Evaluating Slips on Icy Surfaces: A Data Collection Protocol

D. Dadkhah[1, 2], H. Ghomashchi[2] and T. Dutta[1, 2]

[1] Institute of Biomedical Engineering, University of Toronto, 164 College St., Toronto, M5S 3G9, Ontario, Canada
[2] KITE Research Institute, Toronto Rehabilitation Institute, 550 University Ave, Toronto, M5G 2A2, Ontario, Canada

Abstract— **This study presents a protocol for collecting a diverse dataset encompassing motion, video, audio, kinematic, and environmental metrics related to walking on icy surfaces. Aimed at enhancing the understanding of the biomechanics involved in navigating such challenging conditions, the study recruited 27 participants for data collection in the state-of-the-art WinterLab at the Toronto Rehabilitation Institute. The protocol captures a wide array of data points including detailed body measurements, gait patterns, and slip occurrences that were recorded using an array of devices like Android phones, GoPro cameras, wireless microphones, and a Vicon motion capture system. Preliminary analysis of the dataset, involving over 2700 steps from one participant, demonstrates valuable insights into slip frequencies. This research not only advances the biomechanical understanding of walking on icy surfaces but also has practical implications in the design of preventative measures such as slip-resistant footwear and public safety strategies. This dataset will facilitate the development of predictive models for slip risk assessment, contributing to both academic research and better safety in winter conditions.**

Keywords— **Wearable sensors, winter footwear, slip detection, fall prevention.**

I. Introduction

A. Falls on Icy Surfaces

Slips and falls are a major public health concern, causing significant pain, suffering, and economic burden [1; 2]. Fall-related injuries cost Canada more than $12.2 billion in 2023, accounting for approximately 5% of Canada's total public healthcare spending. [3; 4]. Research indicates that a disproportionate number of falls happen on icy surfaces [5; 6]. Furthermore, the risk of injuries has been found to escalate notably in conditions involving snow and ice [7; 8]. Previous studies indicate that the odds of emergency room visits due to falls increased by 70% on snowy days compared to non-snowy days [2]. The presence of snow or ice on walking surfaces has been found to triple the likelihood of falling [9]. Despite its severity, the issue of falls on icy surfaces is underrepresented in current literature [10].

B. Slip-resistant Footwear as a Preventative Measure

To combat the risk of slips and falls in icy conditions, slip-resistant footwear has been identified as a potential solution [11; 12; 13]. These specialized footwear options have been evaluated through tests like the Maximum Achievable Angle (MAA) test, assessing their effectiveness on various in-lab icy surfaces [14; 15]. To test the performance of the best-performing footwear in the MAA test in real outdoor winter conditions, our team ran an outdoor study involving 110 Personal Support Workers (PSWs). This study demonstrated that PSWs wearing slip-resistant footwear had experienced an average of a 68.0% lower slip rate and a 78.5% lower fall rate compared to those not wearing such footwear [11]. This highlights the effectiveness of such footwear in reducing fall risks in icy conditions.

C. Need for a Comprehensive Slip Dataset

While existing studies offer valuable insights, there is a clear need for more comprehensive data to fully understand the factors contributing to slips on icy surfaces. This data includes the type of ice, demographic aspects of individuals, footwear types, gait parameters, and human perception of slips. Our study aims to fill this gap by collecting a comprehensive dataset encompassing human motion, environmental conditions, kinematic data, and wearable sensor data. This dataset will be instrumental in assessing various aspects of human biomechanics in the context of walking on icy surfaces, contributing significantly to the field of fall prevention and safety.

II. Methods

A. Participants

The study recruited 27 healthy individuals (15 females and 12 males) through poster advertisements at the Toronto Rehab – University Centre. Participants were pre-screened to ensure they met the inclusion criteria: age between 20 and 75 years, the ability to walk on ice, and no history of falls or injuries in the past six months. Exclusion criteria included physical or cognitive disabilities affecting walking, vestibular dysfunction, pregnancy, or any medical condition impacting gait. All participants provided informed consent prior to participating in the study.

B. Experimental Setup

The experiments took place in WinterLab, part of the Challenging Environment Assessment Laboratory (CEAL) at the Toronto Rehabilitation Institute. WinterLab, with a temperature range of -10°C to 10°C, features an approximately 5 m x 5 m ice walkway with a 4 cm thick ice surface, maintained below freezing temperature. The study utilized two ice surface types: dry ice and wet ice, the latter created by applying a thin water layer on the ice. The lab's slope could be adjusted up to 15°.

C. Equipment and Data Collection Devices

Data collection utilized a variety of devices:
Android phones mounted to footwear: Attached to each foot, these phones were equipped with sensors and microphones, collecting IMU data at 200 Hz and audio at 44.1 kHz.
Wireless microphones: Attached to boots, recording audio at 48 kHz.
GoPro camera: Mounted in the lab, recording full HD videos at 60 fps.
Android phones for slip reporting: Used for logging self-reported slips, adding a subjective data layer to the objective measurements.
Vicon motion capture system: Consisting of 8 Vicon Vero cameras, capturing motion data at 200 Hz.

D. Procedure

Participants wore winter attire with reflective markers placed on key body landmarks according to the Plug-in Gait marker set and were secured in an overhead harness system in WinterLab. Each participant tested three types of boots and performed calibration movements for data synchronization. The walking trials included six straight-line walks (three uphill and three downhill) and two figure-eight pattern walks. Half of the participants were tested under dry and the other half under wet ice conditions. Participants reported perceived slips verbally.

E. Data Cleaning, Preparation, and Analysis

The cleaning process involves:
Optical motion capture data: Filling data gaps, filtering, and synchronizing data streams.
Foot-mounted phones: Calibration and synchronization with motion capture data.
GoPro camera and wireless microphones: Pre-processing and audio enhancement.

Furthermore, the data undergoes detailed analysis, focusing on:
Step labelling: Each step will be analyzed and classified as either a “slip”, “nonslip”, or “no data” by two human raters. Any conflicts will be resolved by a third rater.
Turning point analysis: Identifying slips during gait turning points.
Slip length measurement: Measuring the length of each slip.
Detailed step analysis: Analyzing each step for timing, trial number, lab slope, and walking pattern.

III. RESULTS

A. Preliminary Findings

This section outlines the preliminary results from the analysis of one participant's data, while the remaining data processing is ongoing. A more comprehensive paper detailing the full dataset will be published upon completion of data processing.

B. Participant Demographics

We collected data on the participants' assigned gender at birth, age, height, weight, and the number of years they have had experience in snow and icy conditions. This approach helped us gather a comprehensive range of demographic information, enhancing the external validity of our study findings.

Additional body measurements were collected, including knee and ankle widths, and leg lengths. These measurements will provide a deeper understanding of individual variations in gait and balance, which are particularly challenged on icy surfaces.

C. Number of Slips

The first participants’ data included 2334 steps. Of these, 542 were labelled as a 'slip' and 1406 were labelled as 'nonslip', and 386 as 'no data'. The 'no data' category was used when raters were unable to conclusively determine if there was a slip during a particular step.

D. Data Visualization

Figure 1 illustrates the percentage of slips, nonslips, and no data labels for the first participant. This visual representation provides insight into the slip occurrences and the robustness of the data collected.

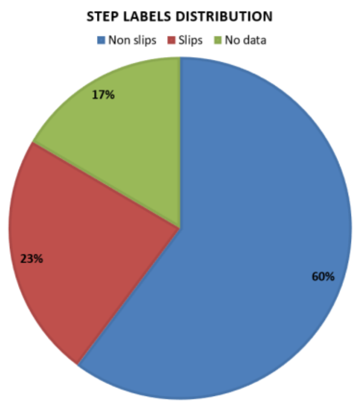

Fig. 1 Percentage of slips, nonslips, and no data for the first participant.

IV. Discussion

The preliminary analysis of the dataset has yielded significant insights into the frequency and distribution of slips among individuals traversing icy surfaces. The nearly balanced gender representation of the participants contributes to the study's generalizability. Given that we've collected detailed measurements of our participants' body structure, our study is well-equipped to explore how these individual physical differences might affect the likelihood and nature of slips on icy surfaces. Furthermore, future analyses should explore the relationships between body biometric variables and slip incidents to develop predictive models for slip likelihood.

The prevalence of slips, as indicated by the data, underscores the real-world implications of icy conditions on public safety. The high number of 'slip' labels compared to 'nonslip' within the dataset reflects the treacherous nature of these environments. Moreover, the 'no data' category points to the complexities involved in slip detection and the need for improved methodologies in data interpretation.

V. Conclusions

This study represents a step forward in understanding the biomechanics of walking on icy surfaces and the risk factors associated with slips. The demographic diversity and detailed biomechanical measurements provide a solid foundation for developing comprehensive models of slip risk.

These preliminary findings highlight the importance of continued research in this area. The insights from this study have the potential to inform the design of preventative measures, including the development of more effective slip-resistant footwear, slip detection systems, and the implementation of public safety interventions during icy conditions.

The completion of data processing and further analysis will likely offer even more nuanced understandings of the intricacies involved in slip incidents. This work not only contributes to academic knowledge but also has practical applications in improving winter safety and reducing the incidence of fall-related injuries.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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