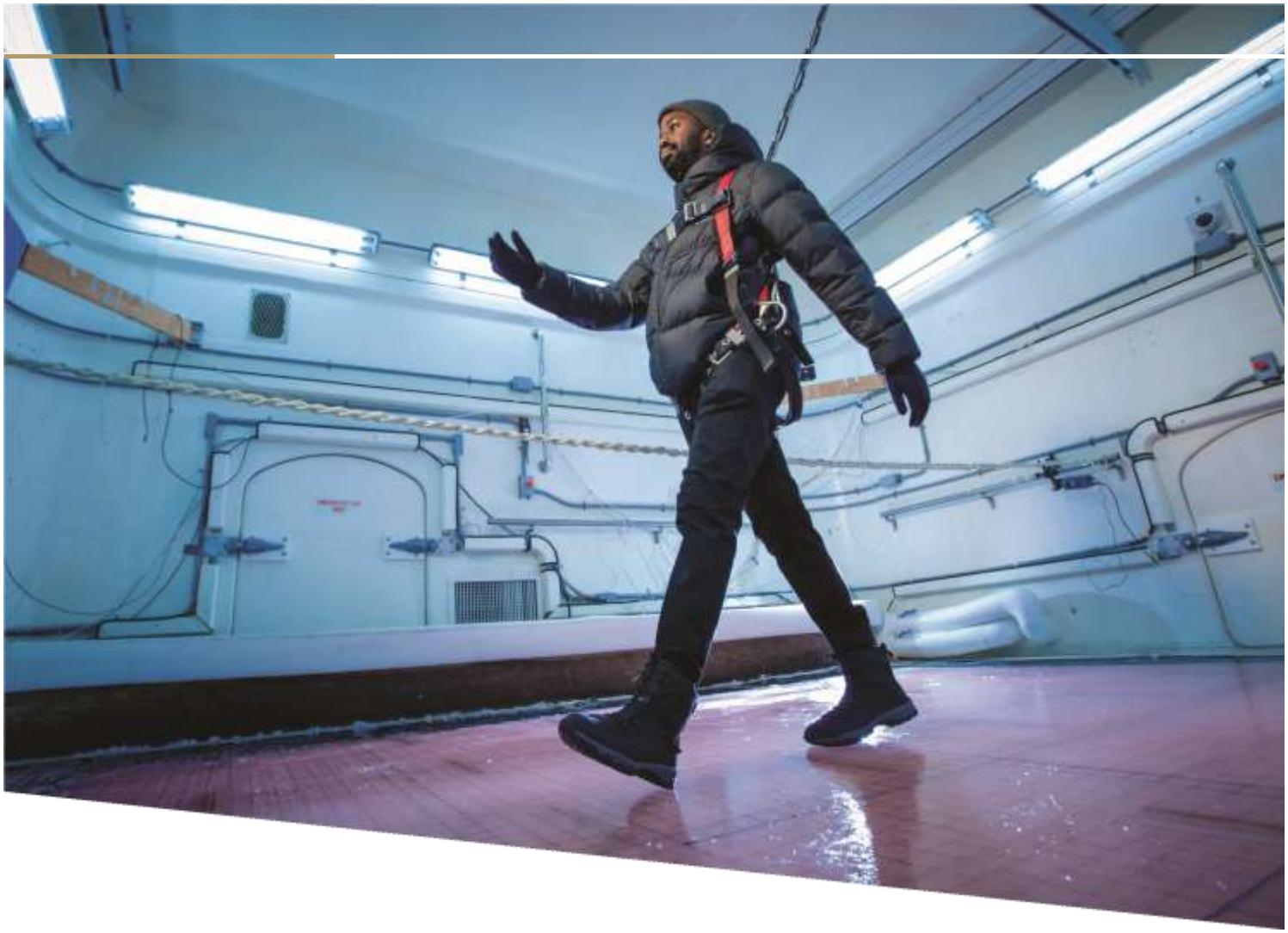
SLIPS, TRIPS, & FALLS

Slips, Trips and Falls International Conference 2023

JUNE 1 & 2, 2023 | TORONTO, CANADA

Auditorium (2nd floor), 550 University Ave., Toronto, Ontario, M5G 2A2



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Conference Endorsed by the IEA International Ergonomics Association

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Parachute is Canada's national charity dedicated to injury prevention. Our mission is to create a safer Canada by preventing serious and fatal injuries through evidence-based solutions that advocate and educate. Parachute's Fall Prevention Program supports expert and peer-to-peer knowledge exchange and implementation of best practices to reduce fall- related injuries. One of the Program's key initiatives is the national Fall Prevention Community of Practice, Loop. Loop's 2,300+ members share information, network, problem-solve together and discuss how to implement evidence-informed practices. The Indigenous Fall Prevention Network is a dedicated group of Loop members focused on issues relevant to fall prevention among Indigenous populations.

CONFERENCE EXHIBITORS:

RateMyTreads is committed to your safety and well-being. With slips having the potential to cause lasting harm, RateMyTreads understands the importance of proper footwear in preventing accidents on icy surfaces. Our goal to provide you with the information needed to select the right footwear so you can stay safe. The KITE Research Institute's innovative slip resistance test method provides reliable results by gradually increasing the floor angle as participants walk on an ice surface. RateMyTreads offers services to companies and organizations seeking to test the slip-resistance properties of winter footwear. Visit us at https://kite-uhn.com/rmt

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Welcome to Slips, Trips, and Falls International Conference 2023!

Welcome to Toronto – we are very pleased that you have joined us.

This 2-day conference will highlight the latest in slips, trips, and falls research and products.

This conference is hosted by The KITE Research Institute-University Health Network (KITE-UHN). KITE-UHN is home to some of the world's most technologically advanced rehabilitation research facilities. The KITE Research Institute brings together the brightest research minds and state-of-the-art technology. It is a unique space where ideas can be cultivated and tested in a real-life setting. New assistive technologies and treatments are developed here to enhance the lives of older people and those with disabling injuries or illnesses. Until now, researchers have lacked facilities where they can safely study how adults with disabilities interact with their environment. By creating real-life conditions, the CEAL (Challenging Environment Assessment Laboratory) enables researchers to deliver practical new therapies and well-designed products. Located in the heart of Canada's Discovery District in downtown Toronto, the CEAL is a $36-million initiative consisting of 4 cutting-edge labs, workshops and other research spaces. In collaboration with the University of Toronto, KITE has more than 56,000 square feet of newly created or renovated research space at Toronto Rehab's University Centre, Toronto Rehab's Lyndhurst Centre and the Rehabilitation Sciences building of the University of Toronto.

Conference Endorsed by the IEA International Ergonomics Association

DAY ONE PROGRAM Thursday, June 1, 2023

8:15am – 8:45am	**Registration, Auditorium (2nd floor), 550 University Ave**
8:45am – 8:55am	**Opening welcome: Dr. Milos Popovic,** **Institute Director of Research, The KITE Research Institute-UHN**
8:55am – 10:15am	**SESSION ONE:** **Technological approaches to risk and hazard assessment** • **Dharmendra Gurve, Toronto Metropolitan University** Real-time multiclass fall detection for wearables • **Hamed Ghomashchi, KITE Research Institute, UHN** Measuring the risk of tripping: design and validation of a system for measuring foot clearance over obstacles found on outdoor walkways • **Davood Dadkhah, University of Toronto** Feasibility of detecting slips on icy surfaces using acoustic signals: can we hear slips? • **Ehsan Rashedi, Rochester Institute of Technology** Developing A risk assessment tool for patients' in-hospital falls using machine learning methods • **Jakson Paterson, University of Toronto** Automated safety and usability assessment methods for outdoor street crossings • **Samuel Dallain, University of Sherbrooke** In situ footwear slip resistance evaluation with sole-embedded IMUs
10:15am – 10:35am	**Morning Coffee & Networking Break**
10:35am – 11:40am	**SESSION TWO:** **Current issues in tribometer use and validity** • **Stephen C. Thorpe, Olver & Rawden** The Pendulum Slip Resistance Test - Slider 55 - further work • **Russell J. Kenzior, The National Floor Safety Institute** Assessment of perceived and measured tribometer readings in evaluating wet barefoot slip resistance: A gait-based approach • **John P. Leffler, Reality Forensics** British Pendulum Slider 55 lifespan considerations versus EN 16165 preparation requirements • **Grant Davidson, Tile Council of North America** Assessment of various ceramic tile floor coverings using different friction test methods • **Richard Bowman, Intertile Research** Logical improvements to the EN 16165 Pendulum Test Method

DAY ONE PROGRAM Thursday, June 1, 2023

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11:40am – 12:40am	**Lunch and Tours**
12:40pm – 1:40pm	**Session 3:** **Designing, identifying and promoting safer footwear** ***Opening remarks by headline sponsor, Mark's Work Wearhouse*** • **Kurt E. Beschorner, University of Pittsburgh** The use of frustrated total internal reflection in understanding shoe friction mechanics and wear related to slipping • **Wanning Yu, University of Toronto** The outcome of the RateMyTreads program: Performance of slip-resistance winter footwear and associated innovative outsole technologies on the market • **Claire Howard, University of Toronto** Understanding consumer reluctance to adopt RateMyTreads Program: Factors affecting the widespread use of health and safety technologies • **Takeshi Yamaguchi, Tohoku University** High-friction design of shoe soles and its underlying mechanisms
1:40pm – 1:45pm	**Stretch Break**
1:45pm – 2:40pm	**Session 4:** **Safer winter walking** • **Marguerite Oberle Thomas, Parachute** Safe winter walking resource for longtime and new Canadians • **Shreya Anand, University of Toronto** Evaluating the long-term slip resistance performance of ICEFX boots over a winter season • **Kaylie Lau, University of Toronto** Identification of slip-resistant quality of winter footwear using Artificial Intelligence • **Chantal Gauvin, Institut de recherche Robert-Sauvé en santé et en sécurité du travail** Comparison of mechanical and human-centred test methods to evaluate footwear slip resistance on icy surfaces

DAY ONE PROGRAM Thursday, June 1, 2023

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2:40pm – 3:00pm	**Afternoon Coffee & Networking Break**
3:00pm – 3:45pm	**SESSION FIVE:** **Characterizing gait, balance, and fall recovery 1** • **Stephen N. Robinovitch, Simon Fraser University** Role of "internal" versus "external" perturbations to balance as the cause of falls in older adults • **Jonguk Lee, University of Toronto** The orthotic effect of functional electrical stimulation to increase the margin of stability during reactive balance in individuals with incomplete spinal cord injury • **Alireza Naderi Akhormeh, Instituto Italiano di Tecnologia** Conceptual design of a Cold Gas Thruster unit to mitigate the falling velocity in low height falls
3:45pm – 3:55pm	**Stretch Break**
3:55pm – 4:45pm	**PANEL ONE:** **Designing and retrofitting for people movement safety in facilities for public assembly seating** • **Jake Pauls, Jake Pauls Consulting Services (Panel Organizer)** • **William Conner, Bill Conner Associates, LLC** • **Daniel A. Johnson, Daniel A Johnson, Inc.** • **Sara A. Harper, Utah State University**
6:00pm	**Optional guided walk to dinner location (approximately 15 minutes)** **Meet at KITE Innovations Gallery**
6:30pm	**Luma Restaurant**

DAY TWO PROGRAM Friday, June 2, 2023

8:30am – 9:20am

PANEL TWO:
Using citizen science and m-health technologies to improve stair fall surveillance

- **Sarah Fraser, University of Ottawa (Panel Organizer)**
- **Alison Novak, The KITE Research Institute – UHN**
- **Nancy Edwards, University of Ottawa**

9:20am – 9:40am — **Morning Coffee & Networking Break**

9:40am – 11:00am

SESSION SIX:
Preventing falls in the workplace

- **Rosa Greenberg, The Center for Construction Research & Training**
  Preventing falls in construction in the United States: the fall experience survey and the national campaign to prevent falls in construction
- **Nicholas Cartocci, Italian Institute of Technology**
  Artificial Intelligence-based wearable solution to prevent fall from heights injuries for the next generation of workers
- **Kei Shibata, National Institute of Occupational Safety & Health**
  Research of behaviors immediately before occupational fall accidents in Japan
- **Akihiro Ohnishi, National Institute of Occupational Safety & Health**
  Problems on occupational truck bed falls in the land transportation industry in Japan
- **Mark Liddle, The UK Health and Safety Executive**
  Work-related slips, trips and fall injuries reported by National Health Service staff in Great Britain: How many are due to slipping?
- **Caleb Williamson, Health and Safety Executive**
  Using text mining to develop a deeper understanding of slips, trips, and falls data

11:00am – 11:10am — **Stretch Break**

11:10am – 12:05pm

SESSION SEVEN:
Characterizing gait, balance, and fall recovery 2

- **Dongyun Gu, Shanghai Jiao Tong University**
  Dynamic corticospinal motor control in visual cues intervention for gait and balance impairment in Parkinson's disease
- **Hidetaka Senzaki, The Japanese Society for Fall Prevention**
  Proposal for a stumble-free gait that raises the knees 2 inches
- **Andres F. Hidalgo, Instituto Italiano di Tecnologia**
  Predictive simulations of human balancing against falling using wearable gyroscopic systems
- **Ehsan Rashedi, Rochester Institute of Technology**
  Recovery efforts from unexpected slips and trips induce substantial low back loads

DAY TWO PROGRAM Friday, June 2, 2023

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12:05pm – 1:00pm	**Lunch and Tours**
1:00pm – 1:50pm	**PANEL THREE:** **Targeted slip, trip, & fall prevention - winter weather safety plans** • **Gary Gibson, School Board Co-operative Incorporated (Panel Organizer)** • **Kerri Stewart, Durham District School Board** • **Julie Welsh, Ontario School Boards' Insurance Exchange** • **Brian Chan, The KITE Research Institute, UHN**
1:50pm – 2:10pm	**Afternoon Coffee & Networking Break**
2:10pm – 3:15pm	**SESSION EIGHT:** **Fall risk and the built environment** • **Benjamin S. Elkin, MEA Forensic Engineers & Scientists** A top-of-flight defect affects foot placement on subsequent stair treads during descent • **Catalina Mantilla, ARCCA** The importance of foot posture strategies at initial contact during stair descent • **Rodney A. Hunter, Hunarch Consulting** Stairway ascent effort and protruding nosings • **Thurmon E. Lockhart, Arizona State University** Effects of aging and bathing surface characteristics on fall risk: Factors influencing slip/fall risk while entering and exiting bathing surfaces • **Lessby Gómez-Salazar, Universidad del Valle** Risk of falls in young and older adults in a Colombian population associated with environmental factors
3:15pm – 3:25pm	**Stretch Break**

DAY TWO PROGRAM Friday, June 2, 2023

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3:25pm – 4:20pm	**SESSION NINE:** **Broadening our understanding and strategies to address falls** • **Rob Shaw, Rob Shaw (TFG) Associates, LTD.** Slips, trips, and falls – dispelling common myths • **Donna Lee, Workplace Health and Safety Queensland** How to prevent slips, trips and falls: Planning, design, maintenance and beyond • **Yashoda Sharma, University of Toronto** A physiotherapists' understanding and assessment of gait stability in older adults • **Katrina Mae Tapang, University of Toronto** A review of cultural differences and practical barriers leads to differences in fall incidents and seeking healthcare for fall-related injuries among immigrants
4:20pm – 4:30pm	**Closing remarks: Co-Chairs and core members, International Ergonomics Association Technical Committee on Slips, Trips, and Falls**

SOCIAL PROGRAM

Tour of Challenging Environment Assessment Laboratory, The KITE Research Institute-University Health Network

Date/Time: Thursday, June 1st, 12:10am-12:40pm
Friday, June 2nd, 12:30pm-1:00pm

Cost: Included in registration

Location: 550 University Ave., Basement
Meet in the Innovation Gallery at
12:10pm on June 1st and 12:30pm on June 2nd

GALA DINNER

Luma Restaurant

Date/Time: Thursday, June 1st, 2023 - 6:30pm

Cost: $120/person
Tickets for conference attendees are included in registration, additional guest dinner ticket(s) must have been purchased in advance

Location: 2ND FLOOR, 350 KING ST. WEST, TORONTO, ON M5V 3X5 (15 minutes walk from the conference venue)

CONTACTUS

For more information about the conference, or the KITE research facilities, please contact:

Dr. Alison Novak - Alison.novak@uhn.ca

Dr. Sophia (Yue) Li - Yue.li@uhn.ca

Session 1: Technical approaches to risk and hazard assessment

Real-time multiclass fall detection for wearables

Dharmendra Gurve*[a], Luzalen Marcos [a], Devon Santillo [a], Kristiina Valter Mai [a]
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Introduction: Fall-related injuries in the aging population are a major public health concern and one of the leading causes of death due to injury. Therefore, accurate and real-time fall detection is vital to health, acting as a critical first step to ensure prompt fall management for the elderly. However, identifying various types of falls remains challenging and limits the performance of the current wearable devices.

Method: The proposed work presents a real-time cascade of binary and multiclass approaches through sensor fusion, which not only detects falls but also detects a specific type of fall. Calibration data for the algorithm was taken from the publicly accessible sisFall dataset, collected on wearable devices for several subjects experiencing various types of falls. A support vector machine (SVM) model was trained for classifying features from 3-axis accelerometer and gyroscope data from sisFall dataset. In particular, seven computationally efficient features were extracted from the dataset to be used as input to the classifier. If a fall was detected using the first binary ML model, it was further categorized using a multiclass model into one of four broad
fall categories: forward, lateral, backward fall, or any other fall (such as a fall caused by fainting).

Results: The performance of the proposed approach was evaluated using random test signals from the sisFall dataset. The proposed fall detection models outperformed recent existing algorithms and achieved a 99.2 % and 92.3% classification accuracy of binary and multiclass fall models respectively for the sisFall dataset.

Conclusion: A multiclass sensor fusion ML approach was shown to accurately classify fall detection categories. Both of the developed models have also been deployed and tested on a wearable device as a proof-of-concept, which shows promising real-time performance. In conclusion, the proposed method has promising applications in commonly used smartwatches and other wearable devices.

Keywords: wearable technology, fall classification, real-time detection

Measuring the risk of tripping: Design and validation of a system for measuring foot clearance over obstacles found on outdoor walkways

Hamed Ghomashchi*[a], Anchana Kuganesan[a,b], Ali Shirzadeh[a], Alison C. Novak[a,c,d], Tilak Dutta[a,b]
*Presenting Author, Hamed.Ghomashchi@uhn.ca

[a]KITE Research Institute, Toronto Rehabilitation Institute – University Health Network, 550 University Avenue, Toronto, Canada
[b]Institute of Biomedical Engineering, University of Toronto, Toronto, Canada
[c]Dept of Occupational Science and Occupational Therapy, University of Toronto, Toronto, Canada
[d]Faculty of Kinesiology and Physical Education, University of Toronto, Toronto, Canada

Background: Tripping on outdoor walkways is a common cause of injury for older adults that can occur when an individual fails to adjust their gait while negotiating obstacles. Therefore, there is a need to develop a better understanding of the human responses to obstacles of different heights so that design and maintenance of outdoor walkways can be safer. This work aims to develop a method for measuring pedestrians' foot clearance over potential tripping hazards on outdoor walkways.

Minimum Foot Clearance Estimation (MFCE) System Design: Our system consists of two synchronized, calibrated video cameras (Z-Cam E2) and a laser dot pattern projector that collect videos of pedestrians' feet and lower legs as they walk by. The locations where laser dots appear on a pedestrian's footwear enable us to select matched points along the shoe edge in both video images to reconstruct its 3D profile using the Direct Linear Transform method. A 3D model of the walkway surface is captured using a high-resolution laser scanner (Artec Leo). Three calibration objects (5 cm tall pyramids) are placed on the walkway surface to align the coordinate reference frames of the surface scan and camera system so that the minimum distance from the foot to the ground surface can be calculated using a Python application.

Figure 1. The dual-camera setup (a), the video images of a pedestrian recorded by the left (b) and right (c) cameras. The green dotted lines show the selected matched areas on the edges. The reconstructed 3D shoe edge (black dotted line) overlaid on the 3D model of the sidewalk (d). the red dot on the top dotted line and the black dot on the sidewalk show the lowest point on the shoe edge and its closest neighbour on the sidewalk, respectively (a case result, MFC = 16.4 mm).

Validation: A Vicon motion capture system was used to measure the accuracy of the MFCE system by comparing the distance of three reflective markers attached to six different types of footwear to the ground in 88 different instances, and the RMS error of the MFCE system was found be 0.55 mm.

Future Work: The MFCE system will be used to gather estimates of minimum foot clearance over different-sized obstacles on public sidewalks to help understand and reduce the risk of tripping on outdoor walkways.

Keywords: foot clearance, tripping, pedestrians, outdoor walkways, direct linear transform

Feasibility of detecting slips on icy surfaces using acoustic signals: *Can we hear slips?*

Davood Dadkhah*[a,b], Hamed Ghomashchi[b], Tilak Dutta[a,b]
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[b]KITE Research Institute, Toronto Rehabilitation Institute—University Health Network, 550 University Ave., Toronto, Canada

Falls on ice cause many life-changing injuries every winter. Our team's lab-based winter footwear testing has shown that a new generation of footwear provides much better slip resistance than most other footwear on the market. However, there is a need to measure the performance of this footwear in real-world use. Our team is developing a machine learning algorithm that uses data from wearable sensors attached to footwear to track how often slips occur with a particular type of footwear. Training this system includes the need to label the sensor data by categorizing each step as a slip or non-slip (ground truth labelling).

Our objective was to determine the feasibility of using human raters to label *slip* and *non-slip* steps by listening to audio (acoustic signals) recorded from microphones embedded within the outsole of footwear used for walking on ice.

Figure 1. A participant walking down a wet ice slope of 13 degrees in WinterLab while wearing the test boots.

Acoustic, inertial, video, and 3D motion capture data were collected from 24 participants wearing three different test boot models. Data from one participant was rated by one human rater to determine the feasibility of our approach. Acoustic recordings from 40 *slip* and 40 *nonslip* steps were presented to a rater who was asked to label them as either *large-slip*, *small-slip,* or *nonslip* steps. These labels were compared to labels created after reviewing the motion capture data to calculate an F1 score.

The results found the human rater achieved an F1 score of 0.87. Additionally, most of the labelling errors were due to inaccurate labelling of *small-slips* (less than 3 cm in length), which accounted for 12 of the slip steps. The F1 score increased to 0.95 if the *small-slip* category was removed. These findings indicate that detecting slips using acoustic signals is feasible and is a promising method for measuring ground truth in real-world studies, particularly slips larger than 3 cm.

Keywords: slip detection, wearable sensors, winter footwear

Developing a Risk Assessment Tool for Patients' In-Hospital Falls Using Machine Learning Methods

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Introduction: Inpatient falls are hospitals' most common safety incidents, leading to injuries and even death. Although extrinsic factors (e.g., medication and human errors) play a key role in conventional fall risk assessment tools (FRATs) such as Morse fall scale (MFS), recent data-driven FRATs have demonstrated more promising results. Hence, this study aims to develop a new data-driven FRAT by considering a comprehensive set of influencing factors and utilizing machine-learning techniques.

Methodology: Our dataset included the in-hospital fall records collected from patients associated with ~500 hospital beds between 2012 and 2017. Various factors such as age, hospital department, a companion's presence at the time of the incident, and whether a restraint prescription were considered in FRAT. Meanwhile, the dataset was divided into three different sets based on shifts (i.e., morning, afternoon, and night). Upon using the stepwise regression to select the important predictors, nominal logistic regression was applied to investigate the relationships between putative predictor factors and falls. Finally, machine learning algorithms (i.e., support vector machine (SVM) and random forest (RF)) were utilized to predict the fall risk level by considering significant variables selected through the nominal logistic regression.

Results: The results of feature selection indicate that 9, 8, and 3 predictors (i.e., mostly extrinsic factors) are closely related to determining the fall risk level in the morning, afternoon, and night shifts, respectively (Table 1). Moreover, the performance of methods is distinct in different shifts; for example, for patients with high severity of fall, SVM (%75) has better accuracy compared to RF (%69) in the morning shift, while RF (%66) outperformed SVM (%60) in the afternoon shift.

Table 1. The significance level of factors that can potentially affect the fall risk among inpatients.

		All Shifts	Morning Shift	Afternoon Shift	Night Shift
Features	*Weekday of incident*	0.67	****	****	0.87
	Hospital department or location of the incident	**	****	****	*
	The age range of patient	****	****	****	****
	Type of injury incurred, if any	0.89	****	****	0.97
	Presence of a companion at the time of the incident	*	****	****	*
	Location or environment in which the incident occurred	0.09	****	****	0.11
	Reason for incident	0.06	****	****	0.87
	Whether a fall prevention protocol was implemented	*	****	0.54	0.74
	Involvement of medication associated with fall risk	**	****	0.65	0.32
	Severity of incident	0.90	0.85	0.45	0.13
	Gender	0.31	0.90	****	0.85
Model Specificatio	**LogLikelihood-Full Model**	616.38	163.10	119.65	205.46
	Number of Observations	1069	374	286	409
	C-Statistics	0.86	0.91	0.92	0.88

p-value <.0001 : **** p-value <.001 : *** p-value <.01: ** p-value <.05: *

Discussion: Our study shows that machine learning methods (i.e., SVM and RF) provide comparable accuracy to conventional FRAT, such as MFS. The insights of this study can form a foundation to create subject-specific self-care plans to prevent falls and their adverse effects.

Keywords: inpatient falls, risk assessment, machine learning, safety

Automated safety and usability assessment methods for outdoor street crossings

Jakson Paterson*[a,b], Hamed Ghomaschi[a], Zeyad Ghulam[a], Alison Novak[a,b], Tilak Dutta[a,b,c]
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[c]Institute of Biomedical Engineering, University of Toronto, Toronto, Canada

Pedestrians (including wheeled mobility device users) can face safety and usability challenges at street crossings because of the inherent risks associated with environmental conditions and by interactions with other road users (e.g., bicycles, vehicles). Each of these external factors have both physical and psychological influences on the perceived safety and risk of fall and injury. As a result, many older adults and persons with disabilities choose to reduce their outdoor activity levels and become more isolated in their homes, restricting their daily mobility, and potentially triggering a downward spiral of deconditioning, frailty, and physical decline.

To date, pedestrian usability challenges at street crossings have been primarily understood through manual observational methods, which would be considerably improved by using more empirical analyses. The objective of this project is to automate the assessment of pedestrian behaviour at street crossings in urban environments to help understand the challenges faced by pedestrians, particularly individuals with the greatest safety or usability concerns.

The pedestrian street crossing evaluation system will use a portable video recording setup that includes a 4k video camera (Z-CAM™ E2) mounted on a 10-metre-tall mast to capture the movements of pedestrians and other road users (e.g., vehicles, bicycles), as shown in Figure 1. Computer vision approaches including YOLOv7 and DeepSORT will be used automate the detection and measurement of pedestrian walking speed and trajectory, as well as the classification of conflicts between pedestrians and other road users.

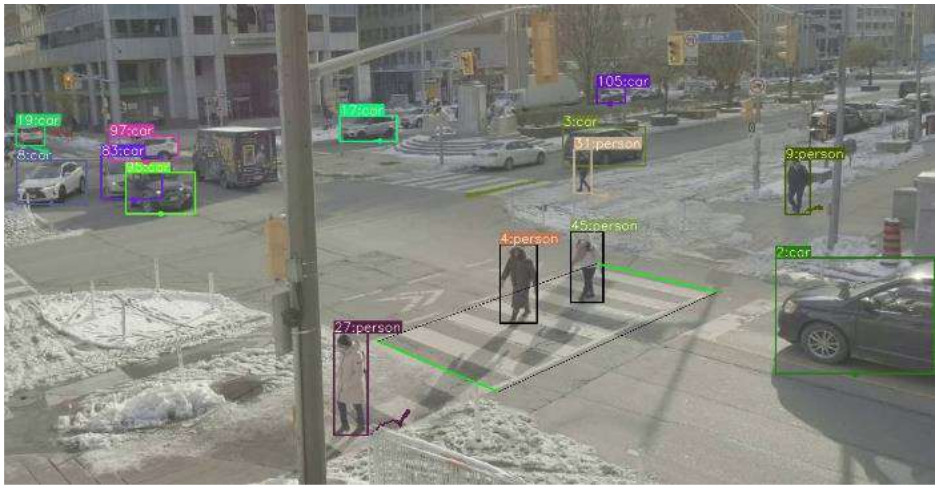

Figure 1 - YOLOv7 and DeepSORT computer vision system. Detection and tracking of both cars and persons with an emphasis on the tracking window around the west end street crossing of University Ave and Elm St. in Toronto, ON, CA.

This project will provide new automated observation tools for evaluating the safety and usability of street crossings. The goal of this work is to understand the complex relationship between pedestrians and the built environment and highlight limitations in current infrastructure design and/or maintenance so that elements of the street crossing can be made safer and more accessible for all individuals.

Keywords: pedestrian safety, slips and fall in winter, fall prevention, risk perception, object detection, computer vision

In situ footwear slip resistance evaluation with sole-embedded IMUs

Samuel Dallain*[a], Alexis Lussier Desbiens[a]
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Introduction: Occupational slips, trips, and falls (STF) are a significant cause of workplace injuries, accounting for 12.7% of injuries in Quebec [1]. To reduce these injuries, slip-resistant footwear remains an active research subject. However, most slip-resistance evaluation methods are laboratory-based [2], which can possibly limit the real-world applicability of the results. As such, wearable slip detection systems would provide valuable data for improving slip-resistant footwear.

Methods: An instrumented boot was developed with Inertial Measurement Units (IMUs) and pressure sensors molded in the sole, both under the heel and under the ball of the foot. Pedestrian Dead Reckoning (PDR), a navigation algorithm commonly used for pedestrian geopositioning [3], is used to calculate the velocity and displacement from the IMUs data. Slips can be detected and quantified by using the displacement of the boot during ground contact. To the authors' knowledge, it is the first time such technique is used for slip analysis. Furthermore, the in-sole IMUs allow for the detection of both toe and heel slips with higher precision than is typically achieved with laces mounted IMU.

Results: Preliminary results from over 200 non-slip steps and 5 slip steps show that non-slip steps consistently measure slip distances of 1.2 ± 0.5cm (max. 2.5cm), while slips result in measurements with mean 23 cm and minimum 13 cm. Figure 1 shows a 42-step outdoor walk on asphalt, frozen grass, and ice. The system measures a toe slip distance of 22 cm at contact highlighted in red.

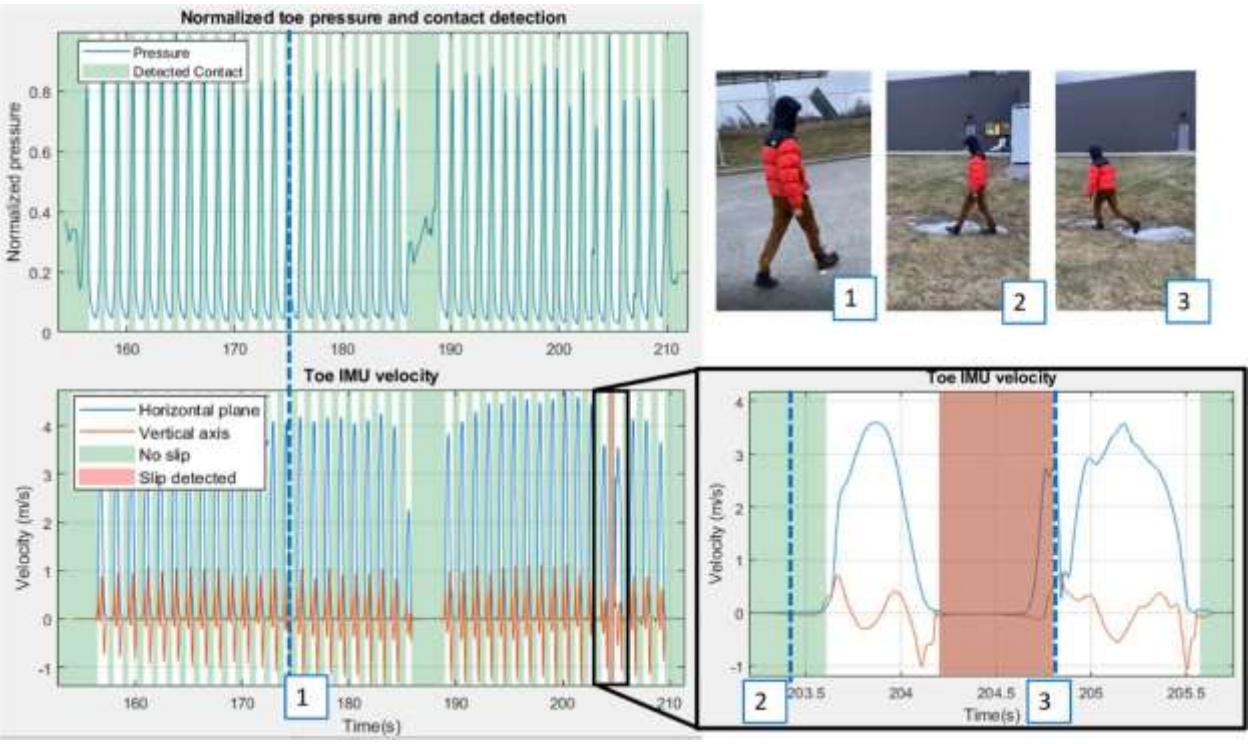

Figure 1 Example test with 41 non-slip steps and 1 toe-slip step

Discussion/Conclusion: Our preliminary results show promising results for in situ slip detection. Further testing is required to establish the system's robustness, including for more challenging scenarios such as going up/down stairs, running, and getting in and out of a vehicle.

Keywords: wearables, IMU, slip-resistance

References: [1] C. Gauvin, D. Pearsall, M. Damavandi, Y. Michaud-Paquette, B. Farbos, and D. Imbeau, “Facteurs de risque associés aux glissades chez les policiers et les brigadiers scolaires – Étude exploratoire”. [2] J.-Y. Cen and T. Dutta, “Development and Evaluation of a Slip Detection Algorithm for Walking on Level and Inclined Ice Surfaces,” Sensors, vol. 22, no. 6, 2022, doi: 10.3390/s22062370. [3] C. Fischer, P. Talkad Sukumar, and M. Hazas, “Tutorial: Implementing a Pedestrian Tracker Using Inertial Sensors,” IEEE Pervasive Computing, vol. 12, no. 2, pp. 17–27, Apr. 2013, doi: 10.1109/MPRV.2012.16.

Session 2: Current issues in tribometer use and validity

The Pendulum Slip Resistance Test using Slider 55* - Further work.

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This work builds on earlier work [1] presented at the IEA 2022 STF Conference in Sendai, Japan. The data presented has been generated post Sendai. Data generated using slider rubber mounted on standard backing plates and slider rubber mounted on modified backing plates, which include O rings, will be presented and discussed.

Data generated at the bench (on samples) and in the field (on installed in service floors) using Slider 55 (as supplied by RAPRA, UK) and Slider 57 (as supplied by BAM, Germany) will be presented and discussed.
We also plan to generate data (at the bench only) using slider working edges up to 4mm i.e. greater than the maximum edge length of 2.5mm as defined in BS EN 16165:2021.

During our earlier work we identified a material that we suggested might be useful as a verification surface when using Slider 57. We are in the process of generating more data on this material with both rubbers and with both the standard and the modified backing plate arrangements. This data will also be presented and discussed. We will also comment on the preparation and use of the potential verification surface.

* Now referred to as Slider 57 in BS EN 16165:2021.

Keywords: Abstract, test methods, pendulum test, slider 55

References: [1] The Pendulum Slip Resistance Test using Slider 55. IEA 2022. Sendai, Japan.

Assessment of perceived and measured tribometer readings in evaluating wet barefoot slip resistance: a gait-based approach

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Test Subjects: 70 volunteer subjects (35 males, 35 females) between the ages of 18 and 65 years (mean age 41.5 years) were recruited for the study. All subjects were healthy and capable of independent ambulation.

Walkway Surfaces and Conditions: Five flat smooth materials and one reference surface were installed on the floor surrounded by a metal guardrail fixture. Each surface was wetted using a 0.1% dilution of Sodium Lauryl Sulfate (SLS).

Procedures: All testing was performed at the at the National Floor Safety Institutes Research Center in Southlake, Texas. The temperature and humidity in the laboratory were controlled. Participants entered the metal guardrail fixture containing each of the five surfaces and one reference surface. Subjects were barefooted and were instructed to walk across each surface normally. Subjects ranked their perceived level of slipperiness of each surface on a scale of one to ten.

Testing: The Dynamic Coefficient of Friction (DCOF) of each surface was tested using three NFSI Approved DCOF tribometers including: the TRACSCAN, ASM-925, and GS-1 tribometers.

Conclusion: Evaluation of each surfaces combined perceived level of slip resistance and corresponding DCOF level were ranked from highest to lowest. The proposed presentation will reveal the results of the wet barefoot human ambulation study which served as the basis for establishing the three Traction Ranges referenced in the NFSI B101.4 wet Barefoot Test Standard.

Keywords: methods, tribometry, barefoot, bathroom, bathtub

British Pendulum Slider 55 lifespan considerations versus EN 16165 preparation requirements

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Slider 55 is a softer polymer used in Pendulum testing for evaluating the available friction of surfaces used barefoot. EN 16165-2021 *Determination of slip resistance of pedestrian surfaces - Methods of evaluation* specifies certain Slider 55 preparation requirements that potentially lead to a short usable lifespan for the expensive slider.

1. The standard specifies that the polymer block is to be mounted to the supporting base using cyanoacrylate or similar permanent adhesive. The polymer block has four edges that could be used for testing; the permanent adhesive eliminates using two of these edges. This study will evaluate the effect on friction measurements of using 3M F9469PC transfer tape for mounting, and the use of polymer blocks that have been flipped and remounted to utilize the third and fourth edges.
2. In Pendulum testing, a range of acceptable chamfer widths are defined (typically 1-4mm) for the slider polymer edge. EN 16165 limits the chamfer width for Slider 55 to 2.5mm, and separately specifies that sliders be broken-in (to get the initial chamfer) via 20 swings across P400 grit sandpaper. In practice, the softer Slider 55 can approach the 2.5mm chamfer limit during this 20 swing break-in, even before testing use. This study will compare Slider 55 friction measurements with a 2.5mm versus 4mm maximum chamfer.

Leffler, Flynn and Lockhart presented “Pendulum friction testing of patterned 3D-profiled bathing surfaces: Challenges, tools, and techniques” at IEA 2022 in Sendai, Japan, which discussed the use of a “conditioning clip” designed by Leffler to improve the reliability of the Slider 55 conditioning process.
The conditioning clip will be used in this study.

Keywords: pendulum, Slider 55, EN 16165, chamfer

Assessment of various ceramic tile floor coverings using different friction test methods

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ANSI A326.3, *American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials*, was revised in 2021 to include five "product use classifications" (see Table 1, below). Since publication of the updates in February 2022, manufacturers have been making classifications available for their products to meet the standard.

Table 1: Product Use Classification

Classification	Reference Category	Criteria
Interior, Dry	ID	≥ 0.42 dry DCOF* (per Section 10.1)
Interior, Wet	IW	≥ 0.42 wet DCOF* (per Section 9.1) or Manufacturer-Declared
Interior, Wet Plus	IW+	Manufacturer-Declared
Exterior, Wet	EW	Manufacturer-Declared
Oils/Greases	O/G	Manufacturer-Declared

While the "0.42" wet and dry criteria are maintained from the 2017-version of A326.3, the new "manufacturer-declared" requirement (Section 3.4) allows manufacturers to define their own internal product selection criteria—which can be based on results from any friction measurement method. Research has been initiated at TCNA to assess manufacturer-declared ceramic tile products using a sampling of friction measurement methods, listed below, that manufacturers can use to define their internal product selection criteria.

1. ANSI A326.3 (wet DCOF testing with a BOT 3000E tribometer)
2. ASTM E303 or DIN 16165 Annex C (skid resistance testing with a "British" pendulum)
3. DIN 16165 Annex B ("R"-value testing using a "German" ramp)

Preliminary results will be available for IEA in June 2023. In addition to potentially providing insights into the relationships between friction measurement methods ANSI A326.3, DIN 16165 Annex B, and ASTM E303 (or DIN 16165 Annex C), this will be the first research of its kind to compare test results on various ceramic tile products to real-world manufacturer declarations per ANSI A326.3. As such, this research could have significant implications on the future development of A326.3's five-category product use classification system.

Keywords: ceramic Tile, friction, ANSI A326.3, product use classification, "German" ramp, "British" pendulum

Logical improhvements to the EN 16165 pendulum test method

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In 2020, Bowman publicly commented on the prEN 16165 slip resistance tests: adoption of appropriate accelerated wear conditioning (AWC) protocols could fulfill EU regulation No 305/2011, allowing products to be specified, having suitable slip resistance throughout economically reasonable life cycles. An EN 16165 pendulum test was essential but manufacturers have yet to declare sample sizes in their product standards. Must they produce supporting data? In situ sample sizes should reflect the nature and purpose of such testing.

Given the mechanical nature of the pendulum, operator skill is a potential source of variability. Proficiency studies have shown the benefits of well-trained staff and laboratory accreditation. The rubber sliders are another potential source of variability. Suppliers may struggle to produce Slider 57 rubbers that comply with the compromise (compromised?) specification. Choice of slider supplier can influence ex-factory product results.

Permitted chamfer lengths have changed but without tabled evidence. Was the slider 57 chamfer limit (2.5 mm) established because of dry testing issues? As slips typically occur on contaminated surfaces, is dry testing of new products relevant?

The high slider costs cause concern in low wage economies. Environmental considerations should lead to use and conservation of stable rubbers. Can greater use be made of sliders? Are eight swings necessary on each specimen?

As most products have anisotropic surfaces, testing a single specimen in three directions may indicate the slip resistance, but not the batch variation. Considerable batch variation can be evident when five specimens are tested (using the last three of five swings).

Pendulum measurements on highly profiled surfaces may be impaired by impact variation. Precise pendulum orientation enables reproducible measurements while minimising slider wear. Consistent measurements require the use and reporting of orientation angles. Might data captured in the overdue verification testing be used to improve the standard?

Keywords: National and International safety standards, tribometers

Session 3: Designing, identifying and promoting safer footwear

The use of frustrated total internal reflection in understanding shoe friction mechanics and wear related to slipping

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Introduction: Shoe contact mechanics and wear influence slip and fall risk. The geometry of the contact region can impact friction through two pathways: 1) large contiguous contact regions that are uninterrupted by drainage channels can lead to high hydrodynamic pressures reducing friction; 2) large contact pressures are associated with decreased friction. Frustrated total internal reflection (FTIR) is a technology that uses optics phenomena to measure contact between surfaces. The presented research aims to use FTIR to characterize shoe contact mechanics as they relate to slip and fall risk.

Methods: Secondary analyses were combined with original FTIR data. Secondary analyses were performed on human slipping data and shoe wear progression data. In the slipping studies, participants were unexpectedly exposed to a slippery surface while donning shoes with varying degrees of wear. FTIR was used to collect imaging of the shoe outsole contact region with a shoe-waveguide angle of 7 degrees to capture wear in the heel region (Figure 1). The relationship between this worn region and slip outcomes was analyzed. In the wear studies, participants walked across an FTIR plate and force plate. Wear progression of their shoes was tracked over several months. The timing of wear in the gait cycle was determined by identifying when the contact region best resembled the shoe's worn region. Furthermore, contact pressures were measured by combining surface area from FTIR data with normal forces from force plate data.

Figure 1 Left: Side view of the shoe resting on the FTIR

Results & Discussion: A larger worn region was associated with a greater risk of slipping ($p = 0.043$). Thus, FTIR may provide value in assessing the worn condition of shoes. FTIR also revealed that shoe contact during early stance (within 100 ms after heel contact) best corresponded to the region of greatest tread wear. Contact pressures were largest occurring during the first 30 ms. Thus, lower friction may be present in early stance. Collectively, this research suggests the potential for FTIR as a research instrument and assessment tool.

Acknowledgements: This research was funded by the National Institute for Occupational Safety and Health (R01OH010940)

The outcome of the RateMyTreads program: Performance of slip-resistance winter footwear and associated innovative outsole technologies on the market

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Slips, trips, and falls are the leading cause of death and hospitalization among older people. Slip-resistant footwear is one of the crucial solutions to reduce slip-related injuries. WinterLab at The KITE Research Institute – University Health Network (KITE-UHN) can simulate winter conditions like low temperatures, strong winds, icy and snowy sidewalks, and slopes. The RateMyTreads Program of KITE has published the results of the slip resistance properties conducted on 284 types of winter footwear using the Maximum Achievable Angle (MAA) test method in WinterLab (dataset downloaded from https://kite-uhn.com/rmt/en Feb. 6, 2023). This dataset covered 184 types of casual and 98 types of safety boots from 52 brands for both genders (162 men's and 122 women's). Of the 284 types of footwear, 132 (46.5%) used innovative slip-resistance outsole material technologies such as Arctic Grip™, IceBite™ Grip, Icelandic Grip®, IceLock™, Polar Traction, and Green Diamond Grip. Of the 132 types of footwear with innovativetechnologies, 115 types (75.7%) have passed the test and received Snowflake ratings. Of the 152 types of footwear that did not use innovative outsole material technologies, only 2 types (1.5%) passed the test and received a One-Snowflake rating. Out of the 117 types of footwear that received a Snowflake rating, 109 types (93.2%) received One-Snowflake, 7 (6.0%) received Two-Snowflake, and only 1 (0.9%) received Three-Snowflake. Of the 52 brands, 16 (30.8%) used innovative outsole material technologies. Green Diamond Grip (the abrasive synthetic quartz embedded into the rubber of the boot) and micro-fibre-based technologies (such as Arctic Grip™, IceBite™ Grip, Icelandic Grip®, IceLock™, Polar Traction) were designed to add extra grip on ice. The passing rates for these two types of outsole material technologies were 90.3% and 66.7%, respectively. The passing rate increased to 100% when Green Diamond Grip and Icelandic Grip® technologies were combined. Field studies have shown that wearing Snowflake-rated footwear can reduce the risk of falls in icy winter conditions by 79%. Therefore, increasing awareness of wearing slipresistant footwear in winter can reduce health concerns, financial loss, and ER visits and encourage manufacturers to produce more innovative slip-resistant technologies to make winter footwear safer.

Keywords: MAA test, slip-resistant footwear, reduce injuries, older people, innovative outsole material, RateMyTreads Program

Understanding consumer reluctance to adopt RateMyTreads program: factors affecting the widespread use of health and safety technologies

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Winter weather can be treacherous, especially when it comes to slips, trips, and falls on ice. Each year, thousands of people end up in the hospital due to such accidents. To address this issue, RateMyTreads Program was developed by The KITE Research Institute – University Health Network (KITE-UHN). This program provides consumers with research-based evaluations of winter footwear to help them make informed decisions about purchasing safe, slip-resistant winter footwear. Field studies have shown that wearing RateMyTreads Program approved footwear can reduce the risk of falls in icy winter conditions by 79%. However, despite the clear benefits of this service, the adoption of RateMyTreads Program has been low. This review seeks to identify possible factors that underlie this consumer reluctance to change their purchase behaviour and to understand the lack of widespread adoption of tools such as RateMyTreads Program that promote health and safety to the general population.

Numerous business and marketing databases have been utilized to gain insight into consumer adoption of new technologies and products. The research points to several reasons for consumers' lack of adoption of new technologies. Consumers may view new technologies as threatening to their social relationships or feel their skills are becoming obsolete. Additionally, if consumers evaluate a product or service and do not see or experience the promised benefits, they are unlikely to adopt the new technology or service. Changing consumer behaviour is a complex process that involves numerous factors.

While the health and safety benefits of RateMyTread Program are undeniable, these factors suggest numerous changes in consumer behaviour are required for widespread adoption of this technology. Therefore, a strategy that accommodates these factors while emphasizing the benefits of RateMyTreads Program may yield greater consumer adoption. For instance, emphasizing the social aspect of adopting this technology, such as purchasing the approved footwear as a group activity, may help overcome consumer reluctance. Another potential approach may be to provide consumers with evidence-based data and real-world examples of how using the service have helped others avoid slips and falls.

In conclusion, consumer adoption of new technologies and products is a complex process that involves many factors. Despite the clear health and safety benefits of RateMyTreads Program, the lack of widespread adoption suggests that more attention should be given to understanding and addressing the factors contributing to consumer reluctance. By doing so, a strategy that accommodates these factors and emphasizes the benefits of RateMyTread may yield greater consumer adoption and help reduce the number of slips, trips, and falls on the ice each winter.

Keywords: RateMyTreads Program, slip-resistant winter footwear, consumer reluctance, health and safety

High-friction design of shoe soles and its underlying mechanisms

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It has been reported that about 40% of falling accidents in work places are caused by slips and falls. Thus, the development of slip-resistant shoe soles on floors wet with oil and other substances is desired. In recent years, many shoes claimed by their manufacturers to be 'slip-resistant' or 'anti-slip' have been developed. The soles of these 'slip-resistant' shoes have rubber blocks with edges at the rubber block end face corner, and the hardness of the rubber used is neither too soft nor too hard, e.g. a shore A hardness of 50-70. These are thought to have been determined empirically or experimentally, but the high-friction mechanism is unclear. In this study, friction tests were conducted under glycerin lubrication between rubber block specimens consisting of several rectangular rubber blocks and smooth glass or stainless-steel plates to investigate the effects of the radius of the rubber block end face corner and rubber hardness on the coefficient of friction. The underlying mechanisms of those effects on the friction coefficient was further investigated through contact surface observations and fluid pressure measurements. The results showed that the coefficient of friction increased with decreasing the radius of the rubber block end face corner. The results also indicated that there was an optimum range of hardness value for obtaining high friction. In both cases, it was found that an increase in the vertical load due to the adsorption force caused by the negative pressure generated in the fluid due to the deformation of the rubber block and the accompanying increase in fluid shear resistance are necessary to achieve high friction. The high-friction mechanism will provide new insight into the development of high-slip resistant shoe sole.

Keywords: slip-resistance, shoe sole, tread deign, corner radius, hardness

Safe winter walking resource for longtime and new Canadians

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Figure 1 A woman walks along an icy path on a winter night

Navigating Canada's winter landscape takes extra care, some advanced planning, and an adventurous spirit. The goal of this oral presentation is to share information that help older adults avoid fall-related injuries during the winter months, while still enjoying winter. The messaging targets both long-time residents and those new to Canada and new to snow, including ice and below freezing temperatures and has been designed to address concerns that newcomers have communicated to us.

The presentation will include a comprehensive collection of evidence-based resources for health care practitioners to access and share with their clients. Information will include practical tips on what is helpful to consider before, during and after the winter walk. The presentation will also address how to choose the best winter boots, as well as including tips for the safe use of mobility devices outdoors.

Key words: safe winter walking, fall prevention, older adults, Canadian newcomers, equity, mobility

Evaluating the long-term slip resistance performance of ICEFX boots over a winter season

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Outdoor slips and falls in icy winter conditions are a major health risk, especially for older adults for whom the resulting injuries can have severe long-term consequences. Our previous work has shown that a new generation of footwear incorporating composite outsoles reduced slips and falls on icy surfaces by 68% and 78%, respectively. However, further research showed that one such slip-resistant composite outsole material (Arctic Grip™) degraded significantly after only 75,000 steps of use.

The objective of this study was to evaluate how much the slip resistance performance of another composite outsole technology (IceFX) changes with use over a full winter season. Twenty participants were recruited and provided winter boots with IceFX outsoles to wear regularly over 3-4 months during winter 2022-2023. Participants were also provided with a data logging device to carry in their pockets while outdoors to log any slips and falls experienced in real-time, in addition to a weekly survey. Finally, participants were also asked to visit our lab to measure the slip resistance of their boots using the Maximum Achievable Angle (MAA) test at five time points (baseline, 4, 8, 12, and 16 weeks). The MAA test measures the steepest ice-covered slope (in degrees) that participants can walk up and down without experiencing a slip.

A sample of the MAA test data collected to-date is shown in Figure 1. Once all the data has been collected, a repeated-measures ANOVA test will be used to look for a significant effect of the number of steps with a significance level of $p < 0.05$. Feedback on the methods employed for this study will also be used to inform the methodology for a future study that will recruit a larger number of participants.

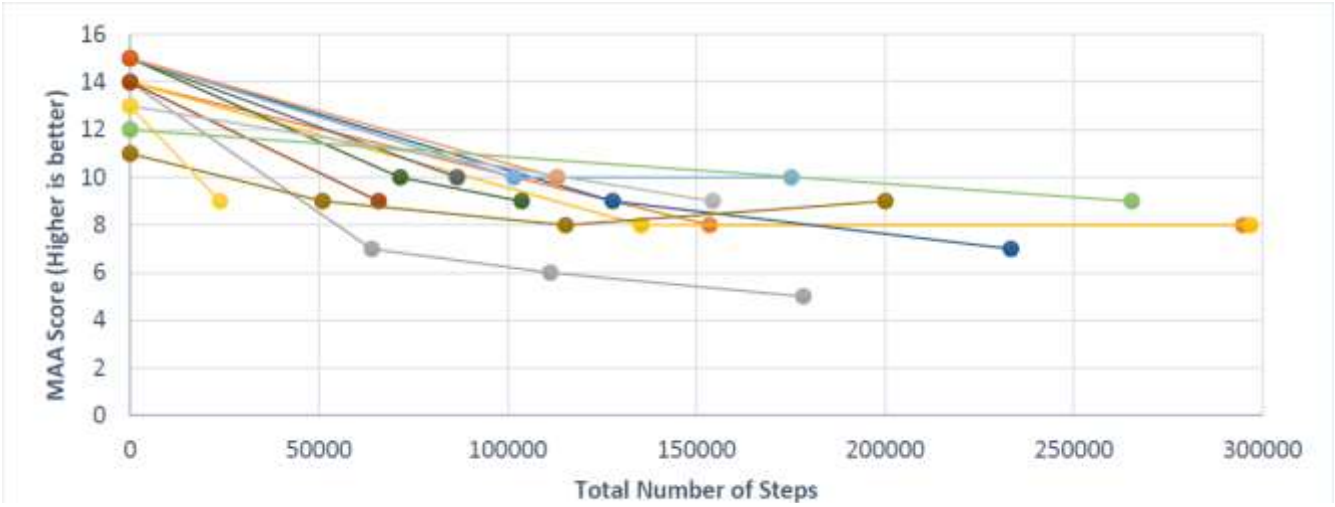

Figure 1. Results collected to-date showing the relationship between MAA score and step count. Higher MAA scores represent better performance. Each line represents a different participant and each point represents a different MAA test score.

Keywords: winter footwear, wear resistance, outdoor, slips, falls, ice, boot

Identification of slip-resistant quality of winter footwear using Artificial Intelligence

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Introduction: Slips and falls on ice are among common causes of emergency department visits and hospitalizations during the winter season. These injuries are costly and can place a financial burden on healthcare systems and municipalities. Using slip resistant winter footwear is a key factor in reducing the risk of slips and eventually falls. In this study, we develop an Artificial Intelligence model that classifies the high and low slip-resistant footwear outsoles on two different types of icy surfaces.

Methods: Our dataset included images of winter footwear outsoles that were made entirely of rubber (n=89), with Green Diamond material (n=76), and with Arctic Grip material (n=101). The slip resistance of all footwear samples was tested and rated with a human-centered protocol called the Maximum Achievable Angle (MAA). We applied a transfer learning technique to develop a 2D convolutional neural network.

Results: The best classification model used the MobileNet pre-trained model and obtained a testing accuracy and F1-score of 0.85 and 0.88, respectively. Additionally, the testing AUC-ROC (Area Under the Curve for Receiver Operating Characteristic) was 0.87.

Conclusion: Our results suggest that the proposed model was able to properly identify high and low slip resistant winter footwear outsoles. Our findings confirmed that a footwear's tread pattern and material composition both have a direct impact on its slip resistance. The proposed model will help footwear manufacturers to improve their workflow and increase product quality which can ultimately decrease the events of slips and falls.

Keywords: coefficient of friction; shoe safety; shoe traction assessment; slip resistant; convolutional neural network

Comparison of mechanical and human-centred test methods to evaluate footwear slip resistance on icy surfaces

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Assessing the slip resistance of footwear on icy surfaces is important for workers who work outside in the winter. However, there are few methods for evaluating the slip resistance property of footwear on icy surfaces. A project was conducted to rigorously fabricate ice surfaces and develop a mechanical test method using the STM603 whole shoe tester in conjunction with a refrigerated ice tray in two laboratories. The measurements obtained with the mechanical method on 10 winter boots were compared to those obtained with a human-centred method. This method, the Maximum Achievable Angle (MAA) test, measured the steepest ice-covered slope (in degrees) that four participants could walk up and down without experiencing a hazard slip.

Several findings emerged from this project. Through an analysis of the temperature fluctuation of the ice trays, specific ice temperature ranges for testing on cold and melting ice surfaces were determined for each lab. With this method, the boot coefficient of friction (COF) ranking was similar between the two labs, both for melting ice or for cold ice. However, the COF values on cold ice were higher in one of the two labs.

Comparison with the human-centred MAA method showed that both methods achieved similar results on melting ice (Fig.1a), but the mechanical method appeared to overestimate the COF of boots F4, F7 and F8 on cold ice (Fig.1b).

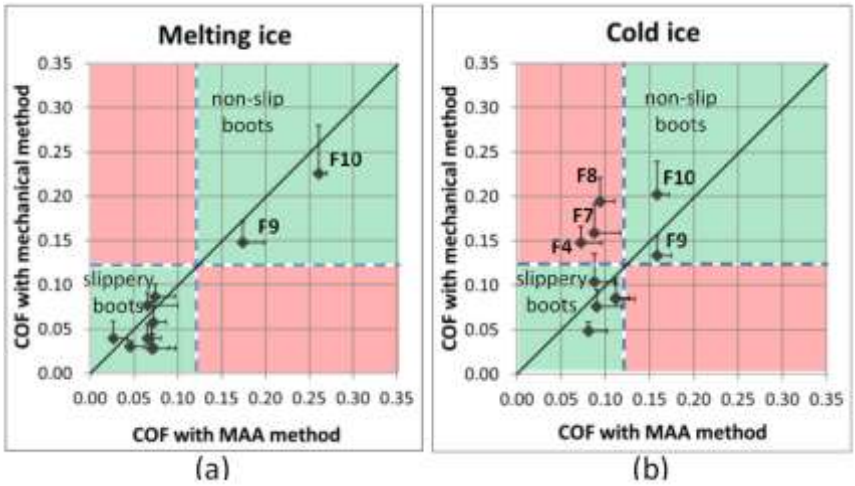

Figure 1 Comparison of COF obtained for 10 boots with the mechanical method (using STM603 on ice) and with the MAA method on (a) melting and (b) cold ice surfaces.

Although our mechanical method still needs to be refined, in its current state it can be complementary to a human-centred method. Indeed, the mechanical method can be a quick and inexpensive way for screening a large selection of boots, but the MAA test is best to rely on for final selection. This study also demonstrated that testing on cold and melting ice could provide a more accurate picture of boot performance.

Keywords: ice surfaces, slip resistance, test methods

Role of "internal" versus "external" perturbations to balance as the cause of falls in older adults

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Introduction: Understanding the causes of falls in older adults can inform efforts to prevent falls through exercise, environmental modifications, and assistive devices. In this study, we analyzed video footage of real-life falls in older adults to determine the prevalence of falls caused by "external" perturbations to balance (slips, trips or bumps) versus "internal" perturbations (such as excessive sway or fainting).

Methods: We collected video footage of 2388 falls experienced by 658 participants (mean age 84.0) in common areas of two long-term care (LTC) facilities. Each video was analyzed with a validated questionnaire (Yang et al., BMC Geriatrics, 2013, 13:40) that included 19 classifications for the biomechanical cause of imbalance. We focus here on the top 10 causes of falls.

Results: The top 10 causes of falls (Fig 1) included seven types of internal perturbations, which collectively accounted for 60.5% of falls: excessive sway (#1; 20.1%); missing the chair when sitting (#3; 12.5%); failure to stabilize posture when rising (#5; 7.0%); misstep (#6; 6.9%); sliding out of chair (#8; 5.4%); leg collapse (#9; 4.4%); and foot tripping on level ground (#10; 4.2%). The top 10 included three types of external perturbations, which collectively accounted for 29.7% of falls: loss of support with a moving object (#2; 14.2%); pushed or pulled by another person (#4; 9.1%); and foot tripping on raised object (#7; 6.4%). Slips caused less than 1% of falls.

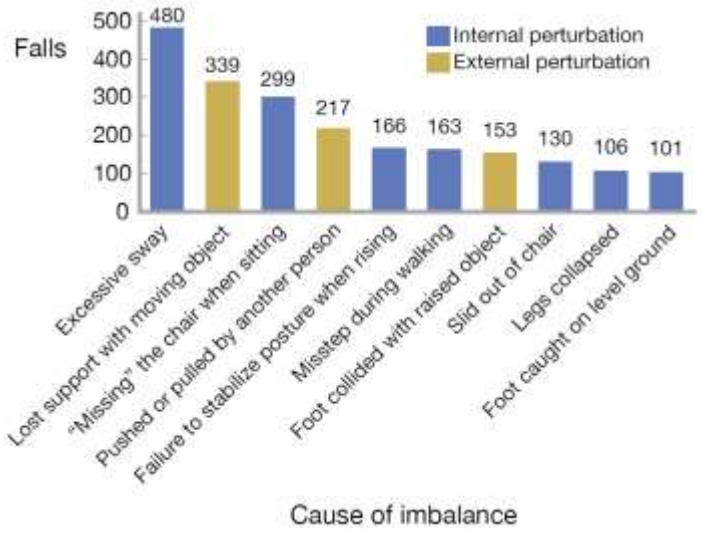

Figure 1. Top 10 causes of falls by older adults in long-term care (n=2388 falls).

Discussion: Fall prevention strategies for older adults in LTC should target both internal and external perturbations to balance, with specific focus on excessive sway, loss of support with an external object (e.g., a walker or chair), and missing a chair when sitting.

Keywords: causes of falls, video capture, older adults, healthcare environments - long term care; fall investigation

The orthotic effect of functional electrical stimulation to increase the margin of stability during reactive balance in individuals with incomplete spinal cord injury

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Functional electrical stimulation (FES) is a technique that uses electric current to augment muscle contractions during a physical task. It has been widely used in the rehabilitative setting to improve various motor tasks of individuals with paralysis. Here we investigated whether the application of FES inducing flexor withdrawal reflex can enhance the ability to take reactive steps in response to balance perturbations in individuals with incomplete spinal cord injury (iSCI). To date, four individuals with iSCI performed up to 20 trials of the Lean-and-Release test with and without FES in random order. The margin of stability (MOS) was calculated using the collected kinematics and kinetics, which related the velocity-adjusted center of mass to the boundary of the base of support. In the current dataset, there was no statistically significant difference in the change of MOS between FES and non-FES trials, which does not support our hypothesis that the flexor withdrawal reflex induced using FES increases the MOS in individuals with iSCI. In a theoretical study, we also investigated whether the MOS can distinguish a stable reactive step from an unstable reactive step (i.e., a step reaction leading to a fall). Using a model consisting of eight body segments, 20 muscles, and seven pairs of neural oscillators, we performed 4,000 simulation trials by adjusting the lean-angle and neural input. We found an inverse sigmoidal-shaped relationship between the MOS of the reactive steps taken by the model and the probability of falling. In the theoretical study, we concluded that the MOS can indicate the stability of the reactive step. In the experimental study, we found that our current stimulation pattern does not necessarily affect the whole-body dynamic response. We will further investigate the changes in kinematics to understand the effect of FES on reactive balance.

Keywords: falling, spinal cord injury, reactive balance, simulation

Conceptual Design of a Cold Gas Thruster unit to mitigate the falling velocity in low height falls.

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Wearable robotics technology for fall prevention or mitigation is an emerging research field. In this paper, we propose a novel fall velocity mitigation system using a wearable Cold Gas Thruster (CGT) unit to decrease the impact velocity and therefore the injuries of people who fall from low heights (3 m). The ejecting pressurized cold gas of CGTs generates a reaction force that is used for attitude control of spacecrafts and satellites, and in wearable manned maneuvering units that help an astronaut to control their attitude and position in space. In this article, we demonstrate the feasibility of using a compact wearable CGT unit to reorient falling humans and reduce their falling velocity to a safe level. We simulated the performance of the conceptual design of the CGT unit considering the following constraints: (1) a maximum weight of 10 kg for the unit, including gas cylinders; (2) an average human of 75 kg and 170 cm height; (3) low height falls from up to 3 m; and (4) a maximum impact velocity of 4.8 m/s (based on OSHA guidelines). Figure 1 shows the design of the CO_2 gas CGT unit using the commercially available MOOG 50-820 model, capable of providing up to 209N thrust. The wearable unit consists of five thrusters (0.4 kg each). It considers carbon-fiber storage tanks (vol. 5.4 liter; dry wt. 4.1 kg) for a fuel mass of ≤ 2.0 kg).

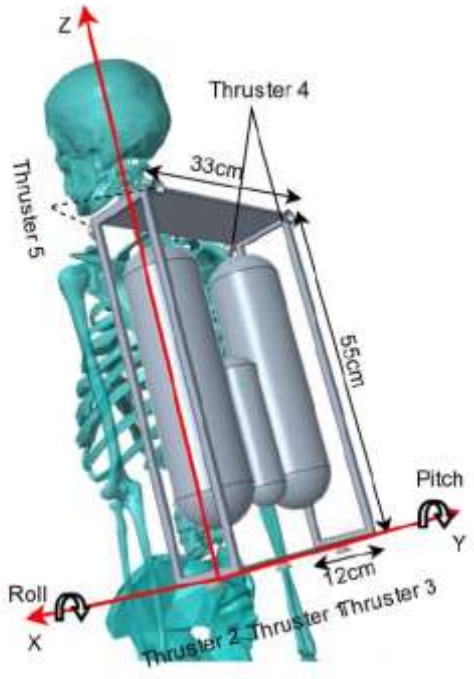

Figure 1. The conceptual design of a wearable cold gas thruster unit for fall arresting in low height falls.

We did the simulations using the data of a pre-existing OpenSim musculoskeletal model obtained from the literature and implemented a closed-loop controller with the CGT unit to enable upper body reorientation and reduction in the impact velocity during falling. The simulation also demonstrates the possible set of initial falling postures that satisfy the above simulation constraints.

Keywords: falling from height, wearable technologies, Cold Gas Thruster, musculoskeletal model, multibody dynamic

Acknowledgements: This research is promoted by and conducted in collaboration with the Italian National Institute for Insurance against Accidents at Work (INAIL), under the project "Sistemi Cibernetici Collaborativi - Cadute dall'Alto".

Panel 1: Designing and retrofitting for people movement safety in facilities for public assembly seating

Panel Organizer: Jake Pauls, Consulting Services in Building Use and Safety, Suite2207, 255 Glenlake Avenue, Toronto, M6P 1G2, Ontario (bldguse@aol.com)

Panelists:
Jake L. Pauls, BArchitecture, Certified Professional Ergonomist, HonDSc.
William Conner, BA, MFA, Theater design & use, Bill Conner Associates, LLC
Daniel A. Johnson, PhD Psychology, Ergonomist, Daniel A. Johnson, Inc.
Sara A. Harper, PhD Exercise Physiology, academic researcher

Outline of Session. The one---hour panel starts with a 12---minute introduction, with significant use of PowerPoint slides of panelists and graphics illustrating the topic:

0. Introduction to Panel members and format of session (1.5 minutes)

1. History of assembly seating facilities (1.5 minutes).

2. Focus on tiered seating systems as this is where most falls occur (1.2 minutes).

3. Front of balcony falls and complications of injurious falls from heights (1.4 minutes).

4. Paradigm shifting code change affecting seating flexibility (2.6 minutes).

5. Transitions between aisle accessways and aisle stairs (1.3 minutes).

6. Movement along aisle stairs (2.3 minutes).

7. Discussion by all Panel members: William Conner, Daniel Johnson, Sara Harper, and Jake Pauls exchange questions, answers and opinions within the panel. (Depending on how expansive panelists are with questions, answers and opinions, more time may be available for audience questions. (30 minutes).

8. Questions from Audience (15 minutes or more).

9. Concluding remarks from Jake Pauls (4 minutes or less).

History. Public assembly seating in lecture halls, theaters, arenas, grandstands is the generic name, used in building and fire codes describing more than 50, and up to about 100,000 people gathered in or on a facility to see and hear entertainment, performances, and sports. They go back millennia in history to Greek and Roman times with amphitheaters and coliseums, such as, respectively, at Epidaurus and Rome, that exist to this day. A few hundred years ago we had the beginnings of modern theaters in England, such as the Globe Theater used for Shakespearean plays. Today they are usually characterized by tiers of seating in rows giving each person 3 to 6 square feet (0.28---0.56 m2) of seating space, most simply with a bench (as with bleachers, seats without backs), benches with backrests and individuals seats, the latter ranging from basic to opulent. 2 Over a hundred years ago, during an age of intensive theater construction, catastrophic fire was the greatest safety threat. Today it is crowd member safety ranging from individual falls (on or from a seating area) through to crowd crush in which individuals in a crowd with uncontrolled density can suffer grave injuries, including brain damage and death, from compressive asphyxia, for example. We defer compressive asphyxia to another conference.

Focus on Falls within Tiered Seating Facilities. Our focus in this panel is misstep and fall---related injuries within tiered seating. One aspect, *addressed by Dr. Pauls*, falls from balconies, can result in serious injuries in individual falls from a higher level of seating to a lower level of seating. Dangers include injuries to the falling person as well as injuries to those below who are fallen onto.

A much more likely fall scenario—*the major focus for two panel members*—does *not* involve a fall *from* a balcony—*except at the foot of aisle stairs on which a misstep and serious fall occurs*. The focus, by *Panel members Conner and Johnson*, is other, underfoot, misstep dangers. These serious falls occur due to missteps and loss of balance within not only a front---of---balcony row, specifically for what safety codes term an "aisle accessway," but on the second seating row or higher up in tiered seating. *(All Panel members address aisle stairs.)*

Front of Balcony Seating Falls. Movement along an aisle accessway can be very congested, requiring seated people to stand (with the seat pan tilted up to create more space) to let others walk by, in a contorted movement to the side, in front to them. The sidling person has many underfoot dangers to avoid, e,g., there are two tripping dangers at every occupied seat—in the form of people's feet. Any railing, if it exists at all at the front of the aisle accessway, is typically much too low to serve as a handrail or, more critically, as a functional guard. Most railings here have a "sightline---constrained" height which is almost too low to be reached and grasped by a standing adult.

In an impact with the railing, ones' center of mass is well above the railing; thus one can pivot over the railing. Away from the front---of---balcony row, aisle accessways usually have no railings. (A prominent Toronto baseball stadium is an exception to this design.) Litigated, serious falls over multiple rows of seating on—*even from*—an elevated seat deck, have been studied by Dr. Pauls in civil litigation cases.

Paradigm Shifting Code Change Affecting Seating Flexibility. For recent editions, a modest change was made in major National Fire Protection Association codes (NFPA 101 and NFPA 5000)—*deleting three words of existing text*—thus allowing an aisle accessway to be behind seating rather than only at the front of seating (the widely employed tradition). Thus an aisle accessway between front of balcony seats and the front of the balcony could be eliminated, replaced by an aisle accessway behind the seating it serves.

Accomplishing the paradigm shift involves replacing immovable seats, tightly spaced in a row with swiveling seats. This involves a small horizontal gap between seats and a slightly larger horizontal gap between each set of paired seats. Three swiveling seats (a paired set and half a paired set) would occupy the same width as four of the former, completely 3 connected seats. The swiveling seats can all rotate 360 degrees—*on a rotation axis near the front of the seat pan*. Thus a seat swiveled 90 to 180 degrees from its normal event viewing position would offer a larger space at the back of the row where there is:

1. A greatly minimized danger of a fall from the front row of seats in a balcony.

2. An aisle accessway pathway to the closest aisle that would not necessarily mean occupants of the intervening seats must stand to allow passage; they can simply swivel their seats by between 90 and 180 degrees.

3. If there is a low, sightline---constrained railing serving the row behind, that railing can be optimized for both (in a win---win combination); that is:

   a. The downward---angled sightlines of the person sitting behind the railing—for whom the people walking in front of him/her can have their upper bodies closer and thus lower in the person's visual field, and

   b. There would be a very good handrail height for those walking in the lower aisle accessway in front of the railing.

(Note, there are helpful graphics illustrating these points for the panel session; these feature artists' quarter---size manikins.) Note also that the front---to---back spacing ("pitch") of seating rows can follow current best practices for the seat pitch to be at least 33 inches (840 mm); thus the rows can be served by a balcony aisle stair with three 11---inch (280 mm) run length steps.

Transitions Between Aisle Accessways and Aisle Stairs. A second category of missteps and falls can occur in transitions between an aisle accessway and an aisle stair (sometimes termed a "stepped aisle") during movement along the aisle stair, most critically in the descent direction. Regarding the latter, missteps leading to such falls include the following: air steps, overstepping, heel scuffs, and understeps—*besides the less likely*, true slips and trips (the latter being especially a possibility in ascent). Trips are also possible in transitioning from an aisle accessway to an aisle stair, especially if there are three steps in the aisle for every row of seats. Conspicuity of such risers is important for trip prevention and this can be achieved with marking on the junction of the riser and the tread with a contrasting stripe on the tread, 1 to 2 inches (35---51mm) wide.

Movement Along Aisle Stairs. Turning now to other fall safety issues related to the aisle stair, consider the stair's interface with the rows of swiveling seats. As these seats are not fixed, they should not be closer than about 12 inches (305 mm), measured horizontally, to the side edge of the steps. Moreover, there should be short handrails at the back half of the end of each aisle accessway. These serve:

1. To keep those descending the aisle away from the side drop off, which is there as well—*and only minimally protected by a seat back*—in conventional, front of seating, aisle accessway designs,

2. To compel those approaching the aisle stair to jog to the one---step or no---step portion of the aisle stair to step onto the stair and this could include stepping onto the elevated tread if people intend to ascend the aisle stair as would likely be the case with a balcony aisle stair, and

3. To provide everyone within reach of this handrail to use it with a handhold for balance and, as a mobility aid generally, while making the transition between aisle and aisle accessway (and vice versa).

This concludes my predictions on how assembly seating can be reconceptualized to be safer and offer new amenities to its users, especially to increase opportunities for face---to--- face interactions, including with people enjoying the event or performance in a wheelchair.

Jake Pauls is a Certified Professional Ergonomist based in Silver Spring, Maryland, and Toronto. He has 56 years of worldwide experience in research, codes and standards development, plus consulting linking Architecture, Ergonomics, Public Health, and Law— *especially in relation to falls*. For 8 of his 13 US safety standards committee memberships, he formally represents the American Public Health Association. In 2017, the University of Greenwich conferred an Honorary Doctor of Science Degree for his contributions to building use and safety including about 150 publications, hundreds of presentations, 30 videos, and significant revisions to model building codes and widely used standards.

Dr. Daniel A. Johnson's early human factors work addressed emergency procedures for airliner passengers, the latter leading to his book, "Just in Case" and airliner seat pocket guides for passenger safety. Later he became expert at incident investigations including stair---related falls. He collaborated with Jake Pauls on stairway safety and incident documentation guides including what is now the "Standard Method" for measuring step geometry. He is also expert in use of tribometers and, again with Jake Pauls, published an IEA paper on terry cloth towels as an effective slip resistance interface, underfoot, on wet bathtub and shower surfaces.

Bill Conner, FASTC, principal of Bill Conner Associates LLC, based in Clayton, NY, has been a professional theatre consultant since 1982, specializing in comprehensive systems planning and facility design services for assembly and performing arts programs. He participates actively in development of national model building and fire codes as senior

member of the Technical Committee on Assembly Occupancies for NFPA 101 (*Life Safety Code*) and NFPA 5000 (*Building Construction and Safety Code*), serving since 1988. Conner also frequently testifies at code change hearings for ICC's *International Building Code* and is a member of ICC's ANSI A117.1 Committee and ICC 300 Committee.

Sara A. Harper is a Postdoctoral Fellow at Utah State University and will transition to Assistant Professor at the University of Alabama in Huntsville in August 2023. Dr. Harper has authored 20---plus peer---reviewed articles, and her laboratory–human factors, aging--- related physical function & ergonomics research emphasizes movement safety. Her recent research includes real---world stairway fall---related events and the influence of riser height and tread depth dimension inconsistencies.

Panel 2: Using citizen science and m-health technology to improve stair fall surveillance

Panel organizer: Dr. Sarah Fraser, University of Ottawa, 200 Lees Ave, Ottawa, Ontario Canada
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Panelists:
Sarah Fraser, PhD, University of Ottawa
Alison Novak, PhD, KITE Research Institute
Nancy Edwards, PhD, Professor Emeritus, University of Ottawa

After accounting for person-time exposure, stairs are associated with the highest incidence of falls and account for a higher proportion of injurious falls than falls in other locations. While many factors contribute to stair falls, there is a growing body of literature supporting ergonomically safer stairs. Specifically, controlled laboratory-based studies have provided evidence on the benefits of considering the contributions of individual elements of stair design to stair fall risk. Unfortunately, evidence that links specific stair features (i.e., rise height, run length, nosing contrast, handrail cross-section shape, etc) to real-world stair falls is lacking. The lack of data from stair falls that occur in the community, and specific stair features associated with these stair falls, limits our ability to advocate for improvements in the built environment via modifications in the Canadian building codes.

With increased use of app-based technologies, particularly within the aging population, there is an opportunity to improve injury surveillance at a population-level using citizen science (i.e., a method of public inclusion that involves the untrained general public in research). Newer interventions include health technologies such as m-health, which consists of using mobile technology to promote information sharing and access. Many new m-health technologies allow individuals to capture information in real-world situations. Using this technology, our team has developed a new m-health app, called *Safer Steps*. The app has been developed with the goal to reduce the incidence of falls in older adults by inviting the user to identify features of their stairs (using the device camera) and having them report on falls that have occurred on the stairs being photographed. The *Safer Steps* app puts the emphasis on the built environment while still collecting relevant personal risk factors (i.e., fear of falling and/or mobility issues).
Data collected using the *Safer Steps* app will allow us to identify associations between a stair fall that occurred in the community and specific stair features (i.e., steps too high, too short, no handrail). At the individual level, this app informs the user of risks and changes they can make within their home. At the population level, the intent is for a citizen science approach that yields community wide data on stair features associated with real-world falls that can be used to inform policy change.
This extended discussion aims to discuss the use of m-health technologies for injury surveillance, particularly as it applies to the factors contributing to stair falls. Specifically, we will discuss:

- Current knowledge of stair fall risk factors and evidence gaps in our current state of knowledge (Novak)
- The use of a citizen science approach for addressing stair-related falls (Edwards)
- The development of *Safer Steps* app (Fraser)

Open discussion with audience members and panelists will discuss application of the *Safer Steps* tool within policy and industry, and broader implications of using m-health technology and citizen science for injury surveillance.

Sarah Fraser PhD is an Associate Professor in the Interdisciplinary School of Health Sciences, Faculty of Health Sciences at the University of Ottawa. Dr. Fraser's research aims to understand how older adults multitask, particularly in situations where they are walking and simultaneously responding to a cognitive task (i.e., stairclimbing and talking). As stairclimbing is particularly demanding, Dr. Fraser is leading an interdisciplinary team of researchers that has developed an m-health app to quantify stair features (i.e., uneven steps, lack of handrail) that contribute to stair falls in older adults. Dr. Fraser's research supports fall prevention initiatives, accessible environments, and aging-in-place.

Alison Novak PhD is a Scientist at Toronto Rehabilitation Institute-UHN an Assistant Professor in the Department of Occupational Science and Therapy and Faculty of Kinesiology and Physical Education, University of Toronto. Dr. Novak's primary research focuses on understanding mobility in challenging indoor and outdoor environments. Her work aims to understand the impact of aging and environmental factors on safe mobility, reduce the risk of falls, and support aging-in-place strategies. Dr. Novak is actively involved with current changes to the National Building Code of Canada and Canadian accessibility standards to build an age-friendly, accessible and safe environments.

Nancy Edwards PhD is Professor Emeritus and Distinguished Professor in Nursing at the University of Ottawa. She is a voting member on the Standing Committee for Building Codes, Housing and Small Buildings, National Research Council. She is a board member and Chair of the Fall prevention working group for C.A.R.P. Ottawa Chapter. Nancy's research focus is multiple interventions in community health. She has several publications on environmental fall hazards associated with bathrooms and stairs and has been an advocate for building code changes to reduce falls since 2007.

Preventing falls in construction in the United States: the fall experience survey and the National Campaign to Prevent Falls in Construction

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Falls are the leading cause of death in construction in the United States (US). Approximately one construction worker dies per day because of a fall to a lower level in the US: in 2020, 353 workers lost their lives in this way. Fall protection in construction has been the most cited violation by the Occupational Safety and Health Administration (OSHA) for the last ten consecutive financial years. This presentation will provide an overview of new research and key fall prevention efforts in the US with a focus on the role of planning.

The Fall Experience Survey provides new insight on key underlying causes of falls. In 2021, CPWR – The Center for Construction Research and Training partnered with the ANSI Z359 National Work at Heights Task Force and the National Occupational Research Agenda (NORA) Construction Sector Council Falls Work Group to develop and administer the survey. Results published in 2022 found that lack of planning was associated with a lower likelihood of using fall protection and that respondents believed lack of adequate planning was a key underlying cause of falls.

The National Campaign to Prevent Falls in Construction (Falls Campaign) was founded in 2012 by OSHA, CPWR, the NORA Construction Sector Council, and the National Institute for Occupational Safety and Health (NIOSH). The Falls Campaign works to prevent falls in construction by promoting awareness of fall hazards and solutions. It emphasizes the importance of planning, and promotes a range of planning resources such as a daily jobsite checklist, a simple fall prevention plan, a more detailed fall prevention plan, and planning resources tailored to the needs of small contractors.

Keywords: Fall prevention and protection in construction, falls from heights, planning for fall prevention

Artificial intelligence-based wearable solution to prevent fall from heights injuries for the next generation of workers.

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Introduction: Falls from heights cause severe injuries to workers with significant consequences for the entire healthcare and economic system. A key aspect of developing fall prevention systems is the early prediction and/or detection of the fall event. However, this is challenging due to the quantity, quality, and heterogeneity of data and processing time requirements (e.g., the fall must be detected within a narrow time frame). This work considers these critical issues using Deep Learning (DL) algorithms and wearable technology for fall prediction, detection, and forecasting.

Methods: Training of algorithms needs data that captures the basic dynamics of falling, while also covering all the different fall variants and human characteristics. Although public datasets exist, the number of subjects and scenarios is very small compared to all possible fall scenarios, and deep learning algorithms need big data to be trained and provide generalized solutions. Therefore, we follow a divide-and-conquer approach. The first subproblem concerns the falling without external forces other than gravity (free-fall), while the second involves subjects falling when in contact with the environment. In the latter fall, the human is approximated by an inverted pendulum (IP), Figure 1.

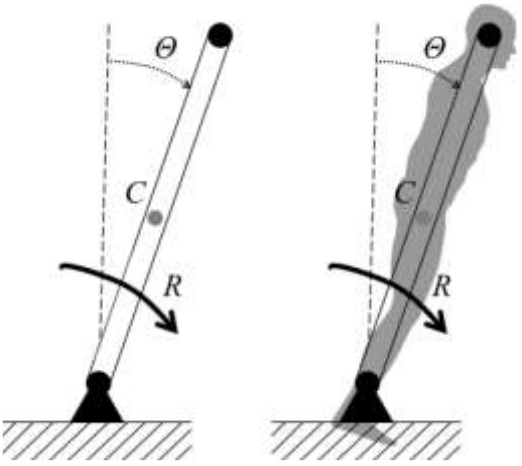

Figure 1 A human modeled as an inverted pendulum for generating simulations of falling.

Results: A recurrent neural network (RNN) was chosen for fall detection. The input is a time series computed from the quaternion of a single IMU and consists of the relative angle of IP and direction of gravity, while the output is the probability of falling. Similarly, an RNN approach is used to extrapolate the subject's orientation in the future and identify when the person will be at risk of injury. The inputs are those used in fall detection, while the output is a time series of the relative angle between the subject's torso and the gravity vector. Finally, a similar approach starting from the subject's biometric signals is used to estimate the future fall probability.

Conclusion: The paper will show positive results using both public datasets and experimental data.

Keywords: accidents at work, artificial intelligence, construction industry, falls from height, falls prevention.

Acknowledgements: This research is promoted by and conducted in collaboration with the Italian National Institute for Insurance against Accidents at Work (INAIL), under the project "Sistemi Cibernetici Collaborativi - Cadute dall'Alto".

Research of behaviors immediately before occupational fall accidents in Japan

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Falls on the same level now occur in one out of four cases in occupational accidents involving four or more days absence from off work in Japan. It is the most common occupational accident that should be prevented. Some exertions have been made to improve the working environment and the physical fitness of the workers. However, there are no signs of a decrease in the number of accidents involving falls on the same level. To reduce the risk of fall, it is necessary to face the issues from a new perspective.

Therefore, in this study, we focused on behaviors immediately before the occurrence of a fall, which has not been considered until now, and to clarify the influence of the behaviors on the fall risk. We targeted the occupational accidents where the type was falls in 2017 involving four or more days off work, and classified and analyzed the behaviors immediately before a fall occurred from the reported text data. The classifications were performed by age group, by industry, by cause of falls (slip, trip, miss step), and by cause of slips (wet, ice and snow).

In all industries, from young to middle-aged, the risk of slip-induced fall in complex working without walking on wet floors was high, and the risk in pure walking on frozen and snow-covered surfaces was high. Elder people have a higher risk of slip-induced fall in working while walking. The risk of tripping in working while walking is high among young people, and the risk of tripping in walking is high among middle-aged people. In addition, the risk of miss step in working while walking is high among young people. Furthermore, in the retail industry, social welfare facilities, and land transportation business, the tendency of fall risk due to behavioral patterns depends on the work content and environment peculiar to each industry.

Keywords: occupational fall accident, behavior immediately before occupational fall, slip, trip, miss step

Problems on Occupational Truck Bed Falls in the Land Transportation Industry in Japan

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Introduction: A typical occupational accident in the land transportation industry is falling from a truck bed for a long time. As an example, not noticing the edge of the bed led to direct falls to the ground. This study aims to clarify the specific situations of falling from a truck bed.

Method: Fatal accidents and accidents of 4 days or more absence from work in the land transportation industry are published on the website of the Authority in Japan. This study analyzed 1,501 cases, including 766 cases in 2010 and 735 cases in 2015, which were considered as falls from truck beds (including foot injuries during landing). Next, all cases were read and then classified according to the feature, situation, and scene.

Result: The trend of occurrences about falling from a truck bed was generally similar in both years. Falling, while climbing down the truck bed was the most common. It accounted for 34.6%–40.0% of the total incidents, including climbing to the bed and jumping down to the ground. The second common was the effects of rain, snow, and ice (7.0%–10.1%). Less than 10% of the cases were related to sheet handling, side gate, misidentification of position on the bed, and cargo handling.

Discussion: Falls from a truck bed are commonly associated with accidents during ascending and descending of workers, and are not so many caused by working on the truck bed. The simplest measure to reduce head injury risk of falls from truck bed in many cases is to wear a safety helmet as well as the provision of proper equipment, such as steps and handgrips on the cargo body. In Japan, there are very few trucks with mounted steps. Therefore, workers are forced to clamber up the bed and then jump down to the ground. Collaborative product development by truck body manufacturers, such as adopting an anti-slip step as a countermeasure against getting wet, will be indispensable for solving this problem.

Keywords: occupational fall, truck bed, ascending, descending

Work-related slips, trips and fall injuries reported by National Health Service staff in Great Britain: How many are due to slipping?

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Introduction: Two Randomised Controlled Trials have evidenced the potential for appropriate slip-resistant footwear to reduce workplace slips. To understand the significance of these findings, it is important to know what proportion of the reported injuries from slips, trips and falls (STFs) are actually caused by slips. This can be difficult to ascertain because the terms slip, trip and fall are often used interchangeably, and the related injury data are often combined. The objective of this research was to review workplace non-fatal injuries reported as STFs under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR) in Great Britain, to determine what proportion of STF injuries reported for staff working within the National Health Service (NHS) were caused specifically by a slip.

Method: There were 1004 STF injuries reported for NHS staff in Summer and Winter 2018/19. Two researchers reviewed the free text description of each incident to assess whether a slip was the primary cause and designated each incident as a slip, non-slip or unclear. In cases where the reviewers did not agree, or at least one felt that the cause was unclear, the reports were referred to a STF specialist to consider if the information provided was indicative of a slip.

Results: The review process resulted in 91.3% agreement; the kappa statistic was 0.842 indicating strong agreement between reviewers. The review found that 431 or 42.9% (95% confidence interval 39.8-46.1%) of the incidents were slips. This percentage was greater in Winter compared to Summer (49.0% and 36.0% respectively, $p<0.001$).

Conclusion: Slips accounted for a large proportion of worker STFs reported among NHS employees. Differentiating between STFs can help to identify and prioritise appropriate interventions, so repeating this exercise in other sectors would be valuable.

Keywords: slips, data analysis, health service

Using Text Mining to Develop a Deeper Understanding of Slips, Trips, and Falls Data

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Work-related incidents in Britain are notified under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR). This rich source of data supports the production of official statistics as well as evidence for policy and research. Published HSE statistics show that 'slips, trips, and falls on the same level'(STF) on average account for a third of all reported non-fatal injuries notified under RIDDOR.

Whilst there are advantages to RIDDOR as a data source there are some limitations, notably:

- no codified distinction between a slip, trip, or fall on the same level.
- accident details are held within free text fields; and
- significant under reporting of incidents by businesses.

These factors create difficulty when trying to extract granular detail beyond the coded data contained in RIDDOR reports. For example, it makes it difficult to assess the potential impact of targeted interventions, such as slip-resistant footwear. Examination of free text about an incident can produce valuable insight, but without the use of automated text mining procedures this is a labor-intensive process. Previous analysis performed manually was limited to 1004 documents in a single industry sector.

Building on previous work, this project has used machine learning to automatically classify whether an accident is a slip. The model was generated using a random sample of STF injuries across all industries. This now allows for analysis to take place to review the prevalence of slips across industries, ages, and seasons. This presentation will cover the work completed to develop a classification model, analytical findings, and the potential to re-analyze historic datasets using text mining techniques.

Keywords: text mining, machine learning, statistics, slips at work, practical analysis and accident investigation, public health policy

Session 7: Characterizing gait, balance, and fall recovery II

Dynamic corticospinal motor control in visual cues intervention for gait and balance impairment in Parkinson's disease

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Introduction: Balance and gait impairments characterize the progression of Parkinson's disease (PD) that increase the risk of falling and reduce the quality of life. These symptoms are particularly aggravated during turning due to the complex motor control involved. Although studies have shown that PD turning can be improved with visual cues, the mechanism behind this improvement is not well understood. The aim of the study is to investigate the changes in corticospinal motor control of PD participants when turning with visual cues, focusing on the relationship between muscle synergy and brain activity.

Method: Twelve PD participants performed ten right-turn trials with and without a laser visual cue. Eight lower limb electromyography (EMG) signals and fifteen electroencephalography (EEG) signals were collected and preprocessed for analysis during the turning trials. The preprocessed EMG signals were decomposed into temporal muscle synergy signals using Non-negative Matrix Factorization. The corresponding preprocessed EEG signals were averaged into Event-Related Potentials (ERPs) and their band power in the gamma frequency band was calculated. The coherence between the temporal muscle synergy and ERP signals in the gamma band was then calculated.

Results: PD participants exhibited significant alterations in the temporal muscle synergies during the stance phase when turning with the visual cue. With the visual cue, the ERP gamma band power of PD participants decrease significantly in the motor cortex while there were no significant changes in the parietal and visual cortices. Compared to turning without visual cue, the coherence between the temporal muscle synergies and the motor cortex increased while the coherence in the visual and parietal cortices reduced when PD participants turning with visual cue.

Conclusion: Improved dynamic corticospinal motor control when turning with visual cues is reflected in the increased coherence between the muscle synergy and the motor cortex, which translates to better balance and gait characteristics in patients with Parkinson disease.

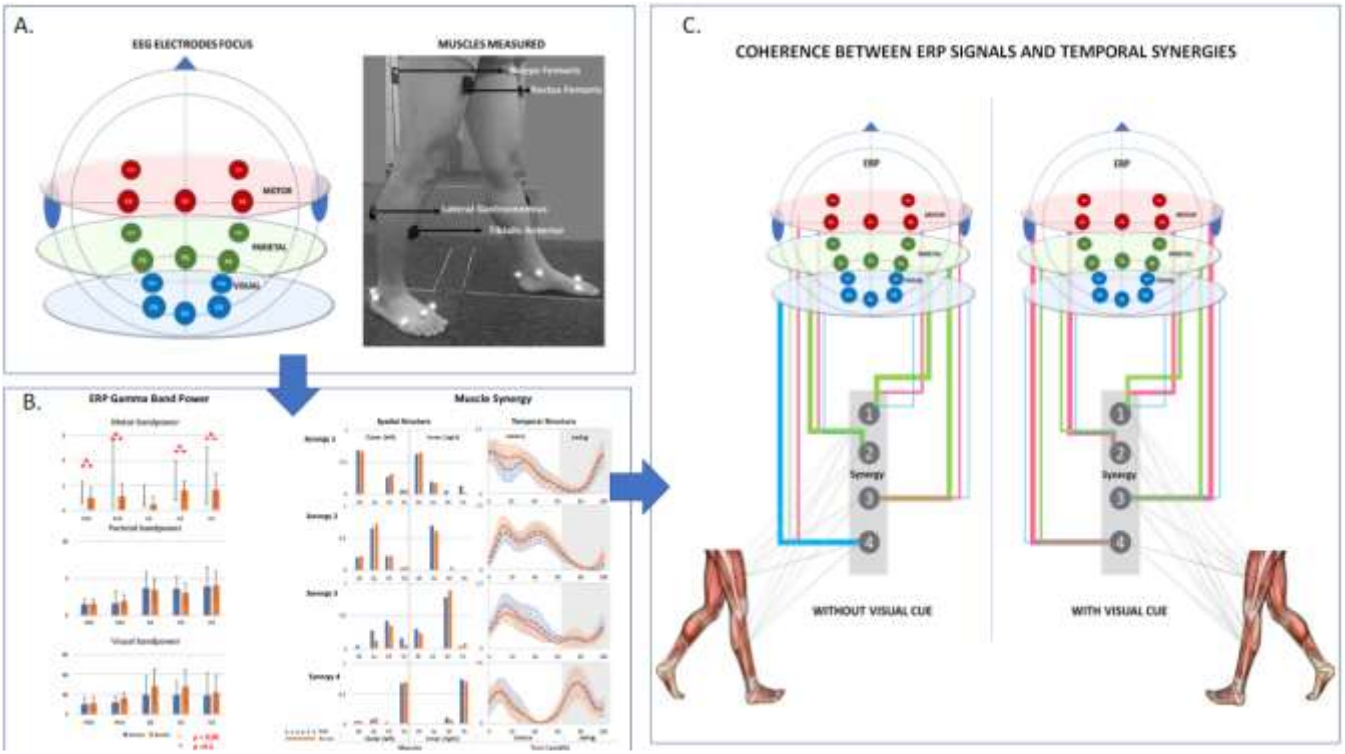

Figure 1 shows the general framework of the study. Fig A shows the EEG channels focused on in this study (FC3, FC4, Cz, C3, C4, CP3, CP4, Pz, P3, P4, PO3, PO4, Oz, O1, O2) alongside the EMG sensor placement (left and right biceps femoris, rectus femoris, gastrocnemius lateral, tibialis anterior). Fig B. displays the changes in extracted features: ERP gamma band power from EEG signals and muscle synergy from EMG signals between experimental conditions. Fig. C. shows the coherence between the cortical areas and temporal muscle synergies with and without the visual cue (red line - motor coherence, blue line – visual coherence and green line – parietal coherence). The width of each line represents the strength of coherence between synergy and cortical areas.

Proposal for a stumble free gait that raises the knees 2 inches: From kicking to stepping, a Copernican shift in thinking

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Humans, who acquired upright bipedal walking, have always walked barefoot on uneven terrain with a great diversity of terrain. In Japan, until about 70 years ago, most people walked barefoot, either wearing footwear such as geta or waraji. The waves of the Industrial Revolution swept over Japan, making it possible to produce inexpensive shoes domestically. After the war, everyone started wearing shoes in no time. The hypothesis was that shoes enabled heel landings, knee extension and a wider stride by kicking with the toes of the back foot, which led to an increase in slips and trips and falls. 20 men and women in their 60s to 80s were taught how to walk by raising their knees 2 inches in a footstep manner and were tested on paved roads, trails and snow to determine the effect of foot slip and foot stability compared to normal walking. Sensory evaluation tests were conducted to evaluate the slippage and stability of the feet in comparison with normal walking on paved roads, mountain trails and snow. The results showed that raising the knees by 2 in. prevented stumbling and increased the stability of the supporting leg, and that the landing area became less slippery as the landing area was shifted from the heel to the entire sole of the foot. The reason for this was a change in gait from a gait powered mainly by stepping back on the toes of the rear foot to a gait powered by bending and stretching the front leg knee. The width of the foot became slightly narrower by raising the knee 2 inches, which can be expected to have the effect of preventing both stumbling and slipping and falling at the same time.

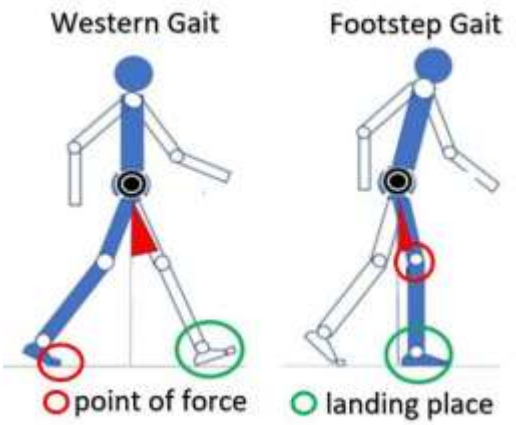

Figure 1. From kicking to stepping, a Copernican shift in thinking

Keywords: raises the knees, from kicking to stepping

Predictive simulations of human balancing against falling using wearable gyroscopic systems

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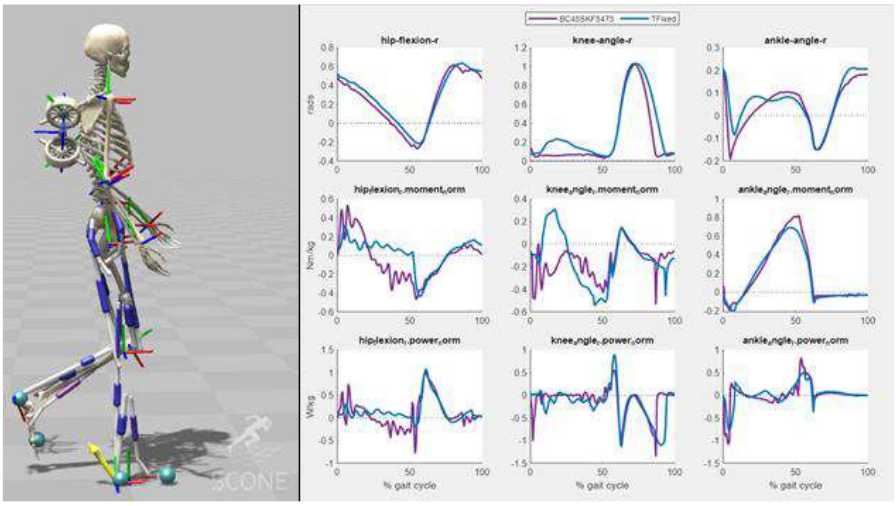

Figure 1: Gait pattern differences between a lumbar fixed model and our integrated cluster of variable speed control moment gyroscopes and neuro-musculoskeletal system.

Loss of balance in humans is a common cause of falling, with potentially severe consequences in elderly people and working at height professionals. Wearable robotic devices for balance support constitute an appealing solution due to the freedom of movement they offer to the users. Within these, recent investigations have emphasized the advantages of portable gyroscopic systems in assisting human balancing. Control Moment Gyroscopes (CMGs) are made of a flywheel rotating at constant rate. To transmit torque to a body, the flywheel must gimbal about an axis fixed to the body. Furthermore, by changing the angular momentum of the flywheel, a small gimbal torque input can produce an augmented torque output on the body. This gyroscopic effect that has traditionally been used for attitude control in space systems, can also be used for balancing a human through the torque transmitted to the torso. The usual approach to design the controllers of these systems relies on simulations of simplified models of humans and robotic devices. However, a more versatile strategy would be to close the loop between human motion and robotic device control using predictive simulations. Predictive simulations of robotic devices integrated with neuro-musculoskeletal multibody human models can reveal the underlying principles involved and provide insights into the mutual interactions and adaptations between the human and the robotic device. In this work, we demonstrate, through predictive simulations, how a gyroscopic device can balance the torso of a walking human model driven by muscles as well as the influence the device has on gait patterns and muscle activity. We implemented an OpenSim model of an integrated neuro-musculoskeletal system driven by 18 muscles and a pyramidal cluster of variable speed CMGs (**Figure 1**) for balancing the torso in 3D space.

Keywords: wearable technologies, predictive simulations, gyroscopic assistance, balance, human-robot interaction

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Recovery Efforts from Unexpected Slips and Trips Induce Substantial Low Back Loads

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Introduction: Slips, trips, and falls are among the most prevalent causes of occupational injuries and fatalities. In response to slip or trip events, a rapid recovery effort is necessary to regain balance. Earlier studies have demonstrated that such efforts, even if leading to successful balance recovery, may be involved in causing low back injuries. Our goal was to identify potential underlying biomechanical mechanisms responsible for these injuries.

Methodology: We quantified lumbar kinematics (i.e., lumbar angles relative to pelvis) and kinetics (lumbosacral loads) and lumbar muscle responses among 12 (6F, 6 M) participants during: 1) normal walking, and during unexpected 2) slip and 3) trip perturbations. To estimate lumbosacral (L5/S1) spine loads, we used a 3D, dynamic, EMG-based model of the lumbar spine, with inputs including individual anthropometry, lumbar muscle geometry, and lumbar angles (from AnyBody), along with electromyography from 14 lumbar muscles (6 flexors/8 extensors). One-way, repeated-measures ANOVAs were used to assess the effect of walking condition on the dependent measures (α=0.05) along with post-hoc paired comparisons.

Results: Compared with values during normal walking, lumbar range-of-motion, L5/S1 loads, and lumbar muscle activations were all significantly higher during the slip and trip events (all p-values < 0.0009; Figure 1). Maximum L5/S1 compression forces exceeded 2700 N during the slip and trip events, compared with ~ 1100 N during normal walking. Mean values of L5/S1 anteroposterior (930 N), and lateral (800 N) shear forces were also substantially larger than the shear force during normal walking (230 N).

Discussion: The observed levels of L5/S1 reaction forces, along with high levels of bilateral lumbar muscle activities, suggest the potential for overexertion and tissue damage during recovery from unexpected slip and trip events, which could contribute to low back pain and injuries. Outcomes of this study may facilitate the identification and control of specific mechanisms involved with low back disorders consequent to slips or trips.

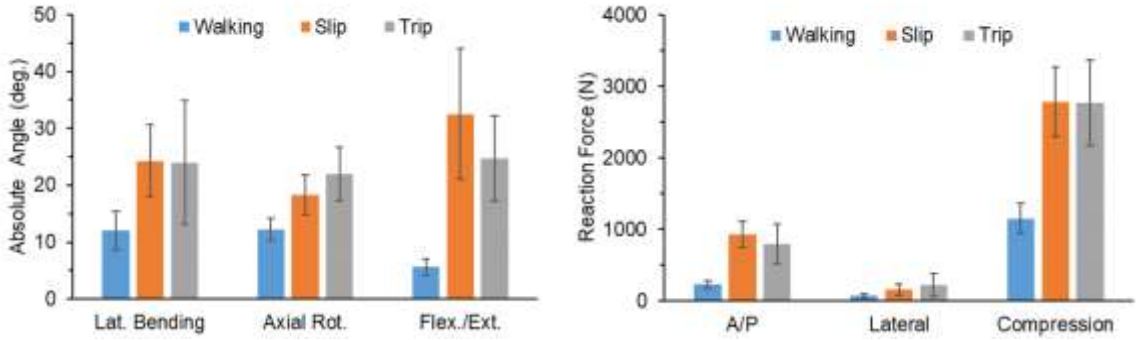

Figure 1. Peak lumbar angles (left) and reaction forces (right) during normal walking, slip, and trip trials. Errors bars are standard deviations. For all results illustrated, differences between slip and trip outcomes were not statistically different, y

Keywords: slips, trips, spine loading, lumbar stiffness, overexertion

Panel 3: Targeted slip, trip & fall prevention – winter weather safety plans

Panel Organizer: Gary Gibson, School Board Co-operative Incorporated (SBCI), 55 Commerce Valley Drive W, Suite 250, Markham, Ontario, Canada. Gary.gibson@sbci.org

In a typical year, Ontario school boards experience more STF injuries than any other incident type – approximately 30%. STFs also account for 80% of all critical injuries. That ranks STFs as number one for both injury frequency and injury severity. STFs are not distributed evenly over the entire school year, but rather heavily skewed to the winter and winter shoulder months. Despite assorted prevention measures, STF injuries remain stubbornly high Provincially.

During the Fall of 2021, a new prevention concept was introduced by SBCI, a not-for-profit consulting cooperative owned by Ontario School Boards. The concept involved developing a multifaceted management plan to address the hazard of wintertime STFs. The basis of these Winter Weather Safety Plans was simple. Other hazards such as asbestos are managed by a formal control program, so why not treat winter weather as a hazard and formally manage all the prevention elements collectively in one plan?

Through a combination of brief presentations and panel discussion, the following questions will be explored –

1. Why Winter Weather Safety Plans?
2. Elements of a Winter Weather Safety Plan?
3. Practical Implementation of a Winter Weather Safety Plan?
4. Student and Insurance Perspective?
5. Economic Perspective.

Panelists:

Gary Gibson, Director, Health and Safety Services, SBCI. Gary is the Director, Health and Safety Services with the School Boards' Co-operative Inc. (SBCI). A seasoned safety professional, Gary supports Ontario school boards with targeted safety solutions that are practical and no cost/low cost. **School Board's Co-operative Inc. (SBCI)** is a member-owned, not-for-profit co-operative, which helps Ontario school boards improve efficiencies, decrease their costs, and mitigate the negative impacts of absenteeism through expert attendance support, health & safety, and workers' compensation consulting services.

Kerri Stewart, Manager of Health and Safety, DDSB. Kerri is a Canadian Registered Safety Professional that has been employed by the Durham District School Board in the Health and Safety Department for the past 22 years. Her current role with the Durham District School Board is Manager of Health and Safety where she also oversees risk management and insurance. **Durham District School Board (DDSB)** is responsible for public education in the rural communities of Uxbridge, Brock and Scugog townships and the cities and towns of Ajax, Whitby, Pickering and Oshawa. DDSB employ over 10,000 teaching and educational services staff in 136 elementary and secondary schools and learning centres. DDSB has more than 76,000 regular day students and thousands more who take continuing education and adult credit courses.

Julie Welsh, FCIP, CRM, RIMS-CRMP, Risk Manager, OSBIE. As the Risk Manager at OSBIE, Julie works with Ontario school board members to identify, assess, and implement risk management strategies with the objective of providing a safe environment for students and school communities. She assists OSBIE members with risk management assessments

and delivers Risk Management Workshops, in both official languages, to school and board personnel. **Ontario School Boards' Insurance Exchange (OSBIE)** is a dynamic, non-profit insurance reciprocal currently serving over 4,200 school locations, representing 79 school boards/school authorities and 40 Joint Ventures. The primary goals of the Exchange is to insure member school boards against losses and to promote safe school practices.

Brian CF Chan, Affiliate Scientist, KITE. Brian is an Affiliate Scientist with the Neural Engineering and Therapeutics Team at KITE - Toronto Rehabilitation Institute and an Assistant Professor at the Institute of Health Policy, Management and Evaluation at the University of Toronto. His research focuses on economic analyses and health technology assessment for individuals requiring rehabilitation including spinal cord injury and dementia. **KITE** is the research centre at the Toronto Rehabilitation Institute. It is a world leader in complex rehabilitation research. KITE is also a part of the University Health Network, which is Canada's top medical research hospital.

A top-of-flight defect affects foot placement on subsequent stair treads during descent.

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Introduction: Non-uniformities in stair dimensions are a potential source of falls on stairways. Here we explore how a non-uniformity of the first step during descent (commonly called a top-of-flight defect) changes foot placement on the first and subsequent stair treads.

Methods: Twenty-eight harnessed participants (25M, 3F) descended a staircase with six treads between upper and lower landings under two conditions: with a uniform 178-mm (7-inch) rise and 255-mm (10”) run for all steps (control condition) and with the first step modified to have a 152-mm (6-inch) rise and 292-mm (11.5-inch) run (experimental condition). A 37-mm (1.5-inch) nosing was present on all treads but the upper landing in the experimental condition. Participants started at least two steps back on the upper landing and walked continuously into stair descent at a self-selected pace. Presentation order of the two conditions was randomized and three repetitions were performed for each condition. All participants wore canvas lace-up sneakers with a flat rubber waffle outsole (Gum Era Shoe, Vans, Costa Mesa, CA) fitted with three reflective forefoot markers that were tracked with a motion capture system at 300 Hz (Motion Analysis Corp., Rohnert Park, CA). For the upper landing and first five steps, the amount of shoe overhang on the nosing was quantified and compared using a repeated-measures analysis of variance.

Results: Our preliminary results indicate that there were significant differences in shoe overhang between the experimental and control trials. For the experimental condition (top-of-flight defect), there was less overhang on the first two steps down and more overhang on the third and fourth steps down compared to the control condition (uniform stair dimensions).

Conclusions: We found that a top-of-flight defect affected foot placement on stair treads during descent. The observed increase in shoe overhang on steps three and four represent a mechanism that could contribute to falls on stairways containing a top-of-flight defect.

Keywords: stair ambulation, stairway defects, biomechanics, falls

The Importance of Foot Posture Strategies at Initial Contact During Stair Descent

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Forward falls on stairs are commonly alleged to be caused by slipping on the tread nosing. When these types of incidents occur, they often result in litigation processes. General stair descent kinematics are described in the literature, focusing on the trunk, hip and legs. Few studies explore specific foot kinematics, which can aid incident investigations involving falls on stairs. Specifically, how feet are positioned over treads at key instances during the gait cycle is still unknown. We investigated foot posture at initial contact with the stair tread during stair descent, and its correlation with foot placement relative to the tread nosing to determine: a) foot posture variability across participants, and b) if there is an effect of foot posture with respect to the nosing on foot placement. We hypothesized that: 1) intersubject variability would be observed, and 2) foot posture would have no effect on foot placement. In order to test these hypotheses, we analyzed previously obtained data, in which seven adult participants were video recorded (GoPro®) while descending a staircase consisting of 7 risers, 6 treads, and a top landing. For the present analyses we focused on the middle tread and calculated foot posture as the angle at initial contact relative to the horizontal plane using three consistent landmark points on the subjects' shoes. Angles were measured in Fiji (ImageJ). Our preliminary results demonstrated significant differences in foot posture across participants ($P<0.0001$), except for two, who showed similar trends when compared to others. No correlation ($R2 <0.3$) was found between foot posture and foot placement on the tread. The differences in foot posture strategies exhibited across participants demonstrate that further exploring this at specific instances of the gait cycle during stair descent is crucial to better understand slip events when investigating incidents on stairs.

Keywords: slip, stair descent, nosing, foot posture, foot placement

Stairway ascent effort and protruding nosings

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It has long been recognised as good practice and, to varying extent is a regulatory requirement that protruding nosings not be incorporated in steps unless in the form of slightly inclined risers or, if protuberant, have inclined or concave undersides and not be too large—because the ascending motion of the forefoot of people with leg prostheses or braces or other ambulatory disability can be disrupted or arrested by the underside of overly-protruding or abruptly protuberant nosings, particularly if forefeet are dragged up risers.

This and an earlier study [1] ranked riser/nosing profiles for ascent effort—as measured by a prototype device. The goals are to develop a method for: a) determining the performance equivalence of disallowed profiles with prescribed profiles and therefore their eligibility for acceptance under performance-based building codes; b) inform producers of alternative nosing products.

This study compared nine riser/nosing profiles (Figure 1): six that are allowed by Australian, British and US codes and three that are disallowed—as tested with an actual shoe and simplified surrogate shoe.

Sensitive differentiation between profiles was achieved, including for riser surface texture, leg and foot angle, and shape and compressibility of the shoe's front and upper-front. Results (Figure 1) confirmed increased ascent effort with increased protrusion. Most noticeable was that: a) the USA-allowed Profile 4.1 required the same (excessive) effort as disallowed Profiles 5.1 and 5.2; b) effort for (disallowed) Profile 1.1 with its 5mm protrusion was only slightly greater than for Profile 3.2 with its 38mm protrusion. Increasing effort corresponded with increasing contribution of the shoe's upper-front. The actual shoe was concluded to be more informative than the surrogate shoe.

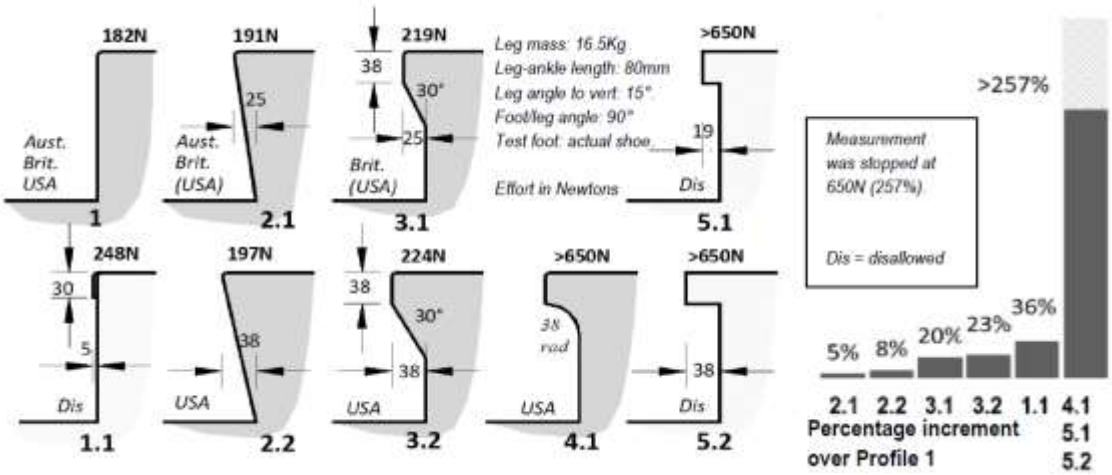

Figure 1 Ascent effort for nine riser/nosing profiles

Keywords: Stair, ascent, effort, riser/nosing, ranking

References: [1] Hunter, R.A. (2022). Measuring the effort required to drag forefeet upwards against risers/nosings during stairway ascent. International Conference on slips, trips and falls. Sendai, Japan, July 22-23, 2022 (unpublished).

Effects of aging and bathing surface characteristics on fall risk: Factors influencing slip/fall risk while entering and exiting bathing surfaces

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In an effort to better understand the effect of aging on bathing fall safety, a study was conducted on four types of simulated bathtub/shower floors (referred to as Reference Surfaces or RS), tested for both a dry and wetted condition with 0.1% sodium lauryl sulfate in water as a contaminant. Sixty-one (61) young and older adults were recruited from the surrounding areas of the Phoenix metro area. The experiments were conducted at the ASU Locomotion Research Laboratory in Tempe, Arizona. All patients included in this study were generally healthy. The focus of this manuscript relates to how older adults navigate entering and exiting bath surfaces (bathtub and shower mockups). We hypothesized that age as well as the demands of entering and exiting the bathing surfaces would influence Friction Demand (μd) and slip distance (SD) thereby increasing fall risk. We also hypothesized that different types of bathtub/shower floors (i.e., Reference Surfaces or RSs) would perform differently, to the extent that they utilize different friction mechanisms. Results indicate that entering and exiting a bathtub/shower represent a significant slip/fall risk as measured by RCOF or Friction Demand and slip distance especially for older adults. Older adults adopt more conservative strategies during obstacle crossing, however, this strategy as measured by stepping time indicates that the transition of the whole-body COM was delayed resulting in increased friction demand and slip distance (i.e., slip and fall risk). Age-related differences in whole-body and segmental control during obstacle crossing may place older adults at greater risk of imbalance during the transition from dry to wet floor surfaces. Relationship between different reference surfaces and PTV and, slip distance as well as the number of slips will be further discussed.

Keywords: aging, bathing surface, bathtubs, shower, friction demand, friction utilization, slips and falls

Risk of falls in young and older adults in a Colombian population associated with environmental factors.

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Introduction: The prevalence of falls and the environmental risk factors that cause them is an ergonomic issue that should be analyzed in the light of the particularities of each population and region.

Objective: To identify environmental risk factors for falls in a population of Colombian adults.

Methodology: Analytical cross-sectional study, 409 adult individuals over 20 years of age were interviewed, as a representative sample of the population of the cities Cali and Jamundí, Valle del Cauca, Colombia. We inquired about sociodemographic characteristics, history and frequency of falls, presence of risk factors inside and outside the home. Descriptive analysis and statistical associations were performed using Chi-square, Fisher and Mantel-Haenzel Chi-square test.

Results: The total prevalence of falls was 27.1%, with 12% of them reporting more than two events . No significant differences were found in the number of total falls between age groups (p=0.2974), although a high number of adults aged 20-29 years reported them (46.6%). Fear of falling increased with age (<0.001). The most reported location of falls was the street (53.3%), followed by the home (40.2), the tripping and slipping mechanism (71.2%). In 23.2%, activities were restricted due to falls.

When entering the home, 87% of the participants reported having no lighting, unevenness (30%), absence of ramps (28%), absence of handrails (19%). Indoors, the following were reported: absence of handrails (52%), smooth floors (41%), lighting far from the bed (38%), dark corridors (25%), high kitchen utensils (18%), among others. The presence of risks in the home presented significant differences for falls .p=0.0258.

Conclusions: The study demonstrates the need to consider ergonomics in the design of cities and living spaces, for the prevention of falls.

Keywords: falls, environmental risk factor, home risk factor, ergonomics

Session 9: Broadening our understanding and strategies to address falls

Slips, Trips, and Falls – Dispelling Common Myths

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Slips, trips, and falls are one of the leading causes of workplace injury and are an issue in all industries as well as public spaces. Despite this, fall risk is often poorly managed. Appropriate risk assessment and risk management solutions are often not in place and interventions to prevent falls are only typically explored after a serious incident has occurred. This oral presentation will explore some of the common assumptions, misconceptions, and myths surrounding slips, trips, and falls and dispel some of these barriers to appropriate risk management using a combination of scientific understanding, examples from practical expert experience, and published clinical studies.

The presentation will address the following missconceptions:

- Slips, trips, and falls are rarely serious.
- The causes of these incidents are very simple.
- Falls are typically the result of human error.
- There is little that can be done to prevent slips and trips.

By addressing some of these common misconceptions and presenting scientific evidence relating to the prevention of falls, the author aims to enhance the audience's understanding of the topic and improve their ability to implement practical interventions to minimize fall risk.

The presentation will consider the role of flooring, footwear, contamination, and the management of cleaning in the prevention of slips. In addition, the causes of trips and falls on stairs will be explored alongside practical interventions for reducing risk.

Keywords: slip, trip, fall, prevention, workplace, myths

How to prevent slips, trips and falls: planning, design, maintenance and beyond

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Slips, trips and falls (STF) (also known as falls at level) continue to be the second most common mechanism for occupational injuries across all industry sectors in Australia. We found that many workplaces continue to focus on the individual characteristics and their action or inaction. What about all the factors that the workplace can address? To make it safer for everyone.

In this session we will walk-through new guidance that all types and sized workplaces can use to meet occupational health and safety (OHS) legislative and community expectations. This guidance is based on systems thinking and consultative approach to comprehensively understand the contributory factors of occupational STF and how workplaces address falls at level through different work stages and work areas. This information can be useful to any role interested in preventing STF. The framework of this new guidance (see Table 1) will be discussed.

Table 1 Framework of guidance to prevent slips, trips and falls

Preventing slips, trips and falls

Plan for safe access and movement

Provide for safe access and movement
- Workplace layout
- Floor surface
- Trip hazards
- Outdoor hazards
- Stairs and ramps
- Contain contaminants

Work planning
- Load handling
- Attentional demands required
- Time pressures/pace of work
- Production demands/incentives
- Interaction of other workers/ activities
- Scheduling/deliveries

Maintain environment for safe access & movement

Keep access safe
- Maintenance
- Cleaning
- Housekeeping
- Weather planning

Detectability & visibility of hazard
- Detectability
- Lighting
- Other distractions

Support design and maintenance

- **Footwear**
- **Individual characteristics and experience**
- **Reporting**
- **Training and supervision**

Consult and work together

We considered and included:

- dynamic workplaces such as construction and rural sites as well more static workplaces such as hospitals and factories
- indoor and outdoor environments
- physical and cognitive demands that impact on safe walking

Also, we will share how we have integrated our guidance with best practice OHS principles of:

- good work design including safety by design
- risk management systems including training, supervision and reporting
- consultation and working together with other relevant parties

Keywords: design, maintenance, prevention, occupational

A physiotherapists' understanding and assessment of gait stability in older adults

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Background: Gait stability can be defined as a person's resilience to perturbations while walking. Older adults have lower gait stability, which increases their risk of falling. Therefore, a physiotherapists' assessment of gait stability is a critical component of a falls risk assessment. Presently, physiotherapists assess gait stability through visual observation. We now have gait technologies to provide objective measures of gait stability, however, it is unclear whether these technologies would enhance a physiotherapists' assessment. To understand the potential clinical role of gait stability monitoring technologies, it is important to learn how physiotherapists understand and assess gait stability.

Methods: Virtual interviews were conducted on Microsoft Teams with Canadian registered physiotherapists who have experience working with older adults. In the interviews, physiotherapists shared their understanding of the term "gait stability", and then described out-loud their gait stability assessment process while watching gait videos of older adults in a long-term care home. Interviews were recorded and transcribed and are being analyzed using a qualitative descriptive approach.

Results: Twenty-six physiotherapists were interviewed, 22 (85%) female. Participants were a mean of 42.5 ±10.3 years old. In a preliminary analysis, physiotherapists tended to define gait stability broadly as a gait pattern that does not lead to falls, or a gait pattern without impairments and/or compensations. Some discussed the importance of withstanding perturbations. The approach to assessment varied, but commonly included an observation of trunk sway, arm swing, and lower extremity movement.

Conclusion: Preliminary results show that the understanding and approach to assessment of gait stability varies considerably among physiotherapists. Thus, there are opportunities for providing a consistent and common understanding of gait stability through education and practice supported by technology. A common understanding and approach to gait stability facilitated by technology may better identify patients with unstable gait and subsequent risk of falling.

A Review of Cultural Differences and Practical Barriers Lead to Differences in Fall Incidents and Seeking Healthcare for Fall-Related Injuries among Immigrants

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Falls contribute significantly to morbidity and mortality in the older population. Despite the increasingly diverse population, there is little research on how different cultural backgrounds and immigration experiences can impact fall incidence and access to treatment for fall injuries. A few studies have compared fall incidence between immigrant populations and native-born populations. The incidence rate was significantly higher in immigrant workers, particularly among Hispanic construction workers, than their white, non-Hispanic counterparts in the USA due to language barriers and inadequate safety training1. However, research also showed that immigrants generally had lower incidence rates of falls in non-work environments. Established fall risk factors did not explain differences in fall rates between the two groups. Some studies suggested that the difference in fall incidence might be due to cultural differences rather than genetic disposition, such as risk-taking behaviour may differ by ethnicity.

On the other hand, in both primary and secondary care, healthcare utilization for injury treatment in Norway was lower for immigrants compared to non-immigrants. This observed difference could reflect language barriers or practical barriers in access to primary care, general dissatisfaction with primary health care services, or poor knowledge and insufficient information about the health care system organization. These studies showed that practical barriers experienced by immigrants and cultural differences could impact attitudes toward fall prevention and seeking treatment for fall injuries. Therefore, healthcare services and education should be diversified to reflect cultural differences and language barriers in fall prevention.

Keywords: immigration, fall incidence, healthcare utilization, culture, fall prevention, language barriers, safety training