pilot work, four participants (2M/2F) completed two sessions separated by a period of one week. Each session included a lifting task (2 hrs) from floor to knuckle height under two repetitive loading protocols designed with equivalent cumulative external biomechanical work (5% and 25% of maximum back strength at a rate of five and one lift(s)/minute, respectively). Baseline blood draws were performed at 8 am on each day and at 0, 2, 4, 6 and 24 hours following completion of the lifting task. Samples were analyzed for inflammatory markers (Tumour Necrosis Factor Alpha (TNF-α), Cortisol, Interleukin-6 (IL- 6), Interleukin-8 (IL-8), and Creatine Kinase (CK)). Each participant also underwent a Dual X-Ray Absorptiometry scan and completed Pain Catastrophizing/Kinesiophobia Scales and Visual Analogue Scales of discomfort. Caloric intake was standardized for all participants according to the Harris-Benedict equation. A preliminary 2-way repeated measures ANOVA was run for each inflammatory marker to determine effects of load condition (5% vs. 25%) and time (Baseline, 0, 2, 4, 6 and 24 hours). These data were utilized to decide which markers and time-points would be used in part 2 of the study (N=12).

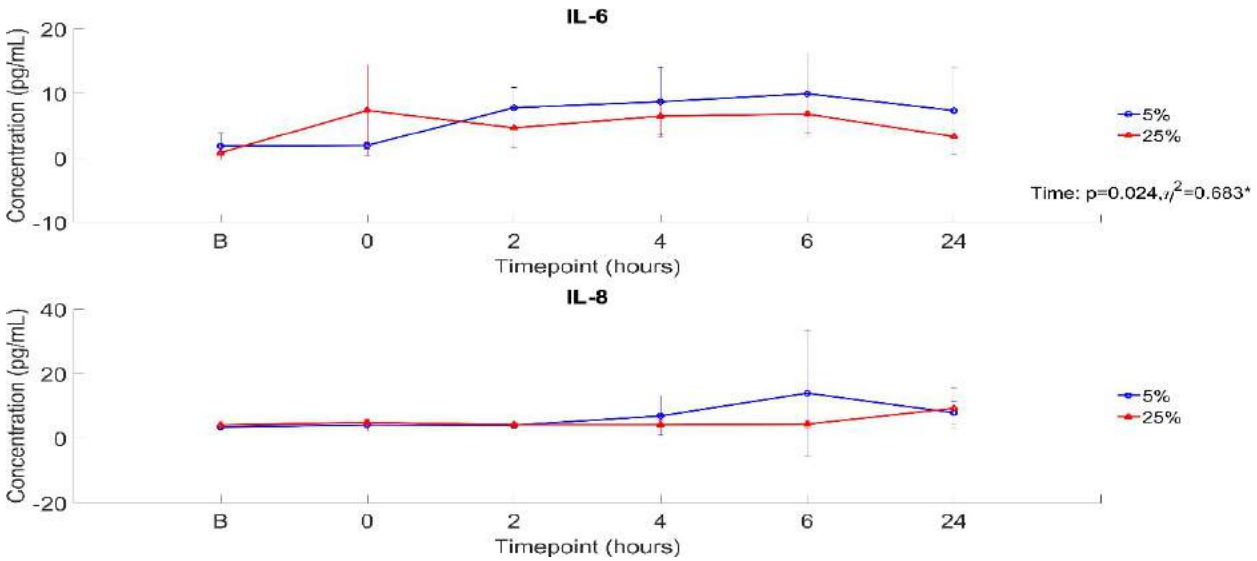

Figure 1: IL-6 and IL-8 concentration levels at 0, 2, 4, 6 and 24 hours

Results

The main effects of time and load, as well as the load*time interaction were non-significant for CK, cortisol and TNF-α. Mean concentration levels for IL-6 and IL-8 in participants 1-4 are shown in Figure 1. Overall, IL-8 and IL-6 exhibited the greatest change from baseline concentrations at 24 hours post-lifting, remaining elevated on average by 5.13 and 2.5 pg/mL, respectively, for the 25% condition, and 4.4 and 5.51 pg/mL for the 5% condition. Il-6 exhibited a statistically significant effect of time on concentration ($p=0.024$, $\eta^2=0.683$) and while not statistically significant, there was a moderate effect ($\eta^2=0.455$) for load*time interaction.

Discussion

The preliminary results demonstrate systemic inflammation that is not resolved 24 hours following a lifting task, and that IL-6 and IL-8 were the most sensitive to the task. In part 2, we will collect data from 8 more participants at Baseline, 0, 4 and 24 hours, and will test for IL-6 and IL-8. Correlational data between psychological scales/adiposity distribution and systemic inflammation will be presented at the conference.

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PAPER SESSION 3: OFFICE ERGONOMICS

Day 2 – Oct 16th	
14:45-16:15	**Paper Session 3** Office Ergonomics Nancy Black Challenges of controlled measures in real office environments: impact of workstation stand-sit height variations Daniel Viggiani Automated prediction of sit-stand desk use from low-cost distance and temperature sensors Nancy Black Matching postural state sequences with fatigue and pain experienced to distinguish low and high risk at sitting and sit-stand workstations Kayla Fewster An evaluation of office chair backrest height on muscular demands

Challenges of controlled measures in real Office environments: Impact of workstation stand-sit height variations

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Introduction

Sedentary behaviours observed in office environments and computer intensive work are associated with multiple health issues [1]. One solution suggested is regularly alternating between standing and sitting [2]. Different controlled periods have been studied: 15 or 30-minute extended standing periods per hour (25% and 50% standing, respectively) [3] and 5-minute standing for 10-minute sitting (33% standing) [4]. Typically, at most 50 % of the workday should be standing, this being interspersed regularly, respecting micro breaks every 20 to 40 minutes [5]. A data collection is currently underway to determine the "best" duration non-sitting (standing or moving) within a 30-minute cycle during typical work. This paper describes: 1) the protocol using a height-adjustable table and controller to compare six standing periods' impact on objective and subjective variables relating to musculoskeletal disorder (MSD) development, and 2) the challenges of this protocol.

Methods

Study design: Twenty-four office workers are currently participating in this natural experimental study design, with at most six at a time. This protocol occurs in participants' working environment with experimental and control conditions. Each participant uses all six stand-sit duration ratios in randomised ordering. At least 3 days' exposure to each condition provides required acclimatisation before an hour-long continuous recording of participant and condition, working normally.

Conditions: An hour-long baseline recording with worker's usual office desk precedes installation of the height-varying dynamic desk and again follows the completion of the six controlled dynamic conditions. For the duration of dynamic conditions, the participant's usual desk is replaced by one of six modified electrically height adjustable table (motorized DL5 system by Linak; Nordborg, Denmark) from Ergotables.com (Thetford mines, QC, Canada), with surface dimensions 1.40 m x 0.76 m with height from 0.68 m to 1.35 m. Casters (0.05 m height) facilitate installation. An in-house designed control system communicates standing and sitting conditions to the table for each participant (i.e. the standing and seated elbow height from the floor when wearing regular shoes), including standing duration (0 %, 10 %, 20 %, 30 %, 40 %, or 50 %) within a 30-minute cycle.

Data collection: Both subjective and objective data series are collected. Firstly, participants answered two questionnaires daily (at start and end of each work day), signalling their perceived agreement along a 10-point Likert-type scale for each of eleven subjective dimensions (stiff, tired, neck pain, back pain, happy, uncomfortable, productive, ability to concentrate, alert, head ache, eye pain). Secondly, objective data were recorded over one-hour at the end of each condition's exposure. Objective measurements quantify: 1) postural variations and group them into healthy and unhealthy categories using inertial sensors, inclinometers and video camera; 2) muscular activity using surface wireless EMG of sternocleidomastoid, superior trapezius, anterior deltoid and gastrocnemius lateralis (on the dominant side); and 3) autonomic nervous system (ANS) activity using heart rate variability (HRV). Video supports task analysis and provides context for data recorded by the other equipment. Overall, the eight data collections occur over at least five weeks.

Challenges encountered

The naturalistic study setting created challenges related to the table and its installation, study design and participant availability.

Dynamic table: Adding casters to tables facilitated their movement, but increased the minimum table surface height to from 0.62 m to 0.68 m. While lower than standard office desk height, this was sometimes higher than seated elbow height with the users' properly adjusted office chair. Then seat height must be increased and a footrest added to respect ergonomics guidelines.

Installation: Each physical office environment differed. Installation must allow video tracking without encumbering work. Offices with built-in desk surfaces, attached to dividers were particularly challenging. In one case, the work surface was detached from the dividers for the duration of the study and replaced by the table. In another, participation was impossible because existing work surfaces were not removable, and were smaller than the supplied table.

Study design: Researchers tried to minimise participant and work disruption, however equipment installation took 30 minutes for each continuous recording session. Calibration of EMG using maximum voluntary contractions were longer and less relevant; task-relevant maxima were quicker. Early participants frequently forgot to fill in daily questionnaires; daily electronic reminders and immediate questionnaire submission improved response rates.

Participants: To date, fourteen participants started the protocol, four completed it and six are in progress. Of the four that dropped out, two were due to vacation and time commitments, and one each due employment change and health. Delays in equipment availability exacerbated constraints.

Conclusions and discussion

While studying real work activities in their natural environment better reflects true MSD risks, implementing usual and necessary scientific controls was particularly challenging. Researchers and practitioners must be creative to overcome spatial constraints and minimise inconvenience to participants. Sharing this study's challenges can help other studies in natural work environments anticipate likely problems. Participants using the dynamic table with this protocol appreciated imposed position variations and the chance to sit-stand changes during their work, but the experimental controls implemented in this study limited participation.

Acknowledgement

Office Ergonomics Research Committee (OERC), the Natural Sciences and Engineering Research Council (NSERC) of Canada DDG2017-00014 and Université de Moncton provided funding.

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Automated prediction of sit-stand desk use from low-cost distance and temperature sensors

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Introduction

Sit-stand workstations have been shown to reduce musculoskeletal (1) and cardiovascular disorders (2) related to prolonged sitting or standing at work. However, these health benefits are reliant on the user transitioning between seated and standing configurations (1). Measuring the effectiveness of a sit-stand workstation in providing the intended health benefits requires accurate and reliable measurement of its usage. Therefore, the purpose of this project was to construct and test a low-cost sensor made from readily accessible components that was capable of automatically detecting whether a user is standing, seated or absent from a sit-stand workstation.

Methods

Sensor Construction

The sensor consisted of three sensing components and an integrator, connected to a laptop through USB. The sensing components included an ultrasonic distance sensor (HC-SR04, Elegoo Industries, Shenzhen, China), an infrared distance sensor (GP2Y0A02YK0F, Sharp Electronics, Osaka Japan), and an infrared temperature sensor (IRTemp 54, Freetronics, Pty Ltd, Maroondah, Australia). The three sensing components interfaced with an Arduino Uno R3 (Arduino LLC, Turin, Italy) which was provided with a short custom script that converted raw sensor outputs into distances and temperatures. All components were mounted in a rectangular foam-core housing that could be easily affixed to the underside of most commercially available sit-stand desks. The ultrasonic distance sensor was pointed at the ground and served to measure the current desk height. The infrared distance and temperature sensors were aimed at the user to measure the distance between the user and the sensor housing as well as the temperature of area around the user's working position. An eight-hour drift test was performed on each sensor component to ensure stability.

Predicting Sit-Stand Desk Use

A pilot study was conducted on 72 participants (38 female) to determine the distribution of preferred standing and sitting desk heights. These distributions carried forward into a laboratory study with the sensor previously described mounted to the same desk as used in the pilot study. Thirty samples were taken from both the standing and sitting distributions of desk heights, ensuring the 1st and 99th percentile of each distribution were included in sampling. Desk heights were set using real-time feedback from an optoelectronic motion capture system (Optotrak Certus, NDI, Waterloo, Canada). Two-thirds of the trials involved a single male participant (26 years, 175 cm, 90 kg) simulating office work at the desk. This was done so that there were twenty trials with a user present and standing at the desk, twenty trials with the user present and sitting at the desk, and twenty trials with the user not at the desk at either a standing or sitting desk height. A multinomial logistic regression was performed to determine if the sensor could accurately classify each of the sixty trials as either a) standing and present

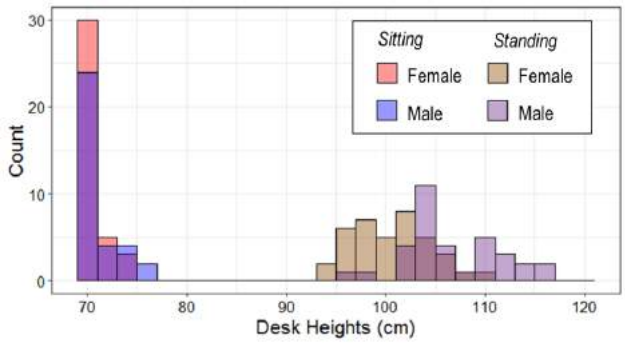

Figure 1: Sitting and standing distributions of desk heights, separated by gender.

(Stand), b) sitting and present (Sit) , or c) away from the desk (Away). Cross-validation was performed using a bootstrapping procedure where 80% of the data set was selected at random and used as a training data set; the remaining 20% of the data was used as a test dataset to assess the regression's accuracy. This procedure was repeated 1000 times.

Findings

There were minimal drift observed in the infrared temperature sensor (0.2°C/hour); the other components did not drift. There was a clear dichotomy between standing desk heights and sitting desk heights regardless of gender (Figure 1). The minimum height of the desk was 70 cm; some participants preferred a desk height below this minimum. All three sensors (ultrasonic distance, infrared distance and infrared temperature) were found to be significant predictors of conditions by a likelihood ratio test (Table 1). Cross-validation determined that the model was 94.1% accurate (95% CI: 93.9 – 94.3%) at predicting novel conditions, with 99.8% of all misclassifications falsely predicted user presence rather than desk height. Figure 2 shows sensor inputs for each of the 60 trials.

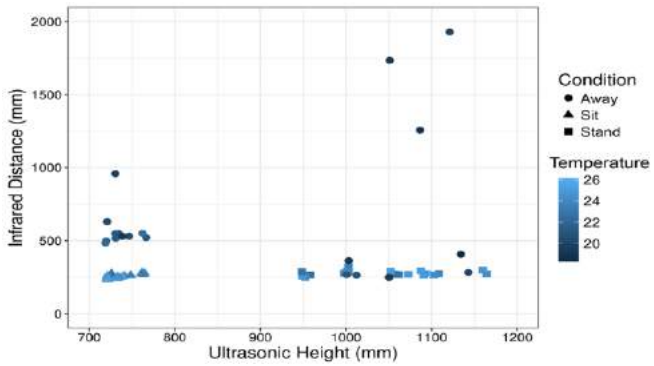

Figure 2: Sensor outputs for the 60 trials collected in the laboratory study.

Table 1: Likelihood ratios for the logistic model used to predict sit-stand desk condition.

	Desk Height (Ultrasonic)	**User-Desk Distance (Infrared Distance)**	**Temperature at Desk (Infrared Temperature)**
Likelihood Ratio	39.381	8.771	32.689
P-Value	<0.001	0.012	<0.001

Discussion

A low-cost, automated sensor was constructed that allows for detecting the sit-stand desk configuration with an estimated 94% accuracy. A distribution of preferred sitting and standing desk heights were also presented. One of the reasons for the high prediction rates is that the standing and sitting desk height distributions do not overlap; this allows the distinction between sitting and standing to rely solely on the ultrasonic sensor directed at the ground. The presence of a user was based on infrared distance and temperature sensors, which were found to be less accurate than the ultrasonic sensor due to variability in clothing and user positioning.

Relevance to Practitioners

Practitioners can design and implement sensors based on this model to automatically track users at sit-stand desks with high accuracy.

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Matching Postural State Sequences with Fatigue and Pain Experienced to distinguish low and high risk at sitting and Sit-Stand Workstations

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Introduction

Office workplaces are typically sedentary and involve intensive computer use (1), and research consistently links sedentary behaviours to health degradation including musculoskeletal disorders (MSDs) (2), with approximately 75% of office workers reporting significant discomfort in one or more body regions, particularly in the neck, back and shoulders (3,4). Regularly changing between sitting and standing, including after 6 or 9 minutes of a 20 minute cycle, has been shown to reduce discomfort relative to continuously sitting (5).

Using a one-hour recorded session representative of any such hour-long period of the working day (5), continuously recorded postural deviations from a neutral position were related to perceived general fatigue and neck and back pain. This paper explores the techniques used to uncover relationships between sequences of postural states, and participants' experience of pain or fatigue. Emphasis on the reasoning behind the methods chosen so that others may apply or adjust this strategy to improve ability to recognise postural patterns associated with MSD risk.

Methods

Data source: A previously recorded hour-long simulated data entry task using seated and two sit-stand alternating postures was used for this study. Continuous physical behaviours during this task were thus related to workstations which typically limit discomfort, pain and fatigue (sit-stand workstations) or not (sitting continuously).

Grouped postural data: Wireless 2-D inclinometers and CAPTIV 7000 analysis software (TEA, France) recorded postural deviation of head and trunk at 15 Hz in both sagittal and frontal planes. These were grouped into levels of increasing deviation and risk levels, defined as postural states designated by a 4-character code (ex. HS-2) following the levels defined by RULA (6) sagittally and Keyserling (7) frontally (see Table 1).

Table 1. Angular deviation (°) groupings by body region and plane

State ID	Head		Back	
	Sagittal (HS)	Frontal (HF)	Sagittal (BS)	Frontal (BF)
-2		-∞ to -10		-∞ to -10
-1	-∞ to -5	-10 to -2	-∞ to -5	-10 to -2
0	-5 to 10	-2 to 2	-5 to 5	-2 to 2
+1	10 to 20	2 to 10	5 to 20	2 to 10
+2	20 to ∞	10 to ∞	20 to 60	10 to ∞
+3			60 to ∞	

Grouped perceived fatigue and pain: Each participant recorded their perceived fatigue, back pain and neck pain at the end of the one-hour study for each workstation. Participants placed a mark on a horizontal line representing a visual analogue scale from 0 (none) to 10 (maximum imaginable). These values were discretized into quintiles, each containing 1/5 of the observed points for a given postural feature and together exactly covering the range of values observed for that perceptual feature. Subsequently, quintiles were aggregated, based on whether the quintile was identified

with the presence or absence of a given perception. This aggregation was performed by plotting the quintile means and noting where the inflection point occurred, dividing "low" from "high" values.

Combined posture and perception: Postural gestures of interest were identified by calculating a χ^2 contingency based on the occurrence of each postural sequence for the set of "Low" versus "High" quintiles of perceptual feature response data. The χ^2 contingency comparison accounts for variation in proportion; that is, if one proportion describes 3/5 of the data, and another 4/5, the χ^2 contingency considers the total size of the data set when estimating whether this difference may be observed by chance. The goal is to distinguish between proportions of occurrences of a pattern that vary between *Low* group relative to *High* group within the same perceived dimension.

Results

A number of "significant postural gestures" were found, indicating that there are identifiable movements that, for a given person, occur at significantly different rates when pain or fatigue is present, versus absent. Nine participants and all three workstation styles contributed to 230 significant patterns and 81 patterns were present for all participants using sit-stand workstations. Different significant patterns were observed when a perception was high, and when it was low. The frontal plane was associated with most significant gestures (83% for 10 participants, 73% for 9).

Conclusions and discussion

The different patterns significantly associated with high and low perceptions of pain and fatigue that are common across all participants indicate that these gestures may describe behaviours that either are risks for, or are potentially protective against, pain or fatigue. By examining patterns associated with generating pain or fatigue, and those that associate with their avoidance, dynamic postural behaviours to induce or avoid may be uncovered. Practitioners should watch for postural gestures that are linked significantly to changes in perception and alert workers to risks. Adding duration analysis to postural pattern ordering may enhance results.

Acknowledgement

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An evaluation of office chair backrest height on muscular demands

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Introduction

Prolonged static sitting has been implicated with a number of negative health consequences, including, low back pain, heart diseases, type II diabetes and worker discomfort (1–4). Sitting for prolonged periods has been associated with an increased incidence of LBP (5,6) regardless of whether or not a worker suffers from current LBP. Damkot and colleagues (7) identified the inability to change position while sitting as a major factor in the development of LBP during prolonged sitting . Ergonomic studies on office seating have found elements that encourage movement, such as adjustable/reclinable backrests, seat pans, arm rests and tilt mechanisms can minimize discomfort and stress to the body during sitting (8).

When investigating office seating designs, the main focus has been on lumbar supports and backrest recline angles. Lumbar supports have demonstrated the ability to improve lumbar lordosis in the low back (9–11) and reduce muscle activity(12,13). There is also preliminary evidence to suggest that a modified backrest allowing the extension of the shoulders during sitting can also improve spine postures in sitting (14). However, to date, there is very limited information on the impact of backrest height on physiologic responses to sitting. Thus, the primary focus of this study was to assess changes in muscular responses to changing backrest height in a standardized office chair.

Methods

Sixteen participants (8 females and 8 males) were recruited from the university population to participate in this study. This investigation simulated 4 different working postures in standardized office chairs with three different backrest heights (Short, Mid, and Tall chair back heights). The four different working postures consisted of: 1) Upright back rest engaged sitting; 2) Forward leaning onto a work surface; 3) Mid reclined; 4) Fully reclined (Fig 1), across the 3 standardized office chair backrest heights. The duration of each trial (3 chairs x 4 conditions x 3 repeats = 36 trials) was 70 seconds in total. In each trail, during the first 5 seconds the participant moved from upright sitting to the desired posture, in the middle 60 seconds the participant held the desired posture, and then in the remaining 5 seconds at the end the participant returned to upright sitting. Postural trials were block randomized by chair across and within subjects.

Figure 1: The Four conditions examined: 1) Forward leaning onto a work surface; 2) Upright back rest engaged sitting; 3) Mid reclined; 4) Fully reclined.

Across all conditions tested, surface electromyography (EMG) was used to track muscle activity from five muscles bilaterally: thoracic erector spinae (TES), lumbar erector spinae (LES), rectus abdominus (RA), sternocleidomastoid (SCM) and cervical erector spinae (CES). Maximum voluntary contractions were collected from each muscle for normalization purposes (%MVC). For each of the conditions collected the middle 30 seconds of each static hold was taken and the average muscle activation of that middle 30 seconds was computed for each muscle. This 30 second average was then averaged across each of the 3 trials for each condition. Right and left muscles were averaged resulting in a total of 5 average muscle activation values for each condition tested. Right and left muscles were averaged since all movements were symmetrical across conditions. In addition, to give an estimate of total activation, each of the 5 muscle averages for each condition was also summed, resulting in one total sum of activation for each condition tested. A three-way mixed general linear model assessed the influence of Backrest Height, Posture and Gender on average muscle activation.

Findings:

Overall muscle activation levels were very low with average activations across all back rests and postures below approximately 5 %MVC (SCM 3.8; CES 5.3; TES 4.7; RA 4.2; LES 4.3 %MVC). There was a significant main effect of Backrest Height for average LES EMG ($p = 0.019$). The Tall Backrest had significantly higher average LES activation in comparison to the Short Backrest height ($p = 0.015$). There was a 3-way interaction across Gender, Backrest Height and Posture for the SCM ($p = 0.005$). Males and Females had significantly less SCM muscle activation when using the Tall Backrest in the Full-reclined position in comparison to the Short and Mid heights. In addition, Females also had significantly less SCM muscle activation when using the Mid chair in comparison to the Short chair. For the total sum of all muscle activation from the 5 measured muscle groups there was a significant Backrest Height x Posture interaction ($p = 0.045$). When in the Forward and Full-recline positions, the Medium backrest height resulted in significantly greater total muscle activation. In addition, when in the Full-reclined position, the Medium backrest height resulted in significantly more total muscle activation in comparison to the Tall backrest height

Discussion

Overall the muscle activation levels were very low across all Backrest Heights and Postures. While there was little impact of Backrest Height on muscle activation, the Tall Backrest height had higher average lumbar erector spinae muscle activation in comparison to the Short height. In addition, there was less neck flexor muscle activity (SCM) when using the Tall backrest height in the Full- reclined position in comparison to the Short and Mid heights. This may be indicative of the Tall backrest supporting the head and neck better than the Short and Tall backrest heights. The finding of greater total muscle activation when in the Forward and Full-recline positions for the Mid chair back height may be indicative of more co-activation of the flexor and extensor muscle groups. This study was limited by the short duration of exposure for each condition investigated. This may not have been sufficient time to reflect muscle activation patterns over prolonged office work.

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PAPER SESSION 4: APPLIED CASE STUDIES

Day 2 – Oct 16th	
14:45-16:15	**Paper Session 4** Applied Case Studies Allison Stephens Do I need a Digital Human Model (DHM) to do Ergonomics? Kristina Zucchiatti One conveyor, prolonged standing, many workers: is a chair the answer? Nicholas Patrick Developing physical demands descriptions from job simulations

Do I need a Digital Human Model (DHM) to do Ergonomics?

Allison Stephens, MSc,CCPE,CPE[1*], Christina Cort, MHK, CPE [,2],
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Background

Digital Human Models (DHM) are disruptive technology for the field of Ergonomics. Prior to their adoption, ergonomic analysis in a virtual environment was limited. The key aspect of the task analysis is the Human. In order to assess the risk factors of a workspace in a proactive design a Digital Human Model such as the Siemens Jack and Jill represent the human. The data received from the DHM is biomechanical in nature. Joint Torques and spinal compression. Visual and analytical anthropometrics can also be assessed. Throughout the years of using DHM, ergonomic analysis tools have been added making their use for both proactive and reactive something to consider.

Objectives

1. What is a DHM and it's underlying assumptions
2. Review of the advanced ergonomic tools and research implementation into DHM's
3. Review of ergonomic tools and measurements that drive ergonomic decisions
4. Understand when a DHM is a good investment and ergonomic analysis tool

The use of Digital Human Models for ergonomics has been used in industries like automotive manufacturing, but has limited use in other industries and in reactive ergonomics. This paper will review the ergonomic tools within DHM's and applications. It will also explore the DHM as a platform for future Ergonomic research. This review is based on experience of the use of Digital human Models within Automotive manufacturing. The objective of the review is allow those unfamiliar with Digital Human models knowledge of DHM capabilities in the field of ergonomics.

Context

Traditional Ergonomic Analysis require observation of existing jobs, with overview tools such as RULA, Sue Rodgers and PDA's (1-2) . In the design phase of setting up the workplace the observation of the worker is not available. Digital Human models allow static and dynamic creation of future workplaces for analysis. Many common task analysis tools can be used with Digital Human Models. Other new or complex ergonomic tools can be accessed with Digital Human Models.

Spinal compression is an accepted analysis parameter to assess lifting and back loading. Many biomechanical models like Uof M3D (3) static strength and Watbak (4) have been utilized in ergonomic assessments. The DHM (Siemens Jack and Jill, include spinal compression but also calculate a joint torque for all interested postures. To assess biomechanical strain on the human, a joint torque assessment can be employed. Accepted practice is to compare the joint torque requirements of a task to those of a 25th percentile female strength.(5) Over the years digital human models have incorporated other ergonomic assessments such as frequency modifiers, cumulative loading, force acceptability and posture prediction(6). These tools and other future additions will be explored. Is the Digital Human model the future platform of all ergonomic tools for reactive and proactive analysis?

Actions

In a proactive Ergonomic application, the DHM has been used for hand clearance, reach assessment

and strength capability. The acceptability decision relies on the anthropometry, workstation parameters and the working posture. Over the year's research has allowed these parameters to be better defined. Global populations with improved anthropometrics allows decisions to made for global populations(7). The ability to predict the working postures have been enhanced by motion capture and posture prediction algorithms(8) Repetitions has posed challenges for biomechanical models. The integration of frequency modifiers has allowed more realistic job evaluations. Full simulations have allowed cumulative analysis such as cumulative back compression and metabolic analysis.

Outcomes

The continued improvement of the DHM to integrate new ergonomic research as it becomes available, makes the DHM not just a biomechanical analysis tool but instead a platform for a comprehensive ergonomic analysis.(9) Full simulation capabilities allows cumulative tools a mechanism to work, that in the past required significant computing power and time. Research such as the Arm Force field recently integrated into process simulate allow access to the latest research in arm strength. Research in the area of perceived exertion being conducted by Dr Jones at the University of Michigan and Ford is targeted for implementation into a digital human model.

Discussion

The cost and expertise to use digital human models has been a barrier to it's adoption. With the DHM being a promising platform to conduct all ergonomic assessments is there a case for Ergonomic, Safety and engineering professionals to adopt the DHM as a tool of the trade in the future? The USCAR Ergonomics task force has viewed the DHM as a conduit for implementing research. This model will be demonstrated and invoke discussion on it's role in the future use of DHM for both proactive and reactive ergonomics.

Relevance to Practitioners

The use of digital human models within ergonomics is limited to larger companies and proactive design analysis(10) It's use as a common ergonomic analysis for both reactive and proactive ergonomics is becoming more of a reality. The advanced analysis capabilities and path for research implementation makes it a tool that all practitioners should look at.

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One conveyor, prolonged standing, many workers – is a chair the answer?

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Background

Specifying the "ergonomic" height for a work surface is a challenge often faced by ergonomists, but it's a challenge that we can meet with the recommendation to make the work surface adjustable. Adjustability offers the opportunity to accommodate workers of varying heights, with a simple adjustment. Adjustable work surfaces have become so prevalent in the workplace that office and factory workers alike have come to expect them.

Problem

However, when the work involves many workers positioned along a conveyor or line, adjustability is a more complex proposition. In many food manufacturing environments such a poultry processing and cookie packaging, workers stand shoulder to shoulder, working at highly repetitive tasks. Despite high rates of shoulder, elbow, and wrist injury, their most common request is typically, "Can I have a chair?" They cannot imagine a solution for the repetitive nature of the work, but they feel sure that sitting would alleviate their leg and back fatigue.

Context

This presentation is a collection of case studies and experiences gained through consulting practice. They are primarily from food and auto parts manufacturing.

Actions

A collection of case studies evaluated various solutions to improve the risks associated with work at conveyors, using CSA reference guidelines for ideal standing work heights (1). In one case study, three types of platforms were implemented at adjacent workstations, to allow height adjustability for operators. Operators were trained and encouraged to adjust the platform height while working at each section of the production line. A second case study depicts how a chair might make the job worse for the upper body and back, as a result of awkward seated postures from limited leg clearance, and conveyor height. Anti-fatigue matting and lean stools were investigated, but new hazards arise with the type and environment in which the task is performed.

Outcomes

Safety actions were implemented to address fall and pinch point hazards from the various heights of the adjacent platforms. Implementation of platforms has had positive feedback from workers operating the lines. Anti-fatigue matting is not suitable in many food-based industries because of quality and sanitary standards. In addition, areas with high amounts of foot traffic surrounding the conveyor, increased the hazard of a trip and fall.

Discussion

The request for seating at conveyors creates a dilemma for ergonomist; we understand the risks of prolonged standing, but we can also understand that seating at a conveyor can increase the risk of upper limb injury. Clearance requirements for appropriate chair use is rarely available at a conveyor. Are lean stools a better solution?

Relevance to Practitioners

We have developed a few recommendations for workplaces facing this challenge:

1. Low profile conveyors are required to make sitting practical
2. Platform solutions are available to allow height-adjustability for standing work at conveyors
3. Use of anti-fatigue matting to address prolonged standing concerns, and challenges in food environments
4. Implications of prolonged standing on operators
5. Job rotation solutions that allow the worker to sit for part of the shift
6. Off-line packaging workstation design to allow leg clearance for sitting

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Developing Physical Demands Descriptions From Job Simulations

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[3]Fanshawe College, London, Ontario, Canada

Background

Physical demands descriptions (PDDs) are used by employers to objectively describe the physical demands associated with a particular job. PDDs serve a vital role in an organization's ergonomics program where they are used to inform prevention efforts, and also serve as critical information to inform the return to work process.

Digital human modeling software packages are tools in which the user is able to create virtual environments with human avatars for the purpose of job task evaluation. The Siemens Tecnomatix Jack (Jack) digital human modeling program has recently been updated, providing the user with the capability use the Task Simulation Builder (TSB) feature to develop PDDs directly from a dynamic job simulation of a series of job tasks(1). For this investigation, these PDD developed from a digital human model will be known as an ePDD (ePDD, for electronic PDD).p

Problem

The cost associated with acquiring a license for Jack, the required operator skillset necessary to efficiently use the program, and the time required to develop a job simulation may increase the development costs for an ePDD. However, the added detail, inclusion of video simulating the work, and opportunity for quick additional hazard assessment may provide benefit to offset the added development costs. For enterprise ergonomists already creating simulations as part of an advance proactive process, ePDDs can now be automatically generated providing potential process efficiencies. To evaluate the prospective utility of the ePDD, this case example describes the development and use of ePDDs, as an additional step over and above traditional PDD development, to support return to works efforts at an automotive assembly facility.

Context

This investigation took place at an automotive assembly facility.

Actions

The process of ePDD development was documented, from initial data collection to report generation to identify barriers and opportunities for improvement. Twenty cyclic assembly line jobs, cycle time <60 seconds, were evaluated in order to generate simulations using the TSB feature in Jack version 8.4. The simulations were subsequently used to generate ePDDs for each job. For this investigationllppp, data collection occurred as if a "traditional" PDD was being developed, with additional data being collected, as required, in order to develop high fidelity simulations e.g. detailed workstation layouts. It was the intention of the return to work (RTW) team to make use of these newly generated ePDDs in order to supplement their PDD current data in the RTW process. Simulations were developed using male and female mannequins scaled to 50th percentile (ANSUR database) for stature and body mass. The goal was to leverage the capabilities of Jack, the TSB, and certain ePDD report outputs as required, to provide advanced information that may not be available within a traditional PDD.

Outcomes

The analysis of the process of ePDD creation uncovered multiple areas for improvement. One important area for improvement relates to the time required to develop a simulation. The process of simulation development, including all stages from shop floor data collection through report generation ranged from 8-24 hours per job with the majority of the time consisting of simulation development. In general, simulation time increased with number of individual tasks performed during a cycle, as each goal oriented movement must be individually simulated. Primary results related to the use of the ePDD within the RTW process suggest the ePDD is able to provide context to the data contained within a "traditional" PDD. The simulation and the graphical representation of job task demands e.g. figure 1, were beneficial in providing easy to understand context to information that may be contained within data tables in a traditional PDD. This context appears to allow for the quick identification of tasks of interest within the job, and potentially an increased ease of use of the data contained within a traditionally developed PDD.

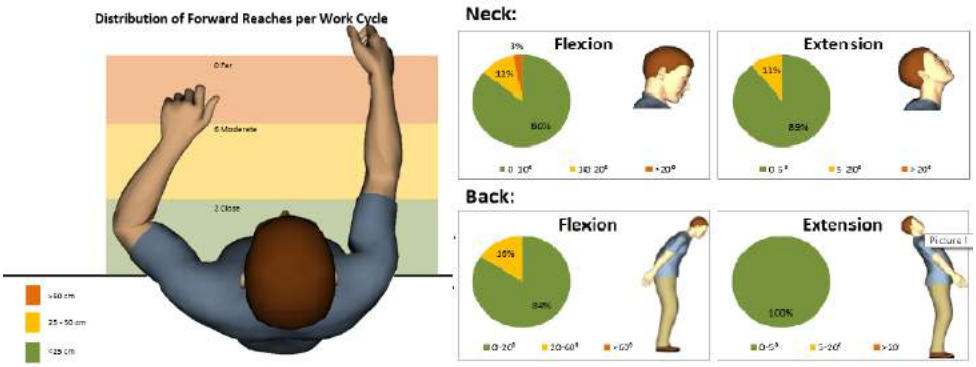

Figure 4. Sample TSB outputs

Discussion

As the ePDD was initially developed in conjunction with input from return to work professionals[1], it was expected that the ePDD should provide value within the RTW process. For select jobs, ePDD outputs were used to supplement the traditional PDD data used during the adjudication process. ePDDs were also used to assist in the matching of individuals with restrictions to alternative work. Interest in the potential use of the ePDD was generated throughout multiple levels of the organization, from employees on the production floor and union representation, through departmental management. Further work regarding the ePDD is continuing to examine the thoughts and opinions of PDD users, e.g ergonomists, clinicians, and RTW professionals, regarding further development of the ePDD as a means for presenting physical demands description data. Potential cost savings were not investigated, as the focus of this work was to develop the documents in a similar fashion as a traditional PDD, not in addition to other proactive evaluations.

Relevance to Practitioners

The ePDD provides practitioners with new possibilities for developing a PDD, as well as more possibilities for presenting the information contained within a PDD that may not be possible with current methods.

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INTERACTIVE PANEL SESSION

Applied Field Research Using Field-Lab-Field (F2L2F) Approach

Facilitator: Sandra Dorman, Director, CROSH

Panelists/Co-authors:
Alison Godwin, PhD, Associate Director, CROSH
Brandon Vance, MHK, Research Technologist, CROSH
Mallorie Leduc, PhD Candidate, Research Associate, CROSH
Tammy Eger, PhD, Research Chair, CROSH

CROSH's research philosophy is based on a Field-to Lab-to Field (F2L2F) approach, with the first step being: problem identification in the field; second step: solution development in the lab; and the third step: intervention evaluation back in the field. The panelists will provide several examples of how CROSH has used the F2L2F approach. Members of the audience will be invited to ask questions and engage in an interactive conversation with the panelists around the theme of the conference: Research to Practice to Prevention.

PAPER SESSION 5: ERGONOMICS IN HEALTHCARE

Day 3 – Oct 17th	
11:15-12:00	**Paper Session 5** Ergonomics in Healthcare Carolynn Kallitsis Estimated action limits and postural ranges for care providers with pediatric populations: an applied case study Jim Potvin Caregiver loads during sit-to-stand patient lifting: A simulation study of three clinical devices

Estimated action limits and postural ranges for care providers with pediatric populations: an applied case study

Carolynn Kallitsis, BHSc.[1]*, Joanne Hodder, PhD[2]
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Background

Care providers for the pediatric population are at high risk for sustaining injuries.[1] Historically, research shows childcare and home support workers account for almost 10% of the lost time musculoskeletal (MSK) injuries.[2] Non-neutral postures like forward bending and squatting can be identified as occupational risk factors in pediatric populations.[3] Lifts from ground level, lifts when sitting/kneeling, lifts with loads with a far horizontal reach from the body, asymmetrical lifts or above head lifts are common for pediatric care providers and may be of concern given the postures adopted during these tasks.[4] Currently, no guidelines exist regarding maximum patient weight for common handling task in a pediatric setting.

Purpose

The purpose of this case study was to capture the postures adopted by one (1) care worker during pediatric patient care tasks and to use their postures to calculate an estimate of the maximum patient weight that would be acceptable to lift for frequent tasks. This study is useful when examining a range of acceptable loads lifted by workers and whether the range would be greater than the average child patient weight. This will allow for more generalizable estimates of acceptable patient weights.

Methods

This case study was conducted over a 5hr period with one (1) volunteer female pediatric care provider (168 cm; 63.5 kg) who provided care for infants 6-18 months. Trunk postures were recorded using the Virtual Corset™ (VC) (Microstrain Inc., Williston, VT, USA). The VC monitored flexion-extension and lateral (left to right) bend angles of the trunk. The device was secured at the sternum for a duration of 5 hours. All tasks carried out by the participant were documented on a tablet (Samsung GT-N8000, Samsung Electronics Co., Suwon, South Korea) with the observational event logging software WorkStudy+ 6 (Quetech Ltd., Waterloo, ON, CA). The postures for all performed, tasks were segmented and mean and peak postures were found. Using a 50th percentile female mannequin in the 3D static strength prediction program (3DSSPP; University of Michigan, Michigan, USA), postures observed were used to find the action limit for acceptable hand loads.

Outcomes

The pediatric care tasks of feeding/meal time tasks, nap time duties, physical activity and other tasks had the peak trunk flexion displacement as large as 109.7°. Trunk flexion observed ranged from 4.2° to 109.7° and lateral trunk displacements ranged from 8.4° to 61.9° (L) and 1.4° to 55.5° (R). The recommended weight limits (as determined from 3DSSPP) for pediatric care tasks analyzed in this study ranged from 6.36 – 10.91 kg. The recommended weight limits for hygienic tasks, nap time duties, and physical activity were found to be approximately 10 kg. Limits for lifting a child from the floor were assessed to be 6.36 kg and from a crib at 9.55 kg (Figure 1).

Conclusion

The results of this study suggest that it is feasible to determine worker specific lifting limits based on postures they utilize. This may be effective in educating workers and with further investigation, to establish a safe lifting guideline for pediatric care workers to help reduce the risk of MSK injuries. This method of analysis was deemed beneficial since the recommended weight limits for the

pediatric care worker observed in this study were less than 50% of the NIOSH recommended guideline.

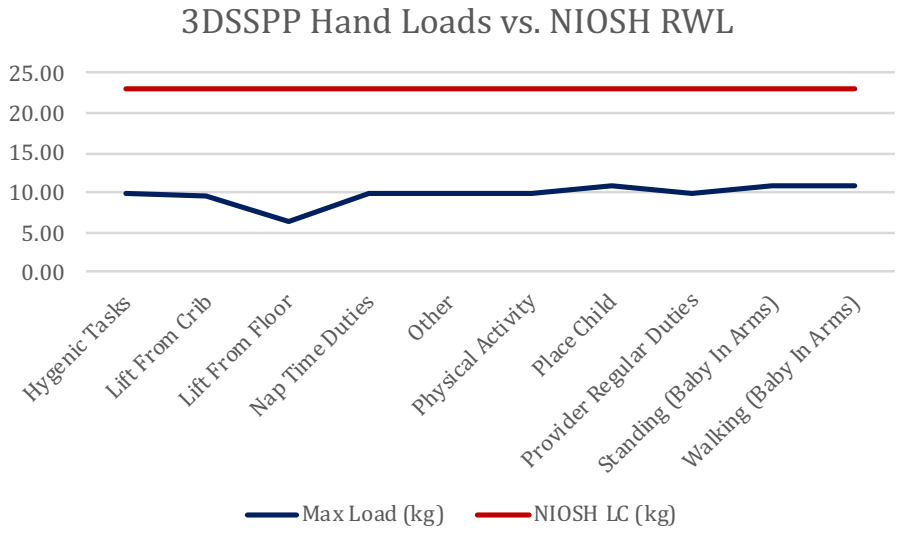

Figure 1. The maximum recommended weight limits established in 3DSSPP in comparison to 1991 NIOSH Lifting Equation Load Constant (LC)[5].

Discussion

There is a lack of published data regarding the acceptable limits for providing care and handling a pediatric population. Due to the considerably lower weight of infants and children compared to adults, this population is not considered when implementing lift guidelines in patient care settings. The applied analysis completed in this case study suggests that identifying guidelines for specific lifts and tasks is feasible in an applied environment. The worker specific results identifying that lifts from the floor should be capped at 6.4kg. This was of specific interest since, according to the World Health Organization Standard for Canada[6], the majority of infants will surpass this weight by the age of 6 months, which would be the youngest of the age group that most daycare facilities would care for. Examining a range of acceptable loads lifted by care workers would be of interest and value to support adopting modified work methods in a pediatric care setting.

Relevance to Practitioners

Despite a large amount of research on the postures and loads that patient care providers are exposed to, the action limits based on postures adopted are widely unpublished. Understanding the risks associated with various pediatric care tasks, based on work methods used, could help with implementation of musculoskeletal injury risk mitigation and elimination strategies. The extreme postures observed in this study highlight the importance of safe lift methods, as well as guidelines when working with an infant or child population.

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Caregiver loads during sit-to-stand patient lifting: A simulation study of three clinical devices

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Introduction

The demands associated with patient handling are a major ergonomics issue in health care. Historically, efforts to reduce patient handling injury risk have focused on the training of proper technique, but these efforts have generally not resulted in a significant decrease in the number of musculoskeletal disorders. This would suggest that interventions should include efforts to decrease the biomechanical demands associated with patient positioning and posture. This can be accomplished with assistive patient-handling devices, which can be effective for reducing injuries related to patient transfers, when incorporated within a comprehensive ergonomics program[1]. The purpose of this study was to use ergonomics simulation methods, digital human modeling and biomechanics software to assess the demands on caregivers when assisting patients with the initiation of standing from a seated position in a clinical: (1) recliner, (2) chair and (3) bed.

Methods

This study involved three devices: (1) Symmetry Plus Patient Room Recliner (termed "D1", Stryker, Portage, MI), (2) Progressa™ Bed System (termed "D2", Hill-Rom, Batesville, IN), and (3) TruRize™ Clinical Chair (termed "D3", Stryker). All anthropometry was set using the National Health and Nutrition Examination Survey (NHANES) (1990) database in Jack (Siemens, Ann Arbor, MI). More details of the larger study are provided in Potvin (2017)[2] but, for this abstract: (a) only the optimal ergonomic conditions are presented for each device (D1 with no seat pan tilt, D2 with its maximum seat pan tilt of 16°, and D3 with its maximum tilt of 21°), (b) the caregivers simulated as 50th percentile females (71.0 kg body mass, 1.63 m stature), (c) the patient was simulated as a 95th percentile male (123.0 kg, 1.86 m), (d) one caregiver performed the lift, (e) they contributed 100% to initiating the lift and (f) they used a gait belt. CAD primitives were used to develop renderings of the seat pan, back rest, arm rests and base for D1 and D2, and CAD data were provided by Stryker for D3. The Jack software was used to perform biomechanical analyses for the caregiver postures associated with the three devices. For each condition, some assumptions were made based on statics to determine the necessary caregiver hand forces to initiate rotation about the patient's ankles, then used the Jack software and Arm Force Field[3] method to determine the patient ankle moment, lumbar compression and shear forces and arm, hip and knee strength percent incapable.

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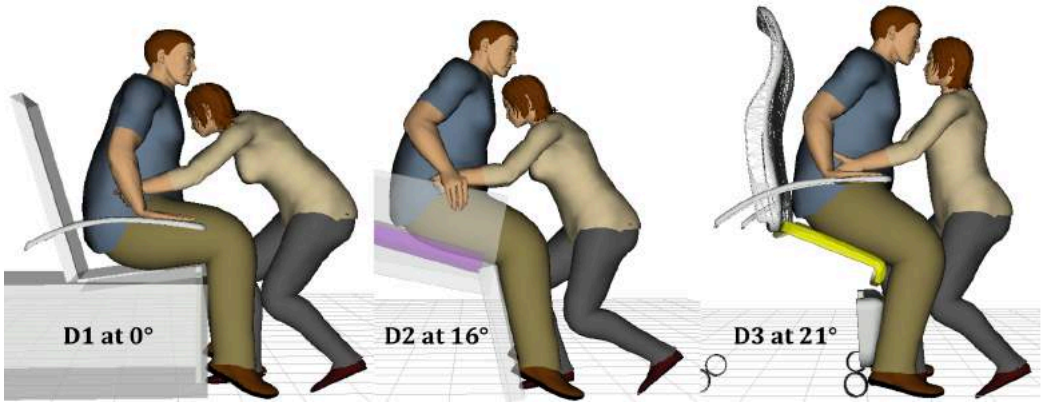

Figure 1: Simulations with D1, D2 and D3, at their maximum seat pan angles, with a 95th male patient and a 50th female caregiver using a gait belt

Findings

The results here were consistent with the findings of other conditions in the larger study[2]. The ankle moment about the patient's ankle generally determined the caregiver forces required to initiate rotation during a sit-to-stand and this greatly influenced the other joint loads. This moment was much lower for D3, than with D1 and D2 (Table 1). Subsequently, the lumbar compression and shear forces, and the percent incapable of the arm, hip and knee strength demands were much lower with D1.

Table 1: Joint loading results for the subset of conditions presented here, for the three devices. Absolute values are presented as are the ratios of the devices with respect to each other. Values in red indicate compression forces >3,400 N [4], shear values > 1,000 N [5] and strength percent incapable values > 25% [6].

	Absolute Values			Relative Values		
	D1	D2	D3	D2/ D1	D3 / D1	D3 / D2
Ankle Moment (Nm)	347.6	357.6	148.8	1.03	0.43	0.42
Compresson Force (N)	4,884	4,048	1,260	0.83	0.26	0.31
Resultant Shear Force (N)	1,381	1,163	371	0.84	0.27	0.32
Max Arm %Incapable	53.4%	45.1%	2.3%	0.84	0.04	0.05
Max Hip %Incapable	34.3%	42.0%	1.9%	1.22	0.06	0.05
Max Knee %Incapable	28.8%	26.6%	2.3%	0.92	0.08	0.09

Discussion

The results were consistent across variables, indicating a much lower risk of caregiver injury when using D3 to assist patients in a sit-to-stand movement, based on typical biomechanical variables used in ergonomic assessments. The design of the TruRize™ Clinical Chair (D3) allowed for the patient's feet to be moved closer to the edge of the seat pan than D2 (reducing the moment caused by their body weight) and allowed for more tilt and increased height of the seat pan than D1 and D2 (initiating the lift and further reducing the moment about the ankles). Both D1 and D2 exceeded ergonomics thresholds (see Table 1) when a 50th female caregiver was providing 100% of the force to lift a 95th male patient. The study had some limitation associated with the assumptions made, and constraints used, to represent as wide a variety of conditions as possible. These constraints included: (1) the elimination of all dynamic loading and use of momentum such that rotation of the patient would occur when their ankle moment just exceeded zero, (2) only analyzing one posture for each condition while a number of postures would be possible for both the patient and caregiver, and (3) limiting hand forces to the sagittal plane. However, ergonomics simulations with digital human models proved to be an effective method to compare the physical demands on caregivers for a wide variety of patient sit-to-stand conditions.

Relevance to Practitioners

The ergonomic benefits of a novel clinical chair (D3), were demonstrated. This chair lifts and rotates the seat pan resulting in a substantial reduction in the effort required by caregivers when assisting with a sit-to-stand. The study also demonstrates the power of work simulation and digital human models for comparing ergonomics demands associated with different product designs.

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PAPER SESSION 6: STUDENT AWARD FINALISTS – UNDERGRADUATE AND MASTERS

Day 3 – Oct 17th	
10:15-12:00	**Paper Session 6** Student Award Finalists **CROSH Undergraduate Student Award Finalists** Jacqueline Toner The impact of different handle orientations on external pushing force and muscle activity of a 4-child stroller Erika Ziraldo Design and validation of a prototype wearable device for automating low back injury risk factor quantification during manual materials handling Courtney Nickel Eliminating the learning effect for mining simulator research **JM Christensen Masters Award Finalists** Matthew Barrett Can seat pan design mitigate lower limb swelling and back pain? Sara Sayed Career firefighters' real-time physiological response to firefighting tasks over 6 months: implications for injury prevention

The impact of different handle orientations on external pushing force and muscle activity of a 4-child stroller

Jacqueline Toner[1,2], Dr. Wayne Albert[2], Dr. Usha Kuruganti[1]
[1] Andrew and Marjorie McCain Human Performance Lab
[2]Occupational Performance Lab
University of New Brunswick, Fredericton, NB, Canada

Introduction

Previous research exploring appropriate handle orientations for pushing tasks has found mixed results. When comparing handle designs past research has suggested: grip strength is weaker using a horizontal handle compared to vertical handle (1); both semi pronated and horizontal handle orientations produced greater pushing capacities than the vertical handles (2); and semi-pronated handle orientations attributed to lower forces than horizontal handle orientations (3). It is important to understand the impact of handle design on force and muscle activity to prevent fatigue and musculoskeletal discomfort that can affect the work force, including daycare workers.

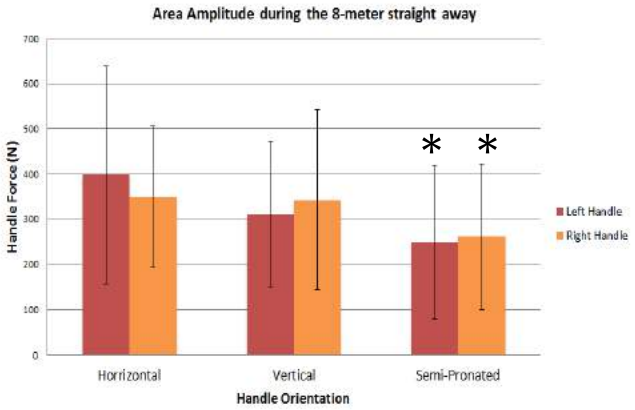
Purpose

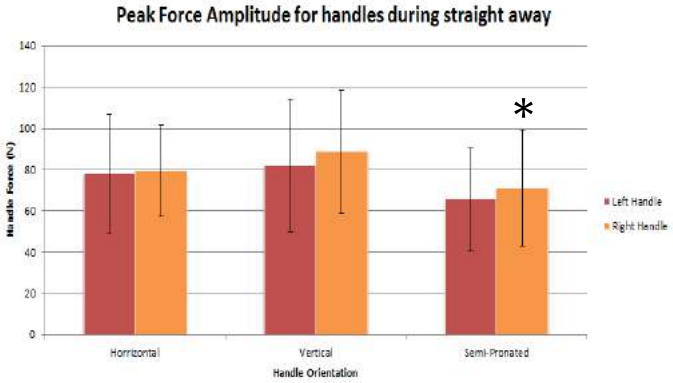
To examine the impact of handle orientation of a 4-child (Quad) stroller on the force and muscle activity created to push the stroller.

Methods

Fourteen women with the mean age 24 ± 4.71 years volunteered for this study. Participants pushed the stroller down an 8-meter stretch, followed by a 90-degree turn to the right or left around a fixed point, and continued for 2 meters before coming to a complete stop. Participants were asked to complete separate trials with each of the three handle orientations: horizontal, vertical, and semi-pronated. To simulate four children in the stroller a total cargo weight of 54.4 kg was added to the stroller. The weight was based on the 85th percentile weight for 2 year old boys and girls. The stroller was instrumented with force transducers within the handles to measure the force required to push the stroller. Surface electromyography (EMG) was used to measure muscle activation during the stroller push (Noraxon Telemyo). Bipolar surface electrodes were placed over the anterior deltoid (AD), biceps brachii (BB), and superior trapezius (TR) muscles to record their activity during each trial. Surface EMG amplitude was estimated using the Root Mean Square (RMS) of the straightaway, left turn, and right turn segments of the push.

Results





Due to the page limit for the submission of the abstract only a portion of the results will be shared. It should be known that there were additional significant differences found when comparing handle orientations and the force & EMG peak and area amplitudes.

EMG Findings

During the straight away segment of the pushing tasks both the horizontal(H) and semi pronated (S) handles had significantly lower mean amplitude values for the ST right (p^H=0.0073) ST left(p^H= 0.00029, p^S= 0.0078),right BB (p^S= 0.048), left BB (p^H= 0.005, p^S=0.014) than the vertical handle. During the left turn, semi-pronated handles created significantly lower mean amplitude of the right biceps (p= 0.0459) when compared to the vertical handle. Finally, during the right turn, the horizontal handle orientation resulted in a mean amplitude significantly lower than vertical handles ST left (p=0.011), BB left(p= 0.0066), BB right (p=0.097) and semi-pronated BB left (p=0.029) handles.

Force Findings

During the straight away segment of the pushing task the semi pronated orientation had significantly lower *peak(p) and area(a) amplitudes* force in comparison to the right vertical (p^p = 0.048) handle and the left (p^a= 0.0387) and right (p^a= 0.0264) horizontal handles. During the left turn, only the left horizontal handle had significantly lower peak amplitude force than the left vertical handle (p= 0.00958). No significant findings found comparing the handle orientations forces during the right turn.

Discussion

Muscle fatigue is commonly seen as a decrease in one's maximal force that the involved muscles can produce, and it develops gradually, soon after the onset of the sustained physical activity (4). If the onset of that fatigue can be delayed through handle design than injuries may be able to be prevented. The EMG data suggests that both the horizontal and semi-pronated handles result in lower levels of muscles activation compared to the vertical handle. Surface EMG has been used to study muscle fatigue extensively in the literature and there is evidence that there is correlation between the development of muscle fatigue and in an increase in the amplitude and decrease in the characteristic spectral frequencies (4). This preliminary study suggests that the task being performed by a worker to push a stroller may cause muscle fatigue due to the force and muscle requirements and that handle design could reduce the amount of strain. Further investigation is warranted to determine the optimum handle design as well as establishment of appropriate work protocols. Future studies should examine muscle activity of both upper and lower limbs and monitor muscle activity over a longer period of time to better simulate typical working conditions.

Future Implications

Understanding the impact of handle orientation on stroller design is critical in order to prevent injury and fatigue of a worker. This study has provided preliminary data suggesting that there are differences in force and muscle activity requirements due to handle orientation and further investigation should examine handles design to ensure the safety for the worker. Outside of the childcare industry these finding could inspire ergonomic changes that will lower the impact on the worker and enhance their physical capacity to complete pushing tasks.

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Design and validation of a prototype wearable device for automating low back injury risk factor quantification during manual materials handling

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Introduction

Work related musculoskeletal disorders (WMSDs) are the leading workplace injury in Ontario generating more than 40% of lost-time injuries (1). According to the Workplace Safety and Insurance Board (WSIB), low back injuries accounted for 17% of Ontario's allowed claims in 2017 with approximately three of four Canadians whose work involves manual materials handling (MMH) experiencing a low back injury during their career (1). Employers can assess risk using well developed ergonomic tools which often involve an ergonomist watching and evaluating employees performing a task. Unfortunately, workers often perform tasks differently while being observed (2). To reduce the need for an ergonomist to directly monitor a worker, the purpose of this work was to design, build and validate a prototype wearable device for the automation of low back injury risk factor quantification.

Methods

Design

To measure the lift vertical location, displacement, twist angle, frequency and duration to be used as input parameters for the 1991 NIOSH lifting equation (3) and Mital tables (4), two sensors were used in combination with an Arduino Micro microcontroller. The first, a Light Detection And Ranging (LiDAR) system uses light in the form of a pulsed laser to measure distance from the sensor to an object. This sensor, attached at the wrist on a freely rotating joint, tracks hand position during the lift. Custom software identifies lifting cycles from the LiDAR position data enabling lifting frequency determination. The second sensor is a nine degree of freedom inertial measurement unit (IMU) containing an accelerometer, gyroscope, and magnetometer. Outputs from these tools are used to calculate pitch, roll, and heading of the IMU, which describe sensor orientation. Placed on the shoulder, the filtered IMU outputs can then be used to calculate maximum and minimum trunk twist. The sensors are attached to the user by an arm band, and all auxiliary electrical components are enclosed within a 3D printed box (Figure 1). Sensor data are saved to a microSD card for subsequent transfer to a custom software program where the user is prompted to input hand coupling, sex, lifting duration as well as the depth and weight of the object being lifted. The software then calculates a recommended weight limit and risk index over durations which can range from a single lifting cycle to an entire work shift.

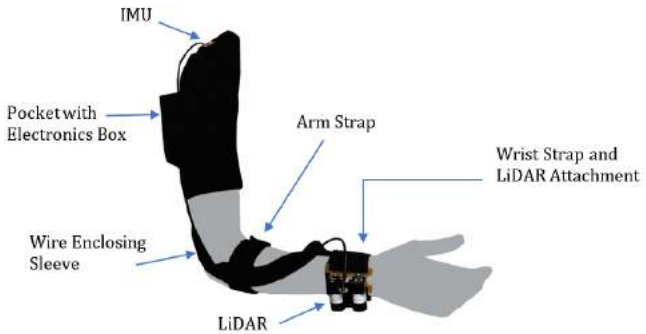

Figure 5: Wearable device components and layout

Validation

To validate sensor and calibration accuracy, sensor data were tested against distances and angles calculated during a sample lift using a nine camera Bonita VICON Motion Capture system. Spherical markers (1 cm diameter) were placed on both the left and right acromion processes and the radial and ulnar styloid processes of the right wrist. All data were sampled at 100Hz and smoothed using a 4th order Butterworth filter. Figure 2 compares the vertical distance from the standing surface throughout the duration of the sample lift as measured by both LiDAR and VICON, while Figure 3 provides an illustration of the twist angle for the same lift.

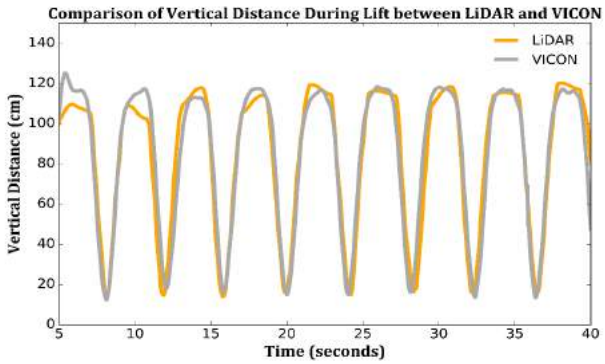

Figure 6: Tracking vertical distance with VICON and LiDAR

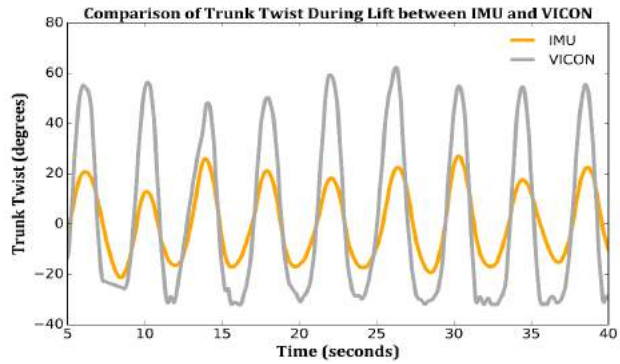

Figure 3: Tracking twist angle with VICON and 9DOF IMU

Discussion

LiDAR results for the vertical distance parameter closely follow VICON measurements (Figure 2). While there is some clipping at the peaks, the average maxima and displacements are very similar. The clipping error is minor given that most hand-calculated lifting risk assessments are simplified by assuming that any lift from the floor starts at 0cm and ends at the height of the finishing surface, despite recommendation from NIOSH to measure from the hand (3). Therefore, the VICON and LiDAR data provide a more accurate measure of vertical distance than a hand-measured value.

In contrast, the trunk twisting angle measured using the IMU does not closely match the values calculated from VICON position data. This can be explained by the magnetometer calibration, which corrects drift in the gyroscope measurements. To improve twist angle accuracy, an extended calibration which compensates for both hard and soft iron errors was developed for the IMU. Data collection is currently in progress to test the method, however, it is anticipated that the new calibration should greatly improve the trunk twist estimation.

Table 1: Summary of experimental input variables as measured manually, by the device sensors, and by VICON.

	Manual	Onboard Sensors	VICON
Final Height (cm)	114	123	120
Starting Height (cm)	0	10	8
Trunk Twist (°)	90	41	86

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Eliminating the learning effect for mining simulator research

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Introduction

Simulators provide a means by which researchers can evaluate training and performance in a relatively risk-free environment. This can be especially useful in high risk workplaces, such as the mining industry. Tichon and Burgess-Limerick (2011) identified not only hazard as a reason to explore virtual reality training methods but also the reduced cost and impact on workplace productivity, and the ability to explore scenarios that are impossible to recreate in the real world. Training novice users in a simulator also has the benefit of improving the perceptuo-motor skills required to enhance real-world decision making, problem solving and hazard identification (Tichon & Burgess-Limerick (2011). These are important constructs that lead to a worker having better situational awareness once they are in the workplace (Saus et al. 2012).

A review of the industry-leading Thoroughtec Cybermine simulator showed that trainees found the simulator to be very realistic and they believed that the competencies developed during training would be transferable to the real world (Bellehumeur & Marquis, 2016). Not all research labs have access to the funds required to purchase and install these high-fidelity simulators. Additionally, the ability to build custom software specific to research interests has merits from a research perspective. With this in mind, our research lab has designed a virtual reality simulator on the Unity gaming platform, with an integrated joystick and pedal controller to closely mimic operation of a load-haul-dump (LHD) machine. The main task in the simulator is for the individual to pick up ore in the bucket of an accurately-scaled LHD and deliver the ore in a simulated mine drift to an ore pass location. Several features intended to test situational awareness have been built into the simulator, and a data log feature records performance features such as machine speed, head direction, collision statistics and reaction time. In preliminary research, it was found that a strong learning curve was affecting analysis of performance variables across different research conditions. As such, this research study set out to determine a) the impact of a tutorial session on the learning effect and b) at what point did the learning effect taper off.

Methods

A total of 18 participants were recruited to this study, and randomly assigned to one of two groups, tutorial or no tutorial. The tutorial was a five-minute session in a separate virtual reality (VR) space that provided an overview of the LHD machine, how the controls worked and how to navigate in VR. All participants then completed five sessions lasting five minutes each in the simulator (Figure 1). The sessions all had the same goal, which was to deliver ore from the muck pile to the ore pass. Along the way, participants encountered pedestrians, which they were instructed to avoid hitting and to respond to with a special button on the joystick. This was logged as a perception-response time by the simulator datalog. After each session, the participant was given a break and asked a situational awareness question.

Figure 1: User with VR headset navigating an LHD machine in the virtual mine environment.

Due to non-normal data distributions, non-parametric tests were used throughout to evaluate the impact of the tutorial session on total collisions, perception-response time and number of correctly answered situational awareness questions. Where applicable, Levene's Test for Equality of Variances was used to evaluate the difference in variance between tutorial and no tutorial groups.

Findings

The Mann-Whitney U provided no evidence of a difference in total collisions (p=0.203) or average perception-response time (p=.515) when comparing the tutorial group to the no tutorial group. Large individual variability was likely driving this relationship (Figure 2), and prompted us to look at a measure to evaluate equality of variance (Levene's Test). The Levene Test violation (p<0.05) for total collisions suggests that the lower variance for the tutorial group (27.7 ± 17.1) compared to no tutorial (56.6 ± 46.4) is worthy of note.

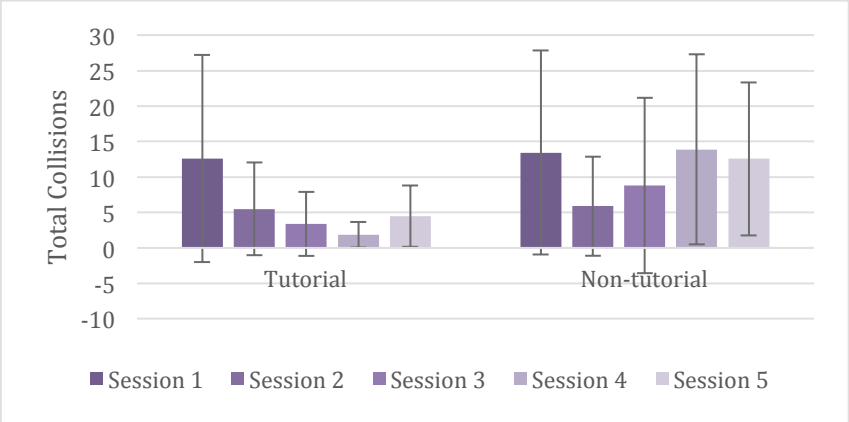

Figure 2: Total collisions across Sessions for tutorial and non-tutorial groups

The Levene Test was not violated for average perception response time so the groups were collapsed and the Friedman test (p=0.04) was used to demonstrate a significant repeated measures effect across time (Session 1-5). Follow up Wilcoxon Signed Ranks Test suggests that perception-response time in Session 1 was significantly slower than all other Sessions.

Discussion

The findings of this work demonstrate that using the tutorial session to orient unfamiliar users with the VR environment is beneficial for reducing intra-individual variability in collision occurrence. Achieving a base level of competency in the physical task of driving allows the researchers to have confidence in the subsequent measures of cognitive load that will be used in the evaluation of interface design.

Relevance to Practitioners

Using VR in a training or research context is gaining traction but a large learning curve exists that must be overcome. Further, many individuals may not tolerate VR as a medium for long periods of time. This work has demonstrated the importance of using a tutorial session to orient the user, and the decreasing variance that can be achieved with increased practice in the VR simulation.

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Can Seat Pan Design Mitigate Lower Limb Swelling and Back Pain?

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Introduction

Prolonged sitting has been shown to have very negative health consequences, including early death and cardiovascular disease, especially when not offset by physical activity[1] Further, there is evidence that prolonged sitting is related to increased rates of low back pain (LBP)[2]. For these reasons, increasing movement during the workday has been advocated for desk workers in office settings. One possible solution to this problem could be alternative chair designs: specifically, a design that permits movement of the low back, hips and lower limbs in seated posture. The purpose of this study was to examine the impact of an "active" multi-axis chair on lower limb swelling and perceived back pain over a prolonged sitting exposure.

Methods

In this randomized repeated measures cross-sectional study, 30 male participants of working age (19-65) were recruited from the local population. Participants completed two, three hour, experimental sessions, at the same time of day, at least 24 hours apart. Each session consisted of instrumentation with two accelerometers at the upper and lower back, followed by a 2-hour standardized typing task at an ergonomically adjusted workstation. Participants were block randomized to either type in the "active" or typical office chair on the first day, followed by the other chair during the second session. Lumbar spine angle was calculated at the relative angle between accelerometers normalized to spine flexion range of motion (% ROM), calf circumference was measured 10 cm distal to the knee cap of the right leg immediately before and after the prolonged sitting trial and ratings of perceived back pain were collected at 7.5 minute intervals throughout the trial using a digital 100 mm Visual Analog Scale (VAS) with anchors of 0 mm = "no pain" and 100 mm = "worst pain imaginable". Qualitative feedback on both chairs was also collected. These outcome measures were compared between chair type using a 1-way repeated measures ANOVA (SPSS version 22.0, IBM Corporation, Armonk, NY, USA).

Findings

Participants sat with significantly less spine flexion on average in the active chair (62.25 % ROM +/- 18.22 SD) compared to the typical chair (70.80 % ROM +/- 11.98 SD; $p = 0.039$). Average peak perceived pain rating in the low back region was found to be significantly lower in the active compared to the control typical chair (p=0.025). Calf circumference measures increased significantly less in response to the prolonged sitting trial with the "active" (average circumference differential + 0.021 cm +/- 0.73cm) compared to the control typical chair (average circumference differential +0.962 cm +/- 0.74) ($p < 0.00$). Qualitative data indicated participants perceived the active chair favourably.

Discussion

The primary finding from this investigation was that participant's exhibit significantly less lumbar flexion throughout a 2-hour standardized office task sitting in the active chair compared to the typical office chair. Participants sitting in an overall less flexed posture could point to a reduction in the risk of injury since the percent of time spent in non-neutral or flexed low back postures is a known risk factor for LBP[3]. Steadily increasing perceived low back pain, was also seen for both

chair conditions in this study, however, participants reached a significantly higher average peak pain rating in the typical compared to the "active" chair.

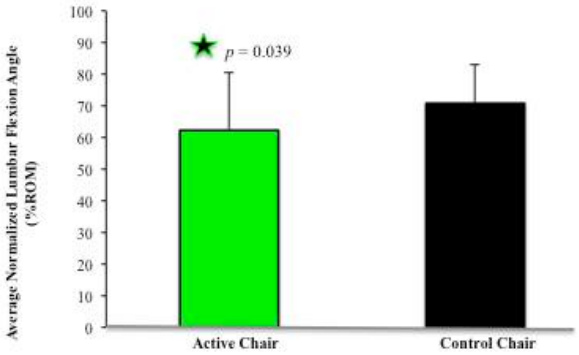

Figure 1. Average Normalized Lumbar Flexion Angle (% ROM) over the 2-hour typing trial for thirty participants in both the active chair and control chair conditions.

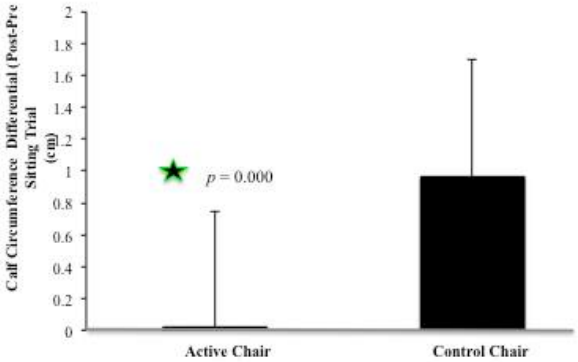

Figure 2. Average change in calf circumference (cm) for thirty participants after the 2-hour typing trial in both the active chair and control chair conditions

These results suggest participants had a less painful experience while seated in the active chair while completing the typing task. Previous literature has shown that increased calf circumference due to leg swelling associated with venous pooling exists after periods of prolonged sitting[4]. Calf circumference increase was significantly lower in the active chair suggesting that the participants had less venous blood pooling in their lower limbs while seated in the "active" compared to the control. This could be related the more erect posture which may have reduced compression of the vascular system at the hips, however, as lower limb posture and/or muscle activity were not measured we cannot say for sure. Future laboratory studies should focus on these measures to provide more insight into the mechanism of this effect.

Relevance to Practitioners

This study found that, in comparison to a typical office chair, the "active" chair design had significant impacts on spine posture, calf circumference and perceived back pain. This result is very encouraging given that these measures should be theoretically related to cardiovascular health and low back pain. Large epidemiological studies would be required to examine the impact on these aspects of health at the population level.

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Career Firefighters' real-time physiological Response to firefighting tasks over 6 months: Implications for injury prevention

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[2]Thunder Bay Fire Rescue

Introduction

Firefighting is a physically demanding job that requires firefighters to perform work tasks under extreme conditions. These conditions are often physiologically taxing, requiring performance of strenuous tasks in challenging work environments (1). Studies of firefighter physiological response are often performed in controlled environments which may limit application to practice (2). The purpose of this study is to determine career firefighters' real-time physiological response to two firefighting tasks over 6-months with a view on firefighter injury prevention.

Methods

Context: This is a cohort study conducted in partnership with Thunder Bay Fire Rescue and the Thunder Bay Professional Firefighters Association. Baseline data is complete; 6-month data will be completed in May 2018.

Sample: 37 career firefighters (36=male) were recruited from the Thunder Bay Fire Rescue.

Data Collection: All study components were performed in the fire department's training facility which allowed access to firefighting equipment. Demographic information (age, height, weight, years of service) was collected prior to task performance. Firefighters were then fitted with a Zephyr BioHarness that was used to collect physiological measures over the course of the task performance (3). Firefighters donned all bunker gear including the self-contained breathing apparatus and were asked to perform a hose-drag task with a charged line and a patient transfer into a stair chair. The hose drag task began with firefighters in a standing position. When instructed, they retrieved the nozzle of the charged fire hose (1000 kpa), from the floor and then dragged the hose 100 ft. The hose was then discharged using a "straight stream" setting for five seconds. This task was performed twice before participants performed the patient transfer. The patient transfer task required a paired lift to transfer a weighted manikin (68 kg) from the floor into a stair chair. The lift was performed twice; once lifting at the head of the manikin and once lifting at the feet of the manikin.

Figure 1. Firefighter discharging hose on straight stream setting.

Data Analysis: The following is analysis of baseline data; the final conference presentation will include a comparative analysis between baseline and 6-month data. Descriptive analyses of demographic and physiological measures were examined; comparative analyses within task (trial 1 vs. trial 2. for hose drag and patient lift) and between tasks (hose drag and patient lift) were also conducted. Cumulative physiological load was determined by calculating change in physiological measures between baseline and post-task (defined as completion of both hose drag and patient-transfer). Physiological measures of interest included: heart rate, heart rate variability, breath rate and estimated core temperature.

Findings

Our sample included active duty, career firefighters who were 39 (+/-8) years of age with an average BMI of 29 which places them in the "overweight" category (4).

Table 1: Demographic Information

	Mean (SD)	Min.	Max.
Age (yrs)	39.8 (7.8)	27	58
Height (cm)	183.95 (8.23)	167.64	198.12
Weight (Kg)	99.6 (23.7)	78.5	187.96
years of service	11.6 (7.2)	3	26

Heart rate variability (HRV) significantly decreased between baseline and end of task completion ($t(19) = 2.473$, $p < .05$). Heart rate (HR) increased through-out task completion, ($t(19) = -3.347$, $p = .003$) whereas breath rate decreased, $t(19) = 2.491$, $p = .022$. Core temperature appeared to remain constant however there was a significant increase between patient transfer compared to the hose drag task, $t(16) = -5.867$, $p < .001$.

Table 2: Physiological response from initiation of firefighting tasks (hose drag) to completion (patient transfer) and between firefighting tasks [$\bar{X}$ (SD)]

	Baseline	End	Hose Drag	Patient Transfer
HRV (ms)	78.5 (35.8)	57.4 (25.1)	80.2 (39.3)	55.7 (24.1)
HR (bpm)	97.4 (21.9)	110.8 (17.2)	118.1 (17.8)	106.6 (17.1)
BR (bpm)	20.4 (6.4)	16.1 (4.8)	18.9 (5.4)	17.6 (4.1)
CT (°F)	99.59 (0.23)	99.88 (0.25)	99.64 (0.24)	99.89 (0.24)

(HRV=Heart Rate Variability; HR=Heart Rate; BR=Breath Rate; CT=Core Temperature)

Discussion

Initial results suggest increased physiological load during performance of these two firefighting tasks as demonstrated by a decrease in HRV and increased in HR. Decreasing HRV suggests an increase in sympathetic activity of the autonomic nervous system (ANS) and is often observed with an increased HR, indicative of physiological or psychological stress (5). The observed decrease in BR may be result of participants employing the Valsalva maneuver during the patient lift, thereby reducing their breathing rate. Measures of physiological load may elucidate manifestation of fatigue and firefighters' ability to regulate physiological response to various stressors (5). These preliminary findings suggest an increasing physiological load over the course of task performance.

Relevance to Practitioners

These study findings provide unique insights into firefighters' real-time physiological load during two physically demanding firefighting tasks. Ergonomists who aim to prevent injury and illness in high work demand occupations may use this information to target strategies aimed to reduce physiological load.

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INTERACTIVE LECTURE

Flawed situational awareness: a stealth killer in the workplace

Richard Gasaway, PhD, EFO, CFO

This session builds on the foundation established during the keynote address and offers attendees specific examples of how flawed situational awareness can impact safety. Flawed situational awareness is NEVER the root cause of a near-miss or casualty. It is a SYMPTOM. The barriers that flaw situational awareness are the root causes. This fast-paced program will introduce you to barriers that flaw awareness and may include

- Pre-arrival lens
- Mission myopia
- Staffing issues
- Normalization of deviance
- Overconfidence
- Miscommunications
- Peer pressure
- Supervisor pressure
- Overload
- Task fixation
- Task saturation
- Mind drift
- Cognitive biases
- The curse of knowledge
- Human factors
- Technology
- Command location
- Command support
- Fear-driven decisions
- Culture
- … and more

PAPER SESSION 7: MOBILE EQUIPMENT

Day 3 – Oct 17th	
13:15-14:45	**Paper Session 7** Mobile Equipment Kevin Gillespie Forensic Ergonomics: Line of sign and visibility assessment in critical injury and fatality 'struck-by' investigations; a case study Heather Kahle Efficacy of broadband alarms: use, perception and safety Brandon Vance Documenting construction worker knowledge and attitude around reversing aids and visibility policies Amandeep Singh Investigation of occupational ride comfort in cultivation operation by Taguchi's method

Forensic Ergonomics: Line of Sight and Visibility Assessment in Critical Injury and Fatality 'Struck-by' Investigations; A Case Study

Kevin Gillespie
Ontario Ministry of Labour, Ottawa, Ontario, Canada

Introduction

Struck-by incidents are one of the leading causes of critical injuries and fatalities in Ontario workplaces. The goals of any Ministry of Labour (MOL) investigation into a workplace health and safety incident are to prevent a reoccurrence and identify any contraventions of the Occupational Health and Safety Act and associated regulations that may have contributed to the incident. During 'struck-by' investigations, the investigation team typically includes a MOL ergonomist to conduct a line of sight and visibility assessment which is usually key to identifying the incident's root cause.

This paper outlines the methodology and findings of the ergonomics assessment that was performed as part of a fatality investigation.

Description of Incident and Ergonomist Investigation

A worker using a torch to dismantle equipment in a scrap metal yard was fatally injured when he was struck and run over by a 47 tonne crawler (track) excavator. The excavator was reversing through the yard while pulling a city bus using the hydraulic shear mounted on the excavator's boom. A visibility and line of sight assessment was conducted as part of the investigation to identify blind spots or areas with an obstructed view, from the perspective of the excavator operator and/or areas visible using mirrors. Physical and cognitive factors affecting the visibility of the fatally injured worker to the excavator operator were also investigated including the human eye visual field, resolution and position of the fatally injured worker, contrast between the worker's clothing and the background, object size and movement, operator's expectancy and task complexity.

Forensic mapping of the scene was conducted using a Robotic Total Station; an electronic/optical instrument consisting of an electronic theodolite (transit) integrated with an electronic distance measurement (EDM). Using the horizontal and vertical angles from the electronic theodolite and the slope distance from the EDM, precise three-dimensional point coordinates in a physical environment are recorded. The total station was also used to map the boundaries of the area visible using the right side mirror as it was the only means of visibility toward the vicinity of the fatally injured worker. The recorded data were used to create a three-dimensional digital model of the equipment and depict the area visible to the operator using the right side mirror (Figure 1).

Investigation Findings and Outcomes

The field of view provided by the right side mirror extended rearward along a line tangent to the right side of the excavator's body and in a pie shape to the right (Figure 2). With the operator looking at the hydraulic shear and bus, the right side mirror was positioned 70° to the right, at the outer edge of the operator's visual field (Figure 2) where objects are unlikely to be noticed, especially if not large, high contrast and moving (1). In this case, the fatally injured worker was stationary with his back to the excavator and his clothing provided low contrast with the surrounding background environment. The position of the mirror and its convex shape also resulted in small reflected images of objects and distortion which affects distance perception. Furthermore, the mirrors were not being maintained in a condition to maximize their effectiveness, with dust and dirt on the reflective surface reducing the visibility in the mirrors. As a result of the low contrast, small reflected image size and lack of movement of the fatally injured worker,

particularly while positioned near the edge of the operator's visual field, it is unlikely that the fatally injured worker would have been detected by the excavator operator in the right side mirror (2, 3). Furthermore, the right side mirror was completely obstructed by the excavator's boom unless the operator leaned forward away from the seatback and turned his head significantly to the right. It was determined that the operator was not likely using the right side mirror while reversing through the yard and the operator was focused on the hydraulic shear towing the bus. However, even if he had been using the mirrors, there was no visibility to behind the excavator and therefore no ability for the operator to see the path of travel when operating in reverse.

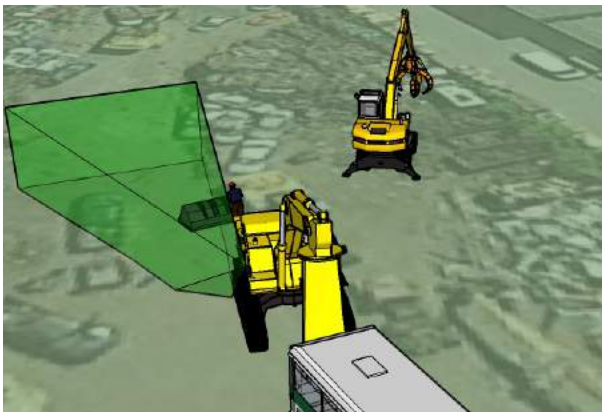

Figure 1: Digital model of equipment & LOS depiction

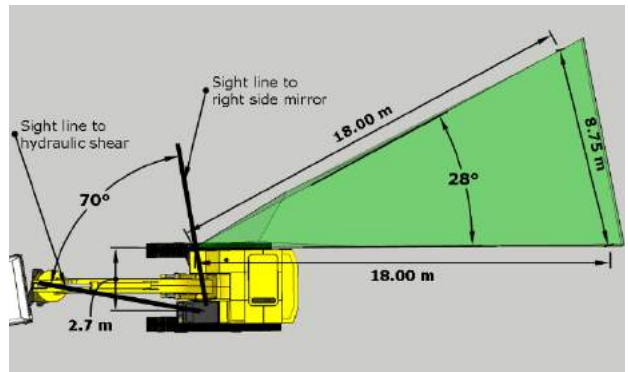

Figure 2: Line of sight (LOS) dimensions and sight line angle

The complexity of the task of pulling the bus through the scrap yard was increased due to the amount of congestion with large amounts of scrap metal, heavy equipment and vehicles, reducing the operator's likelihood of noticing obstructions or pedestrians (2, 3). The lack of dedicated pedestrian work areas in the yard and the lack of delineation between areas where heavy equipment operates, delivery vehicles are moving and pedestrian traffic increased the probability of a pedestrian/vehicle incident. Despite the operator being previously aware of the fatally injured worker's presence and position, the operator's primary focus was on the bus that was being pulled through the yard and not on his position or that of other workers in the yard.

The employer was charged with multiple contraventions including failing to ensure that barriers, warning signs or other safeguards for the protection of all workers were used in areas where vehicle traffic may endanger the safety of workers as well as failing to ensure that a competent signaller was used as the operator did not have full view of his intended path of travel.

Relevance to Practitioners

Understanding line-of-sight and visibility factors involved in struck-by incidents can assist practitioners setting up workplaces, policies and training programs to prevent workplace injuries. An understanding of the investigation process for these types of incidents can also assist practitioners investigating complaints or near miss incidents where the MOL is not involved.

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Efficacy of broadband alarms: use, perception & safety

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Introduction

When equipment or vehicles – especially large ones - are reversing, people and objects may not be in the driver's view due to the size of the vehicle, the equipment on board, or other vehicles or objects in the vicinity. Rather than only rely upon the driver's view, acoustic backup alarms are often used to alert those nearby of the impending danger so that they know to get out of harm's way.

Despite the availability and use of audible alarms however, accidents and fatalities involving reversing vehicles continue. Data from WorkSafeBC's data warehouse identified 550 backover incidents from 2001 to 2015. Among the identified incidents, 13 workers were killed when they were pinned, struck or rolled over by mobile equipment or vehicles that were reversing.

The ubiquitous conventional single-frequency tonal (beep…beep…beep), reversing alarms have a typical volume of 97-112 decibels (dB) and a sound that propagates up to three kilometers from the danger zone; needlessly alerting others (1). In environments such as busy construction or mining sites with various pieces of equipment and machinery constantly arriving, working and leaving the site, many of which also emit beeping and alarm noises, single-frequency tonal alarms can be ignored, difficult to localize, and masked such that they might not be audible above the other sounds. Recently – the broadband alarm (BBA) is gaining popularity as a means to mitigate risk from reversing equipment. The BBA emits a unique "pssht....pssht.." sound comprised of all audible frequencies from 400-10, 000 Hertz broadcast simultaneously, rather than a single frequency like that of the tonal alarm. Broadband alarms have many potential benefits such as being easier to localize, or pinpoint which vehicle is reversing but few studies have investigated workers' real-world perceptions to the BBA that ultimately effect worker safety.

Methods

A multidisciplinary, team from WorkSafeBC developed a survey to assess workers' perceptions regarding the broadband alarm. The research was conducted as a controlled experiment by exposing respondents to the sound followed by a survey. Building on the work of Dr. Deborah Withington (2), the online survey asked participants if they had heard the broadband alarm before. If the participant had heard the BBA sound before, they were asked to complete the survey comprised of 15 questions. If respondents indicated they hadn't heard the broadband alarm, the survey jumped to the outro page where respondents were thanked and exited out of the survey. It is noted that excluding those who hadn't heard the noise previously limited the depth of findings, and is a limitation of the current study.

Questions 1-3 assessed overall awareness of the BBA, questions 4 and 5 probed reaction to and comprehension of the BBA, question 6 asked about association with a reversing vehicle, questions 7-9 asked about interpretation as a warning, questions 10-11 asked if noises interfere with the BBA, questions 12-13 asked about levels of annoyance and questions 14-15 queried training for the BBA.

Findings

The total number of respondents who had heard the broadband alarm before was 138. Among those, 63% heard it at work; 30% heard it near a construction site; 22% heard it in a loading bay. 24% of respondents heard the alarm elsewhere not listed.

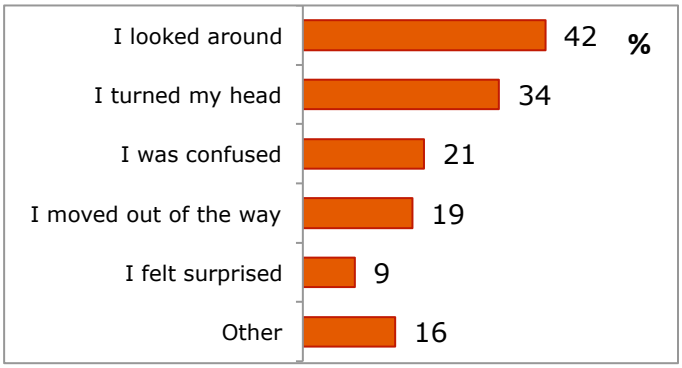

Figure 1: First reaction to hearing the broadband alarm

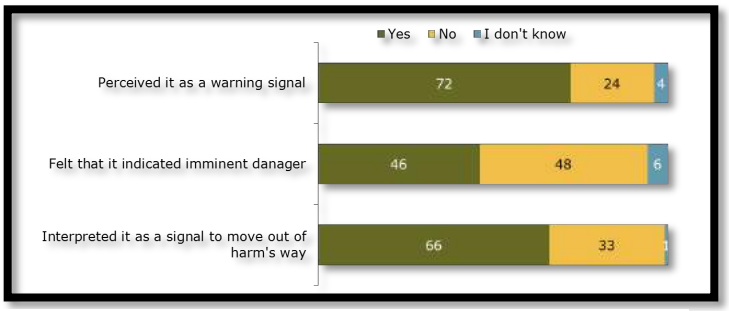

Figure 2: Interpretation as a warning/danger

When asked what did you think the sound meant, 24% thought it sounded like a bird in distress. Others thought the alarm sounded like strange duck noises while others believed the sound meant something was broken on a piece of equipment such as an air leak. Others thought it meant there was an issue with the alarm; believing the beeper might be broken. Still several others indicated that they had no idea what the sound was. There were multiple, varying perceptions as to how the signal was taken. 72% of respondents perceived it as warning signal; 24% did not. While 66% thought it meant to move out of harm's way, a third did not. Over half of respondents didn't feel it indicated imminent danger.

Discussion

BBAs have several favourable features including being easier to localize, and projecting a more uniform sound field behind the vehicle (thereby providing fewer misleading proximity cues), and the BBA alarm signal is more focussed in the area where a person may be at risk. Also, it is less likely to be masked by other noises on a worksite and causes less noise annoyance for neighboring communities. However, as the BBA is relatively new to worksites in B.C., hence, focus is needed to boost understanding of the meaning of the broadband signal and its interpretation as both a warning signal to move out of harm's way and as an indicator of imminent danger.

The research supported our hypothesis that respondents will find the broadband alarm effective in capturing attention to indicate the location of the hazard ***but*** has limited effect in consistently signalling what the hazard is and whether it is a life threatening hazard.

Relevance to Practitioners

Applying these findings will help practitioners develop effective education programs that become part of any employee orientation and/or safety discussion across industries when deploying new technology such as the BBA.

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Documenting construction worker knowledge and attitude around reversing aids and visibility policies

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Introduction

Accidents and fatalities related to reversing machinery continue to be a large issue and are very costly to the industrial sector. Even with the policies and legislation efforts established on worksites that aim to reduce the number of equipment-human interactions, these accidents and fatalities continue to occur. This can be attributed to the dynamic environment of worksites and, at times, confined spaces in which workers are required to perform tasks[1]. The most common contributing causes to struck-by accidents have been found to be human factors involving misjudgment of a hazardous situation, as well as large blind spots[2]. Even with current precautions such as spotters, back up alarms, PPE in place, these incidences still manage to occur. Therefore, efforts have been made to improve operator's situational awareness and line of sight to blind areas around the machine.

In Ontario, it is mandated that a dump truck must have an automatic audible alarm that alerts individuals when it the truck is reversing (s.105)[3]. The constant beeping is often considered a nuisance noise; and operators reportedly disable these alarms. In fact, in 56 out of 69 fatalities using heavy machinery reviewed by Hinze and Teizer, the back-up alarms were disabled or non-functional[1]. Using a spotter for reversing maneuvers may also help to reduce pedestrian-equipment interactions but one study found that unqualified individuals often attempt to work as a signaller to accelerate worksite operations[4]. The use of back-up cameras and other proximity awareness technology (PAT) has begun to creep onto worksites but is not routinely found. The goal of this work was to document construction worker knowledge and attitude towards back-up policies and technologies.

Methods

A total of 56 participants from the construction industry were recruited from a health and safety training facility to complete a survey related to visibility knowledge. The survey took about 15 minutes to complete and included questions related to knowledge of visibility policy, ratings of reversing aid utility and frequency of use, and ratings of visibility around common pieces of machinery. Participants were asked to differentiate whether they were operators or someone who worked around the machinery. Data were summated and presented as descriptive data below.

Findings

Participants were asked to rate the frequency of use for five types of reversing aids: mirrors, cameras, RFID system, spotters, audio. The percent of participants reporting usage of each aid is presented in Table 1. The rating of effectiveness was measured on a 3 point scale ranging from 1 = not effective to 3 = very effective (Figure 1).

Participants then provided a rating of perceived visibility in eight sectors around the machine and subsequently, when given a birds-eye view of the area around a machine, were asked to indicate with a freehand 'X' where they would position themselves if they were tasked with being a spotter for that machine operating in reverse. Results for the dump truck are presented in Figure 2 below.

Table 1: Frequency of use for various reversing aids in the construction sector.

Type of Reversing Aid	Reported Frequency of use (% respondents)			
	Never use	Sometimes Use	Always Use	Unavailable
Mirror	1.8	7.1	82.1	1.8
Camera	21.1	19.3	17.5	29.8
Spotter	5.3	31.6	47.4	1.8
RFID	29.8	15.8	14.0	21.1
Audio	21.1	33.3	26.3	8.8

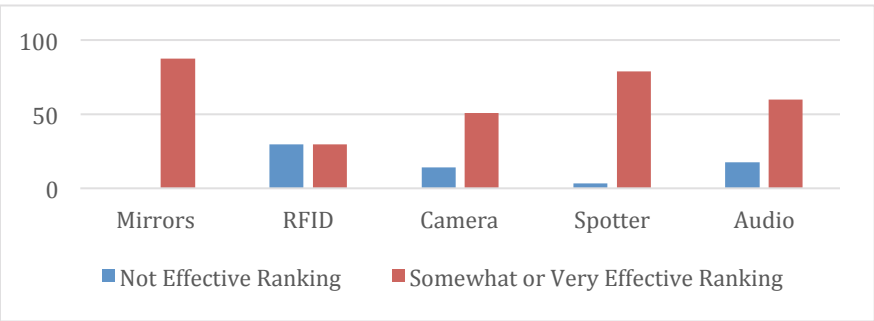

Figure 7: Ratings of effectiveness for a variety of reversing aids

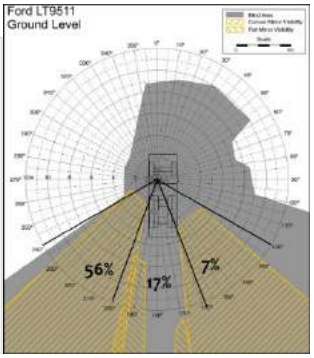

Figure 2: Chosen spotter location behind a dump truck. Grey (blind area). Yellow (mirror visibility)

Discussion

The most consistent reversing aid to which construction workers have access was the mirror, with camera and RFID systems were unavailable to most workers. Furthermore, despite perceptions in the industry, nearly half (47.3%) of all respondents reported using a spotter for reversing and only 1.8% reported spotters as being unavailable. This suggests that mandated legislation has had a positive impact on that role. The effectiveness rankings of the reversing aids mirrored the use question with mirrors having the highest utility ranking of all devices (88%). The RFID systems received equal ratings of not effective or being somewhat or very effective. When evaluating the spotter location values overlaid on a NIOSH visibility graph, one can see that the majority of workers would position themselves in the left rear sector to help a dump truck perform a reversing maneuver. A concerning 17% would position themselves in the rear sector, which is mostly a complete blind spot to the operator, unless a camera system has been installed.

Relevance to Practitioners

Data from the surveys can be used to guide future training sessions related to operator visibility from a variety of machinery.

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Investigation of occupational ride comfort in cultivation operation by Taguchi's method

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Introduction

Tillage is an essential agricultural activity for preparing soil to develop the ideal optimum conditions for seed germination, seedling establishment and growth of crops. A number of primary and secondary soil tillage operations are required in every agricultural field. Cultivation is a secondary tillage operation performed by a toothed type cultivator often similar to chisel plows. It is mounted to a tractor by using a three-point hitch and driven through a power take-off (PTO). The tractor and its mounted implements give rise to vibration during interactions with uneven terrain [1]. Vibration transmits to the driver through many sources (e.g. steering wheel, seat, seat backrest, tractor platform etc.) that may affect the ride comfort [2]. Moreover, prolonged exposure to vibration can increase risk of low back disorders among tractor drivers [3]. This may be due high amplitudes to which a tractor driver is exposed during off-road operations. In current era, the tractors are being equipped with advance technology like cab and effective suspension system to provide better ride. However, these are very expensive to buy by the farmers of developing countries like India. Therefore, it is important to provide optimum driving conditions in existing tractors to improve ride comfort. Therefore, the present study attempted to investigate the effect of three ride conditions namely, forward speed, pulling force and tilling depth on ride comfort in terms of overall vibration total value (OVTV).

Methods

The study was carried out in the field situated at Punjab Agriculture University, Ludhiana, Punjab (India). A 50 hp tractor 'T' of 2014 model was selected for the study. The ride conditions and their levels include forward speed (1.3, 1.5, 1.7 m/s), pulling force (2, 4, 6 kN) and tilling depth (0.10, 0.13, 0.16). The study aimed at to obtain optimum ride conditions to reduce the overall vibration total value response. The experimental design is formulated by using Taguchi's L27 orthogonal array in Minitab 17.0 software.

Findings

The mean overall vibration total value in this tillage operation ranges from 0.625 to 0.831 m/s2. The computed S/N ratios are further used to obtain optimum levels of input parameters for getting reduced overall vibration total value. The response for Signal to Noise (S/N) ratios with respect to ranking of each input factor is represented in Table 1.

Table 1: Response Table for Signal to Noise (S/N) Ratios (Smaller-the- better)

Level	**Input Factors**		
	Forward Speed (m/s)	**Pulling Force (kN)**	**Tilling Depth (m)**
1	3.359	2.172	2.422
2	2.323	2.608	2.615
3	2.002	2.904	2.648
Delta	1.357	0.732	0.226

In Table 1, the delta value was calculated for each ride conditions and it can be observed that forward speed had maximum delta value (1.357) followed by pulling force (0.732) and tilling depth

(0.226). The delta value showed the intensity of effect of respective condition on the output response. Therefore, the forward speed has maximum contribution in affecting the overall vibration total value. The trend of S/N ratios with respect to selected input factors and their respective levels is shown in Figure 1.

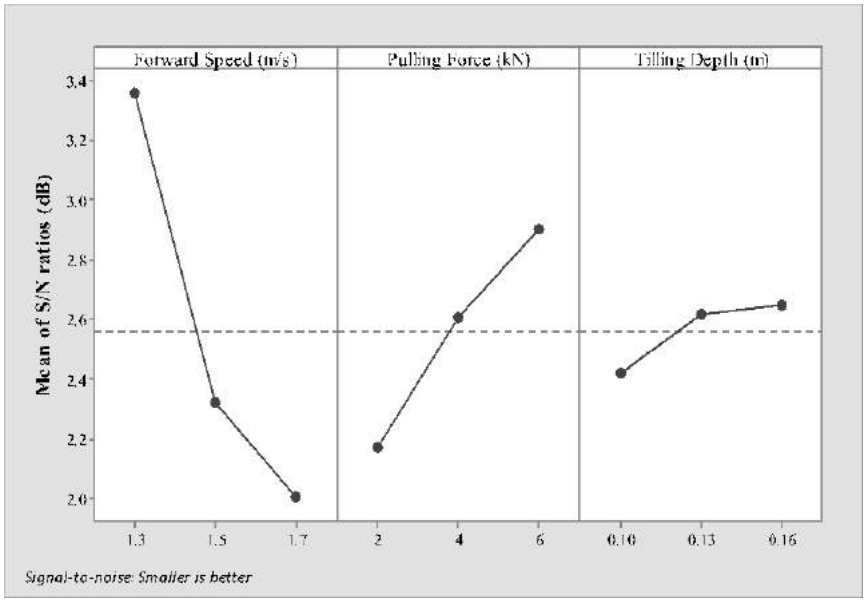

Figure 8: Main Effects Plot for Signal to Noise (S/N) Ratios

Discussion

The mean OVTV response increases with increase in forward speed and it get decreases with increase in pulling force. This increase in OVTV could be due to the increase in vibration caused by accelerating speeds on uneven terrains [4]. The OVTV tends to decrease suddenly with increase in the tilling depth from 0.10 to 0.13 m, however this change represents a slight decrease with increase in tilling depth from 0.13 to 0.16 m. It means that the vibration get absorbed while increasing the tilling depth. It was observed that forward speed and pulling force had significant effect on overall vibration total value at 95% significance level.

Relevance to Practitioners

Ride comfort has become a challenging issue for tractor manufacturing industries to satisfy customer demand. Information pertaining to ride comfort among drivers could be useful to the tractor manufacturers for suitable improvements.

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PAPER SESSION 8: STUDENT AWARD FINALISTS – PHD AND POST-DOCTORAL FELLOWS

Day 3 – Oct 17th	
13:15-14:45	**Paper Session 8** Founders Award Finalists: PhD and Post-Doctoral Fellows <u>Michal Glinka</u> Chair design challenges for accommodating postures between traditional sitting and standing <u>Katie Goggins</u> Anatomical locations for capturing magnitude differences in foot-transmitted vibration exposure <u>Colin McKinnon</u> The influence of hand location on lumbar spine axial twist and flexion postures during simulated industrial reaching tasks

Chair design challenges for accommodating postures between traditional sitting and standing

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Introduction

Height-adjustable sit-stand desks have seen widespread use in the workplace. These devices allow users to freely transition from sitting to standing with minimal disruption to work flow. Though standing is often touted as an active alternative to sitting, a range of health concerns—including low back pain (LBP)—remain unresolved in workers who stand for prolonged periods. The persistence of back pain in both sitting and standing may be related to the effect each posture has on load-bearing structures in the lumbar spine. In sitting, the pelvis slopes backward, introducing a convex curve that loads the posterior tissues of the lumbar spine and compresses the anterior portion of the intervertebral disc. Standing presents the opposite scenario, whereby the pelvis tilts forward more naturally, but the lumbar spine often extends too much, introducing stress concentrations on the posterior elements of the vertebral column (i.e., facet joints). Interestingly, radiographic [1] and magnetic imaging [2,3] studies suggest that trunk-thigh angles between sitting (90°) and standing (180°) may provide some relief to the lumbar spine and hip joint tissues. Accordingly, chair manufacturers have developed sitting solutions aimed at supporting users in postures that approach a more open trunk-thigh angle. The work presented herein consolidates data from three studies aimed at understanding the biomechanical response and perception of effort and discomfort of individuals when transitioning, while supported by different seat configurations, from sitting up toward standing. The goal was to highlight chair and postural constraints that may affect user perceptions of comfort and physical demands in open trunk-thigh postures, with an eye toward informing user sit-stand workstation guidelines.

Methods

The first study involved 24 participants (mean age = 25.0 ± 2.2 years) transitioning in 5° trunk-thigh angle increments from conventional sitting (hips and knees at 90°) to standing (hips and knees at 180°). Participants were supported at each increment by a flat, rigid surface under their buttocks and thighs. The second study involved 16 participants (mean age = 25.0 ± 2.2 years) performing a similar transition to study 1, but only up to a 135° trunk-thigh angle and this time in a contoured prototype chair with a higher friction fabric on the seat pan and a lumbar support pad. In the first two studies, participants performed simulated office work for 1 minute at each trunk-thigh increment while biomechanical data were collected. The third study involved 24 participants (mean age = 25.0 ± 2.2 years) simulating different working postures (e.g., forward leaning versus reclined) in three different office chairs with varying backrest heights. Mean values were computed for the following measures: foot-floor support forces (studies 1,2), lumbar spine and pelvis angles (studies 1,2,3), chair interface pressures (study 2), and muscle activities of the leg extensors (study1), lumbar extensors (studies 1,3), and neck flexors (study 3). Subjective ratings of perceived effort and discomfort associated with the different chair products in each posture were also assessed. Finally, a trade-off index was calculated, which incorporated normalized values of required foot-floor force (i.e., representing physiologic cost) and the resulting lumbar spine posture (i.e., the potential benefit for paying that cost). Relevant measures were compared across trunk-thigh angles (studies 1,2), backrest heights (study 3) and between support types (study 2,3) using a mixed-model ANOVA with $\alpha = 0.05$.

Findings

As chair height increased to facilitate larger trunk-thigh angles (study 1), participants' body weight shifted from the seat pan to the feet. In order to keep the buttocks from sliding forward at these

intermediate postures, knee extensor activity increased (up to 12% of maximum), which allowed the feet to apply the required stabilizing force at the floor. This physiologic cost of increased leg muscle activity was reduced in study 2 with a contoured seat pan ($p < 0.001$), but this came at the expense of greater pressure under the thighs at more open trunk-thigh angles ($p = 0.001$). The trade-off index encapsulates this competing dynamic, indicating that while the prototype chair generally involved a more favourable trade-off of leg muscular demand versus lumbar spine posture ($p = 0.012$), raising the chair to induce more open trunk-thigh angles did not reduce lumbar spine flexion enough to offset the required increase in foot-floor force (Fig. 1A). Individuals' subjective responses mirrored these findings, with greater levels of perceived physical demand and discomfort at increasing chair heights (Fig. 1B).

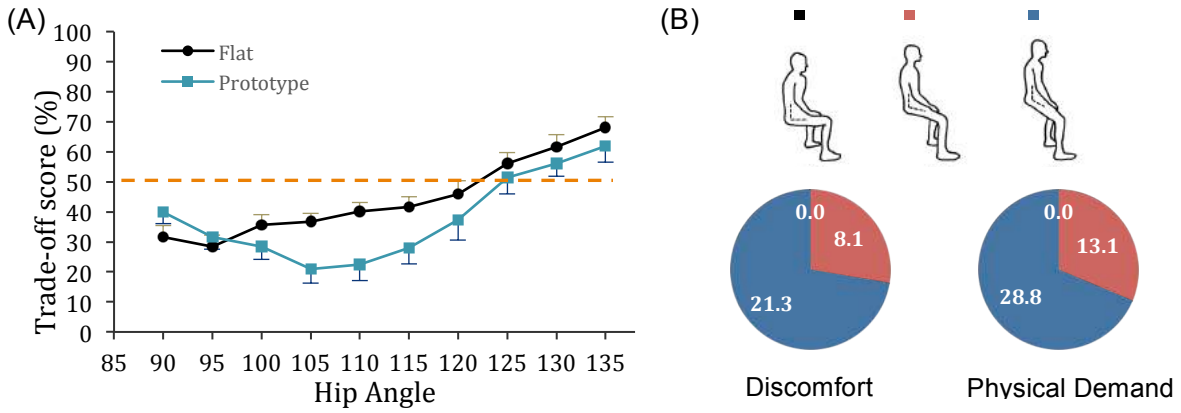

Figure 9: (A) Trade-off index compared between the flat and prototype chair, and (B) subjective discomfort and physical demand responses for the prototype chair. Lower trade-off scores represent more favourable scenarios, where the lumbar spine is further away from maximum flexion, and foot-floor forces are lower.

Discussion

Chairs that accommodate intermediate sit-stand desk heights introduce important tradeoffs between physiologic demands and potential postural benefits. Several biomechanical measures in the current work (e.g., thigh pressure, foot force, pelvic tilt) started to deviate from sitting values around trunk-thigh angles of 115-120°. This suggests that there is a limit to the height—or trunk-thigh angle—at which existing chair products can comfortably support users. Practitioners should be mindful of the unintended consequences that accompany the intended postural improvements associated with more open trunk-thigh angles. A determination should be made as to whether the magnitude of the postural improvement is worth the physiologic cost. Without adequate support for the pelvis and thighs, and even distribution of body weight at the seat interface, sustained leg muscle activation requirements and higher pressure on the soft tissues of the thigh can lead to muscle fatigue, blood flow occlusion, and increased discomfort—as reported by participants in our studies. As measures indirectly related to these issues (i.e., foot force, pressure) were modestly higher in the intermediate postures than in conventional sitting, perhaps these postures should be used only as a short-term alternative to sitting and standing. Future products might benefit from exploring how to reduce the costs observed in this work, for example, by incorporating greater back support and allowing backrest tilt (which has shown minimal effect on neck and upper back muscle demands (study 3)).

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Anatomical locations for capturing magnitude diffferences in foot-transmitted vibration exposure

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Introduction

Vibration exposure may result in vibration-induced white feet (VIWFt), a condition that is similar to vibration-induced white finger (1). One shortcoming common to previous foot-transmitted vibration (FTV) studies is that measurements have been limited to a few anatomical locations on the foot: the head of the first metatarsal, and the medial and lateral malleoli (2, 3). Based on the results from a FTV study capturing transmissibility at 24 anatomical locations, it is unlikely that the response of a structure as complex as the foot can be characterized with two or less anatomical locations (4, 5). Resonance is used as an indication of injury as it leads to the maximum displacement between organs and skeletal structures, placing strain on the tissues involved and increasing injury risk (6). As transmissibility magnitude is a measure of the ability of the body to either attenuate or amplify an input vibration signal, understanding how to capture the regional differences in transmissibility magnitude of the feet by identifying which anatomical locations need to be measured may aid in the prevention of injury. The purpose of this research is to determine the number and locations of the minimum points required to capture the differences in magnitude of the transmissibility response of the foot.

Methods

Transmissibility measurements of 21 participants (15 males and 6 females), submitted to a vertical sine sweep from 10-200Hz, taken at 24 anatomical locations, were analysed (4). Multiple correspondence analysis (MCA) (7) was conducted on the maximum transmissibility magnitude in three standing positions (natural, forward and backward lean). A transmissibility magnitude threshold of 2.0 was used, meaning the vibration inputs were evaluated based on reaching 100% amplification. From the MCA analysis results, anatomical measurement locations were then grouped based on comparable response. Recommended minimum measurement locations were determined based on the response groupings, anatomical proximity, and ease of measurement.

Findings

The results of the MCA analysis are summarized in Figure 1. In order to capture the differences in transmissibility magnitude of the biodynamic response of the foot, while accounting for centre of pressure changes, measurements should be taken at: [1] T1P3, [2] any toe location except T1P3, [3] M1 or L1, [4] M2 or L2, and [5] M4 or L4. Measurements at H1, M3 and L3 should be avoided as these locations are difficult to capture with an accelerometer or laser Doppler vibrometer due to skin artifact.

Discussion

It is imperative to understand resonance (maximum transmissibility) in order to prevent injury from vibration exposure (6). This study identifies five measurement locations for capturing the pattern of maximum transmissibility magnitude at a threshold of 2.0 over 21 participants. This study suggests that the biodynamic response of the foot cannot be fully captured with 2 anatomical locations (2, 3), and requires additional measurements at the midfoot and toes. In order to capture the most potential for injury, measurements at the red anatomical locations (Figure 1) had the most

participants with transmissibility magnitudes over 2.0. Subsequent studies of FTV exposure should be mindful of the transmissibility magnitude differences at anatomical locations.

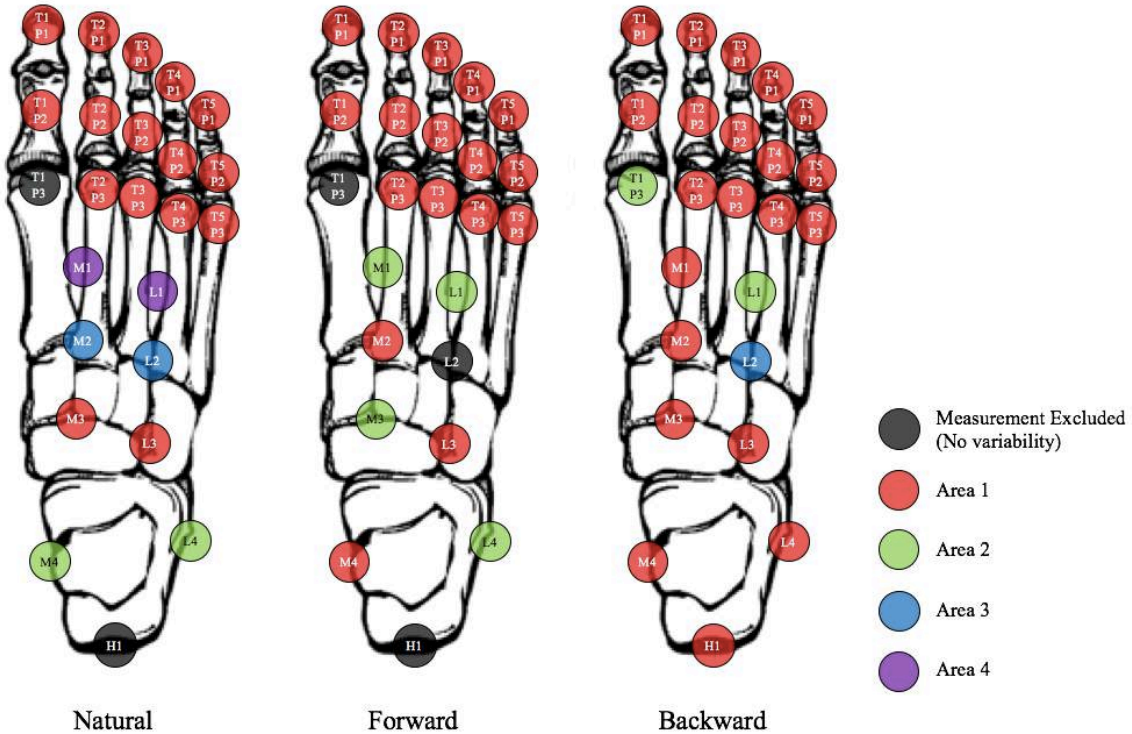

Figure 1: Anatomical representation of the clustered measurement locations from the MCA conducted at a transmissibility magnitude threshold of 2.0.

Relevance to Practitioners

When measuring FTV exposure, there are regional anatomic differences in the biodynamic response of the foot. This study identified anatomical locations with the greatest potential for injury (red) from the transmissibility magnitude response of 21 participants. Future FTV studies focused on injury prevention based on transmissibility amplification should include measurements at the five specified anatomic locations, at a minimum, in order to ensure that the regional responses of the foot are characterized.

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The influence of hand location on lumbar spine axial twist and flexion postures during simulated industrial reaching tasks

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Introduction

Current workstation design guidelines include recommendations for forward and lateral reach distances during occupational tasks based on task frequency and anthropometry. Forward reach guidelines focus on maintaining a neutral shoulder posture since large reaches create large shoulder loads, cause people to fatigue more quickly, and cause more reporting of shoulder pain (1). For lateral reaches, current guidelines are underdeveloped and do not have the same research-based foundation. Rather, lateral reach guidelines generally apply forward reach concepts to the lateral reach envelope determined by worker size and arm length. Low back twisting has been strongly associated with low back pain and injury development (2), and the relationship between reaching task hand location and low back twist is currently unknown. The purpose of this study was to investigate low back twist during simulated manual labour tasks across a range of forward and lateral reach distances, task heights, and exertion directions.

Methods

Twenty-four (12 male, 12 female) right-handed participants performed single-handed exertions against a load cell (MSA-6, AMTI, USA) attached to the end of a 6-DOF robotic arm (Motoman HP50, Yaskawa, USA). Eleven right-hand target locations corresponded to Canadian Standards Association forward and lateral reach guidelines for frequent (A), infrequent (B) and occasional (C) tasks (3). Exertions were performed at each hand location in all combinations of three directions (forward push, upward exertion, downward exertion) and two heights (standing acromion and olecranon heights) for a total of 66 1-second isometric exertion trials. Participant thoracopelvic and right upper limb postures were recorded using reflective markers on boney landmarks and an optical motion capture system (MX20+, Vicon, USA). Thoracopelvic angles (YZX Euler sequence) and right upper arm angles (YXY Euler sequence) were calculated using custom-written Matlab software. Thoracopelvic angles were normalized and expressed relative to a static upright standing trial. Joint angles were compared using a mixed general linear model (RStudio 1.0.136) with sex (M/F), target location (11 levels), height (elbow/shoulder) and direction (up, down, push) as factors ($\alpha = .05$). A Tukey HSD post hoc test tested levels within significant main and interaction effects.

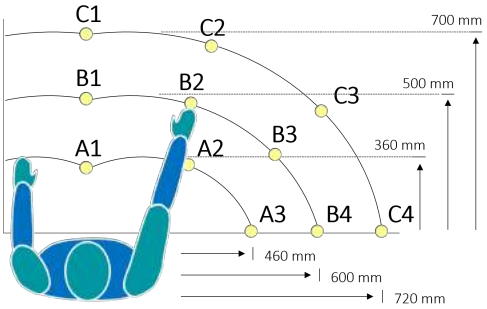

Figure 1: Eleven hand target locations used for manual exertions. Targets correspond to current ergonomics reach guidelines (CSA, 2012).

Findings

Significant target-by-direction ($p<.003$) and direction-by-height ($p<.03$) interactions were observed for all three axes of thoracopelvic motion (axial twist, flexion/extension, lateral bend). These motion axes also showed target ($p<.0003$) and direction ($p<.007$) main effects. Post hoc analyses showed axial twist angle increased with more lateral hand targets, and this increase was generally similar - regardless of reach distance (A vs. B vs. C). Thoracopelvic flexion showed the opposite

response, with less flexion at more lateral targets and more flexion with increased reach distance (Figure 2).

Significant target-by-direction-by-height (p=.01), direction-by-height (p<.0001), target-by-height (p<.0001), and target-by-direction (p<.0001) interactions were observed for glenohumeral elevation angle. Elevation was highest for straight forward targets and decreased laterally. Elevation showed similar levels with A and B reaches but increased for C reaches. Plane of elevation showed several significant 2-factor and 3-factor interactions including direction-by-height (p=.003) and target-by-direction (p<.0001). Plane of elevation tended to be closer to shoulder abduction for lateral targets and closer to shoulder flexion for forward targets, as expected.

Discussion

These results indicate a trade-off between the twist and flexion motion axes, with opposing postural demands for forward and lateral reaches. Participants used a contralateral twist strategy for straight forward hand locations, with an average 7.3° of leftward lumbar axial twist across the three reach zones. This twist indicates that participants may favour lumbar twist over shoulder flexion, as this contralateral twist would reduce the effective reach distance for these hand targets. The most lateral hand targets elicited approximately 15° of axial twist, which represents between 36 and 41% of maximum twist range of motion in an upright, neutral posture (4,5). Elevated risk of lumbar spine axial twist injury is estimated to occur at approximately 25% of twist range of motion, or 8.5° (5). Hand target locations in the current study greater than 60° from the midline of the body (A3, B4 and C4) exceeded this threshold and may elicit elevated injury risk regardless of task height or exertion direction.

Lumbar flexion demonstrated the opposite response of twist, with a less flexed, more upright posture at more lateral hand targets and greater flexion with increased reach distance. Flexion angle was similar for the frequent (A) and infrequent (B) reach zones and showed greater flexion for the occasional (C) reach zone. While clear trends were evident across hand target locations and exertion directions, it should be noted that lumbar flexion was less than 5° across all conditions.

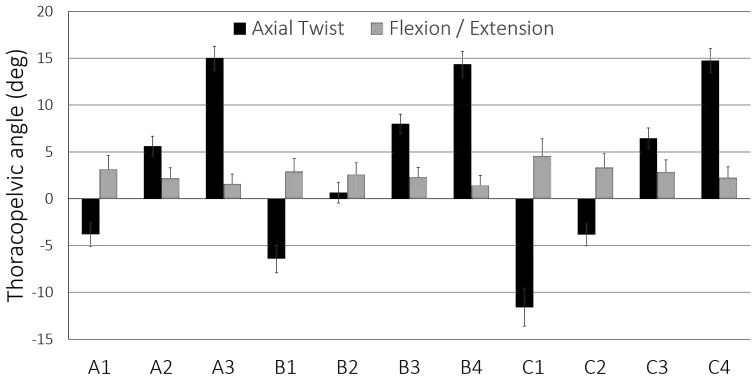

Figure 2: Thoracopelvic axial twist angle and flexion angle by hand target location. Positive values show rightward twist and flexion.

Relevance to Practitioners

Thoracopelvic axial twist was characterized across a range of hand target locations and indicates that future ergonomics guidelines should suggest limiting design of reaching tasks beyond 60° from the midline of the participant or worker. Beyond this threshold, lumbar intervertebral injury risk may be elevated. It appears that while shoulder demands are appropriate for derivation of forward reach guidelines and task recommendations, lumbar axial twist is the primary concern for lateral reaching tasks, and future guidelines should be adjusted accordingly.

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PAPER SESSION 9: GENERAL ERGONOMICS

Day 3 – Oct 17th	
15:15-16:45	**Paper Session 9** General Ergonomics Catherine Trask Egress technique in agricultural machinery and the risk of falls Mallorie Leduc Vibration Toolkit: Evaluation of an educational intervention Corey Bouwmeester The effect of underground mining footwear on lower limb gait characteristics and comfort

Egress technique in agricultural machinery and the risk of falls

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[2]School of Rehabilitation Sciences, University of Saskatchewan, Saskatoon, Saskatchewan, Canada

Introduction

Falls from a height are an important contributing factor to injury hospitalizations in Canada. According to the Canadian Institute for Health Information (CIHI) (1), over 60% of all injury hospitalizations were due to falls from a height. In Saskatchewan, falls have been identified as the leading cause of farm injuries (2); dismounting (egressing) from farm machinery is a primary form of exposure to falling hazard with very tall modern agricultural machinery, requiring tall ladders or stairs to get access to the cab.

Egress from machinery is a complex action that requires precise coordination of the body (3). According to Fathallah (4) there are two possible scenarios in which egress from machinery could lead to driver injuries: 1) drivers might jump out of a vehicle cab, entirely or partially (i.e. from stair or steps) that would impose excessive forces on the joints, especially on ankles, knees, and the lower back; and 2) the risk of slip and fall rises immediately after landing due to factors such as step surface grip and presence of surface contaminants.

In addition to the aforementioned factors, drivers' egress technique may also be a contributor to egress injuries; It has been observed that tractor operators preferred the egress method of facing away from the tractor that mimics going down the stairs, whereas the recommended method is egressing while facing toward the cab, like climbing down a ladder (5-6). While the facing-away egress method might be preferred because of the resulting "comfortable" (i.e. less flexed) knee joint angles (5), it is more difficult to maintain a secure grip on the handrails when facing away from the tractor (6). An additional factor that has not been addressed in the literature, is the foot contact area on the machinery steps; foot contact area can be significantly smaller when facing away compared to facing towards the cab. The objective of this study is to compare facing-in vs facing-away egress methods in terms of lower body kinematics as well as whole-body contact points for better understanding of egress performance in agricultural vehicles.

Methods

This study used a staircase and cab platform developed to simulate the stairs of an agricultural tractor in the Ergonomics Laboratory at the University of Saskatchewan. Twenty-four healthy participants with at least one season of experience operating agricultural machinery were recruited to complete the trials. The participants were assigned to perform five egress trials while facing away of the cab (Figure 1a), and five while facing towards the cab (Figure 1b) in a randomized order. Repeated measures ANOVA was used to determine the effects of egress technique (i.e. facing-in or facing-away) on points-of-contact, duration of three-point-contact, kinematics of lower limb, and plantar pressure. Points-of-contact was defined as the number of body segments that were in touch with the stairway during egress. Participants' egress performance was captured using a video camera that was processed post-trial for counting contact points and calculating the duration of three-point-contact. Kinematics of lower limb parameters were calculated, including range of motion and minimum flexion angles of knees, ankles, and forefeet. A Vicon motion capture system with 10 cameras (Vicon MX system, Oxford Metrics, Oxford, UK) was used to record participants' motion during trials. Finally, foot plantar pressure was measured using Novel Pedar sensor insoles (Novel Electronics Inc., St. Paul, MN, USA).

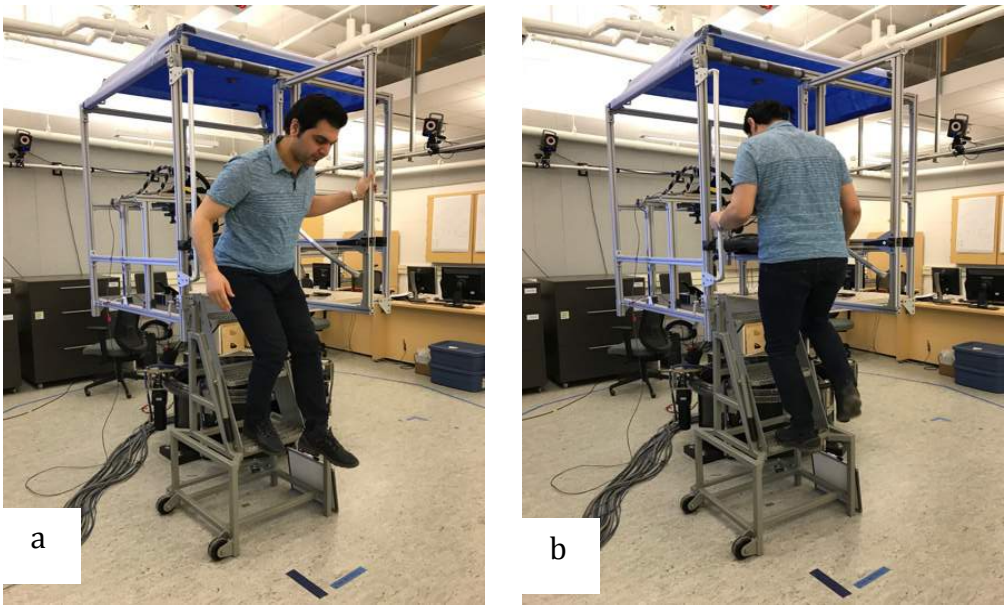

Figure 1: the staircase and cab platform in the Ergonomics Laboratory allows egress (dismount) both a) facing away and b) facing in.

Findings

Preliminary findings indicate that facing away egress method resulted in shorter duration three-point contacts. In addition, results from the motion capture system shows that facing away of the cab resulted in less flexions in lower limb joints during egress. Finally, the maximum plantar pressure at landing is significantly higher during facing away egress compared to egressing while facing towards the cab. We anticipate further analysis will demonstrate in more detail how facing away of the cab egress method would expose operators to risk factors for falls from machinery.

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Vibration toolkit: development and evaluation of an occupational health education intervention focused on vibration exposure in mining

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Introduction

Workers in the mining industry are typically exposed to three types of vibration exposure while performing their job tasks: whole-body vibration (WBV), hand-arm vibration (HAV), and foot transmitted vibration (FTV). Occupational health and safety (OHS) programming is critical in influencing workers' knowledge, attitudes and/or behaviours regarding hazardous workplace exposures and occupational injuries and diseases[1]. Findings continue to support the understanding that OHS education and training positively impacts the overall work practices of workers[2]. Despite the potential impact on the health of the workers, there is currently a lack of education and training resource material available to address the health and safety issues related to vibration exposure within the mining industry.

The objective of this study is to design, implement, and evaluate a comprehensive occupational health education intervention to improve knowledge, attitudes, and/or behaviour beliefs associated with underground mining-related vibration exposure.

Methods

An empirically based and theoretically informed vibration education intervention, the 'Vibration Toolkit', was developed and customized for an underground mining setting to address the identification of hazards, health effects, and control strategies for WBV, HAV, and FTV exposure. The Vibration Toolkit consists of: education sessions for each type of vibration exposure, corresponding posters, stickers, hazard identification cards, WBVPod, and personal protective equipment samples. The implementation of the 'Vibration Toolkit' intervention was conducted with an international mining company with mine sites in Northern Ontario over a period of five months. The Vibration Toolkit was customized following consultation with the participating mining company. All workers attending the mine site's start of the shift line-up meeting were eligible to participate. Pre-intervention surveys were completed 1 month prior to the 3-month implementation of the intervention and post-intervention surveys were completed 1 month after the end of the last session.

Findings

142 workers took part in various aspects of the Vibration Toolkit intervention. There were 61 participants at the mine that attended all education sessions and completed the pre-intervention and post-intervention surveys. Data analyses were performed for the 61 matched pairs. The highest percentage of participants, 37.7% (n=23), reported exposure to WBV, HAV, and FTV in their current job (Table 1). Statistically significant positive improvements were observed for workers' behaviour belief scores, for pre-intervention (M=4.46, SD=5.697) versus post-intervention scores (M=8.02, SD=6.417), $t(60)=4.212$, $p<0.001$.

Figure 10: Vibration Toolkit Design

Table 1: Self-reported vibration exposure in current job

Vibration Type	Frequency (N)	Percent (%)
HAV Only	7	11.5
WBV Only	6	9.8
FTV Only	0	0
HAV and FTV	3	4.9
HAV and WBV	13	21.3
HAV and WBV and FTV	23	37.7
None	9	14.8
Total	61	100.0

Discussion

An identified gap was found in education courses and materials focused on educating workers in the mining industry about vibration exposure in their workplace. The Vibration Toolkit was developed to fill the identified gap and provide education resources for the mining industry. However, a customized approach to consider the organization, work site, and equipment characteristics is needed to ensure success. The Vibration Toolkit resulted in statistically significant improvement in behaviour beliefs related to vibration exposure. Understanding worker's knowledge, attitudes and behaviour beliefs regarding vibration exposure is important to assist with education, prevention, and control strategies in the mining industry.

Relevance to Practitioners

Continued OHS education and training focused on vibration exposure should continue within the mining industry as one element of a larger overall plan to prevent the injury and illness of workers. Continued efforts from OHS professionals, ergonomists and engineers need to address the technical and design changes that also have the potential to reduce vibration exposure.

The Vibration Toolkit also has the potential to provide meaningful vibration specific education for other sectors that also experience vibration exposure: transportation, agriculture, forestry, and construction. Each sector presents unique equipment and operating conditions for their respective workers and as a result, the Vibration Toolkit should be tailored to the target population and industry to improve future outcomes of the intervention.

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The Effect of underground mining footwear on lower limb gait characteristics and comfort

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Introduction

Slip, trip, and fall (STF) incidents accounted for 15% of the reported lost-time injury/illness claims in the Ontario Mining sector[1]. Low light conditions, high heat and humidity levels, hazardous terrain and environment, fatigue, and cumbersome personal protective equipment (PPE) have been reported as risk factors for STF in underground mines[2-4]. Control strategies to reduce STF risks, for many of these factors, can be difficult to implement; however, improvements to footwear may be feasible. Although, boots currently worn by underground miners are heavy, stiff, and uncomfortable for the worker[5,6], the impact these footwear types have on lower limb gait characteristics and comfort level is under researched. This study looked to determine the impact that various underground mining footwear have on lower limb gait characteristics and perceived comfort.

Methods

15 participants were selected from convenience sample. Participants were required to have Men's 9-12 (~Women's 10-14) sized feet and free from lower limb and back injuries in the past 6 months. Participants were habituated to each of three underground mining footwear conditions before completing the laboratory trials. After the habituation period participants completed a comfort questionnaire for each condition. The laboratory trials consisted of five passes of the walkway for each randomized underground footwear condition in addition to a control running shoe condition. The walkway consisted of two force plates halfway down the walkway, a Microsoft Kinect camera system positioned in front of the participant, a digital video camera system positioned to the right of the participant, and the Notch[7] motion sensor system positioned on the subject. The force plates measured the landing and push off forces; Kinect system measured the gait phase timing and walking velocity; video camera system measured the toe height clearance of the swing leg; and the Notch sensor system measured the hip, knee, and ankle joint angles of both the right and left legs.

After completion of the five passes in a footwear condition the participant completed the comfort questionnaire and after all four conditions had been successfully completed the participant completed an exit questionnaire to determine their underground mining footwear preference and to rate the footwear conditions to one another.

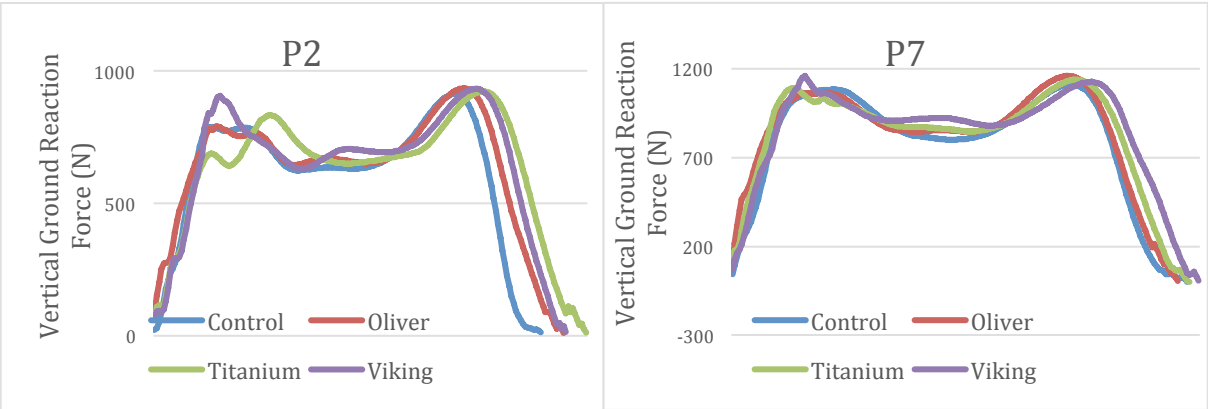
Findings/Discussion

Study results and findings are still pending, to be completed by August 2018.

Data analysis will use Repeated Measures ANOVA to determine if any significant differences are present between the three underground mining footwear conditions. Comparisons will be made between the three underground mining footwear conditions to the control condition as the deviation from the participant's normal gait in a control footwear is a better measure of the impact of the footwear on the participant than the overall gait pattern changes. The variables used for comparison are impact force, push off force, walking angle, hip joint angle, knee joint angle, step and stride length, toe height clearance, and subjective comfort levels.

Preliminary data can be seen in Figure 1. The data shows the 'Viking' condition, and to a lesser degree the 'Titanium condition', to cause increases in peak impact force and changes to the profile of the impact. Increases in peak impact force and deviations from normal landing profiles may have implications for STF risk. These changes are likely due to the cumbersome boot design and materials.

Figure 1: Vertical ground reaction force profile of right foot during gait, taken during the 3rd gait cycle of the trial. Comparison of all four footwear conditions.



Relevance to Practitioners

Safety footwear is designed to protect workers from crush type injuries to the foot and shank but the effect it can have on movement and comfort may cause deficits to gait patterns and increase the risk of STF, lower limb injuries and worker discomfort. The ideal footwear for the job at hand should be a major consideration to reduce these risk factors for all workers in their work places.

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PAPER SESSION 10: GENERAL ERGONOMICS

Day 4 – Oct 18th	
10:30-12:00	**Paper Session 10** General Ergonomics <u>Peg Scherzinger</u> Ergonomics assessment methods and guidelines used in the investigation of a critical injury and a fatality due to falls from ladders <u>Heather Kahle</u> 'What goes right' Using appreciative action research to understand work performance and promote system-level resilience in the silviculture industry <u>Ornwipa Thamsuwan</u> Field-based electromyography to assess shoulder muscle activity during repetitive tasks: an application in apple orchards <u>Cyrus Lee</u> Evaluation of smartphone sound level meter applications for spectral analysis by comparing internal and external microphones

Ergonomics assessment methods and guidelines used in the investigation of a critical injury and a fatality due to falls from ladders

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Introduction

When a fatal or critical injury occurs in a workplace, and an investigation is done, one of the goals is to determine the cause of the incident, in order to help prevent future similar occurrences. Investigations are also done to determine if there were contraventions to the Occupational Health and Safety Act or Regulations that contributed to the incident.

This paper outlines two case studies where ergonomics assessment methods and related guidelines were used as resources to help determine the causes of the incidents, and whether contraventions occurred.

Description of fall incidents and methods used

Case 1: A young worker on his first day of work was tasked with carrying bundles of shingles up an extension ladder leaned against the edge of a roof. He supported a single bundle on his shoulder during each ladder climb. He carried several bundles up and placed them on the roof in front of the ladder. As this area became filled, he then leaned sideways to a place the bundle beside the others. The ladder slid sideways and he fell, breaking his femur. There was a request for an assessment of the handling method and whether it contributed to the fall. A biomechanical modeling analysis program (1) was used to model the effects on a person's handling demands and stability for a) a load placed on the shoulder while climbing, and b) while reaching to the side.

Case 2: A grocery store worker was arranging (flattening) items on shelves in the store to make them easier to count during an upcoming inventory. She was using a small step ladder that consisted of one step and a cap (Figure 2). Store video showed that the worker's foot appeared to slip from the cap of the ladder and she fell backward, sustaining a fatal head injury. The step ladder had the words "NO STEP" imprinted on the cap. There was a question of whether the task required the worker to reach in a manner that would require her to step up higher than the first step of the ladder. Anthropometric information (2), along with the worker's height was used to estimate her reach capacity in both horizontal and vertical directions. This information, along with dimensions of the ladder and the shelving, was used to make a determination on this question.

Investigation Findings and Outcomes

Case1: A review of guidelines regarding roofing work and ladder use (3, 4) indicated that carrying packs of shingles up a ladder was not a recommended practice due, in part, to the weights involved (~36 kg), the inability to use 3 point contact while ascending the ladder, and the possible availability of mechanical assists such as ladder hoists or boom trucks.

The placement of a 36 kg load located over the right shoulder and upper arm will shift a person's centre of gravity to the right, which is illustrated in the 3DSSPP analysis shown in Figure 1. The balance was classified as unacceptable when the right foot is above the left during the ladder climb. The balance point moved considerably to the right, and the strength demands also increased into the unacceptable range for the shoulder and leg.

The ergonomics investigation report concluded that the shingles were moved in a manner that endangered the worker. The employer pleaded guilty to a charge of failing to ensure that materials are moved in a manner that does not endanger a worker.

Case 2: The worker was 157.5 cm in height which places her at about the 25th percentile in terms of height. Anthropometric data for shoulder height and arm reach indicated that in order for a 50th percentile sized female to reach the back part of the shelving from the first rung of the ladder, her shoulders would have to be at the same height as the shelving. However, the upper shelf was 20 cm above this height, requiring 50th percentile or smaller workers to step to the top cap of the ladder. The cap was a hard smooth plastic material that may have contributed to the slip and fall (Figure 2).

The ergonomics investigation report concluded that the height of first step was not adequate to allow the worker to properly access the shelving, which could have contributed to the worker in this instance stepping to the top (cap) of the step ladder to access the items on the shelving. The employer plead guilty to a charge of failing to take the reasonable precaution of providing appropriate equipment for the protection of the worker while performing the flattening task.

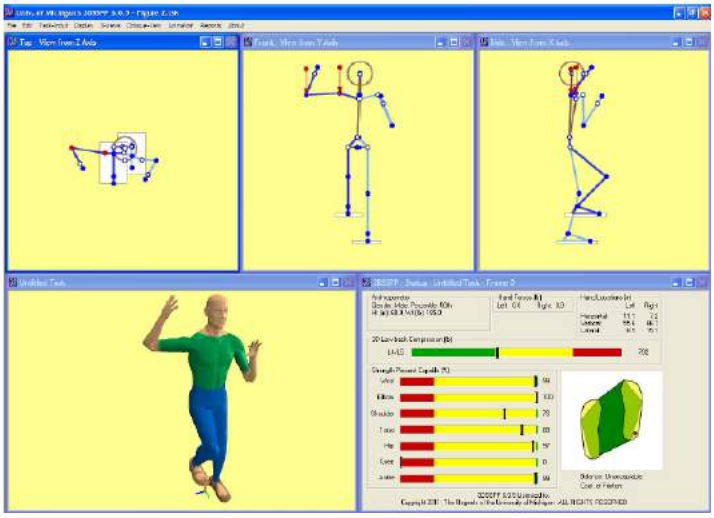

Figure 11: Michigan 3DSSPP model: ladder climb carrying pack of shingles

Figure 2: Step Ladder: Case 2

Relevance to Practitioners

This description of investigations can assist those who investigate and/or work to prevent workplace injuries related to ladder use as it outlines methods to identify: a) causal factors in a ladder fall incident, and/or b) possible hazards related to ladder use to aid in prevention of fall incidents.

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'What goes right' Using appreciative action research to understand work performance and promote system-level resilience in the silviculture industry

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Introduction

Appreciative Action Research (AAR) is a qualitative, participatory methodology for understanding how people conduct successful work within the context of a specific environment. It's based on gathering narratives and observations from multiple perspectives to appreciate how features of an environment and system-level factors influence peoples' performance both positively and negatively (1). In the context of the Silviculture industry, the qualitative data was able to provide insights into how planters at the front line successfully manage workplace factors and were able to do so without experiencing an injury state. Ultimately, the goal of AAR research is in understanding what 'goes well' (successful outcomes) so those actions can be learned from, and replicated to assist and advance occupational health and safety initiatives. The purpose of this research was two-fold; 1) to address the high rate of Musculoskeletal Injuries (MSIs) which has persisted amongst tree planters in spite of efforts to reduce this rate. It accomplished this by gathering information about systemic beliefs, practices, assumptions and safety culture from tree planters who planted a high number of trees and were injury free. Uniquely, the research approach engaged with the planters who had not had injuries by hearing their stories and experiences to determine how they managed this very complex and demanding work environment. This information was then used to assist new planters or those who had already experienced an injury to better cope with the tree-planting environment. 2) This research also augmented the historical, individual-focused approach of many traditional MSI prevention initiatives. It expanded the focus from the individual worker to other system-level factors such as; the pay-structure, industry incentives, the environment, the context of the work as well as the influences of the social network of foremen and supervisors and the safety culture. This provided a framework for collaborative problem solving around complex and consistent risks.

Methods

Step 1: Collecting data

The study resulted from interest by the Western Silvicultural Contractors' Association (WSCA) in tackling the historically high rate of MSIs using a different approach. The research team consisted of a collaboration between WorkSafeBC's human factor group, the WSCA and associates from Second Curve Systems, a division of Action Learning Systems in Boston, Massachusetts. Employers registered with the WSCA were contacted to recruit participants for this project. Three industry representatives, one senior manager, three supervisors as well as six planters, were interviewed to gather their observations, stories, experiences, and anecdotes. Data gathering was conducted between May-June, 2012 using a story-telling guide and semi-structured interviews. The interviews queried what the problems or opportunities were from their perspective; what they had tried so far and what 'worked best' in given situations; probing for times when their work was successful and what factors they believed made it possible. This approach was selected in order to discover possible complex, system-level workplace factors that might be affecting musculoskeletal injuries in addition to simply the individual worker. For purposes of planning and debriefing as well as analysis of the pilot study data set, the human factors team at WorkSafeBC and Second-Curve Systems, engaged in multiple teleconference calls.

Step 2: Analysis

Data from the interviews was transcribed and analyzed using a framework to establish repeating emerging themes or patterns (2). The Hourglass model framework was used to help summarize, aggregate and explain data. From the analysis, factors became transparent (see Figure 1) showing their importance and influence on performance and MSI rates. Shared stories inferred clues about performance and practices in the context of the organization's structure. The factors were verified in collaboration with the study

participants against actual day-to-day work and a matrix of major themes was developed. These insights and themes – concerning both the problem and the solution, gave glimpses into the systematic beliefs, culture, assumptions and patterns of practice. By learning and understanding the work of planting trees in complex and challenging settings from multiple perspectives, this methodology provided a broad insight into the system-level workplace factors affecting the onset of MSIs.

Findings

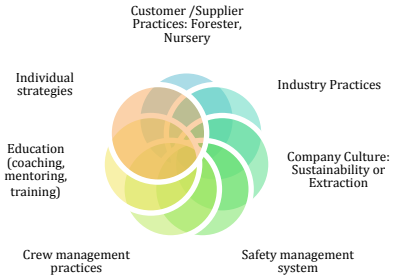

Figure 1: Performance Shaping Factors

Figure 1 depicts the system of factors reported in interviews that influence and shape performance. Individual strategies among planters, foremen, crew managers and contractors were shown to produce improvements. Multiple and varied organizational, customer/supplier and crew management practices emerged in support of safe production. Project data regarding this successful work can be used to support future planning, goals and objectives. While structural interventions such as return-to-work programs can improve safety culture and performance, moving from teaching to 'action learning' (using AAR) can make similar improvements as well as enhance safety and industry sustainability; rather than having separate strategies. Importantly, tacit knowledge of skillful planters, supervisors and owners can be surfaced, used and re-used. Notably, even seasoned planters were found to benefit from peer learning. The AAR method can be used to gather and spread learnings as well as accelerate industry progress all while bolstering a learning strategy and environment to promote achieving higher performance levels sooner.

Discussion

This project examined the silvicultural system of work using the AAR approach; gathering perspectives of participants from different levels in the system in order to discover and understand what strategies worked well (and those that did not) to be successful in the dynamic and complex environment of tree planting. This project identified key factors and how they are applied in different situations as well as how planters actively adapt, learn and anticipate hazards on the job. These strategies can be tried in the field - building on them as necessary - to achieve success. Using the AAR approach is in contrast to the traditional, prescriptive approach that applies prevention solutions to 'what goes wrong' (re: post injury). Rather than defining data narrowly, and pursuing lagging indicators, this research approach collaborates closely with those who produce the work giving access to leading indicators. Overall, the value of the AAR is that people like to talk about what goes well rather than waiting for injury/incident to occur; it was discovered that participants enthusiastically shared perspectives outlining strategies that worked well during day-to-day activities.

Relevance to Practitioners

Practitioners with an interest in alternative approaches for injury prevention and mitigating stubborn risks can benefit from this applied research approach. Applying the principles of AAR to understand how positive workplace system factors can be replicated and enhanced to increase what goes right on the job rather than just managing negative outcomes, can produce effective, sustainable results.

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Field-based electromyography to assess shoulder muscle activity during repetitive tasks: an application in apple orchards

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Introduction

Semi-automated mobile orchard platforms have been implemented in industrialized orchards to help with thinning, pruning and harvesting tree fruits. With this technology, workers can stand on a height-adjustable platform while the platform transports the workers along tree rows (Figure 1). Although mobile orchard platforms could prevent injuries due to workers falling from ladder and may improve work posture,(1) it is unknown whether they may introduce new ergonomic risk factors due to static repetitive movement in a constricted space. The high work repetition could lead to chronic muscle injuries.(2)

Surface electromyography (EMG) is a non-invasive technique for estimating muscular load. It may not be suitable for agricultural use due to environmental issues such as sweating resulting in loss of skin-electrode connection. EMG signal quality needs to be examined to permit deriving muscle activity parameters.

Objectives of this study were (1.) to develop methods to measure shoulder EMG in agricultural setting and detect errors in EMG signals and (2.) to investigate differences in shoulder muscle activities of workers during harvesting apples using a mobile orchard platform compared to the traditional method of using a ladder.

Methods

Twenty-four farmworkers with at least one season of apple harvesting experience participated in the study. Eight workers used ladders ("ladder" group), eight used a semi-automated orchard platform ("platform" group), and the eight harvested apples while walking ("ground" group).

Figure 1: Mobile Orchard Platform

Figure 2: EMG Data Collection System

Figure 3: Reference Activity for EMG Normalization

Upper trapezius EMG was collected at 1,000 Hz using pre-gelled disposable electrodes (Blue Sensor N; Ambu; Ballerup, Denmark) connected to a battery-powered data logger (Biomonitor ME6000; Mega Electronics Ltd.; Kuopio, Finland) that the participants wore on their low back (Figure 2). Anti-sweat adhesive, which includes benzoin tincture, was applied to secure skin-electrode connection. EMG signals were filtered using a 2nd-order Butterworth dual-pass 10-350 Hz bandpass filter. Root-mean-square (RMS) amplitudes of the filtered signals were calculated for every 125-millisecond window. For each second, the 1st percentile (PCT) of RMS signals and median power frequency (MDF) of the filtered signals was calculated. A sudden and prolonged increase or decrease

in the 1st PCT or MDF over time was inspected and used to indicate when skin-electrode connection was lost.

The 10th percentiles of RMS amplitudes were used to represent the levels of static muscle activities. EMG amplitudes were normalized to the reference voluntary contractions, which were performed as a standardized reference static activity of stretching each arm forward and holding a static load of 0.91 kg (Figure 3). Static muscle activities during only the first hour were used to compare the three harvesting methods. Differences were tested using ANOVA with harvesting method and body side as main effects, participants as a random effect, and a type I error of 0.05.

Findings

Systematic shifts in MDF and/or the 1st PCT of the EMG indicated the time when electrodes came off participants' skin (Figure 4). Data in three "ladder" participants and one "ground" participant could not be used due to the loss of EMG-skin connection before the end of the first work hour. With the remaining data, static muscle activities were not significantly different across harvesting methods or side of body (Figure 5).

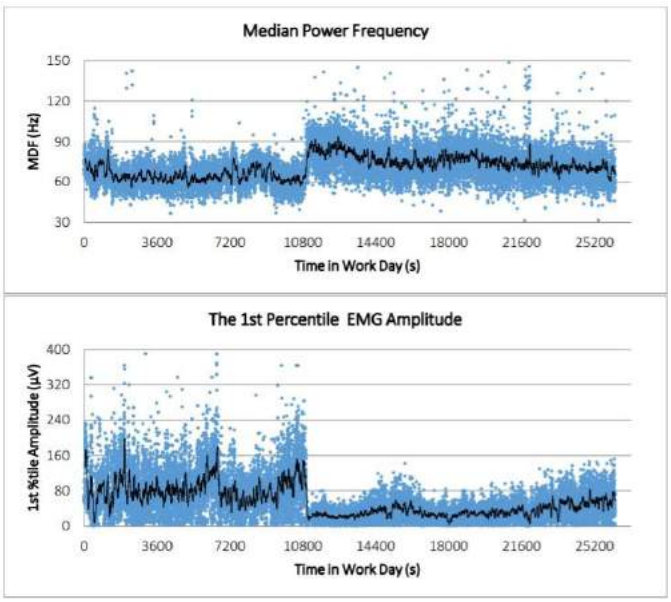
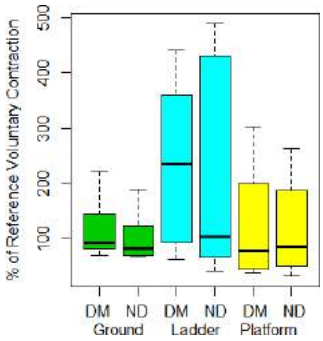


Figure 4 (left): Median power frequency and 1st percentile RMS amplitude of EMG in work day.

Figure 5 (below): Static muscle activities, 10th percentile of EMG amplitude, normalized to reference voluntary activity; DM = dominant body side, ND = non-dominant body side.



Discussion

This study characterized muscle activity in a challenging environment. Anti-sweat skin preparation helped maintain electrode connections. However, the way some participants carried a ladder on their shoulder still caused electrodes to come off participants' skin. The EMG error detection technique developed in this study made the collected data still usable for 80% of the participants.

Static muscle activity is an indicator of the repetitive nature of apple harvesting task. Harvesting method did not have a significant effect on static muscle activities in this study. That is, the use of mobile orchard platform may not introduce the ergonomic risk factor of static repetitive tasks.

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Evaluation of smartphone sound level meter applications for spectral analysis by comparing internal and external microphones

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Abstract

Noise is a prevalent health hazard affecting many workers in various industries around the world. The management of noise is predicated on accurate and reliable measurements of noise, and therefore the quality and precision of equipment is paramount. Our initial study tested the accuracy and viability of smartphone sound level meter applications (apps). Ten iOS and Android smartphones were used to conduct noise level management on five apps from each respective platform. Five different sound signals were used to represent the entire spectrum present in an occupational environment (60, 70, 80, 90dBA) for a total of 1000 tests. A calibrated Larson Davis LxT sound level meter was used as a reference. This study concludes that most apps are limited for use as screening tools and cannot be used for accurate determination of noise levels. Building on this study, investigators look to further this study by testing the accuracy of external and internal microphones for 1/1 octave band analysis which resembles the conditions of work environments.

Introduction

Noise is a constant and ongoing health hazard across many workplaces and industries worldwide. The effective management of noise-related health effects is predicated on accurate measurements of noise levels. In our initial study, the accuracy and feasibility of smartphone sound level meter (SLM) applications (apps) used for monitoring noise in occupational and environmental scenarios were tested. Ten iOS and Android smartphones were used to conduct noise level measurements with five apps on each respective platform. These were considered a representative sample of the most popular smartphones at the time of testing. Five devices were iOS and five were Android. The inclusion criteria for the selected apps required octave band analysis and the ability to save recorded data for subsequent analysis.

Five different sound signals were used to represent the entire spectrum present in an occupational environment at four different reference noise levels (60, 70, 80, and 90 dBA). A total of 1000 tests were collected. A calibrated Larson Davis LxT sound level meter was used as reference. Results suggest that apps on the iOS platform have less variation associated with noise level measurements and are thus more reliable and accurate than Android apps. However, this study concludes that most apps on the iOS platform are currently limited for use as screening tools and cannot be used for accurate determination of noise levels. Our present study aims to compare the accuracy of external and internal microphones of the eight different octaves for analysis that resembles workplace conditions.

Methods

Ten different smartphones were collected from students on the Ryerson University

(Toronto, Ontario) campus. Five iOS and five Android apps with the ability of octave band analysis were downloaded and installed on the devices for testing. Prior to each testing session the SLM was calibrated using a Larson Davis CAL200 calibrator. The two external microphones (Dayton Audio iMM-6 microphone and MicW i436 microphone) were calibrated using the apps calibration function with reference to the Larson Davis LxT SLM. All smartphone cases and covers were removed prior to testing to prevent any possible interference with microphones and the microphones were oriented towards the speaker. Background sound level measurements never exceeded 40 dBA. Smartphones and the reference SLM were mounted on tripods at a height of 91 cm and a distance of 100 cm from the speaker.

An Apple MacBook Pro (containing all sound files) connected to a Pioneer AV receiver (Model VSX-524- K) and five Polkaudio loudspeakers (four of which were of model RM6751 and the other model RM6752) were used to generate the signals. Noise level was manually controlled using the volume knob of the receiver. Signals were generated at 60, 70, 80 and 90 dBA. Sound levels were confirmed using a Larson Davis LxT SLM (factory calibrated two weeks prior to testing).

Three different sound signals (sweeping sound, an office, and an industrial work environment) were generated in the experimental setup. Single measurements were recorded for each app, on each smartphone model, at each noise level for all three sound signals totaling one hundred measurements per app and six hundred measurements in total.

Discussion

The sound range of 60-90 dBA was used to represent the most likely occupational noise exposure levels present in real life scenarios. Directionality was not taken into consideration in this study, as pilot study testing showed no significant difference in the results.

Furthermore, during the pilot study repeated measurements were taken on two randomly chosen smartphones (one from each platform) using all five apps at all four sound levels and for all five sound signals. Results showed no significant difference between repeated measurements, therefore conducting repeated measurements on each device was considered not necessary.

Relevance to Practitioners

Industrial grade sound level meters are expensive industrial tools that require a certain level of care and maintenance. Sound level meters are an integrate tool in the recognition and management of noise related health effects. In this study, we are accessing the viability of an alternative option to industrial grade sound level meters in the form of smartphones. Smartphones have become a cornerstone of everyday life with their multifaceted uses; which makes them a potential alternative that can be accessible and economically feasible.

PAPER SESSION 11: ERGONOMICS IN HEALTHCARE

Day 4 – Oct 18th	
10:30-12:00	**Paper Session 11** Ergonomics in Healthcare Amy Doan Medical device user interfaces and blame: use and user error Perceptions Nicholas La Delfa Quantifying upper extremity muscle exposures During manual pill crushing Josie Blake The fundamentals of ergonomics win again: adjusting the patient (work) to the nurse (worker) Ryan Smiley Case study: BCEHS patient handling equipment implementation

Medical device user interfaces and blame: use and user error perceptions

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Computer-Human Interaction Lab at Laurentian (CHILL)

Introduction

In today's healthcare environments, the rise of the number and increasing sophistication of medical devices presents an increased risk of medical device error occurrence. Widespread belief that the user is the primary cause of medical device error is the current mindset for a majority of individuals in the healthcare environment(1)(2)(3). The culture surrounding the word 'error' in these environments perpetuates blame and decreases the confidence and morale of those who have created such an error(4). As a result of this mindset, the act of retraining and reminding the user "to be more careful" in order to encourage vigilance to prevent future events and subsequently reduce the frequency of errors related to medical device usage is typically employed(4)(5). The current mindset surrounding the blame of the user related to all medical device errors needs to shift towards evaluating the medical device's role in creating these errors(2)(6). This meta-study aims to identify the frequency of medical device related errors that have been classified as resulting from an error origination from the use of the device or the user of the device.

Methods

This meta-study aimed to evaluate pertinent literature surrounding the outcomes of medical device user interface errors and their resulting root cause classifications. Articles selected for this meta- study were not limited to a specific publishing date. The selected articles were evaluated and uncovered using the following databases: Google Scholar, Cumulative Index of Nursing and Allied Health Literature(CINHAL) and PubMed using a combination of the keywords: "medical device", "use error", "user error", "user interface error", "error classification" and "blame".

Findings

The database search results proved to produce limited results that pertained to this area of interest. However, the database search yielded 7 articles that were included in this meta-study. Two articles that were explored contained scenarios in which elements of bias and blame culture may have incorrectly concluded that the user and not the use of the medical device was the cause of an error(7)(8). In addition, articles were uncovered which expressed the need to clearly define use and user error within the healthcare context in order to properly classify erroneous events in order to prevent their occurrence and improve patient and user safety(9)(10)(11). And lastly, two articles were uncovered that proposed that erroneous root causes were being incorrectly classified due to biases that exist towards users of devices in healthcare environments due to the nature of blame culture(12)(13). These 7 articles may

indicate a potential effect that blame culture in healthcare environments have on effectively classifying medical device errors appropriately.

Discussion

A need currently exists to properly classify erroneous medical device events so that all members in the healthcare sector can increase their knowledge of the prevalence of medical device use and user error and how to best learn from these erroneous events. In addition, allowing the incorporation of biased assessor opinions is problematic considering the heavy blame culture that exists in healthcare which often allocates the blame of errors towards human counterparts involved(13). In addition, varying levels of work experience that an assessor has can influence what they perceive to be the root cause of an error as well as the severity and seriousness of an error. Through this current technique, it is easy to understand how a single erroneous event involving a medical device can be interpreted and categorized into several different types of errors with different root causes. This creates a problem with classification consistency, accuracy and confusion in the literature as well as in the healthcare environment.

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Quantifying upper extremity muscle exposures during manual pill crushing

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Introduction

The nursing occupation suffers from a high prevalence of work-related musculoskeletal disorders (1), with injuries to the low back and shoulder representing the most common and severe reported claims (2). Nurses in long-term care homes often administer several medications throughout their shift (3). To aid in consumption, pills are often crushed into a fine powder using a manual device (Figure 1). Despite the forceful and repetitive muscular effort anecdotally reported by nurses who perform this activity regularly, the physical demands germane to this task have yet to be quantified. The purpose of this study was to quantify the upper extremity muscle exposures while operating a pill-crushing device in a variety of job-relevant simulated experimental conditions.

Methods

Eighteen healthy female participants were instrumented with surface electromyography (EMG) over 12 muscles of the dominant arm (Figure 2). Several muscle specific maximum voluntary contractions were conducted to elicit maximum voluntary excitations (MVEs). EMG signals were digitally sampled at 1500 Hz, de-biased, linear enveloped, and normalized to MVEs to represent proportional muscle activation (%MVE). In a standing posture, participants used a Silent Knight™ device to crush pills in 18 factorial conditions, defined by: working height (87, 102, or 117 cm), device orientation (parallel or perpendicular to the sagittal plane) and pill quantity (1, 3 or 5 pills). Amplitude probability distribution functions (APDFs) were used to compute condition static (P=0.1), median (P=0.5) and peak (P=0.9) muscle exposure levels. EMG amplitudes (%MVE) were compared to recommended maximum acceptable efforts (%MAE) at the static (2.5%), median (15.3%) and peak (42.5%) exposure levels (4), with a value above 1.0 indicating an exposure ratio above recommended ergonomics limits. Separate 3 (height) x 3 (pill #) x 2 (orientation) factorial ANOVAs were conducted on the static, median and peak exposure ratios for each muscle, but only static demands are presented here as they were most implicated. Tukey's HSD comparisons ($p<0.05$) were used to assess factor level differences post hoc.

Findings Overall Static, Median & Peak Muscle Exposures:

Collapsed across all conditions, exposure ratios were highest at static levels in comparison to median and peak exposures (Figure 2). The static limits exceeded the MAE thresholds (1.0 exposure ratio) in the supraspinatus (1.30), pectoralis major (1.07) and upper trapezius (1.65) muscles. Median and peak loading had an exposure ratio below 0.63 in all muscles studied expect for the triceps, which was the only muscle to exhibit its highest exposure ratio for peak loading (0.66).

Effect of Height, Pill Number & Device Orientation:

The most prominent finding was an interaction between working height and pill number for middle ($p<0.05$, $\omega^2=0.02$) and posterior ($p<0.05$, $\omega^2=0.03$) deltoids, upper trapezius ($p<0.04$, $\omega^2=0.05$) and pectoralis major ($p<0.04$, 0.03) (Figure 3), as well as triceps and flexor carpi ulnaris (not shown).

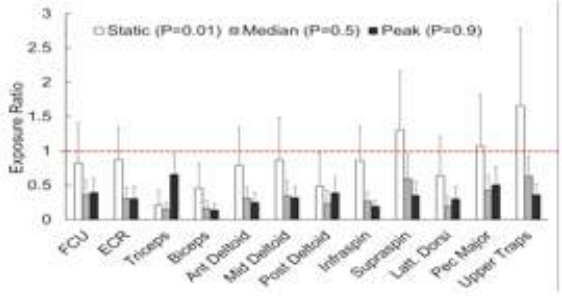

Figure 2: Overall static, median and peak EMG exposure ratios across all conditions. Any bar surpassing the red line indicates a muscle exposure exceeding its respective MAE limit.

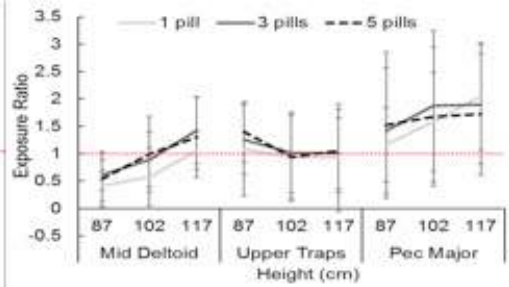

Figure 3: Height x pill quantity interaction plots for selected static shoulder muscle exposures.

Middle deltoid, posterior deltoid and upper trapezius activations were significantly higher at the 117 cm height in comparison to the low 87 cm heights. Pectoralis major was the only muscle that had an increased exposure ratio (1.16) at the 87 cm height in comparison to the 117 cm, and the magnitude of this difference increased with the number of pills being crushed (1.25 for 3 pills and 1.35 for 5 pills). Device orientation had a marginal effect on muscle activity. The parallel orientation resulted in higher muscle activity for upper trapezius (by 27%) and pectoralis major (by 45%), but the perpendicular orientation resulted in higher activity for middle deltoid (by 12%) and FCU (by 18%).

Discussion

This study discovered high levels of static muscle loading when performing manual pill crushing in a variety of occupationally relevant conditions. Static muscle exposures above 2.5% MVE indicate prolonged, lower level muscle loading, and are risk factors for the development of muscle fatigue over the course of an 8-hour workday (4,5). The work surface height and number of pills being crushed were important factors that influenced the static shoulder muscle activations. In most cases, working at approximately a 50th percentile female's hip height (87 cm) reduced the level of muscle activity, often times to below the MAE limit, compared to higher heights. A perpendicularly oriented device required substantially lower muscle activity in some shoulder muscles, with marginal differences occurring in muscles of the elbow and wrist. Future research should evaluate specific postural and joint loading demands during pill crushing work, as well as different device orientations (e.g. 45° relative to sagittal), to further establish best practices for nurses who perform this work regularly.

Relevance to Practitioners

This study is one of the first to provide quantitative data on the muscle loading experienced during pill crushing. Given population demographics, this task will continue to be frequently performed by long-term care nurses. These data can inform specific design recommendations to reduce muscular activity while performing pill crushing. Specifically, when a motorized pill crusher is unavailable or not preferred, manual pill crushing should be conducted with the fewest amount of pills possible, with the device oriented perpendicularly to the sagittal plane at approximately hip height (~87 cm for a 50th percentile female).

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The fundamentals of ergonomics win again: adjusting the patient (work) to the nurse (worker)

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Background

Accommodating workers with limitations can be a challenge, especially when the work is unpredictable or variable. Nurses, and other workers in the health care industry, are susceptible to back injuries due to varying patient abilities, statures and conditions, and the workplace environment. After a serious injury, permanent damage has been done, and often, permanent limitations are put in place to further protect the worker from doing more damage. The employer must accommodate these limitations, while continuing to provide patient treatment.

Problem

This paper presents a case study of two nurses who have back injuries, with limitations as extreme as "no back bending at all", and "no over shoulder work". Prior to the assessment, the nurses were *not* performing all duties, as they felt that some of the tasks required significant back bending and were outside of their capabilities. The task of "ear syringing" was the nurses' most significant concern. As a result, the clinic was unable to perform *any* ear syringe services. The Ergonomist was contacted to assess the suitability of the *entire* job for the two nurses, and provide solutions to allow the nurses to return to full duties.

Context

This paper is a case study that reviews a project undertaken by a consulting ergonomist. The nurses' supervisor and the clinic's HR specialist contacted the consulting Ergonomist to assist with identifying solutions to allow the two experienced nurses, working full time at a family health clinic, to return to performing all duties, including ear syringing. The supervisor and HR specialist also asked the Ergonomist to identify any other tasks that may be outside of the nurses' capabilities, and to provide solutions for these concerns as well. The nurses were present throughout the entire assessment, and provided input on recommendations. The assessment and reports were completed over a total of 4 days. After the reports were completed, the supervisor and HR specialist worked without the consulting ergonomist to source the products recommended in the report.

Actions

The ergonomist observed, measured, and photographed the job, completing a detailed physical and cognitive demands analysis. She interviewed and observed the two nurses with permanent medical limitations, and also clarified some of their limitations with their treating health care providers. The ergonomist compared the physical demands of each essential duty with each of the nurses' capabilities and limitations. If the duty was unsuitable for the employee, the ergonomist worked with the nurses to identify accommodations that would allow the nurses to work within their capabilities. The ergonomist researched appropriate products from local vendors, and provided specific dimensions and details on product features to assist the supervisor and HR specialist in purchasing the most appropriate products.

Outcomes

The ergonomist met with the stakeholders in the project to discuss the findings and accommodations for both nurses. The key stakeholders were pleased with the objective assessment of the suitability of the job for each of the nurses, and the accommodations identified by the Ergonomist were deemed reasonable. The nurses returned to full time duties, after the recommendations had been implemented. The accommodations also benefitted other nurses at the family health clinic, in particular, a height-adjustable chair/bed as all nurses are now able to adjust the patient to a comfortable height to perform all treatments.

Discussion

Solutions considered the two nurses' specific limitations, considerations for the rest of the nurses and staff in the health team, patient accessibility, and cost. One of the challenges was to find a height-adjustable chair/bed that would allow sufficient clearance and accessibility in the small patient assessment room. Nurses and supervisors had to trial several configurations before finding an appropriate layout. Other challenges included keeping all commonly use items stored below shoulder height, sourcing a step stool with sufficient height but was light-weight enough to be lifted and carried within the nurses' capabilities, and limiting use of the step stool to retrieve less commonly use items. A follow up was scheduled to ensure that the changes implemented met the intent of the report.

Relevance to Practitioners

Developing recommendations to accommodate injured employees can be challenging, but even more so when the employees' job involves working with patients who also need accommodations. This case study is unique in that the solutions could not in any way inconvenience or increase demands for the patients who receive care.

Case study: BCEHS patient handling equipment implementation

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Background

In 2014 WorkSafeBC (WSBC) issued orders to Provincial Health Services Authority (PHSA) and its agency, British Columbia Emergency Health Services (BCEHS) to eliminate or minimize risk of musculoskeletal injury (MSI) to paramedics. A systematic review was completed, and beginning in 2017, BCEHS has been transitioning to powered patient handling equipment to reduce risk of injury associated with patient lifting tasks.

Problem

Paramedics are known to perform regular unsafe patient and equipment handling tasks associated with a high prevalence of MSI (1). BCEHS stretchers have historically been manually operated to raise and lower their height; and load/unload in and out of ambulances. Additionally, paramedics are commonly injured lifting patients without lifting equipment.

The objective of this case study is to highlight controls implemented along with challenges that BCEHS has experienced along the way with such a large scale equipment roll out.

Context

BCEHS is a province-wide ambulance service that employs over 3,600 paramedics at 193 stations using 511 ground ambulances, 4 helicopters and 7 airplanes. BCEHS paramedics completed over 900,000 responses in 2017, and are the largest emergency health care provider in Canada.

Actions

In 2014, PHSA ergonomics completed an ergonomics assessment including historical injury analysis and determined that the top three injury causing activities were loading and unloading the stretcher in the ambulance, lifting and lowering the stretcher/patient, and manually lifting patients (see Table 1). Recommendations to the organization included implementing powered equipment to mechanize these tasks. As the cost to implement this equipment is significant, a business case was developed to determine possible reductions in injury related costs, showing an expected return on investment within 7 years post implementation. A similar outcome was found by Armstrong (2), although this paper was not available at the time the business case was completed.

As several ambulance services in Canada have implemented power stretchers without power loading systems showing injury reductions, justification was needed for BCEHS to move ahead with power loading systems. The fact that loading and unloading the stretcher in the ambulance was the leading cause of BCEHS MSI by a large margin, a solid foundation to justify implementation of power loading systems existed. Furthermore, our own internal trial of power stretchers without power loading systems failed to show injury reduction.

PHSA Ergonomics also completed ride-alongs and meetings with York (power load equipped) and Brantford (power stretcher with no power load) ambulance services in Ontario. This qualitative review confirmed that power load systems are superior in reducing risk to paramedics.

In July 2016, an organizational decision was made to procure this equipment, resulting in the selection of Stryker power stretchers and loading systems, and Mangar Elk lifting cushions.

Outcomes

After 16 WSBC inspection reports beginning in December 2014 and 15 responses by BCEHS/PHSA, the MSI reduction order was deemed complied in February 2018. This occurred after BCEHS demonstrated significant implementation progress and a comprehensive plan and commitment to implement power stretchers and cushions in all ground ambulances by July 2018, and power load systems in all ground ambulances by March 2020.

As of May 2018, approximately half of the response volume is using power stretchers and power load systems with a large percentage of the remaining responses being completed with power stretchers without power load systems. It is arguably too early to look at changes in injury rates associated with these activities as equipment implementation began in mid-2017, with a gradual implementation timeline. However, in 2017 BCEHS has seen timeloss incident increases in load/unload stretcher, significant reductions in lift/lower stretcher, and slight reductions in patient lifting. BCEHS will monitor incident data closely moving forward.

Table 1: 2014-17 Time Loss Incidents are listed by activity type. Power stretcher, loading system and lifting cushion implementation started in spring of 2017, and will be completed provincially in 2020.

Activity	Number of Timeloss Incidents				Activity Description
	2014	2015	2016	2017	
Load/Unload Stretcher	79	95	76	86	Lifting stretcher into and out of the ambulance.
Lift Patient without equipmen	39	43	55	42	Includes injuries occurring when lifting a patient to the stretcher from the floor, chair, toilet, or vehicle.
Lift/Lower Stretcher	72	55	56	33	Manually raising and lowering the stretcher and incidents where the stretcher drops unexpectedly.
TOTAL Overexertion Incidents	341	379	372	331	All BCEHS incidents related to patient and equipment handling resulting in MSI.
TOTAL BCEHS Incidents	525	555	549	506	All BCEHS incidents.

Discussion

The implementation of powered stretchers and loading systems are anticipated to profoundly reduce BCEHS Paramedic MSI incidents and costs in part because there is no other way to perform these activities than by using power with the push of a button. In contrast, while the Mangar Elk lifting cushion reduces risk of injury when it is used, it still requires the paramedics to bring this piece of equipment from the ambulance to the scene and make the decision to use it. We anticipate some challenges around the province with paramedics taking time to use the Elk, but believe it is a critical tool for paramedics to have available.

Due to financial and logistical reasons, the power stretchers and lifting cushions were implemented before power load systems in many cases. This results in Paramedics loading heavier power stretchers manually until installation of the power load is complete. The increased loads require two paramedics to manually load and unload the stretchers, but they were not designed to be used this way. Loading/unloading is physically more awkward and determining when the stretcher has been pulled out of the ambulance far enough is more difficult, increasing risk of the stretcher falling out of the ambulance.

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