Advancing Towards Automated Ergonomic Assessment: A Panel of Perspectives

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Abstract. Direct and continuous exposure measurement has posed challenges to human factors engineering (HFE) professionals when conducting risk assessments. However, emerging technologies have utility to automate elements of HFE assessment and strengthen opportunities for direct and continuous exposure measurement. Leading HFE researchers provide perspectives on how advances in technology and computing, including computer vision, machine learning and wearable sensors, can aid in the automation of exposure measurement to inform ergonomic assessment while also bolstering the opportunities for objective, data-driven insight. Drs. SangHyun Lee and Michael Sonne share perspectives on the development and validation of computer vision-based pose estimation approaches. Such pose estimation approaches allow HFE professions to record video data where software can convert video into a kinematic representation of a worker and then calculate corresponding joint angles without the need for any tedious posture matching, or additional post processing approaches. Dr. Cavuoto discusses how wearable technologies can unobtrusively measure kinematics in work, showcasing the potential of direct measurement, data-driven injury risk assessment. Finally, Dr. Gallagher showcases how data collected through automated approaches can be integrated with models to evaluate injury risk through a fatigue-failure injury mechanism pathway. In addition to showcasing how emerging technologies and approaches may enhance exposure and risk assessment in HFE, panelists also highlight anticipated challenges and barriers that need to be addressed to support more ubiquitous integration of such technologies into HFE assessment practice. The future for innovation and advancement in exposure measurement and assessment is bright.

Keywords: Ergonomic assessment · Physical ergonomics · Artificial intelligence · Risk assessment · Computer vision · Wearable technology

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1 Introduction

Ergonomic assessments have relied on an ergonomist going out in the field to make measurements within the workplace primarily using a tape measure and a force gauge. Those measures can be used to inform risk assessment tools or biomechanical models to quantify exposures and ultimately assess the risk of work-related musculoskeletal disorders (WRMSDs) associated with the job. While this approach has been the standard in the field, there are limitations. For example, posture is an important risk factor where subjectivity or human error in the observation of a posture could influence the resultant risk assessment outcomes. Additionally, ergonomist can spend a lot of time taking detailed measurements which may take time away from learning more about the work from the workers who do the job, or from designing and implementing efficacious proactive ergonomics solutions. Given our reliance on time consuming measurement coupled with subjective, visual-based observation of postures, innovations that can both automate direct measurement and enhance objectivity of assessment are a necessary future direction.

Emerging technologies may have utility in automating ergonomic assessment. While force data remains more elusive, body worn wearable sensing technologies and video-based pose estimation provide approaches to directly and continuously measure posture and movement. In the near-term, access to such rich, objective time-series motion data may help to automate aspects of some existing assessment tools, providing HFE professional with insights more quickly. Over the longer term, availability and access to objectively and continuously measured motion data may support the development of new and innovative tools that were not possible in the absence of such data.

To achieve these overarching goals of automating ergonomic assessment, wearable technologies such as inertial motion units (IMUs), accelerometers or heart rate sensors can provide useful, direct measurement capabilities. IMU data can be used to describe worker kinematics, and heart rate data can inform understanding of the cardiovascular demands during work. Generally, these sensors are small in size and not overly cumbersome for workers to wear making them a potentially feasible solution. Additionally, they do not capture any potentially identifying information about the worker or workplace, an important contrast to video-based approaches. Examples of such technologies being used include the use of wristband heart rate sensors [1] or accelerometers [2, 3] being used in construction settings. While the use of wearable sensors has increased to measure exposure in the workplace, opportunities persist to develop algorithms that can relate or map direct, continuous measures on the biomechanical exposure measures related to MSD [4]. Pioneering efforts to evolve processing methods have included the use of machine learning to facilitate activity recognition [2] and fatigue detection [5–9]. Future innovations will surely continue to provide robust analytical frameworks to gain unique insights from wearable sensing technologies as necessary to inform ergonomic assessment.

The use of computer vision, and more specifically pose estimation approaches to quantify worker kinematics from 2D video data, is a second emerging technology with promise for the automation of ergonomic assessment. Pose estimation approaches enable machines to learn to identify the kinematic linkages of a human based on an image or series of images in the form of video [10]. From an ergonomics perspective, pose estimation-based methods permit body joint positions to be estimated in 2D or even in 3D space using a 2D image or video. The use of such computer vision solutions has shown good agreement between posture metrics measured with a computer vision-based approach and a gold-standard motion capture system where McKinnon et al., [11] showed an average of 75% agreement across ten simulated occupational tasks. Similar methods have been applied in the construction sector where the use of computer vision techniques have been used to quantify 3D body motion and then detect unsafe actions from the motion profiles [12–14]. Additionally, the quantification of motion data from computer vision-based methods have been shown to be of sufficient quality to conduct biomechanical analyses [15], which can provide further insight into risk assessment. While these computer vision approaches have shown utility, there are potential ethical drawbacks as they require video being collected from the workplace. However, these data may provide a more intuitive understanding to the ergonomist compared to the types of signals collected with wearable sensors such as IMUs.

Both wearable sensors and computer vision methods provide opportunities to objectively and directly collect continuous time-series data in the workplace, but there is a need for corresponding analytical methods to help glean insightful information. Concurrent advances in data science provide analytical approaches that may help yield greater insight for ergonomists to help identify and mitigate risks. For example, feature selection and classification methods have been applied to lifting motion data to identify unique movement strategy differences between lifters that significantly reduced their resultant biomechanical exposures relative to other lifers [16]. This insight was leveraged to develop a supervised machine learning model to classify lift motion strategy as having high exposure or low exposures [17], which in turn, can be used to provide more targeted movement coaching where appropriate. While these previous studies provide examples of how direct and continuously measured data can inform ergonomic assessment, relating accessible measures from wearable sensors or computer vision approaches to injury risk remains as an important consideration to maximize the impact of emerging technologies and data science methods.

One specific area where direct and continuous measurement may have great potential is the assessment of cumulative exposure. With several work tasks being repetitive in nature, the development of tools that infer cumulative injury risk is particularly important to provide insightful injury risk appraisal within automated ergonomic assessment approaches. The validity of such a risk assessment approach is supported by evidence suggesting that WRMSDs may result through a fatigue-failure injury pathway [18], where direct and continuous measurement may yield important insight. Recently, tools have been developed to appraise WRMSD risk through fatigue-failure pathways at the low back [19], shoulders [20] and distal upper extremity [21]. Automated methods may enhance the utility of emerging tools to provide more comprehensive injury risk assessments.

Advances in wearable technologies and data science methods, including computer vision will change ergonomic risk assessment. The goal of this panel discussion is to discuss emerging technological advances in more detail and to share insights about how these advancements may inform the automation of ergonomic assessment. However, these approaches do not provide a silver bullet to solve the MSD problem, so the barriers and limitation to the adoption and use of emerging technologies will be discussed. Panel speakers include: Dr. Lora Cavuoto, Dr. Sean Gallagher, Dr. SangHyun Lee and Dr. Michael Sonne, innovative leaders in HFE. Each speaker shares their unique perspectives on the potential for automating ergonomic assessment.

2 List of Speakers

2.1 Dr. SangHyun Lee

Dr. Lee is the founder and president of Kinetica Labs as well as a professor in the Department of Civil and Environmental Engineering at the University of Michigan. Kinetica Labs' "*Motion*Capture" application allows a user to record video data on their smartphone and generate corresponding posture data. The frequency, duration and severity of each posture are then calculated and can be used to inform ergonomic risk assessments.

> "*Ergonomic risk assessment involves time consuming, cumbersome, and subjective data preparation, which prevents the application of such necessary comprehensive evaluation in the field. Recent advancement in computer vision and deep learning have allowed for the development of rapid, easy-to use, and objective risk assessment solely using processing videos captured from a mobile device like a smartphone, and without attaching any sensors to workers and/or objects. I discuss how such technologies for the improvement of ergonomic risk assessment have been advanced and where they are heading next.*" – Dr. Lee.

2.2 Dr. Michael Sonne

Dr. Sonne is VP Innovations and Research at MyAbilities, co-founder of ProPlayAI and an adjunct professor at Brock University and Ontario Tech University. His work at MyAbilities helps create software to leverage artificial intelligence to perform ergonomics job analysis. Their software can be applied to video data to identify higher-risk work techniques and highlight high-risk body areas. Additionally, ProPlayAI uses computer vision methods to quantify kinematics in baseball pitching with the goal of improving performance through biomechanical insights.

> "*Ergonomics assessments have traditionally been completed by an ergonomist getting out their tape measure and force gauge, and surveying the plant floor. In the COVID era, access to facilities has been limited, making this traditional practice more and more difficult. Recent technological innovations in computer vision have made pose estimation in 3D, all from a cell phone video, more and more accessible. While these methods are not without fault, the ability to collect data remotely and through video has major implications for how ergonomists work. I identify the pros and cons of the approach, the current state of the art and where it is heading next.*" – Dr. Sonne.

2.3 Dr. Lora Cavuoto

Dr. Cavuoto is an associate professor in the Department of Industrial and Systems Engineering at the University at Buffalo. Dr. Cavuoto's research program aims to investigate workplace injury mechanisms, human capacity and physical performance while developing ergonomic controls and interventions. Her research program uses wearable sensors and machine learning techniques to quantify occupational fatigue.

> "*Sensor technology supports the feasibility of data collection, both in terms of accuracy and amount. Many existing ergonomics risk assessment tools are intended for short observations and have not been designed to consider cumulative or long-term risk for extended duration tasks. I discuss data-driven assessment to understand, model, and monitor changes in worker and task conditions for longer duration tasks.*" – Dr. Cavuoto.

2.4 Dr. Sean Gallagher

Dr. Gallagher is the Hal N. and Peggy S. Pennington professor in the Department of Industrial and Systems Engineering at Auburn University. Dr. Gallagher's research focuses on musculoskeletal disorder etiology and ergonomics. His recent work includes the development of tools to assess injury risk of the low back, distal upper extremity, and shoulders from a fatigue-failure perspective.

> "*The advent of techniques that allow continuous monitoring of MSD risk measures is an exciting advance in exposure assessment technology. However, with this advance comes with the complexity of determining exactly how such data should be analyzed, where these data may include a worker performing multiple tasks each having highly variable loading exposures. Fortunately, fatigue failure theory offers analysis techniques designed precisely for such situations and provide an assessment of the cumulative risk associated with highly variable load histories. I discuss potential benefits of fatigue failure techniques in automated MSD risk assessment, along with the challenges involved.*" – Dr. Gallagher.

3 Conclusion

Direct, objective, and continuous measurement coupled with analytical models based on strong theory (i.e., fatigue-failure) offer a promising direction in ergonomics, overcoming limitations such as subjectivity and time demands associated with current assessment practice. Panelists showcase emerging applications and discuss pitfalls and risks associated with the use of wearable technologies and computer vision techniques. Examples such as (near) real time, continuous postural analysis, fatigue prediction and cumulative failure risk offer new and unique opportunities to assess the demands of work, and ultimately overcome the MSD problem [22].

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