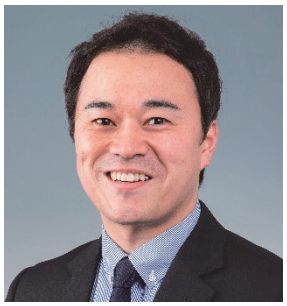
STF Sendai 2022
Abstract book

Date	July 22 (Fri.) – 23 (Sat.), 2022
Venue	**Onsite** : Tohoku University Science Campus Hall **Online** : Zoom
Organizer	International Ergonomics Association (IEA) Slips, Trips, and Falls (STF) Technical Committee
Co-organizer	School of Engineering, Tohoku University
Endorsed by	International Ergonomics Association (IEA)

Welcome Message from the Conference Chair of the Organizing Committee



On behalf of the Organizing Committee, it is my great honor and pleasure to welcome you to the International Conference on Slips, Trips, and Falls Sendai 2022 (STF Sendai 2022).

International Conference on Slips, Trips, and Falls (STF) was first held in Hopkinton, USA in 2007. Following the 1st Hopkinton conference, it was held successfully in Nottingham, UK (2008), Beijing, China (2009), Morgantown, USA (2010), Buxton, UK (2011), Recife, Brazil (2012), Tokyo, Japan (2013), Melbourne, Australia (2015), London, UK (2016), Toronto, Canada (2017), Florence, Italy (2018), and Madrid, Spain (2020). In 2022, we are very proud to host this conference in Sendai, also known as the “City of Trees”.

In this conference, an integrative approach is imperative to clarify issues related to STF, and interdisciplinary studies and discussion on the future direction are strongly encouraged. Therefore, we desire that the study of STF will be further developed through contact and communication of researchers, policymakers, technical experts, and others around the world throughout various disciplines at STF Sendai 2022.

This conference includes four plenary lectures, 45 oral presentations, and exhibisions. Furthermore, we also have over 70 registered participants from more than 10 countries. STF Sendai 2022 will be an excellent opportunity to hear about the latest research from a line-up of globally recognized speakers and experts. I hope all of the attendees enjoy the in-person/online conference events and can gain a meaningful outcome through the conference. Additionally, you will also have the opportunity to expand your networks and strengthen existing relationships with colleagues.

Welcome to our wonderful city, enjoy the conference and please come and visit us again.

Yours sincerely,

Takeshi Yamaguchi

Takeshi Yamaguchi
Chair of Organizing Committee,
International Conference on Slips, Trips, and Falls Sendai 2022 (STF Sendai 2022)

General Information

Date
July 22(Fri.) - 23 (Sat.), 2022

Conference format
Hybrid (in-person and online)

Conference Venue
Onsite: Tohoku University Science Campus Hall
Aramaki-Aza-Aoba 6-6, Aoba-ku, Sendai, Miyagi 9808579, JAPAN
Online: Zoom

Organizer
International Ergonomics Association (IEA) Slips, Trips, and Falls (STF) Technical Committee

Co-organizer
School of Engineering, Tohoku University

Endorsed by
International Ergonomics Association (IEA)

Supported by
Japan Human Factors and Ergonomics Society
Japanese Society for Fall Prevention
National Institute of Occupational Safety and Health, Japan (JNIOSH)
Society of Biomechanism Japan

Organizing Committee
Takeshi Yamaguchi (Conference Chair, Tohoku University, Japan)
Kei Shibata (Conference Secretariat, JNIOSH, Japan)
Akihiro Ohnishi (JNIOSH, Japan)
Atsushi Sugama (JNIOSH, Japan)
Hisao Nagata (Advisor, JNIOSH, Japan)
Katsutoshi Ohdo (JNIOSH, Japan)
Sophia Yue Li (The KITE Research Institute, Toronto Rehabilitation Institute-University Health Network, Canada)
Yoshiyuki Kobayashi (AIST, Japan)

Scientific Committee
Satoshi Muraki (Kyushu University, Japan)
Yasutaka Nakajima (Kyushu University, Japan)
IEA TC members

Program at a glance

July 22 (Fri.), 2022

JST (UTC+9:00)	Events (hybrid)	UTC	PDT (UTC-7:00)	EDT (UTC-4:00)
9:00	Opening Remarks	0:00	17:00	20:00
9:20	Keynote Lecture 1	0:20	17:20	20:20
10:00	Keynote Lecture 2	1:00	18:00	21:00
10:40	Break			
10:50	Technical Session (I)	1:50	18:50	21:50
11:50	Lunch	2:50	19:50	22:50
13:20	Technical Session (II)	4:20	21:20	0:20
14:20	Break			
14:30	Technical Session (III)	5:30	22:30	1:30
15:30	Break			
15:40	Technical Session (IV)	6:40	23:40	2:40
16:40	Break			
16:50-17:50	Technical Session (V)	7:50-8:50	0:50-1:50	3:50-4:50

July 23 (Sat.), 2022

JST (UTC+9:00)	Events (hybrid)	UTC	PDT (UTC-7:00)	EDT (UTC-4:00)
9:00	Keynote Lecture 3	0:00	17:00	20:00
9:40	Keynote Lecture 4	0:40	17:40	20:40
10:20	Break			
10:30	Technical Session (VI)	1:30	18:30	21:30
11:30	Lunch/Lab tour (onsite)	2:30	19:30	22:30
14:00	Technical Session (VII)	5:00	22:00	1:00
15:00	Break			
15:10	Technical Session (VIII)	6:10	23:10	2:10
16:10	Break			
16:20	Technical Session (IX)	7:20	0:20	3:20
17:20-17:35	Closing Remarks	8:20-8:35	1:20-1:35	4:20-4:35

Plenary Lectures

July 22 (Fri.), 2022
9:20-10:00 (JST)

Voluntary and reactive step training for the prevention of falls in older people

Stephen Lord
Neuroscience Research Australia, Australia

[Short Biography]

Stephen Lord is a Scientia Professor at the University of New South Wales and a Senior Principal Research Fellow at Neuroscience Research Australia, Sydney, Australia. He has published over 500 papers in the areas of applied physiology, instability, falls and fractures in older people and clinical groups with balance impairment. His research follows two main themes: the identification of neuropsychological, sensorimotor and balance risk factors for falls and the development and evaluation of fall prevention strategies. His current projects include voluntary and reactive step training and cognitive-motor intervention studies using new technologies to prevent falls and studies addressing fall risk in clinical groups at high risk of falls including people with dizziness, multiple sclerosis, Parkinson's disease and dementia.

[Abstract]

Step training is defined as training of volitional or reactive steps while standing or walking in response to environmental challenges. For example, stepping onto a target, avoiding an obstacle or responding to a postural perturbation large enough to require reconfiguration of the base of support. Volitional step training uses stepping targets or distractors (no-go zones) whereas reactive step training exposes participants to repeated mechanical perturbations that induce stepping responses. There is growing evidence for step training programs to improve balance and prevent falls in older people. Accurate and appropriately timed stepping is crucial for avoiding falls as it underpins many daily tasks including obstacle and stair negotiation as well as recovery from slipping and tripping. A systematic review of seven randomised controlled trials, showed volitional and reactive step training in older people could reduce falls by 50%. The promising effects are likely due to the high task-specificity of step training to real world situations, such as trips and slips, leading to improved reactive balance and responses to avoid falling. This presentation will place step training within the context of interventions for preventing falls and synthesise the findings of recent trials that have included step training as a fall prevention strategy.

10:00-10:40 (JST)

Tripping biomechanics and application of assistive technologies for falls prevention

Rezaul Begg

Victoria University, Australia

[Short Biography]

Professor Rezaul Begg received his BSc and MSc in Electrical Engineering from Bangladesh University of Engineering and Technology (BUET) and a PhD in Biomedical Engineering from the University of Aberdeen, UK. At Victoria University he is the Chair in Assistive Technologies within the Program in Assistive Technology Innovation (PATI), and leads a multidisciplinary “Gait and Intelligent Technologies” research group. He uses a combination of engineering and biomechanical principles to understand and diagnose locomotion-related deficits, and to provide intelligent technology solutions to improving walking efficiency and safety, and minimising injuries during manual handling tasks. He has published one research monograph, 4 books and over 300 refereed papers in scientific journals and conference proceedings. Professor Begg is Associate Editor of Frontiers in Bioengineering and Biotechnology and an editorial board member of the Journal of Biomechanics and Sensors.

[Abstract]

The primary cause of falls is tripping-related balance loss due to foot-ground contact when accommodating small surface irregularities or obstacles. A fundamental requirement of human locomotion is maintaining foot elevation to avoid tripping, due to destabilising contact with the walking surface. Safety is also compromised by disorders due to ageing, neurological diseases and other causes. Biomechanically, tripping can be defined as an event in which the most distal feature of the swing limb, usually the lowest part of the shoe or foot, makes unanticipated contact with either the supporting surface or objects on it. When stability cannot be recovered, the individual sustains a fall. Minimum foot clearance (MFC) approximately mid-swing in the gait cycle poses the greatest tripping risk, because the foot passes within only 1.0-2.0 cm of the ground. This presentation will focus on two areas. First, the fundamental biomechanics of foot trajectory control, and associated tripping probability modelling of MFC distributions from data sets extending to hundreds of step cycles. The second focus will be advances in gait-assisting technologies; combining data from wearable sensors, machine learning algorithms to predict foot-obstacle contact risk and exoskeleton-assisted joint activation to provide corrective joint control.

July 23 (Sat.), 2022
9:00-9:40 (JST)

High-performance design of sports gear based on tribology

Kenichi Harano
Institute of Sport Science, ASICS Corporation, Japan

[Short Biography]

Mr. Kenichi. Harano has received B.E. degrees in science and engineering from Konan University. Immediately after graduation, he joined the ASICS Corporation. He is currently the head of the Institute of Sport Science (ISS), a position he has held since 2018. The mission statement of the ISS is to provide valuable products and services for all athletes based on "human-centric science". To complete this mission, he leads research on human attributes, material design, structural design, production technology and digital technology. For his latest research, he earned the 2019 Japan Open Innovation Award-Special Award from the Selection Committee and the 2019 Society of Rubber Science and Technology, JAPAN Award.

[Abstract]

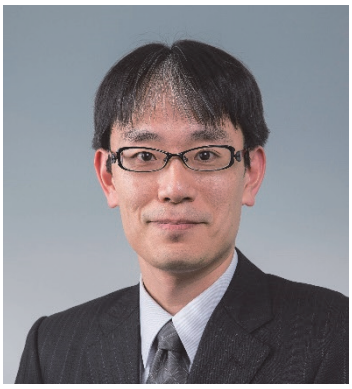
Sports gear is constantly evolving to maximize user performance, from top athletes to enthusiasts working to improve their health. However, it is also important for such gear to help prevent injury and provide comfort to users. To this end, shoes are generally designed based on eight major functional properties. Factors that maximize the ability include "lightness" that reduces the burden on the body, "grip" that tightly captures the surface, and "durability" that maintains various functionalities that shoes should develop. From an injury prevention perspective, "cushioning" absorbs the reaction force when making contact with the ground, and "stability" suppresses excessive movement of the subtalar joint. To maintain comfort, factors of "fitting" and "flexibility" that follow the movement of the foot and "breathability" that keeps the temperature and humidity inside shoes comfortable are considered. In particular, research on shoe grip is important not only for performance enhancement but also for safety, such as fall prevention. In this lecture, after explaining technology transition of sports gear, research cases will be discussed, including that concerning the marathon shoes in use at the 2021 Summer Olympic Games held in Tokyo as an example.

9:40-10:20 (JST)

Adaptable AI-enabled robots to create a vibrant society

Yasuhisa Hirata

Tohoku University, Japan



[Short Biography]

Yasuhisa Hirata is a Professor in the Department of Robotics at Tohoku University, Sendai, Japan. He received the B.E., M.E., and Ph.D. degrees in mechanical engineering from Tohoku University in 1998, 2000, and 2004, respectively. He has been conducting research and development on non-driving robots with high safety and wearable devices with vibration devices, aiming to develop robots that support the user to perform independent activities. He is also conducting research and development of multi-robot cooperative systems that can be applied to a wide range of fields from human assistance to environmental exploration. He is currently working on the introduction of human-assistive/human function-enhancing robots, especially in the fields of nursing care and healthcare as the project manager of the Moonshot R&D program in Japan. He is also serving as an AdCom member of IEEE Robotics and Automation Society (RAS), an associate vice-president for the Technical Activity Board of IEEE RAS, and Co-chairs of IEEE RAS Technical Committee on Rehabilitation and Assistive Robotics.

[Abstract]

This talk introduces our Moonshot project which is a project in the National Research and Development (R&D) program in Japan. The Moonshot program promotes high-risk, high-impact R&D aiming to achieve ambitious Moonshot Goals and solve issues facing future society such as super-aging populations. Our project is accepted under the Moonshot Goal 3: Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence, and act alongside human beings, by 2050. Our project aims to create adaptable AI-enabled robots available in a variety of places. We are now developing a variety of assistive robots called the Robotic Nimbus which can change their shape and form according to the user's condition, environment, and the purpose of the task, and provide appropriate assistance to encourage the user to take independent action. Especially, in this talk, we focus on the human-assistive/human function-enhancing robots in the fields of nursing care and healthcare including robots for preventing a fall during human daily activities.

Technical Program

July 22（Fri.）, 2022

10:50-11:50 Technical Session (I) Architectural Design

Chair: Richard Bowman (Intertile Research Pty Ltd, Australia)

S1-1 **Stairs ramps and tactile surfaces. Aspects of inclusive design**

Stephen C Thorpe[1], Rob W Shaw[2], Richard Bowman[3]

1. Olver & Rawden, 2. Rob Shaw (TFG) Associates Ltd. (UK), 3. Intertile Research

S1-2 **Fall prevention in the bathroom: understanding and informing public perception of grab bars for safer bathing**

Iris Claire Levine[1], Emily C King[2,3], Alison C Novak[1,4,5]

1. KITE Research Institute-University Health Network, 2. Dalla Lana School of Public Health, University of Toronto, 3. VHA Home HealthCare, 4. Rehabilitation Sciences Institute, University of Toronto, 5. Faculty Kinesiology and Physical Education, University of Toronto

S1-3 **Risk points for falls and other risks setting in building information modeling from the design phase**

Naotaka Kikkawa[1], Nobutaka Hiraoka[1], Hiroki Takahashi[1], Katsutoshi Ohdo[1]

1. National Institute of Occupational Safety and Health, Japan

S1-4 **Measuring friction between forefoot and step risers/nosings as a method of ranking their characteristics for snagging—during stairway ascent by people with ambulatory disability**

Rodney A. Hunter[1]

1. Hunarch Consulting

S1-5 **New countermeasure for prevention of serious falling accidents under the construction works on the low-rise housing**

Yasumichi Hino[1]

1. National Institute of Occupational Safety and Health, Japan

13:20-14:20 Technical Session (II) Gait & Balance Control (I)

Chair: Yoshiyuki Kobayashi (National Institute of Advanced Industrial Science and Technology, Japan)

S2-1 **Neuro-musculoskeletal model for bipedal locomotion with a lower limb amputation**

Daisuke Ichimura[1], Genki Hisano[1,2,3], Hiroto Murata[1,4], Hiroaki Hobara[1]

1. National Institute of Advanced Industrial Science and Technology (AIST), 2. Research Fellow of Japan
Society for the Promotion of Science (JSPS), 3. Tokyo Institute of Technology, 4. Tokyo University of Science

S2-2 **Relationship between fast backward walking and balance evaluation**

Teerapapa Luecha[1], Ping Yeap Loh[1], Satoshi Muraki[1]

1. Kyushu University

S2-3 **Relationship between clinical stream scores and MTC-based gait features in post-stroke patients**

Nusrat Sadia Khan[1], M Tarik Arafat[2], Catherine Said[3], Lisa James[1], Soheil Bajelan[1], Rezaul Begg[1]

1. Institute for Health and Sport, Victoria University, 2. Department of Biomedical Engineering, Bangladesh University of Engineering and Technology (BUET), 3. Physiotherapy departments of Austin Health and Western Health, Australian Institute of Musculoskeletal Science and Melbourne School of Health Sciences, University of Melbourne

S2-4 **Dynamic stability during obstacle crossing in children aged 2–5 years: A pilot study**

Kohei Yoshimoto[1], Hiroki Mani[2], Takaki Kurogi[3], Takumi Aiko[3], Yuto Urano[3], Masahiro Shinya[1]

1. Graduate School of Humanities and Social Sciences, Hiroshima University, 2. Faculty of Welfare and Health Science, Oita University, 3. Graduate School of Welfare and Health Science, Oita University

S2-5 **Kinetic and electromiographic analysis during and after gait perturbations**

Konstantinos Gianikellis[1], Miguel Rodal[1], Santiago Gómez-Paniagua[1], María José González-Becerra[1]

1. BioErgon Research Group, University of Extremadura

14:30-15:30 Technical Session (III) Slip resistance: Footwear & Wearable device

Chair: Kei Shibata (National Institute of Occupational Safety and Health, Japan)

S3-1 **The effectiveness of five-star GRIP-rated slip-resistant footwear at preventing workplace slips among healthcare workers in Great Britain**

Gillian Frost[1], Mark Liddle[1], Sarah Cockayne[2], Caroline Fairhurst[2], Rachel Cunningham-Burley[2], Michael Zand[3],
Heather Iles-Smith4, David Torgerson2

1. Health and Safety Executive, Science Division, HSE Science and Research Centre, 2. York Trials Unit, University of York, 3. Health and Safety Executive, Science Division, 4. Leeds Teaching Hospitals NHS Trust

S3-2 **Experimental method to quantify the planar distribution of slip resistance contribution for shoes**

Toshiaki Nishi[1]

1. ASICS Corporation

S3-3 **Effect of end-face corner radius of shoe-sole tread block on slip resistance**

Arata Ishizako[1], Masaki Tomosada[1], Takeshi Yamaguchi[1]

1. Tohoku University

S3-4 **Measurement of the friction coefficient between shoe sole and icy surface using a sole sensor system**

Takeshi Yamaguchi[1,2], Yuya Takahashi[1], Yoshihiro Sasaki[3]

1. Graduate School of Engineering, Tohoku University, 2. Graduate School of Biomedical Engineering, Tohoku University, 3. Research Institute for Electromagnetic Materials

S3-5 **Evaluation of a wearable slip detection system during real-world use in winter conditions**

Tilak Dutta[1,2], Davood Dadkhah[1,2]

1. KITE Research Institute, Toronto Rehabilitation Institute –University Health Network, 2. University of Toronto

15:40-16:40 Technical Session (IV) Slip resistance: Tribometer & Standards

Chair: Takeshi Yamaguchi (Tohoku University, Japan)

S4-1 **Validation of a low-weight portable friction-testing device to measure in situ shoe-floor friction**

Kurt E Beschorner[1], Arnab Chanda[2], Brian E Moyer[3], Alexander Reasinger[3], Sarah C Griffin[1], Isaiah Johnston[1]

1. University of Pittsburgh, 2. India Institute of Technology Delhi, 3. XRDS Systems, LLC

S4-2 **Publication of EN 16165 - background, advantages and application possibilities**

Christoph Wetzel[1]

1. Berufsgenossenschaft Handel und Warenlogistik

S4-3 **Study of precision data of the pendulum test in spain**

Juan Queipo de Llano[1], Elena Frías-López[1]

1. Instituto de Ciencias de la Construcción Eduardo Torroja - CSIC

S4-4 **Socially responsible slip resistance standardisation: factoring in public expectations of sustainability and life cycle performance**

Richard Bowman[1]

1. Intertile Research

S4-5 **The pendulum slip resistance rest using slider 55**

S Hall[2], K Palmer[3], I Roberts[3], B Powers[4], Stephen C Thorpe[1]

1. Olver & Rawden, 2. Lucideon Ltd, 3. Knightcott Surface Solutions, 4. Munro Instruments

16:50-17:50 Technical Session (V) Slip resistance: Floor & Surface Texture

Chair: Toshiaki Nishi (ASICS Corporation, Japan)

S5-1 **Ergonomic flooring design for health care settings**

Mike Minett[1]

1. Polyflor

S5-2 **Risk of slipping: standards development using the power of meta-analysis via an evidence-based epidemiological approach**

Carl Strautins[1]

1. Safe Environments Pty Limited

S5-3 **Slip and fall risk assessment of ablution floors in mosques from three major cities in the United Arab Emirates**

In-Ju Kim[1], Omar Hassan Omar[1]

1. University of Sharjah

S5-4 **The quest to report the surface texture characteristics of slip resistance test specimens**

Richard Bowman[1], Marcel Engels[2], Gonzalo Silva[3]

1. Intertile Research, 2. Forschungsinstitut für Glas | Keramik (FGK), 3. Instituto de Technologia Ceramica (ITC)

S5-5 **Pendulum friction testing of patterned 3D-profiled bathing surfaces: challenges, tools, and techniques**

John P Leffler[1], James E Flynn[2], Thurmon E Lockhart[3]

1. Forcon International, 2. J2 Engineering, Inc., 3. Arizona State University

July 23（Sat.）, 2022

10:30-11:30 Technical Session (VI) Gait & Balance Control (II)

Chair: Atsushi Sugama (National Institute of Occupational Safety and Health, Japan)

S6-1 **Margin of stability (MoS) based prediction of balance and fall after introducing external slip stimulations**

Yicheng Zhang[1], Koki Honda[1], Ayato Kanada[1], Motoji Yamamoto[1], Yasutaka Nakashima[1]

1. Kyushu University

S6-2 **Relation between perception of slipperiness and frictional property when walking on wooden floors while wearing socks**

Satoshi Shibata[1], Hiroki Nakashima[1], Yoshihiro Yomogida[1], Arata Ishizako[2], Takeshi Yamaguchi[2], Kazuo Hokkirigawa[2]

1. Kao Corporation, 2. Tohoku University

S6-3 **Why is it so easy to fall in a slippery environment? Innovative walking method to prevent falls proposal of the footstep walk method. Shifting into a Copernican revolution in gait: From "forefoot load theory" to "heel load theory"**

Hidetaka Senzaki[1]

1. Wellness Project Ltd.

S6-4 **Differentiating between benign paroxysmal positional vertigo and vestibular migraine using walking stability analysis and machine learning**

Tianyi Hu[2,3], Qineng Shao[2,3], He Wang[2,3], Xuhong Sun[4], Liang Tian[5,6], Jing Yu[5,6], Lei Zhang[5,6], Jing Wang[5,6], Dongyun Gu[1,2,3]

1. Shanghai Key Laboratory of Orthopaedic Implants, Department of Orthopaedic Surgery, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, 2. School of Biomedical Engineering and Med-X Research Institute, Shanghai Jiao Tong University, 3. Engineering Research Center of Digital Medicine and Clinical Translation, Ministry of Education of People's Republic China, 4. Department of Neurology, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, 5. The Eye and ENT Hospital of Fudan University, 6. National Health Commission Key Laboratory of Hearing Medicine

S6-5 **Winter footwear slip resistance determined by maximum achievable angle method validated with maximum level walking speed**

Yue Sophia Li[1], Weiran Cheng[1], Kayla Morrone[1]

1. KITE Research Institute, Toronto Rehabilitation Institute –University Health Network

14:00-15:00 Technical Session (VII) Aging

Chair: Satoshi Muraki (Kyushu University, Japan)

S7-1 **Situational factors of ladder overreaching in older adults**

David Williams[1], Kurt Beschorner[1], Daina Sturnieks[2,3], Stephen Lord[2,3], Erika Pliner[4]

1. University of Pittsburgh, 2. Neuroscience Research Australia, 3. University of New South Wales, 4. University of Florida

S7-2 **Relationship between hip joint power and step length in lateral stepping reaction of the elderly**

Yahiko Takeuchi[1], Kimiya Fujio[2]

1. Josai International University, Department of Physical Therapy, 2. Research Institute of National Rehabilitation Center for Persons with Disabilities, Department of Rehabilitation for movement functions, Motor Control Section

S7-3 **Plantar shear patterns provide prognostic information for detecting postural instability in the elderly population**

Lewen Qian[1], Hu Luo[1], Xiang Geng[2], Xin Ma[2], Wenming Chen[1]

1. Fudan University, 2. Huashan Hospital, Fudan University

S7-4 **Aging and sex-specific differences in gait characteristics: A study on Japanese elderly**

Irma Nur Afiah[1], Hiroki Nakashima[2], Ping Yeap Loh[3], Satoshi Muraki[3]

1. Universitas Muslim Indonesia, 2. Nagasaki University, 3. Kyushu University

S7-5 **Age-related changes of intersegmental coordination in lower-limb joints during standing posture**

Kimiya Fujio[1], Yahiko Takeuchi[2]

1. Research Institute of National Rehabilitation Center for Person with Disabilities, 2. Josai International University

15:10-16:10 Technical Session (VIII) Balance assessment

Chair: Yasutaka Nakashima (Kyushu University, Japan)

S8-1 **Status analysis of the fall risk and balance assessment tool**

Ye Luo[1], Feng Li[1], Xiaofang Huang[1], Xuan Zhao[1], Xinwei Huang[3], Shaobai Wang[1,2]

1. Shanghai University of Sport, 2. Key Laboratory of Exercise and Health Sciences of Ministry of Education, 3. Duquesne University

S8-2 **Investigation of postural balance and lower limb loads while squatting with various foot positions**

Atsushi Sugama[1], Kazuki Hiranai[1], Akisue Kuramoto[2], Akihiko Seo[3]

1. National Institute of Occupational Safety and Health, Japan, 2. Tokyo Institute of Technology, 3. Tokyo Metropolitan University

S8-3 **Standing-function and sensory evaluation system for fall prevention**

Keisuke Shima[1], Mami Sakata[1], Koji Shimatani[2]

1. Yokohama National University, 2. Prefectural University of Hiroshima

S8-4 **Effects of momentary loss of hand reaction forces on postural balance during manual pushing tasks: a time-series analysis of handling and ground reaction forces**

Kazuki Hiranai[1], Atsushi Sugama[1]

1. National Institute of Occupational Safety and Health, Japan

S8-5 **Acute effects of anodal transcranial direct current stimulation on ankle position sense and joint force sense**

Jianglong Zhan[1], Bin Shen1, Changxiao Yu[1], Weijie Fu[1]

1. Shanghai University of Sport

16:20-17:20 Technical Session (IX) Falls in the workplace

Chair: Akihiro Ohnishi (National Institute of Occupational Safety and Health, Japan)

S9-1 **Look at the bigger picture - Systems thinking in occupational falls at level: case studies from the construction industry**

Donna Lee[1]

1. Workplace Health and Safety Queensland

S9-2 **Who has roles and responsibilities in providing safe access and movement at work? There are more than you may think**

Donna Lee[1]

1. Workplace Health and Safety Queensland

S9-3 **The required coefficient of friction during roof to ladder transitions**

Sarah C Griffin[1], David D Williams[1], Kurt E Beschorner[1]

1. University of Pittsburgh

S9-4 **Evaluation of Friction Perception by Simple Foot Rubbing**

Kei Shibata[1], Akihiro Ohnishi[1]

1. National Institute of Occupational Safety and Health, Japan

S9-5 **Preventing slips, trips, and falls –The importance of good data**

Rob Shaw[1]

1. Rob Shaw (TFG) Associates Ltd

S1-1

Stairs Ramps and Tactile Surfaces. Aspects of Inclusive Design.

*Stephen C Thorpe[1], Rob W Shaw[2], Richard Bowman[3]

1. Olver & Rawden, 2. Rob Shaw (TFG) Associates Ltd. (UK), 3. Intertile Research

Stairs Ramps and Tactile Surfaces. Aspects of Inclusive Design. Steve Thorpe, Olver & Rawden, Coventry, CV7 7EJ, UK: Rob Shaw, Rob Shaw (TFG) Associates Ltd. (UK), Hope, S33 6RW, UK and Richard Bowman, Intertile Research, VIC 3187, Australia. Corresponding author: Steve Thorpe: thorpes1867@gmail.com. **Abstract**. Inclusive design is important to allow environments to be accessed and used by as many people as possible, regardless of age, gender or disability. One of the key principals of inclusive design is enabling everyone to use the environment safely, easily and with dignity. Stair falls, especially falls in stair descent, can result in serious injuries and even death. Falls on stairs are often seen as simply human error, but stair design has a significant influence on the likelihood of pedestrians making a mistake when using the stair. Human behaviour is hard to control but good stair design reduces fall risk for all stair users. This paper considers safer stair and ramp use by visually impaired pedestrians. The paper will consider the design features that contribute to fall risk, applicable standards, regulations and other guidance in the UK and Australia, and the experience of visually impaired pedestrians as stair and ramp users. The paper will also consider the use of tactile paving surfaces and how such surfaces are understood and used by visually impaired people. The paper will make recommendations for good practice in stair and ramp design and the education of stair and ramp users in order to reduce fall risk for all users, including those with visual impairments. **References.** The Building Regulations 2010, “Approved Document K –Protection from falling, collision and impact” (2013 edition)’’. The Building Regulations 2004, “Approved Document M –Access to and use of buildings” (2013 edition)’’. British Standard BS 5395-1:2010, “Stairs –Part 1: Code of practice for the design of stairs with straight flights and winders”. BRE Information Paper IP 15/03 (2003), “Proprietary nosings for non-domestic stairs”. Guidance on the Use of Tactile Paving Surfaces, Department for Transport, 2021, available from https://www.gov.uk/government/publications/inclusive-mobility-using-tactile-paving-surfaces, last accessed 05.02.2022. British Standard BS 8300:2009+A1:2010, “Design of buildings and their approaches to meet the needs of disabled people –Code of practice”. British Standard BS 8300-2:2018 “Design of an accessible and inclusive built environment. Buildings - code of practice”. https://ncc.abcb.gov.au/editions/2019-a1/ncc-2019-volume-one-amendment-1/contents-and-introduct ion/introduction-ncc-volume Investigating Stair Accidents. S. C. Thorpe, R. W. Shaw and K. A. Hallas. Proceedings of the XXIVth Annual International Occupational Ergonomics and Safety Conference, Fort Lauderdale, Florida, USA. June 2012.

Keywords: Stairs, Ramps, Tactile surfaces, Inclusive Design

S1-2

Fall prevention in the bathroom: understanding and informing public perception of grab bars for safer bathing

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Bathing is an essential part of daily life, yet environmental features of the bathroom pose the greatest fall risk compared to other rooms in the home. Grab bars can be used to prevent falls while bathing, but there are barriers to their use, including social stigma, the perception that a grab bar is unnecessary, unwillingness to make a permanent change to a home, and concerns about where and how to install a grab bar. In this presentation, we will give an update to our ongoing grab bar and bathing fall prevention research, focusing on understanding and informing public perception of grab bars. First, we surveyed 443 Canadians, asking whether they currently had a grab bar in their home, and their perception of mandatory grab bars in building codes. Briefly we found that while over 85% of respondents were supportive of mandatory grab bars in building codes, only 35% of respondents currently had grab bars in their homes. Responses were affected by age, self-reported impairment, and home ownership status. Second, we developed a draft decision support tool for families to use when selecting and positioning grab bars to assist with common bathing challenges. This tool has been developed based on a review of the literature, recent findings from our group and consultation with Occupational Therapists to identify grab bar recommendations based on individual ability, bathroom environment and bathing preferences. Third, we developed an infographic summarizing current grab bar research findings into a general recommendation tool for a lay audience. The infographic provides information about why grab bars are important for fall prevention, what features to look for in a grab bar, generic grab bar installation locations for a standard bathtub, and financial and professional resources in Canada. We will discuss how public opinions and consultation with Occupational Therapists have shaped our research direction and plans for further development of knowledge translation materials.

Keywords: Building Codes, Bathrooms, Aging in place, Knowledge Translation

S1-3

Risk points for falls and other risks setting in building information modeling from the design phase

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Nowadays, throughout the life cycle of a construction project, including planning, basic design, detailed design, construction, maintenance, repair, and demolition, it is becoming more and more common to use Building Information Modeling (BIM) to manage attribute information such as materials, dimensions, and components while making 3D CAD drawings. The usefulness of BIM lies in the fact that it allows us to make 3D drawings as if we were doing virtual construction work while arranging materials and components, and to immediately compile the attribute information of those materials and components as a table. On the other hand, in the EU, UK, Singapore, etc., it is obligatory by regulations, guidelines, etc. to compile a register of assumed risks from the design stage. Therefore, in this study, a new risk point was created as a BIM component (family) so that risks such as falls can be handled as attribute information in BIM. In the risk point, the name of the risk, the magnitude of the risk, and the phase in which the risk should be reduced can be entered. The color and size of the risk point can be specified according to the magnitude of the risk. These risk points can be placed anywhere in the 3D CAD drawing, and all placed risk points can be immediately listed as attribute information. This makes it possible to create and manage a risk register in the BIM software by placing risk points such as falls on the 3D CAD drawing, without having to prepare a separate list of risk registration. These risk points can be easily shared within the same software and can be applied to fall prevention measures for all construction projects using the software.

Keywords: Building Information Modeling, risk register, risk point, design phase, construction industry

S1-4

Measuring the effort required to drag forefeet upwards against risers/nosings during stairway ascent

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SUMMARY

A method of measuring and comparing the effort required to drag forefeet upwards against step risers/nosings during stairway ascent—behaviour associated with ambulatory disability— is demonstrated, indicating the feasibility of impedance ranking of risers/nosings.

KEYWORDS: Stairway, ascent, forefoot, effort, disability

INTRODUCTION

It is widely accepted that protruding step nosings can impede stairway ascent for people with ambulatory disability, including those with prosthetic legs or feet, calipers, or other ambulatory aids, and who therefore may drag their forefeet upwards against risers[1]. Resistance to upward movement increases required ascent effort, contributes to stumbles, and possibly falls, and can diminish user confidence with stairs. It is therefore an established recommendation and, to varying extent, regulatory requirement that protruding nosings not be incorporated in steps unless they are in the form of slightly inclined risers or, if protruberant, have an inclined underside[1]. The recommendations and requirements suggest that a vertical riser impedes less than a slightly inclined riser, which impedes less than a protuberant nosing with an inclined underside; and that all impede less than a protuberant nosing without an inclined underside. But quantification of this appears to be unavailable, as is also quantification of the effect of different surfaces; nosing protrusion dimensions, and novel nosing profiles such as those that are illuminative.

Many countries have performance-based building codes which bestow regulatory compliance upon methods or forms which can be shown to achieve the same performance as those that are prescribed. Under Australian prescriptions, most stairways in public buildings can only have vertical or slightly inclined risers. Protuberant nosings are disallowed, including those that are illuminative even though they can increase stairway usability—but there is presently no empirical basis upon which to assess their performance equivalence to the building code's prescribed nosings, nor for assessing the equivalence of other profiles such as those that are allowed in other countries. The ability to rank riser profiles for required effort might be one solution for this. Additionally, published accounts indicate that protruding nosings can facilitate safe stairway descent[2]; the ability to quantify resistance to upward movement of the forefoot against the riser would help reconcile the merits of nosings that protrude (for descent) with nosings that do not (for ascent).

RESEARCH OBJECTIVE

The objective is to determine the feasibility of measuring the effort required to drag forefeet upwards against risers/nosings, and of thereby ranking risers/nosings for their impedance.

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[1] E.g. ref. A117.1-1961 USA); Templer (1992); Goldsmith (1984); AS1428.1 (Australia); ADAS (USA).

[2] Ref. Templer (1978); Templer et al (1985); Pauls (2013); Agha et al (2021); Novak et al (2013).

METHOD

A prototype tester leg is pulled upwards (at constant inclination and speed): the foot moves up the riser, the leg rotates about its hinge, and the load against the riser and therefore the pulling effort increases (and measured by a digital strain gauge)[3]. Fifteen riser profiles and leg angles of 5°, 10° and 15° to the vertical, were tested. Most risers were smooth (Fig. 2).

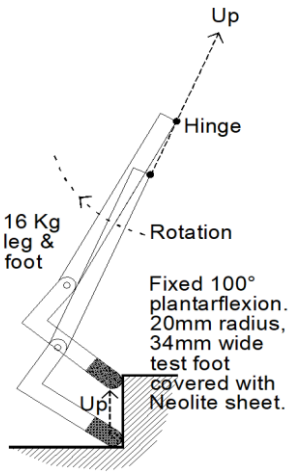

Figure 1 Prototype tester

RESULTS

Fine differentiation between riser/nosing profiles was achieved. Generally, ranking was in the anticipated order; least effort was required for the vertical riser and the greatest for the bullnosed riser (Fig. 2). The tester was sufficiently sensitive as to clearly respond to a smooth 1 mm radius metal rod on a riser; repeatability tests showed very high consistency in device performance.

DISCUSSION

Extrapolation of these results must consider: a) forefoot/riser interface—as the forefoot moves upwards, the interface on it also moves including to its upper surface (for protuberant nosings); b) the parallel, constant-contact forefoot trajectory assumed here does not necessarily typify actual trajectories[4]; c) differences between compressible forefoot material, actual footwear and the firm material used here. Future work will need to address these.

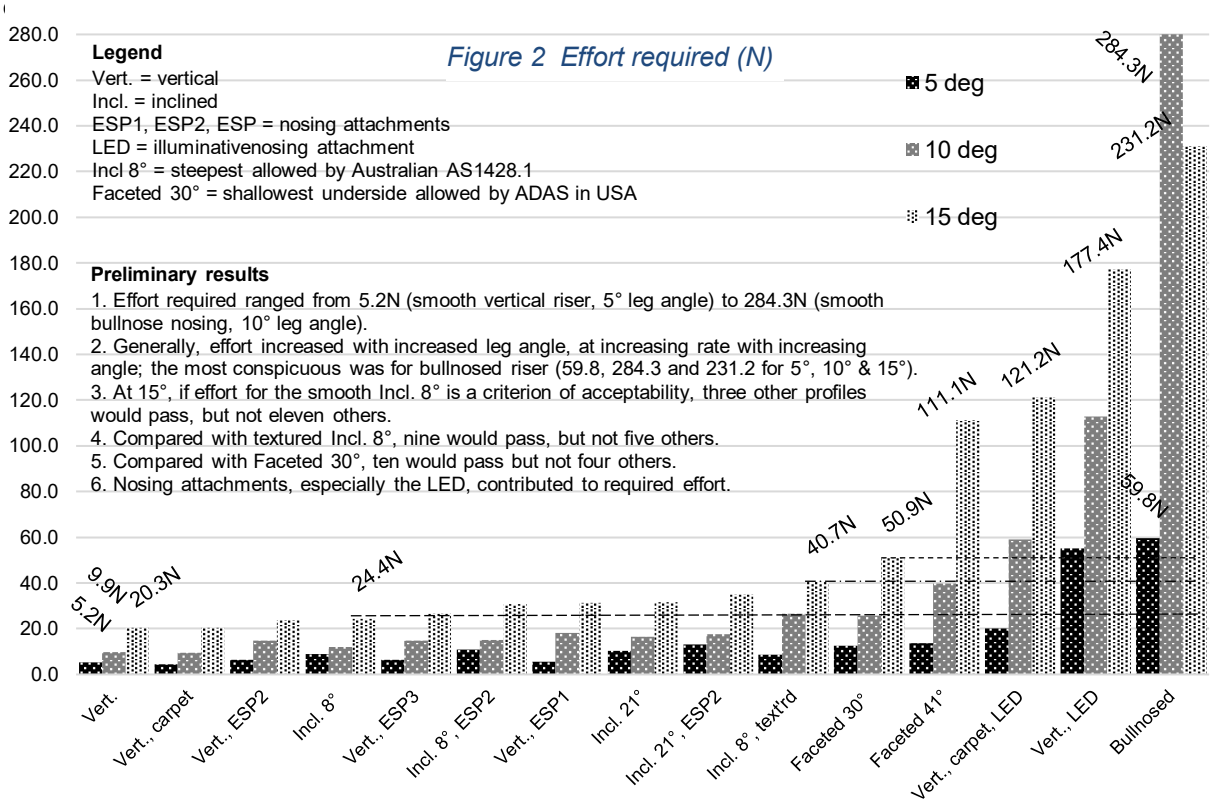

Figure 2 Effort required (N)

CONCLUSIONS

The prototype tester reliably and sensitively differentiated between riser/nosing profiles and surfaces. The initial results support the feasibility of ranking riser/nosing using this tester and warrant continuation of the research.

[3] Selection of leg mass has been guided by Deleva (1996); Dempster and Gaughran (1967); Drillis et al (1964).
[4] E.g. Hobara et al (2014); Ramstrand et al (2009).

S1-5

New Countermeasure for Prevention of Serious Falling Accidents under the Construction Works on the Low-Rise Housing

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Many serious falling accidents have occurred under the construction works especially in the low-rise housing in Japan. Though the major countermeasure is to set up temporary scaffolds, it is usually difficult to set up enough safety measures in the short-term works such as repair works. In such cases, a full harness type safety belt is used for the countermeasure. However, the frequently replacements of a safety belt hook are troublesome for construction workers. As a result, enough effects for preventing falling accidents due to this countermeasure by using safety harness cannot be obtained. Moreover, falling distance should be short because of the distance between the work position of the worker and grand surface is usually very short. We should solve this problem. This study proposes a new countermeasure for prevention of serious falling accidents under the construction works especially in the low-rise housing. This new countermeasure is constructed with temporary scaffolds, the full harness type safety belt, two safety blocks and two slide rails. The safety brock quickly stops falling and supports the worker when the worker starts dropping down to the ground. This slide rail is to support each safety block and to be able to move it to the horizontal direction freely. Therefore, the construction worker can move horizontal direction freely without frequently replacements of a safety belt hook. Some full-scale experiments were carried out to verify the effectiveness of safety against falling. Effective installation method of the safety block, effect of combined use of shock-absorber are discussed in this study.

Keywords: falling accidents, safty harness, low-rise housing, construction work

S2-1

Neuro-musculoskeletal model for bipedal locomotion with a lower limb amputation

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More than half the number of individuals with lower limb amputation have a history of falls (Miller et al., 2001), and less than 20% can walk without walking aids (Kamrad et al., 2020). Several factors should be considered for gait rehabilitation after lower limb amputation, such as physical function, prosthetic properties, living environments, or any combination of these. However, little is known about how these factors influence gait mechanics in individuals with lower limb amputation. Recent technological advancements, such as computer simulation based on the unified platform, enable us to investigate the effect of various factors on gait mechanics in individuals with functional impairments (Ichimura and Yamazaki, 2019). Thus, it is possible to build a neuro-musculoskeletal model that takes into consideration the conditions of a specific individual with lower limb amputation and test various factors using the model. Moreover, changes in various biomechanical parameters of the model could help predict the muscular strength and prosthesis function required for walking, or comfortable living environments. In this study, we built a two-dimensional neuro-musculoskeletal model for bipedal locomotion with transtibial prosthesis. This model includes a musculoskeletal system with 7 segments and 18 muscles, a neural system with central pattern generators (CPG), and various feedbacks from sensory organs. The neural rhythmic information from the CPG was sent to the muscles to generate locomotion patterns in this model. Subsequently, we removed the right ankle muscles (gastrocnemius, soleus, and tibialis anterior) of this model and attached a virtual passive prosthesis. The prosthesis possesses linearity of the passive ankle torque-angle relationships. Furthermore, the prosthetic mass and moment of inertia of the prosthesis were defined as 65% and 40% of the biological limb, respectively, to simulate a typical transtibial prosthesis (Russell Esposito and Miller, 2018). To walk in these conditions, 24 unknown parameters, such as weighting coefficients of the nervous system, were searched using a genetic algorithm. Subsequently, the model successfully acquired a robust walking, which exhibited a kinematic asymmetry as observed in individuals with lower limb amputation (Sanderson and Martin, 1997). Therefore, the results of the present study suggest that (1) our model could simulate the gait after unilateral transtibial amputation, and (2) individual models for gait reconstruction could be built on the computer.

Keywords: Gait, Amputation, Neuro-musculoskeletal model, Prosthesis, Genetic algorithm

S2-2

Relationship between Fast Backward Walking and Balance Evaluation

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Background: Since speed is an important factor for balance mobility, balance mobility has been evaluated by fast forward (FF) walking in numerous assessments. Currently, the assessment of balance mobility assessments has poor sensitivity in the healthy population. However, more challenging tasks, such as backward walking at a high speed, can increase the sensitivity of assessing balance mobility. Therefore, this study aimed to investigate the relationship of the gait parameters of fast backward (FB) and FF walking with the commonly used balance evaluation.
Methods: Twenty young adults (age: 23.2 ±1.3 years) underwent FB, FF, and balance tests. Three-dimensional motion analysis with 10 cameras was used to collect spatiotemporal and center of mass (COM) parameters of the FB and FF. A force plate with a foam balance pad was used to obtain the center of pressure (COP) values in the postural sway tests. In addition, the Timed Up and Go test (TUG) and the Functional Reach Test (FRT) were performed in this study. The linear correlation coefficients between spatiotemporal parameters of FF and FB walking, including COM, COP, TUG, and FRT, were analyzed using Pearson's correlation test.
Results: The spatiotemporal parameters and COM of FB walking demonstrated considerable significance in moderate ($p < 0.5$) to high ($p < 0.01$) relationships to the anteroposterior COP of the existing postural balance tests compared to FF walking. Although the TUG and FRT revealed stronger relationships to spatiotemporal parameters in FF walking, FB walking demonstrated stronger relationships to the mediolateral and *superoinferior* COM.
Conclusion: We conclude that FB walking could improve balance mobility evaluation in young adults with a higher sensitivity than FF walking.

Keywords: Backward walking, Gait, Balance, Postural sway, Motion analysis

S2-3

Relationship Between Clinical Stream Scores and MTC-based Gait Features in Post-stroke Patients

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Background: Stroke Rehabilitation Assessment of Movement (STREAM) is a clinical score that measures the degree of recovery in the voluntary movements of people with stroke. Biomechanically, Minimum Toe Clearance (MTC) is a crucial gait feature that has been associated with the tripping risk probability in individuals of different age groups. This study analyses the correlation strength between STREAM scores and the descriptive statistical features of MTC in stroke patients and age-matched healthy participants to identify the dominant MTC features that might have an association with gait impairment.

Method: MTC data of 35 healthy adults (aged > 65 years) and 41 post-stroke individuals (aged 71.7 ± 12.2 years) were used in this correlation analysis. Gait and MTC data were collected during preferred walking on the treadmill. The STREAM scores with mobility and lower extremity (LE) movement assessment for stroke and healthy participants varied between 0.46 to 1. Each participant's MTC heights of 200 steps were used to extract nineteen statistical descriptive features - mean, median, standard deviation, variance, range, first quartile, third quartile, intra-quartile range, kurtosis, skewness, maximum, minimum, fifth, tenth, fifteenth and twentieth percentiles, 95% confidence interval (95% CI), and lower and upper limit CI.

Results: Pearson correlation analysis indicated moderate correlations between the STREAM scores and three statistical MTC features: range, skewness, and 95% CI. The Pearson correlation coefficient (r) was below 0.29 indicating low degrees of correlation in the cases of the rest of the MTC features. A significantly ($p < 0.01$) negative correlation was found between the MTC range and STREAM scores with $r = -0.32$ (LE) and $r = -0.42$ (mobility). Moderate positive correlation ($p < 0.01$) was observed while correlating the STREAM scores with the skewness ($r = 0.38$) and 95% CI ($r = 0.49$).

Discussion: Both range and 95% CI of the MTC scores indicate the limits of mean MTC for participants with different gait conditions. MTC skewness influences MTC distribution asymmetry and has been shown to be affected due to aging and limb dominance in previous studies. In this study, these 3 features of 95%CI, skewness, and range were observed to be moderately correlating with the clinical scorings of the stroke participants exhibiting their influence on identifying gait abnormalities in stroke patients.

Conclusion: In this study, we have identified the statistical features of MTC that have associations with the STREAM scores. A more diverse range of clinical scores with patients in different stroke stages may increase the strength of the correlation between the considered variables. Thus, MTC's key statistical features correlating to the degree of gait impairment can further be useful for determining the severity level of the gait pathology and may help the gait diagnostic and rehabilitation process.

Keywords: stroke, minimum toe clearance (MTC), stroke rehabilitation assessment of movement (STREAM), gait rehabilitation

S2-4

Dynamic stability during obstacle crossing in children aged 2–5 years: A pilot study

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BACKGROUND AND AIMS: Not only the elderly people, but young children have a higher risk of falls during obstacle crossing than healthy adults (Berard & Vallis, 2006; Michel et al., 2010). To date, no study has reported obstacle crossing behavior of children younger than 6 years old. In this pilot study, we measured the obstacle crossing behavior of ten children aged 2–5 years by using a markerless motion capture technique. In addition to classical kinematic parameters like clearance, we quantify the dynamic stability during obstacle crossing by using the margin of stability (MoS) introduced by Hof et al. (2005). METHODS: Ten healthy preschool children participated in this study: 2 years (n = 2), 3 years (n = 2), 4 years (n = 2), 5 years (n = 4). An informed consent was obtained from the parent of each child prior to the start of the experiment. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethical committee of Oita University Faculty of Welfare and Health Science (approval number: F200016). The children crossed an obstacle with a height normalized to 10% of their leg length and repeated at least 2 trials (5 trials at most). The gait motion was captured by three video cameras
(1980 ×1080, 120 fps). We used OpenPose (Cao, 2017), a marker-less motion capture algorithm, to estimate the 2D coordinates of the body and we transformed them into 3D coordinates using the direct linear transformation method. From the kinematic data we firstly calculated the extrapolated center of mass (xCoM) based on the position and the velocity of the center of mass. The MoS was calculated as the difference between the xCoM position and the edge of the base of support which was defined as the location of the markers placed the foot.
RESULTS: All the participants successfully stepped over the obstacle. The common feature was a large forward MoS at the instant of the toe-off of the trail limb, which might be interpreted as a secure strategy to prevent forward falls just in case the trail limb contacts with obstacles. The medio-lateral MoS at the toe-off of the lead limb was smaller in the 2-year-old participants (0.02 and 0.12 % of pelvis width; n = 2), than in the older children (0.22 ±0.04 % of pelvis width; n = 8). The result indicates that the 2-year-old children were close to the loss balance toward the trail limb side during the lead limb crossing over the obstacle.
CONCLUSIONS: Although human can successfully cross over small obstacles from the age of 2, caution should be taken in medio-lateral loss of balance when toddlers cross over obstacles. ACKNOWLEDGEMENTS AND FUNDING: This work was supported by JSPS/MEXT KAKENHI Grant-in-Aid, Grant Number: 17H04750, 19K19901, 21H05334.

Keywords: Obstacle avoidance, Preschoolers, Locomotion, Margin of stability

S2-5

Kinetic and electromiographic analysis during and after gait perturbations

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Falls are a common source of injury in the elderly, with hip fractures and head traumas being the most serious results. Walking is the most common activity before to falls that result in damage or hospitalization, and it is also the most common activity prior to falls that result in injury or hospitalization. The aim of this study was to evaluate the strategies adopted by healthy adults to recover from an anteroposterior gait perturbance. One healthy adult performs a 6-minute walking warm up, continuing with a test protocol at self-selected speed experiencing an anteroposterior perturbation every 20 seconds. Gait parameters and perturbation were analyzed using the GRAIL system (Motek Medical BV, the Netherlands), which allows to evaluate kinematic and kinetic data during motor tasks as it includes a motion-capture system (VICON) with 10 optoelectronic cameras (100 Hz) and a instrumented dual-belt that integrates 16-channel force plates (1000 Hz). Additionally, electromyographic examination was carried out to characterize the neuromuscular performance caused by the stumbling following international recommendations (SENIAM). The joint angles of the lower body, the electrical activity of the soleus and tibialis anterior as well as the vertical force exerted by the subject were evaluated during the previous steps, the stumble, and the subsequent steps. In terms of joint angles, all show an increase in the range of motion, especially in maximum flexion; during the perturbation, followed by a raise in variability during the recovery step as well as a diminution in spatiotemporal parameters (step length and time). The soleus tripled its electrical activity during the perturbation compared to the previous and posterior step, while the tibialis anterior experiences greater variability during the end of the disturbance and throughout the recovery, generating greater electrical activity during the latter. Finally, alterations were found in the typical morphology of the vertical force, losing its double hump pattern; as it increases in variability during the disruption. Also, an enhancement of the first vertical peak force during recovery was found. Kinematic, kinetic and electromyographic analysis are objective methods to assess the risk failure in different populations and allow to establish diverse lines of actions and training programs to be undertaken by professionals. This cannot be accomplished without the characterization of the different strategies adopted by each subject and the appropriate evaluation methods to develop objective and valid conclusions, so this area of knowledge still shows actually a gap in scientific knowledge that must be urgently eliminated by future studies due to the economic and social consequences derived from the falls.

Keywords: Gait perturbation, Fall risk, Prevention, Recovery

S3-1

The effectiveness of five-star GRIP-rated slip-resistant footwear at preventing workplace slips among healthcare workers in Great Britain

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Background: Recent statistics from Great Britain (GB) show that 29% of work-related non-fatal injuries were due to a slip, trip or fall on the same level, and it is estimated that these incidents account for approximately 1 million lost working days each year. Slip-resistant footwear is often used in workplaces to help reduce slip risk. However, through their testing, the Health and Safety Executive (HSE) in GB has demonstrated that some footwear provides better protection from slips than others. To provide useful information to procurers of footwear HSE have developed the GRIP rating scheme, which tests and rates footwear slip-resistance using star ratings, with five stars being awarded to those which offer the best slip-resistance in their challenging test conditions. The aim of this work was to generate evidence on whether the offer and provision of five-star GRIP-rated slip-resistant footwear could help to reduce workplace slips among healthcare workers.
Methods: A recent randomised controlled trial, the Stopping Slips among Healthcare Workers (SSHeW) trial, was undertaken within the UK's National Health Service (NHS). The study involved 4553 NHS staff working mainly on wards, clinical areas or in the community. Half the participants were randomised to the intervention group (offer and provision of five-star GRIP-rated footwear to wear at work), while the other half were randomised to the control group (continue to wear their usual work footwear) to compare how many workplace slips they had over a 14-week trial duration.
Results: The trial found that the offer and provision of five-star GRIP-rated footwear reduced the rate of self-reported slips among NHS workers by 37% (95%CI 30-43%), and that this could be a cost-effective intervention from a societal perspective. Many intervention participants (~45%) did not wear the footwear all the time while at work, and results suggested the reduction in slips could have been greater if worn more. Additional analysis focusing on age found that participants aged 60+ tended to have twice as many slips compared to those aged <30 years (95%CI 1.40-2.87), and the footwear reduced slips by 61%
(95%CI 35-75%) in this older group.
Conclusion: This work shows that the offer and provision of five-star GRIP-rated footwear could be an effective and cost-effective measure to help reduce the occurrence of workplace slips among healthcare workers. Repeating the trial in other settings would be of benefit. The trial has also provided a rich dataset and further analysis has offered valuable insight into how slip risk and the effectiveness of five-star
GRIP-rated footwear varies by age. As the workforce ages, slips will continue to be an important issue for workplaces and appropriate slip-resistant footwear can be a useful preventative measure in areas where it is not possible to prevent floor surfaces becoming slippery, especially for older workers. It would be useful to further explore the issue of compliance and what impact the footwear could have if worn most of the time by workers.

Keywords: workplace slips, slip-resistant footwear, healthcare, GRIP-rating

S3-2

Experimental method to quantify the planar distribution of slip resistance contribution for shoes

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To prevent slip-and-fall accidents, it is important to ensure enough slip resistance of shoes. Commonly, the structure and material of outer-sole treads are designed to improve the slip resistance. Here, the distribution of slip resistance contribution would be nonuniform within an outer-sole from toe to heel, and can be experimentally measured with shoes with some electric devices, e.g. a load cell. However, it is difficult to know the distribution of slip resistance contribution for shoes without such devices. The purpose in this study is to establish a method to measure the distribution of slip resistance contribution not mounting electric devices on shoes but using floors with nonuniform slip resistance. In detail,
ISO-standard floors (euro tire) locally covered with polytetrafluoroethylene plates (PTFE) was prepared, and the friction force of shoes on these floors was measured. Because the friction force between a tread and PTFE was lower than a tread on euro tire, the total friction force changed depending on which treads slid on PTFE area. The friction force of each tread was calculated from the change in friction force between whole outer-sole and floors. As a result, it was confirmed that the contribution of slip resistance was the highest around a heel edge, and that more over 80% of total friction force of whole outer-sole was determined by this region regardless of outer-sole materials. Because the shoe was set on the slip meter as the angle between outer-sole and floor at 7 deg., the normal force would be concentrated around the heel edge region, it is considered that the higher contact pressure the higher friction force. Therefore, the structure and material of each tread should be designed based on the contact pressure distribution, and this method for measuring the distribution of slip resistance contribution would be helpful in designing practical shoes.

Keywords: shoes, slip resistance, experimental method

S3-3

Effect of end-face corner radius of shoe-sole tread block on slip resistance

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BACKGROUND AND AIM: Slipping is responsible for approximately 40% of all occupational falling accidents in Japan. Because slip-induced falls occur on a floor contaminated with water or oil, high slip-resistant shoes with high friction must be worn for an extended amount of time. One of the causes of reduced slip resistance is the wear of the shoe tread block. Hemler et al. [1] found that when tread blocks are worn on a large scale and tread grooves disappear, the ability of the shoe sole–floor interface to drain lubricant decreases, resulting in increased fluid pressure and reduced friction coefficient. However, in the early phases of the wear process, wear occurs at the end-face corner of the tread block, which can considerably affect slip resistance. In this study, we prepared rubber block specimens with varying end-face corner radiuses to simulate the degree of wear and studied the influence of the radius on the friction coefficient under dry and lubricated conditions.
METHODS: We prepared rectangular rubber block specimens with the end-face corner radiuses of r = 0.11, 0.83, or 1.84 mm. Friction coefficients were determined between a rubber block specimen and glass plate at various sliding velocities (0.01–0.2 m/s) under four lubrication conditions: 1) dry, 2) water lubricated, 3) 50 wt% glycerin solution lubricated, and 4) 90 wt% glycerin solution lubricated. The contact area between the rubber block and glass was monitored during the sliding test using a high-speed camera.
RESULTS: Under dry conditions, as the end-face corner radius increases, the friction coefficient and contact area increase by 23%–112% and 50%–122%, respectively. This implies that the larger the end-face corner radius, the larger the contact area, resulting in a larger friction coefficient. In contrast, under lubricated conditions, the friction coefficient decreases by 15%–83% as the end-face corner radius increases and the rate of decrease increases with increasing sliding velocity or lubricant viscosity. Under the lubricated conditions, when the corner radius is larger than 0.83 mm, the friction coefficient is less than 0.4. For r = 0.83 and 1.84 mm, the Stribeck curve indicated that the friction coefficient decreases by 42%–63% as the bearing characteristic number increases. However, for r = 0.11 mm, the friction coefficient increases by 59% as the bearing characteristic number increases. Using a cart-type shoe–floor friction testing, the similar effect of end-corner radius on slip resistance was validated for shoes with rubber tread blocks.
CONCLUSIONS: Our results show that an increase in the end-face corner radius of the tread block caused by wear greatly reduces the slip resistance of shoes when they are lubricated. The results shed light on the effect of wear on slip resistance and the design criteria for high slip-resistant shoes.
REFERENCES: [1] S.L. Hemler, et al.: Changes in under-shoe traction and fluid drainage for progressively worn shoe tread, Applied Ergonomics, 80 (2019) 35-42.

Keywords: end-face corner radius, shoe-sole, tread block, wear, Friction coefficient

S3-4

Measurement of the friction coefficient between shoe sole and icy surface using a sole sensor system

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BACKGROUND AND AIM: Falling accidents account for 25% of all occupational accidents in Japan, resulting in individuals taking up to 4 days off work. Slip-induced falls account for about 40% of the total falling accidents [1]. The slip resistance of the floor and sole can be evaluated in a laboratory or by a test device that can be brought to the site. However, it is difficult to measure the friction coefficient under the contact conditions between the sole and the floor during walking using these methods. In this study, we have developed a sole sensor system in which an inertial measurement unit (IMU) and compact, high load-capacity 3-axis force sensors are mounted on the sole and the friction coefficient is measured when a slip occurs during walking. The number of slipping accidents tends to increase in winter, occurring mainly on frozen road surfaces [1]. Therefore, this sole sensor system has been used to measure the friction coefficient, sliding velocity, and sliding distance between an icy surface and a shoe sole using a forward step test on an ice-skating rink.
METHODS: We placed four 3-axis force sensors with capacities of 1000 N in the vertical (*z*) direction and±500 N in the horizontal (*x* and *y*) directions on the heel, ball, hypothenar area, and toe positions, and installed two IMUs on the rear and forefoot. An adult male participant, wearing the sole sensor system on his right shoe, was asked to take a step forward on the icy surface of an ice-skating rink. The environmental and icy surface temperatures and relative humidity were 2.5°C, −4.2°C, and 55%, respectively. The step length was 0.6 and 0.8 m. The sliding velocity and distance were estimated by using integrals of acceleration data obtained from the IMUs. The friction coefficient at each force sensor position was calculated from the normal and horizontal forces obtained by each force sensor.
RESULTS: The estimated sliding velocity and distance were equivalent to the values calculated by tracking the heel position in a digital video camera image. The study results indicated that the step length did not affect the peak sliding velocity and distance. Furthermore, the mean friction coefficient at the heel and hypothenar area was lower than that at the ball, and exhibited low values <0.1 which was due to the large normal force at these locations.
CONCLUSIONS: Our preliminary results indicated that the shoe sole sensor system was effective in measuring on-site slip resistance. Therefore, it may prove to be a useful tool in the determination of slip risks in real-world environments.
REFERENCES: [1] A. Ohnishi, Causes of Occupational Falls on the Same Level More than Four Days Absence from Work: Features Based on Monthly Aggregation, The Japanese Journal of Ergonomics, 56, 3 (2020) 101–107.

Keywords: Slip resistance measurement, Shoe, Icy surface, Fall

S3-5

Evaluation of a wearable slip detection system during real-world use in winter conditions

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Fall-related injuries are a massive public health problem and a disproportionate number of these injuries occur because of slips on icy surfaces. The use of slip-resistant footwear can prevent falls and our recently developed lab-based Maximum Achievable Angle (MAA) winter footwear test has found there is wide variability in the performance of commercially available winter boots [1-4]. In particular, our testing has found that a new generation of footwear that incorporates composite materials in the outsole performs much better than most other footwear. The MAA test measures the steepest ice-covered slope that participants can walk up and down without experiencing a slip in a simulated winter environment.

Footwear that performs best in the MAA test has been shown to reduce slips on icy surfaces by 60% in real-world use compared to conventional winter footwear [5]. However, the testing methods used to determine real-world performance has relied on self-reporting of slips, which is subject to recall errors. The objective of this project is to evaluate a wearable slip detection system that has the potential to make real-world slip-detection more objective by removing the need for self-reporting of slips. Our wearable slip detection system includes an algorithm trained on data from audio, vibration, and inertial sensors to detect slips in a simulated winter environment.

Twenty outdoor workers will be asked to wear our slip detection system for one-week in real-world winter use. The system will be evaluated by comparing system-detected slips with ground-truth slip detection done by a pair of raters who will identify slips by listening to the audio recordings captured by the system.

This work will result in a wearable slip detector tool that can be used by researchers and the footwear industry to evaluate winter footwear more objectively compared to current methods in real-world settings. The data collected in this work will also be used to establish the relationship between the Maximum Achievable Angle score and real-world slip risk that will ultimately improve the quality of winter footwear recommendations provided to the public.

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Keywords: Slips, Ice, Real-world, Winter

S4-1

Validation of a low-weight portable friction-testing device to measure in situ shoe-floor friction

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Shoe-floor friction is a widely-measured metric to quantify the friction performance of footwear. Devices for measuring shoe-floor friction can be broadly categorized into laboratory devices and portable devices [1]. Measurements in real-world environments offer the potential to enhance environmental fidelity of experiments. Unfortunately, portable devices are under-developed compared with laboratory devices and, are not broadly used to assess footwear [1]. A recently-developed device, NEXTSteps, offers similar testing capacity to a laboratory device, STEPS, while weighing 18 kg. In this study, we present a validation study to determine whether the device is capable of predicting slip risk across different floor, contaminant, and footwear conditions. This research is also submitted for presentation at a separate conference [2]. The device was used to measure coefficient of friction (COF) under testing conditions that have previously been shown to predict friction (250 N, 0.5 m/s, and 17° shoe angle) [3]. Force sensors embedded in the device measured the friction and normal force and COF was their ratio over a 50 ms period when the test conditions were met. The device was validated against 67 human exposures to slippery floor conditions. Each participant wore a different pair of shoes that were composed of a combination of slip-resistant and non-slip-resistant shoes. Flooring including laminate and porcelain tile and fluid contaminants included diluted glycerol (at different concentrations) and canola oil. The material were intended to assess the device across a diverse set of operating conditions and broad range of COF values. The slip outcome of each participant was measured based on slip distance of their heel marker using a cutoff of 3 cm. A logistic regression analysis was performed to determine whether the COF values from the device could predict the slip outcome results. Slip predictions were made based on a COF cutoff of 0.122. Slips were predicted when COF was below the cutoff and no-slips were predicted when the COF was above the cutoff. This cutoff was based on a separate training data set. The COF values from the device were determined to predict human slipping ($p = 0.006$) with fewer slips associated with higher COF values. The slip prediction model yielded a sensitivity of 91% and a specificity of 62%. Thus, the device appears to provide valid, highly sensitive, and moderately specific predictions of slipping. We intend to continue using this technology in future research to determine the impact of footwear interventions on slip risk in real-world environments. References: [1] Chang, Leclercq, Lockhart, and Haslam, 2016. State of science: occupational slips, trips and falls on the same level. *Ergonomics*, *59*(7), pp.861-883. [2] Beschorner, Chanda, Moyer, Reasinger, Griffin, Johnston, 2021. A portable device for measuring shoe-floor coefficient of friction in situ, National Occupational Injury Research Symposium, in review. [3] Iraqi, Cham, Redfern, and Beschorner, 2018. Coefficient of friction testing parameters influence the prediction of human slips. *Applied ergonomics*, *70*, pp.118-126. Acknowledgements: This work was funded by the National Institute on Aging (R44AG059258).

Keywords: Tribometer, Slip and fall, Shoe friction, Coefficient of friction, in situ testing

S4-2

Publication of EN 16165 - Background, Advantages and Application Possibilities

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Towards the end of 2021, the new European test standard EN 16165:2021 "Determination of slip resistance of pedestrian surfaces - Methods of evaluation" was published. It contains four different methods for measuring the slip resistance of floorings:
- Ramp test barefoot
- Ramp test shod
- Pendulum test
- Tribometer test

This contribution is intended to give an overview of the development and background, how this new standard came about in its current form, what advantages it has for users, flooring manufacturers, testing institutes and regulators and what application possibilities it offers.

For a comprehensive understanding, it is important to gain an insight into the structural peculiarities of the European Union: The placing of construction products on the market is regulated at European level to create an internal market, whereas the requirements for the safety of buildings are regulated in separate sets of rules at national level in the individual states. In addition to product law, there is also occupational health and safety law, which in turn allows separate requirements for workplaces. The standardisation work in the field of flooring is special, as various product-related Technical Committees are responsible, which are supplemented by Horizontal Committees that are charged with more general tasks such as the description of test methods.

In this European legal framework, it is a progressive approach to juxtapose different test methods available in Europe and create the dire needed harmonization of different standards dealing with the same measurement device. For all stakeholders this provides consistent, reliable handling, and transferability and comparability of results. The situation before sees several standards based upon the same test principle but with differences in preparation, testing and calibration details. So such a step is prerequisite for any attempt to generate validated and transferable slip measurements. The choice of method, as well as the interpretation and classification, remains the responsibility of the individual states and/or product-TC.

Keywords: Slip resistance, Measurement method, European legislative framework, Flooring, Standardization

S4-3

STUDY OF PRECISION DATA OF THE PENDULUM TEST IN SPAIN

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This paper presents the analysis of data from several inter-laboratory tests carried out within the framework of building laboratory quality control in Spain. The data have been collected over several years, but have never been analyzed as a whole, looking at the evolution over time of the performance of this test in Spain.

The pendulum test was included in the Spanish Building Code in 2006. At the European level there is a debate about the suitability of this test, its precision and its quality compared to other tests. The Spanish administration considered it to be the best option to date and therefore included it in the code, but as the discussion remains open it is important to gather data that supports or deny this decision.

The regional governments of Spain, in the exercise of their competencies in building quality control and laboratories performance, implemented an inter-laboratory test at national level in 2014. Every year since then a series of tests are chosen and the inter-comparison is carried out in order to verify the performance of laboratories.
The pendulum test, in different modalities (dry and wet, laboratory and onsite testing) has been selected on several occasions, and a large number of laboratories have participated each time:
- in 2016: 73 laboratories in wet conditions
- in 2017: 72 laboratories in wet conditions and 66 laboratories in dry conditions
- in 2019: 68 laboratories onsite test in wet conditions and 56 laboratories onsite test in dry conditions.
Laboratories also tested an identical tile onsite to allow inter-comparison.
We can make an analysis of a very large number of results and different test conditions. Because we have data from several years it is possible to analyze the evolution of the results over time and the differences between the different test modalities.
The objective is to obtain more reliable data on test precision, but also on errors to avoid and lessons learned.

We will retrieve original data to redo previous analysis, and also to perform a uniform statistical analysis over different years and modalities. The basis of the statistical analysis is the ISO 17043 standard. Also, the study of photographs, written remarks of the laboratories or the available experience of the coordinators can provide very useful information.

The results are historical evolution of precision data of the pendulum test in Spain, difference of precision by test modality and learned lessons

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Keywords: slip resistance, test methods, pendulum test, round robin tests

S4-4

Socially responsible slip resistance standardisation: factoring in public expectations of sustainability and life cycle performance

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While standards development organisations develop compelling guidance policy documents, too few developers are aware of the valuable content. This presentation considers how such guidance favours developing a slip resistance standard (using a single test method) capable of fulfilling European Union Construction Products Regulation 305/2011 (CPR): that floors be safe (retain sufficient slip resistance) throughout an economically reasonable life cycle. EN 16165:2021 fails in several regards.

ISO Guide 82 (2019), *Guidelines for addressing sustainability in standards*, recognises that the achievement of sustainability is a critical consideration in all human activities, where the three dimensions of sustainability (economic, environmental and social) are interdependent and can be mutually reinforcing. It provides a systematic approach to addressing sustainability issues in a coherent and consistent manner, related to the objective and scope of any standard. While the terms “sustainability”, “sustainable development” and “social responsibility” have a close relationship but are not interchangeable. Sustainability is the goal of sustainable development. Social responsibility encompasses an organisation’s responsibility for the impact of its decisions and activities on society, the environment and economy, and therefore its contribution to sustainable development. ISO Guide 82 requires standards developers consider sustainability, stating and describing identified issues in a sustainability plan before they are addressed in the standard.

CEN-CENELEC Guide 2 (2001), *Consumer interests and the preparation of European Standards*, recognised the need for "consultation with and representation of consumers in the framing of decisions affecting their interests".

CEN-CENELEC Guide 11 (2012), *Product information relevant to consumers: Guidelines for standard developers*, recognises a consumer should be able to get all essential information concerning a product, allowing informed decisions to be made prior to purchase. Consumers need to know the probable long-term slip resistance of flooring products, not just potentially misleading ex-factory values.

CEN Guide 13 (2008), *Validation of environmental test methods*, sensibly requires test methods to be validated at the start of the standardisation process. Robustness testing and interlaboratory testing should yield standards with sufficient repeatability and reproducibility. Test methods relating to public safety should similarly be thoroughly validated.

CEN-CENELEC Guide 36 (2020), *Guidance on the rules for drafting and presentation of candidate harmonised product standards for construction products*, requires candidate standards contain an Assessment and Verification of the Constancy of Performance (AVCP) clause, indicating how the constancy of the declared performances (the essential construction product characteristics) is kept under control and assessed. AVCP clauses have a performance focus and must be written normatively. Manufacturers must take full responsibility for products, avoiding provisions that shift responsibility to someone else: an AVCP cannot be deemed to be fulfilled if based on supplier’s declarations.

Different floor products may require bespoke accelerated wear conditioning (AWC) protocols to satisfactorily indicate probable long-term slip resistance (assuming compliance with manufacturers' stated maintenance requirements). Protocols exist for some but not all products.

The objective is to consider a potential slip resistance standard, that complies with pertinent Standards policy guidance documents, based on use of the pendulum in conjunction with appropriate AWC protocols.

Keywords: slip resistance, standard, sustainability, life cycle performance, pendulum, accelerated wear conditioning

S4-5

The Pendulum Slip Resistance Test Using Slider 55

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The pendulum test is the preferred method of test for the determination of pedestrian slip resistance in the UK. The methodology followed when using the test is detailed in guidelines developed by the United Kingdom Slip Resistance Group (UKSRG). The current version of the guidelines is Issue 5, 2016. The UKSRG is undertaking various pieces of work, including this work, to inform the revision of Issue 5 and to prepare Issue 6 of the guidelines. We hope to complete this work in the near future and then be able to align the revised guidelines as closely as possible with the recently published EN 16165:2021. The publication of the EN will lead to the consequent withdrawal of BS 7976 + A1:2013 (Parts 1 –3) in the coming months.
Slider 96 is the slider used for the majority of pendulum work in the UK. Slider $55_{(a)}$ is used when evaluating surfaces used by barefoot pedestrians. It is recommended that both Slider 96 and Slider 55 are used when evaluating profiled surfaces. Historically the spread of pendulum test data generated on a given surface using Slider 55 has been greater than the spread of data generated using Slider 96.
This ongoing work aims to develop a better understanding of potential reasons for this greater variation and then identify how the variation might be reduced. This work focusses on the preparation of the working edge of Slider 55 and a method of maintaining a more consistent working edge as testing is undertaken.
Data generated on a range of hard and soft flooring materials during round robin work currently being undertaken by the authors will be presented and discussed.
More information about the UKSRG can be found at: https://www.ukslipresistance.org.uk The sliders used throughout this work were Slider 55 purchased from Smithers Rapra. The sliders met the specification of Slider 57 as described in EN 16165:2021.

Keywords: Slip resistance, Pendulum test

S5-1

ERGONOMIC FLOORING DESIGN for HEALTH CARE SETTINGS

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1. Polyflor

Resilient flooring is durable, flexible and impermeable. It is available in a wide range of designs and has an excellent cost performance profile in comparison to alternatives. For these reasons it is the most widely specified flooring for healthcare applications around the world. Floorings installed in modern healthcare facilities must provide a suitable environment to address patient safety and welfare needs. Resilient floorcoverings are unique in that they have the flexibility to be formulated and produced in different formats adapted to specific end use requirements. In this paper an overview will be given on recent advances in the design of resilient floor coverings to improve their ergonomic performance when used in healthcare settings. Topics which will be addressed are:

- Principles of selecting the correct slip test for specifying end use applications
- Specification of slip resistant floors for healthcare environments
- The importance of slip sustainability
- Design for dementia
- Hygiene performance
- Acoustic performance
- Environmental Sustainability

Keywords: Slip, Dementia, Flooring, Hygiene

S5-2

Risk of Slipping: Standards Development using the Power of Meta-analysis via an Evidence-based Epidemiological Approach

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Falls are the second leading cause of accidental or unintentional injury deaths worldwide and for Australian society between July 2002 and June 2005 totalled some 343 deaths and 105,968 hospitalisations, presenting a direct economic impact of about 250 million and 1.285 billion dollars annually respectively. The most likely cause of falls for those under the age of 75 are extrinsic factors
(environmental hazards, footwear and inappropriate mobility aids), with some 20% to 50% attributable to the built environment which includes exposure to floor surfaces that are slippery.

There is little if any epidemiological studies that has implemented a framework that allows a systematic review or meta-analysis to evaluate the association between the frictional properties of flooring and the risk of an injurious fall. The *a-priori* risk (or probability) of slipping can be hypothesised by evaluating the difference between the slip resistance of the floor (available friction determined by the physical characteristics of the surface and contamination present) with the utilised friction (activity and behaviour of the individual). Where the utilised friction exceeds the available friction, a slip will occur.

While there are laboratory studies that provide an initial insight as to this probability of slipping, they are plagued by the number of limited number of subjects, variables, and applicability to the complexity of *'real world'* situations. Laboratory-based probability analysis has certain limitations and does not consider the adjustment of gait when individuals perceived conditions to be wet and/or hazardous. There are a number of effect modifiers (location and perception of the floor's slipperiness, age and the condition of the surface) and confounders (environment, organisation and individual) that need to be considered. These risk factors need to be identified and considered as part of study design in quantifying the effect to evaluate potential benefits in any meaningful intervention.

Consequently, there is a fundamental gap in the current state of knowledge which research is unable to address because of this fragmented approach. Without a reliable indicator of the strength of association using an objective measure of slipperiness, future studies will continue to provide low quality evidence and poor outcomes in providing cost effective interventions for those vulnerable at falling.

The objective here is to initiate discussion to standardise evidence-based studies to facilitate systemic reviews and meta-analysis to quantify the strength of association between the slipperiness of a floor and the outcome of an injurious slip induced fall.

Keywords: Slip Probability, Tribometer , meta-analysis , Friction, Epidemiology

S5-3

Slip and Fall Risk Assessment of Ablution Floors in Mosques from Three Major Cities in the United Arab Emirates

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Mosques have an exclusive area called an ablution space that may require specific design attention because they are often encountered in lubricated circumstances from prayers' cleansing rituals. Accordingly, slip and fall risks would be a significant challenge to the Muslim prayers under such saturated ablution surfaces. Thus, this study investigates the current conditions of ablution spaces from a fall safety viewpoint. Thirty mosques from three cities in the United Arab Emirates were randomly chosen to examine traction properties and textural states of ablution floors. A portable tribometer and profilometer were used to measure in-place traction properties and surface conditions of the ablution floors, respectively. Traction properties were assessed in two areas: busy- and non-passage under three environments: arid, wet, and soapy. The surface textures of ablution floors were also measured in the two areas under the arid ones. This study identifies that the assessed ablution floors from the participated mosques are not suitable against slip and fall dangers. Their traction properties show a low level (< 0.4) in terms of a coefficient of friction (COF) quantity under the lubricated situations. Assessment results on the surface finishes of busy ablution floors reveal that they have smooth textures (< 2.0 μm in the R_a parameter) overall, so they need significant enhancements in the surface textures to provide better traction functions. However, as assumed, the surface conditions from the non-passage areas show rougher structures than the busy-passage ones and good relationships (r_2 > 0.7) amongst the measured COFs and peak roughness parameters (R_p, R_t, R_v, and R_z) under soapy environments. Therefore, this study proposes that chief executive officers and administrators from Mosques should put their efforts into improving the safety of ablution spaces to prevent any risks of fall incidence. Such attempts would be a great step forward to create safer and bettered ablution conditions for Muslim prayers.

Keywords: Ablution spaces, floor finishes, slip and fall incidence, surface texture, traction properties

S5-4

The quest to report the surface texture characteristics of slip resistance test specimens

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While many past slip resistance studies have considered ceramic tiles, their characteristics were poorly defined. If slip resistance standards are to become more evidence based, we will need to report exactly what has been tested and how, before we can consider any useful aggregation of data.

As tactile texture is the physical feel of something, it can be easily perceived. However, it is much more difficult to describe the surface characteristics and appearance of an object as determined by the size, shape, density, arrangement, proportion of its elementary parts. We may use 2- or 3-dimensional surface roughness parameters to describe texture, but both contact and optical measurements of surface roughness are highly dependent on the equipment used and how the data is processed. Several roughness characteristics can be generated, but which of these are most relevant, and can they be readily determined, relatively inexpensively, by a test auditor working in the field (even if a surface cast is made)?

While tactile texture may be described as smooth or rough, soft or hard, coarse or fine, matt or glossy, etc., there are natural textures, man-made textures, and artificial textures. There are also several types of visual textures with varying degrees of scale, randomness, regularity, homogeneity and orientation. From a slip resistance perspective, we are concerned with tactile texture although we may use one of several visual texture terms, such as timber, leather, eggshell, orange peel, honed, sandblast, etc., to describe natural and man-made textures. Ceramic tile and resilient flooring manufacturers produce “timber” products with varying degrees of directional tactile texture.

The DIN 51097 and 51130 ramp test standards required that test reports identify the surface structure of test surfaces “(e.g., smooth, profiled, structured)”. Although these standards have been superseded by EN 16165 (2021), *Determination of slip resistance of pedestrian surfaces - Methods of evaluation*, the surface structure requirement has been retained in the wet barefoot and shod ramp tests and introduced into the pendulum test. Unfortunately, EN 16165 does not define such surfaces, where language barriers posed difficulties in arriving at consistent definitions.

The IEA Slips Trips and Falls established an initiative to consider how best to describe the surface texture of floor surfaces. A workshop at the 17th World Congress on Ceramic Tile Quality in June 2022 will discuss various options. We will consider the findings of the European SlipSTD project (that sought to classify hard floor coverings according to their contribution to reduce the risk of pedestrian slipping) and how they have been used as the starting point for Spanish studies of the slip resistance life cycle performance of ceramic tiles with various surface structures and textures.

The objective of this presentation is to bring the IEA STF TC up to date and to open the floor to wider international participation. It is quite probable that a visual/tactile classification based on the surface texture of floor surfaces will not allow a reliable ranking of ex-factory slip resistance to be established, nor of its lifecycle performance.

Keywords: slip resistance, surface texture, surface structure, surface roughness, life cycle performance

S5-5

Pendulum friction testing of patterned 3D-profiled bathing surfaces: challenges, tools, and techniques

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Bathing surfaces constructed of vacuum-formed sheet plastic or molded thermoset resin (fiberglass composite or solid surface) typically utilize patterned 3D-profiled "friction features" to provide mechanical interlocking during the shear loading imparted by the bather's foot. The patterning and profile of these features create challenges to reliable tribometer friction testing. The British Pendulum tribometer has advantages over other tribometers with regards to sampling area size, positional control of the sampling trajectory, and compliance of the slider carriage over 3D features. Nevertheless, this study revealed that differences in 3D features, pattern periods, and pattern orientations (with respect to the tribometer) introduce broad variability that affects test results.

The Pendulum is a device that measures energy dissipation. The spring-loaded slider is released from a standard height and produces test values as a function of speed loss as it is slowed by slider contact with the tested friction features. Softer slider polymers like TRL (Slider 55) should conform better to a 3D feature than would a harder polymer. However, the Pendulum features an axial pivot for the slider mounting, and depending upon the instantaneous positions of the 3D features under the slider chamfer, the slider may simply rotate away from a 3D feature rather than deforming the polymer or causing the spring to deflect. As part of this study, testing was conducted with various bracket designs intended to reduce this axial pivoting.

The Pendulum swing height (relative to the test surface) is set using a "sliding length gauge" marked to facilitate the correct slider chamfer contact distance of 126mm. One challenge with using the Pendulum on dispersed 3D-profiled features was in setting this slider contact distance. An array of 3D feature peaks is not a flat stable surface upon which to place the gauge or rest the slider chamfer. This study developed a method to address this by using a shim plate on top of the 3D surface and a corresponding shim under the slider lifting lever.

When testing certain 3D-profiled patterns without feature “overlap” along the slider trajectory, such as a pattern with 3D features in rows spaced every 15mm, the period (and amplitude) of the feature pattern serves as an excitation frequency to the slider and its carriage. The slider carriage component masses, moments of inertia, damping, and the spring response all result in slider movements that may resonate, attenuate or otherwise fail to follow the period and amplitude of the 3D pattern. In this scenario, varying groups of 3D features may not even be contacted by the slider, and repeatability/reproducibility will be questionable. Given the virtually limitless array of patterns that could be produced when manufacturing a bathing surface, this is an issue that may be resolved by limiting such testing to certain 3D feature overlap densities and test orientations.

Despite these challenges, there are clear societal benefits to using tribometry for patterned 3D-profiled bathing surfaces, rather than relying only on human testing or experiential data. A reliable method would benefit manufacturers, inspectors, and ultimately bathers as well.

Keywords: bathing, bathtub, barefoot, friction, tribometer, tribometry, shower

S6-1

Margin of Stability (MoS) based prediction of balance and fall after introducing external slip stimulations

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Intro: One of the causes of falls in the elderly is a decline in the range of motion (ROM) of the joints of the lower limbs. However, it is not clear how much of a decline in the ROM of the joints is associated with a sharp increase in the risk of falling, i.e., the relationship between the amount of decline in the ROM and the risk of falling. Therefore, in order to examine the effect of the amount of reduction in the ROM of the lower limbs on the risk of falling, this study confirmed from experiments how much the stability of humans during a slip stimulus is reduced when the knee joint flexion angle is restricted. ***Method:*** Two healthy and young subjects are involved in this study. Their knee joints' flexion RoM are limited by restrictor fabricated by GYTH equipped on both sides. While walking on the split-belt treadmill fabricated by Bertec, a slip stimulus is created at the heel contact period by rotating in the reversing direction only one side belt on the foot we want to stimulate. Also, the magnitude of this stimulus can be controlled by an acceleration in the reversed rotating belt. In this case, the subjects are introduced stimulus in acceleration is 10 m/s2. The restricted RoM are adjusted before the experiments to the three following conditions: no-restriction, 60 degrees of flexion and 40 degrees of flexion. In order to distract the subjects' attention from the movement of their feet and the treadmill, they are looking towards to the videos shown on a screen. Their motions during the experiment process are recorded by motion capture devices. During the slip experiment all the subjects will undergo a full session from external slip stimulation onset to balance restored or lost with their knee joint flexion RoM being restricted. The subjects' base of support(BoS), center of mass(CoM) and velocity of CoM(Vcom) during the whole experiment process are calculated and recorded, in order to calculate the time series of sagittal and horizontal Margin of Stability(MoS), as to evaluate their stability during the whole experiment process. ***Result:*** The time series of sagittal and horizontal MoS of the subjects during their full session of slip experiments are calculated, and the maximum, minimum and average from the data are used to describe the highest recovered stability; the lowest stability after stimulation and total stability during balance restoration period respectively under different knee joint flexion RoM restrict conditions. The results show that the maximum value, minimum value and average value descended by 44%, 122% and 45% respectively as the knee flexion 40 degree restriction compared to no-restriction in the comparison of sagittal MoS. The corresponding data also shows that MoS values descends as the restriction of knee joint flexion RoM enlarges. While in the comparison of horizontal MoS, no clear relationships between restriction of knee joint flexion and MoS are found. These results indicate that the restriction of knee joint flexion RoM acts as an important factor during balance restoration period after the subjects have encountered and affected by external slips.

Keywords: Balance recovery, Balanced state identification, Rehabilitation

S6-2

Relation between Perception of Slipperiness and Frictional Property when Walking on Wooden Floors while Wearing Socks

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BACKGROUND AND AIM: People in Japan often walk on wooden floors while wearing socks. As such, a slip-resistant floor is necessary to prevent slip-induced falls. Usually, friction coefficient is commonly used to evaluate the slipperiness of floors. However, the measured friction coefficient often has less correlation with the human sense of slipperiness during walking. Thus, we focused on this specific lifestyle and aimed to investigate the relation between human perception of slipperiness and the friction coefficient between a sock-clad foot and wooden floor.
METHODS: This study enrolled 28 healthy adult males (n = 18, aged 25–58) and females (n = 10, aged 27–56). Prior to the experiment, participants were informed of the protocol, and they provided written informed consent. The protocol was approved by the Research Ethics Review Board of Kao Corporation. Participants were requested to walk on non-treated and four treated wooden floors lubricated using different silicone oils. The semantic differential (SD) technique was used to evaluate slipperiness, with scores ranging from 1 (very sticky) to 5 (very slippery). The friction coefficient between an artificial foot made of silicone rubber wearing a sock and each of the wooden floors was measured using a cart-type friction measurement device ("μ-cart") [1)] at normal loads W = 200 and 500 N and various sliding velocities (v). The correlation between sensory ratings and the friction coefficient under different normal load and sliding velocity conditions was investigated to determine the suitable friction measurement conditions for explaining the perception of slipperiness.
RESULTS: Slips occurred in the toe-off phase, and the slip distance was measured using video data. The sensory evaluation score of slipperiness revealed a strong positive correlation with the measured sliding distance (r = 0.99). The dynamic friction coefficient measured at W = 500 N and v = 0.15–0.35 m s^{-1} had a strong negative correlation with the sensory score of slipperiness (r > 0.97), indicating that the friction coefficient measured under this normal load and sliding velocity conditions can explain the perception of slipperiness. In the sliding friction test utilizing the cart device, the contact pressure and sliding velocity were 86.4 kPa and 0.15–0.35 m s^{-1}, respectively, which are similar to those of the real sliding phase in walking (68.1 kPa and 0.15–0.31 m s^{-1}).
CONCLUSION: The perception of slipperiness when walking on a wooden floor while wearing socks had a strong positive correlation with the sliding distance of the toe during the toe-off phase. With respect to tribology, equivalent contact pressure and sliding velocity to those of the real sliding phase in walking are necessary for measuring friction coefficient, to obtain high correlation with the human sense of slipperiness. These results will aid in bridging the gap between the human perception of slipperiness and tribology.
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Keywords: Slipperiness, Wooden Floor, Socks, Friction Coefficient, Contact Pressure, Sliding Velocity

S6-3

Why is it so easy to fall in a slippery environment? Innovative Walking Method to Prevent Falls Proposal of the "Footstep Walk Method. Shifting into a Copernican revolution in gait: From "Forefoot load theory" to "Heel load theory"

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Purpose: In Japan, Western style walking is the norm. It is believed that it is better to walk more actively with a larger gait. However, this way of walking can easily lead to falls on snow, ice, and slippery environments. Why is this? Why is it that the Western way of walking does not work at all in adverse conditions? It seemed to me that there was a problem with the Western gait system itself, in which the foot swings forward, lands on the heel, and moves forward by stepping back with the rear foot. I hypothesized that the Western way of walking, represented by the Ranchos Amigo way of walking, might be in violation of the laws of physics. I would like to find out where the problem lies and eliminate falls by physically clarifying the risks involved in Western-style walking and the mechanism of falls.
Methods: Seven women in their 60s and 70s conducted a walking experiment in which they took one step on an indoor wooden floor while wearing nylon socks. From a standing position with both feet together, the right foot was moved forward with strides of 15 cm, 30 cm, and 45 sm, and the slipping condition at heel landing was observed in a ranchos amigo-style gait with knee extension (hereafter, Western-style gait). The same experiment was also conducted with the "foot stomping gait," which was learned from an ancient Japanese walking method that improved on the physical problems of Western-style walking, and the differences in slipperiness were compared.
Experimental results: In the Western-style walking, the participants did not slip at 15 cm, slightly slipped at 30 cm, and all slipped at 45 cm.On the other hand, when the same experiment was conducted after the participants were instructed in foot-step walking, they did not slip at 15 cm, 30 cm, or 45 cm.
Discussion: In the modern Western style of walking, the stride is wide, the knee is extended, the foot is thrown out horizontally, the heel lands on the ground, and the rear foot kicks out. When the heel lands on the ground, the forefoot is tilted and not independent. The center of gravity is not on the forefoot, but is merely standing leaning on the hind foot. Even when stepping back on the hind foot, the center of gravity is not on the hind foot, and the heel lifts up and slips so far off the floor. Also, when the rear foot is thrown forward in a pendulum motion, it is easy to trip. With the spread of Western-style walking and shoes, foot bone deformities and pain also became widespread. With the increase of bunions and the spread of podiatric diseases all over the world, the Western way of walking may not be a sustainable way of walking. We need a Copernican-style change in thinking to rethink walking.
Conclusions: The Western gait method is a gait system that physically induces falls, and there is room for improvement.

Keywords: Slips, Trips, Rancho Los Amigos gait cycle, Walk Method, Hallux Valgus

S6-4

Differentiating between benign paroxysmal positional vertigo and vestibular migraine using walking stability analysis and machine learning

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OBJECTIVE: Benign paroxysmal positional vertigo (BPPV) and vestibular migraine (VM) have similar vertigo manifestations, leading to unsteady gait and an increased risk of falls. However, there is a lack of an objective and simple method to differentiate between the two diseases to avoid and reduce the incidence of misdiagnosis. This study developed a novel method to differentiate between BPPV and VM using accelerometer-based walking stability analysis and machine learning.
METHODS: 16 BPPV outpatients and 16 VM outpatients completed level walking trials at normal speed in clinical settings while wearing four accelerometers on the head, the fifth lumbar vertebra(L5), and both sides of the ankles, respectively. We extracted a set of walking stability-related features from the acceleration signals, including root mean square (RMS), harmonic ratio (HR), amplitude variability(AV), step/stride regularity, and gait symmetry. Then, we developed five machine learning models, including decision tree, linear discriminant analysis (LDA), support vector machines (SVM), AdaBoost, and the
K-Nearest Neighbor (k-NN), to differentiate between BPPV and VM.
RESULT: Compared with walking stability in BPPV patients, significant lower vertical HR at the head(p=0.03) and L5(p=0.002) were found in VM patients. Mean classification accuracies achieved by k-NN over 5 folds in the testing set are 0.901 for differentiating between BPPV and VM. The decision tree classifier is 0.831 accurate. The LDA classifier is 0.848 accurate. The SVM classifier is 0.881 accurate. The AdaBoost classifier is 0.846 accurate.
CONCLUSION: The study demonstrates the feasibility of machine learning in differentiating between BPPV and VM using accelerometer-based walking stability analysis.

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Keywords: Benign Paroxysmal Positional Vertigo, Vestibular Migraine, Walking Stability, Accelerometer, Machine Learning

S6-5

Winter Footwear Slip Resistance Determined by Maximum Achievable Angle Method Validated with Maximum Level Walking Speed

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BACKGROUND AND AIM: In the winter months, slip-resistant footwear plays a vital role in reducing slip and fall incidents. Human-based ramp tests were developed to evaluate footwear slip resistance, but limited efforts were made to verify its application on level surfaces, especially on ice. The purpose of this study was to evaluate the validity of an existing ramp-based winter footwear slip resistance test maximum achievable angle (MAA) [1] test on level ice.
METHODS: The MAA test was conducted with 10 participants walking up and down a sloped ice walkway with a melting ice surface. The maximum angle at which the participants walked up or downslope without slipping was recorded for 5 selected footwear styles (A-E). To assess how the ramp-based slip resistance result reflect slip resistance on level, the 10 participants were asked to walk as fast as possible on an hourglass-shaped track on a level concrete surface (as a reference surface) and on a level melting ice surface, wearing the same 5 selected footwear styles.
RESULTS: On concrete, the main effect of footwear styles was insignificant in affecting the walking speed ($p = 0.06$). The average walking speed over all participants and footwear models was 1.35 m/s ±0.19 m/s. This suggested that the footwear characteristics, such as the style and weight, did not impact level walking speed when participants tested the footwear on the concrete surface. On melting ice, the footwear styles significantly influenced the participants' maximum walking speeds ($p < 0.0001$). The average walking speed of 10 participants on melting ice was 0.70 m/s ±0.11 m/s. The upslope and downslope MAAs displayed significant correlations with the walking speed on wet ice, $r= 0.81$ ($p < 0.0001$) and 0.74 ($p < 0.0001$), respectively. The rankings of the footwear were the same according to the maximum level walking speeds and the MAA scores.
CONCLUSIONS: The consistent footwear slip resistance rankings and strong correlations between the MAA test results and the maximum level walking speed confirmed that the MAA test was capable of measuring the slip resistance properties of the footwear and could be used to indicate how the footwear would perform during level-ground walking.

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Keywords: Winter footwear, Slip resistance, Walking speed, Maximum achievable angle (MAA) test, melting ice surface

S7-1

Situational Factors of Ladder Overreaching in Older Adults

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INTRODUCTION:
Ladder falls are the second most common cause of falls [1]. People over 65 years have the highest hospital and intensive care admission rates due to falls from ladders [2]. Among emergency department ladder fall cases, 37% identified overreaching as a factor in their fall [3]. To better understand ladder fall risks for an aging population, this study examined the role of situational factors on reaching during ladder use in older adults.

METHODS:
One-hundred four healthy older participants completed a gutter-clearing task on a straight ladder. Participants climbed to the third step of a straight ladder and removed tennis balls from a gutter until all the balls were removed. Participants were allowed to move the ladder as many times as necessary to complete the task in a safe and quick manner. The maximum center of pressure (COP) location relative to the ladder center was used to quantify reach. A reach is the maximum COP of each climb. In preliminary work, this measure was correlated with maximum hand displacement during the gutter-clearing task.

Extracted situational factors were the percent of time between initial and final ladder contact (% time), ladder position relative to the gutter (categories based on ladder location: left, middle left, middle, middle right, right), whether the tennis balls extended so far from the ladder that they could not be removed without descending and moving the ladder (remaining debris), if the reach occurred from the participant's dominant side (dominant side), and the farthest distance the participant was able and willing to reach when standing on the ladder, measured separately (reaching disposition). These factors were entered into a bidirectional stepwise regression with reach as the dependent variable.

RESULTS:
Certain situational factors had a significant impact on reach ($F_{9,818}$=19.4; p<0.001). Reaching disposition ($F_{1,818}$=111.4; p<0.001), ladder position ($F_{4,818}$=3.4; p=0.006), and remaining debris ($F_{1,818}$=10.2; p=0.001) were all significant predictors of reach. Maximum COP values were significantly farther from the ladder's center when the ladder was positioned in the right middle of the gutter, compared to the right and left ends (Tukey HSD; p<0.05). Increased COP was associated with the presence of remaining debris (i.e. tennis balls) after the reach. Reaching disposition predicted 12.4% of the variability in reaching, with the total model predicting 18%.

DISCUSSION:
Reaching was predicted by a combination of situational factors. Reaching disposition had the highest correlation reflecting its integration of an individual's ability and their willingness to reach. Remaining debris may be acting as a motivator to overreaching. Ladder positioning can restrict overreaching as shorter reaches were observed to the outside where physical limits of the gutter existed. These findings can help guide interventions (e.g. limiting lateral workspace or adding physical barriers) to lower overreaching risk during ladder tasks.

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Keywords: Ladder Falls, Reaching, Decision Making

S7-2

Relationship between Hip Joint Power and Step Length in Lateral Stepping Reaction of the Elderly

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Crossover stepping to the lateral direction is an important postural strategy to prevent falls in the elderly. The purpose of this study was to clarify the relationship between the joint power exerted by the hip joint of the supporting leg and the lateral step length of the stepping foot in crossover stepping. Twelve healthy elderly people (mean age 73.1 years) living in the community and twelve younger people (mean age 20.3 years) were participated in this study. All participants received explanations about the purpose of the study and experimental procedure and provided written informed consent. This study was approved by the ethics committee of the Chiba Prefectural University of Health Sciences, which is the former institution of the first author. In this study, we used an electromagnetically controlled disturbance loading device to induce lateral crossover steps in the subjects. A three-dimensional motion analyzer and force plates were used to measure the crossover stepping reaction. The hip joint power of the supporting leg on the frontal plane was 0.19±0.1 W/kg in the elderly group and 0.39±0.2 W/kg in the young group, with significantly lower values in the elderly group ($p< 0.01$). The crossover step length ratio was 30.1±5.7% in the elderly group and 32.3±3.2% in the young group, with no significant difference between the two groups. Single regression analysis revealed a significant regression equation for crossover step length ratio and hip joint power in the younger group ($y = 0.13x + 0.28$, $R_2 = 0.47$, $p< 0.05$). No significant regression equation was obtained in the older group ($y= 0.38x + 0.24$, $R_2= 0.32$, $p= 0.054$). The characteristics of the crossover step in the elderly induced by lateral disturbance indicated that the hip joint power on the frontal plane was lower than that of the younger group. In addition, the results suggest that the contribution of the supporting leg hip joint power on the frontal plane to step length gain is low in the crossover stepping of the elderly.

Keywords: elderly, crossover stepping, hip joint power, step length

S7-3

Plantar shear patterns provide prognostic information for detecting postural instability in the elderly population

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Force-plate posturography offers a convenient way for quantitative assessment of posture stability in the elderly. However, studies focusing on routine balance assessment have usually not taken reginal shear patterns (i.e., arising from horizontal forces) into consideration.
The current study is motivated to address the following question: (1) Does plantar shear distribution differ between young and elderly subjects during upright standing? (2) How do the maximum plantar shear forces vary at different regions of the foot?
A reginal shear measurement (RSM) method was developed to obtain the spatial distributions of the tri-axial forces in the vertical, anterior-posterior (AP) and mediolateral (ML) directions from regional plantar sites while subjects maintaining standing balance. The feasibility of the proposed method in characterizing the magnitude and distribution of plantar shear forces were tested in 32 normal young and 19 elderly subjects. Statistical analysis was performed using the independent samples t-test for both the continuous and ordinal variables.
For regional AP shear forces, statistically significant differences were found between the two groups for the toe region of the left foot and the midfoot of both feet. For ML shear distributions, statistically significant differences were found at nearly all plantar sites expect for the hallux and lateral metatarsal. The maximum increase in ML shear forces occurred in the toe region of the right foot, where the peak shear values were 113.16% higher than those of the young subjects. The peak ML shear occurred in the midfoot were averagely 83.19% and 70.57% higher in the elderly’s left and right feet, respectively.
The RSM method may offer unique solutions to identify functional decline in postural control of the elderly. The plantar shear pattern has potential to become an important parameter in evaluating one’s balance performance during upright standing.

Keywords: Plantar surface, Shear, Elderly, Fall

S7-4

Aging and sex-specific differences in gait characteristics: A study on Japanese elderly

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Background

Differences in physical factors between men and women contribute to specific walking patterns. In addition to differences attributable to age, sex-specific differences have an important role in gait characteristics. This study aimed to investigate gait differences in joint angle behavior according to sex in elderly Japanese individuals and to identify specific gait characteristic of elderly men and women.

Methods

102 elderly Japanese individuals were participated in this study and divided into two categories; elderly men (53 individuals) with a mean age of 72,8 ±4.1 years and elderly women (49 individuals) with a mean age of 73.5± 4.7 years. Before the measurements, all participants were screened by using a medical questionnaire to ensure that participants did not have any serious orthopedic symptoms in the lower limb and were capable of independent walking. Three-dimensional (3D) kinematic data were collected by using a 3D motion analysis system. All gait parameters were analyzed using KineAnalyzer software. In total, 28 gait parameters were measured in this study, namely; 7 basic gait parameters and 21 joint angle parameters including its peak value and peak timing at the hip, knee, and ankle joints.

Results

Elderly women had significantly shorter stride ($p < 0.05$) and step lengths, faster cadence, and lower walk ratio (all $p < 0.01$) than those observed for elderly men. At the hip joint, the peak extension timing for elderly women was significantly later than that observed for elderly men ($p < 0.01$), and the maximal angle range for elderly women was greater than that for elderly men ($p < 0.05$). At the knee joint, the second peak flexion timing of elderly women was also significantly later than that of elderly men ($p < 0.05$). At the ankle joint, the first peak dorsiflexion timing for elderly women was significantly earlier than that for elderly men ($p < 0.01$), and the second peak dorsiflexion angle for elderly women was smaller than that for elderly men ($p < 0.05$). The maximal angle range for elderly women was significantly greater than that for men ($p < 0.01$).

Conclusion

In conclusion, sex-specific differences such as lower walk ratio, greater hip maximal angle range, delayed peak extension timing at the hip joint, and delayed second peak flexion timing at the knee joint are unusual for elderly individuals. Additionally, specific gait motions in elderly women identified using delayed peak extension timing at the hip joint, delayed peak flexion timing at the knee joint, and greater hip maximal angle range.

Keywords: Gait, Sex-differences, Japanese elderly, Walki

S7-5

Age-related Changes of Intersegmental Coordination in Lower-limb Joints during Standing Posture

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Inter-joint coordination in lower limb is one of the fundamental mechanisms to maintain upright standing. Previous studies demonstrated that there are, at least, two different types of joint coordination: kinematic coordination for center of mass (COM) movement, and dynamic joint interaction for joint angular acceleration. The purpose of this study was to clarify the age-related changes on the joint coordination, especially dynamics of joint interaction. Sixteen young adults (20.3±0.6 years old) and sixteen elderly people (73.3±3.9 years old) participated in this study. Kinematic signals and ground reaction force were measured using motion capture system composed of eight infrared cameras and two force plates. All participants performed three experimental conditions: quiet standing with eyes-open, quiet standing with eyes-closed, and bipedal standing on foam mat. For data analysis, COM, joint angular acceleration, and joint torque were calculated with a double-link inverted pendulum model consisting of ankle and hip joints. Joint angular acceleration from homonymous joint torque and that from interaction torque were calculated respectively. Finally, the coordination between these components were quantified by the uncontrolled manifold analysis (UCM ratio). Two-way ANOVA was performed for statistical analysis (age × posture). Results showed that UCM ratio for ankle joint angular acceleration was not changed with aging, while COM acceleration was significantly increased in elderly people (age and posture: $p<0.001$). The UCM ratio for hip angular acceleration was significantly large in elderly people (age: $p<0.001$, posture: $p=0.001$), indicating that the intersegmental dynamic interaction was not affected by aging. On the contrary, the kinematic coordination for COM acceleration was obviously decreased in elderly people compared that in young adults (age and posture: $p<0.001$). These results imply that two coordination systems were controlled by separated neural mechanisms. Age-related changes were emerged more clearly in the coordination for COM movement that is relevant directly to task goal for maintaining balance.

Keywords: postural control, inter-joint coordination, age-related changes, uncontrolled manifold analysis

S8-1

Status Analysis of the Fall Risk and Balance Assessment Tool

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Objectives: Falls of the elderly, which cause economic losses, have clinical research implications. There are numerous factors that influence falls in the elderly. In addition to external fall factors such as the environment, substantial evidence emphasizes that intrinsic risk factors (e.g., visual impairment, lower extremity strength weakness, increased spatial-temporal gait variability, and impaired balance) contribute to the increased risk of falls. Among these are decreased neuromuscular control and sensorimotor function that impairs postural control and increased postural sway in the elderly. Therefore, assessment of balance and prevention of falls is essential. Assessment of balance is also often required to verify the effectiveness of clinical treatment. The purpose of this review is to assist clinical researchers in selecting the appropriate assessment device and the appropriate testing modality for their balance assessment. Method: Searches were conducted in the databases of EBSCO, PubMed, Web of Science, and Google Scholar using a combination of the following three sets of keywords. Sets 1: scale, measure, analyze, test. Sets 2: kinematic, motion, force, coordinate, position, center-of-pressure. Sets 3: slip, trip, fall, balance, control, postural equilibrium. And other relevant literature was obtained through the reference list of the selected papers. Results: The Y Balance Test, the Romberg test, and the Single Leg Stance Test are regularly used to assess fall risk and balance in current research. The Berg Balance Scale Method and the Tinetti Scale Test are often used in scale assessments. To obtain data on balance ability, balance assessment equipment is usually used. Commonly used balance assessment equipment such as Balancemaster (NeuroCom, USA), Prokin-B (Tecnobody, Italy) ,which uses pressure plates for the assessment of balance ability. Existing equipment tests only the center of pressure (COP). Comprehensive testing of upper and lower extremity and trunk posture is lacking in current balance assessment equipment. Conclusion: To better reduce the risk of falls in older adults, it is necessary to select appropriate tests, scales and devices for balance and fall risk assessment. Existing devices neglect the dynamic postural stability and degree of resistance to disturbance of somatic activities, especially upper and lower extremity dynamics (e.g., hip strategy, gait strategy). Future research and improvements to the device should incorporate the effects of upper and lower limb activity on balance. For example, a motion capture system can be used to capture human posture information and extract key features of the human skeleton. This data can be combined with the COP data collected by the force plate. And a training program can be developed for hip and stride strategy.

Keywords: Balance, falls, assessment, devices

S8-2

Investigation of Postural Balance and Lower Limb Loads while Squatting with Various Foot Positions

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The loss of balance is a major cause of occupational falls from heigh places. Workers standing on elevated and limited surfaces are required to maintain the postural balance under various working postures depending on the surrounding environment and required tasks while minimizing the body sway caused by external disturbances. In previous studies, the functional stability limits (FSLs) are often used for an index of the postural control ability, and the longer FSLs is interpreted the more robust the posture against body perturbation. The authors investigated the relationship between FSLs for squatting postures and found that FSLs decreased with the depth of squatting. This result suggests that the squatting posture increases the risk of falling during manual tasks because of the reduction of voluntary control ability. However, the previous study evaluated only the normal standing posture with both feet parallel and shoulder-width apart and did not examine the posture with asymmetrical foot positions and angles. Therefore, the present study aimed to evaluate the effects of foot position and orientation on FSLs in the crouching posture. The experimental task was to voluntarily move the pelvis horizontally as wide as possible in a circular motion maintaining the waist at a constant height. The hip height (HH), defined as the vertical height from the floor to the greater trochanter in the upright posture as 100%, was controlled at three levels of height at 100%, 70%, and 40%. For each HH level, the anterior-posterior position, which is the difference in anterior-posterior positions of the left and right feet was changed at 40 cm and 0 cm (parallel), as well as the distance between the medial ends of the feet, was set to 15 cm and 40 cm as the left-right width condition. Additionally, the direction of the right foot was set at two levels: square (0°) and outward (45°). The foot reaction force and the whole-body posture were measured to calculate the center of pressure (CoP) and the center of mass, respectively. Additionally, to evaluate the lower limb loads, the joint torque ratio for lower limb joints was estimated using the three-dimensional biomechanical model. Experimental results showed that the FSLs expanded in 70%-HH conditions in most asymmetrical foot positions compared to 100%- or 40%-HH conditions. This trend was different from that under normal foot positions. On the other hand, estimated torque ratios for knee and ankle joints became large with the depth of squatting. The reason why is that the range of motions for hip, knee, and ankle joints are restricted by high joint torques in 40%-HH conditions, and the degree of freedom of motion was decreased in 100%-HH conditions. These results also showed that the deep squatting postures with 40%-HH conditions decrease FSLs and therefore increase the risk of falls for asymmetrical foot positions, while further studies are needed to comprehensively understand the effects of foot positions and lower limb postures on postural balance.

Keywords: Squatting, Functional stability limits, Center of pressure, Postural control, Falls from height

S8-3

Standing-Function and Sensory Evaluation System for Fall Prevention

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This paper proposes a simplified standing function and sensory evaluation system based on virtual light touch contact. This involves on/off control to implement random changes from a virtual partition. Such a set-up allows medical staff to quantitatively judge standing function from somatosensory stimulation changes. Experiments were implemented to determine posture controllability among subjects based on external stimulation in consideration of contact with the virtual partition, with outcomes indicating the method's suitability for clarification of how standing function and age are related, and this allow evaluation of fall risk among subjects judged to be at low risk in physical testing via comparison of sensory system evaluations using wavelet analysis.

Keywords: Fall prevention, Light touch effect , Wearable light touch

S8-4

Effects of momentary loss of hand reaction forces on postural balance during manual pushing tasks: a time-series analysis of handling and ground reaction forces

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Loss of human postural balance caused by changing working motion and external forces is a major factor in fatal and non-fatal falls. In the tasks with exerting force by workers, it is essential to maintain the balance between handling and reaction forces. Momentary loss of hand reaction forces during manual works might cause the loss of human postural balance and fall accidents. This study aims to identify the time-series features representing the effect of momentary loss of hand reaction forces and to clarify the relationship between that features and traditional human postural balance evaluation indexes such as displacement of the center of pressure (COP) and perceived postural instability. In the experiment, fifteen healthy subjects performed the operating handle pushing tasks under different experimental conditions. The operating handle fixed onto the body of experimental equipment via the belt pulley, slides to the pushed direction when participants apply the handling force over the predefined threshold value. The handling force that participants applied to the operating handle was measured using a digital force gauge, as well as the three components of ground reaction force (GRFs) were measured using two force plates and utilized to calculate the displacement of the COP. In addition, participants were asked to provide their perceived postural instability after each trial. Results showed that onset time of decreasing GRFs was delayed than that of decreasing handling forces. This time lag is presumed as one of the factors that accelerates the body when occurring momentary loss of hand reaction force and might enable it to use for human postural balance evaluation. In addition, the impulse, the impulse of difference between GRFs and handling force might also enable to use for human postural balance evaluation.

Keywords: postural balance evaluation, momentary event, time-series analysis, handling force, ground reaction force

S8-5

Acute Effects of Anodal Transcranial Direct Current Stimulation on Ankle Position Sense and Joint Force Sense

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Background: Recently, studies have found that anodal transcranial direct current stimulation (a-tDCS) can enhance foot functions by increasing brain cortical excitability. A-tDCS is used as a brain stimulus technology, which has been introduced into the field of sports to improve human capacity. This study aimed to examine the acute effects of single-session a-tDCS on ankle joint position sense (JPS) and ankle joint force sense (JFS).
Methods: In this double-blinded self-controlled study, 10 healthy younger adults were asked to complete assessments of JPS and JFS before and after a 20-minute session of either a-tDCS or sham tDCS (s- tDCS) at two visits separated by one week. Absolute errors (AE) and variable errors (VE) of JPS and JFS were calculated, separately. Two-way repeated measures analysis of variance (ANOVA) was used to examine the effects of a-tDCS on JPS and JFS. Model effects included intervention (a-tDCS, s-tDCS), time (pre-, post-) and their interaction.
Results: The study demonstrated that no main effects of time and intervention were observed for AE and VE of JPS and JFS ($p > 0.05$). Specifically, no significant interaction were observed for VE of JPS ($F_{(1, 9)} = 0.983$, $p = 0.347$, η_p^2= 0.099). However, the two-way repeated measures ANOVA indicated that intervention ×time interaction for VE of JFS appeared significant ($F_{(1, 9)} = 6.183$, $p < 0.05$, η_p^2= 0.407). **Conclusion:** The results suggested that single-session a-tDCS may improve the ankle force sense, although no significant differences were observed with regard to such effects between a-tDCS and
s-tDCS. This may be potentially due to ceiling effects in this healthy cohort of a small sample size. Nevertheless, these preliminary findings may inform future studies with larger sample sizes aimed at confirming and expanding the findings of this study by providing knowledge on optimal stimulation parameters, effect size, and power estimation of the a-tDCS intervention.

Keywords: transcranial direct current stimulation (tDCS), ankle joint position sense, ankle joint force sense

S9-1

Look at the bigger picture - Systems thinking in occupational falls at level: case studies from the construction industry

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It is well established that falls at level are usually a combination and interaction of different factors (Chang et al 2016, Bentley 2008, Leclercq et al 2021). As a Workplace Health and Safety Regulator, we see many workplaces looking at obvious and observable risk factors without considering other contributory factors. This is a missed opportunity to achieve a complete and sustainable solution to the problem and improve the safety of all workers for future work.

System thinking (Underwood & Waterson 2013, Meadows 2008, Newnan et al 2020, Naweed 2015, Goode et al 2019) can be used to understand the nature of falls at level and then target measures to prevent future accidents occurring. System thinking has been applied across many disciplines with growth of translational research particularly looking at safety in the workplace. Fundamentally, the approach facilitates us to look at the direct and indirect factors that can influence the risk of falls at level. These factors can be from within the workplace as well as outside the organisation.

A focus group with experts who have significant knowledge and experience investigating occupational falls at levels, convened and reviewed the state of science knowledge on causes of falls at level using a system thinking approach. A visual model of the contributory factors of occupational falls at level was developed to reflect this work. The model brings together the work environment, work activity, individual factors, work organisation and other system factors that influence falls at level risks occurring at work.

This model aims to be easily understood by decision makers in the workplace and is applicable to:

• indoor and outdoor environments

•static (e.g. factories) and dynamic (e.g. construction and rural) work situations

• all industries

Case studies from the Australian construction industry will be shared to show how the model is applied. Resources to assist workplaces prevent falls at level will also be shared.

Keywords: system thinking, safety, occupational, construction, model, dynamic work

S9-2

Who has roles and responsibilities in providing safe access and movement at work? There are more than you may think

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This session shares an Australian Work Health and Safety Regulator's perspective on the roles and responsibilities (or obligations) of those who contribute to slips and trips injuries at work. This includes parties both within and outside of an organisation.

There have been recent legal cases and investigations that highlight how different parties have a role in causing serious slip and trips at work. The parties include project managers, sub-contractors, host employers, labour hire agencies, landlords, body corporates, designers for example. Many may not be aware of their contribution to and responsibilities of the occurrence of slips or trips related injuries of workers and others.

The aim of this session to raise awareness and understanding of how different parties within and outside an organisation have a role and what they can do to reduce the risk of slips, trips and falls at work.

This presentation will share and discuss:

• The responsibilities of relevant parties (or duty holders) in safety laws (*Work Health and Safety Act 2011, Work Health and Safety Regulations 2011*). It will also explore how each party can contribute to the prevention of occupational slips, trips and falls. The examples are universal and can be applied to many other work health and safety jurisdictions.

• Findings from legal cases and accident investigation across a range of industries to illustrate the issues considered in the different cases.

• Practical and systematic measures to mitigate the risk of occupational slips, trips and falls

Keywords: safety laws, safety responsibilities, legal, ways to prevent slips and trips, supply chain, contractors

S9-3

The required coefficient of friction during roof to ladder transitions

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Introduction:
Falls from ladders pose a threat to workers [1]. Transitioning to and from an elevated surface has been shown to be particularly dangerous, causing 14% of all ladder fatalities [1]. An important factor contributing to same-level falls is the required coefficient of friction (RCOF) which has recently been applied to ladder climbing [2,3] This study investigates the effect of different ladder configurations and roof conditions on the RCOF at the ladder transition rung. It is hypothesized that a lower peak RCOF value will be associated with a ladder accessory designed for ladder to roof transitions and when transitioning from a flat versus pitched roof.

Methods:
The experimental setup consisted of two different elevated roof conditions (flat and pitched to 22.4°) and two different ladder transition conditions (traditional and walk-through accessory (AES Raptor Grab-Safe Portable Ladder Extension)). The ladder transition rung was attached to a force plate which collected three dimensional forces. Simultaneously, 12 motion capture cameras collected kinematic data. This is a preliminary analysis for five participants. Participants transitioned to the ladder from the roof and descended to the floor at a self-selected pace. Force data was transformed to the coordinate system of the foot and decomposed into the shear and normal components. RCOF was the ratio of the shear force to the normal force. Peak RCOF was the first local maximum which corresponded to a shear force greater than 20 N. A repeated-measures ANOVA test with peak RCOF as the dependent variable and roof and ladder conditions as independent variables tested for significance.

Results:
Statistical analyses confirmed a slanted roof yields a higher peak RCOF (RCOF=0.394) than a flat roof (RCOF=0.326) ($F_{1,4}$= 9.19, p= 0.039). No significance was found between the two ladder conditions ($F_{1,4}$ =0.61, p=0.47). Despite the lack of significance, the traditional ladder had a higher peak RCOF value (RCOF=0.386) than the walk-through ladder (RCOF=0.335).

Discussion:
As expected, a slanted roof demonstrated a higher peak RCOF, meaning this transition task is likely more dangerous than a flat roof. This could be due to the increased height between the roof surface and the transition rung. A meaningful difference in the RCOF values across the transition conditions was observed, indicating transitioning to a traditional ladder top is more likely to cause a slip than using a walk-through device. While the present data may be under-powered to make conclusions, this association should be monitored as more participants are included in the study.
RCOF values in this analysis (range: 0.21-0.59) were much higher than were found in [3] (0.15-0.24). These higher RCOF values may indicate that roof-to-ladder transitions or descending may increase the RCOF compared to ascending during steady-state climbing [3].

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Keywords: Ladder Falls, Friction Requriement, Ground Reaction Forces

S9-4

Evaluation of Friction Perception by Simple Foot Rubbing

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BACKGROUND AND AIM: Slip-induced falls have attracted attention from Japanese companies and administrative organs in recent years because of their high rates of occupational injuries associated with them. To reduce slip-induced falls at the workplace, we might first evaluate the slip resistance between a type of flooring and shoes using a tribometer. Existing tribometers possess meaningful reliability for measuring friction properties, such as slip resistance. However, it is sometimes difficult to introduce tribometers into the workplace because of their portability, handleability, expense, and time costs. Therefore, a simple and inexpensive method to evaluate slip resistance that can be readily introduced into the workplace is required. We believe that a sensory evaluation by people is a better way to evaluate slip resistance if it is accurate. Thus, in the present study, we investigated the relationship between a simple sensory evaluation of anti-slipperiness by foot rubbing and actual friction properties obtained with in situ measurements.
METHODS: Nine commercially available sheets were selected for testing to determine differences in their coefficients of friction (COFs). Participants wore a type of training footwear commercially available in Japan. This footwear was selected because it has almost no curvature in the shape of its sole and moderate weight. A smooth nitrile butadiene rubber sheet was attached to the sole of the shoe to eliminate the effect of the tread block. The participants were 15 healthy adults in the age group of 20–59. The sensory testing positions were two different types: standing and sitting. The participants were asked to rub their foot against the oil-lubricated sheet once in the forward direction. During rubbing, the friction forces were measured using a force plate. The sliding velocities were calculated from sliding distances measured using a laser rangefinder. After rubbing once, the participants gave two sensory scores for the slip resistance using a visual analog scale. The minimum point was zero, and the maximum was 100.
RESULTS: More than half of the participants in experiments could adequately perceive the slip resistance using the proposed method without any education on its perception. Furthermore, the sensory score threshold, where a friction coefficient of 0.2 was detected as a hazardous area, was obtained from a linear regression model for the participants with friction perception capability.
CONCLUSIONS: Our elementary results indicated that the proposed simple foot rubbing evaluation of friction was effective in evaluating slip resistance. Therefore, it may prove to be a useful method in the awareness of slip risks in workplaces.

Keywords: foot rubbing, friction perception, visual analog scale, sensory score threshold

S9-5

Preventing Slips, Trips, and Falls –The Importance of Good Data

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Slips, trips, and falls in the workplace are frequently regarded as minor incidents or even an inevitable consequence of having people access the premises. As such, many businesses only begin to identify relevant risk controls in response to a serious incident, which would have been preventable had the issues been considered before the event. This paper will consider the importance of gathering, and appropriately analysing, good quality near miss data and conducting appropriate incident investigations in proactive workplace falls prevention.

Common issues and challenges will be explored via the analyses of slip, trip, and fall data sets from several anonymised companies in a range of industry sectors. The free text boxes of these incidents will be studied by a falls prevention specialist in an effort to determine the root causes of the incidents and look for patterns and shortcomings in both the data sets and the subsequent analyses and categorisation undertaken by the company involved.

The paper will consider the typical issues and limitations with both incident reporting and subsequent data analysis, potential challenges to engagement with the reporting process, and the fundamental misconceptions regarding slips, trips, and falls that complicate the gathering of good quality data.

Finally, the paper will present an example of a digital reporting system that addresses some of the shortcomings that have been explored and will make recommendations for helping an organisation gather better data, make better use of this data, and, ultimately, improve the management of slip, trip, and fall risk within their organisation.

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

Exhibition

1. Atom Corporation
2. Research Institute for Electromagnetic Materials