Joint CSCE Construction Specialty & CRC Conference 2025
Conférence conjointe spécialisée en construction de la SCGC et CRC-2025

Montreal, Quebec
July 28-31, 2025 / *28-31 juillet 2025*

Biomechanical Analysis of Stability and Fall Risk in Novice Roofers Working on Sloped Surfaces: Investigating the Role of Center of Pressure

Sujan Acharya[1], Rujan Kayastha[1], Sabrin R Gautam[1], Tarek Mahumad[1], Ayush Pokharel[2], Krishna Kisi[1]

[1] Department of Engineering Technology, Texas State University, San Marcos, Texas, USA
[2] Department of Computer Science, Texas State University, San Marcos, Texas, USA

ABSTRACT:

This study investigates how foot zones, slope inclination, and standing posture influence Center of Pressure (CoP) displacement during simulated roofing tasks among novice roofers. Four participants performed static postures (facing upward, downward, left, right) and simulated falls on flat and sloped (30°) surfaces while wearing pressure-sensing insoles and Inertial Measurement Unit (IMU) motion sensors. Data from 12 repetitions per posture were analyzed using three-way Analysis of Variance (ANOVA). Results revealed significant effects of foot zones ($F = 4.08$, $p = 0.008$) and slope ($F = 5.31$, $p = 0.022$) on CoP displacement, while posture showed no statistical significance ($p = 0.315$). The midfoot (2.36 units displacement) and toe regions (3.2 units on slopes) exhibited the highest CoP movement during falls. On 30° slopes, average CoP displacement increased by 36% compared to flat surfaces ($p = 0.022$), with the toe region showing a 52% increase in instability. Interaction effects between slope and foot zones further highlighted heightened complexity in the midfoot and toe areas under inclined conditions. These findings challenge posture-centric fall-risk models, emphasizing localized foot mechanics as critical determinants of stability. The study suggests ergonomic footwear designs targeting midfoot/toe reinforcement and slope-specific safety protocols, such as limiting prolonged work on steep roofs. Future research should validate these findings with experienced roofers in field settings to improve generalizability. This work contributes biomechanical evidence for refining fall-prevention strategies in construction, prioritizing foot-zone dynamics over postural adjustments.

Keywords: Center of Pressure (CoP), Postural Stability, Roofing Safety, Foot Biomechanics, Sloped Surfaces

1. INTRODUCTION

1.1 Background

Construction work is both dangerous and labor-intensive in nature and has a very high incident rate of accidents resulting in deaths (Antwi-Afary et al. 2020). In United states, the construction industry is listed as one of the most dangerous with a worker being killed every 96 minutes from a job-related injury in the year 2022 (BLS, 2023). Elevation falls are also the most prevalent cause of death in this industry, accounting for one-third of all construction-related deaths (BLS, 2019). A number of physical risk factors, including unfavorable postures, working conditions, and environmental conditions, lead to these accidents (Kisi & Kayastha, 2024). Construction workers are also frequently exposed to biomechanical risk factors that are likely to lead to Work-Related Musculoskeletal Disorders (WMSDs) (Wang et al. 2024). These conditions touch on muscles, joints, and tendons and have a substantial impact on flexibility, coordination, and balance and therefore result in falls (Valero et al. 2016). Under extreme circumstances, WMSDs can result in permanent disability, resulting in lost working days, early retirement, and decreased productivity (Aumann & Galinsky, 2009; Phillips et al. 2008).

Among carpenters, masons, drywall installers, and roofers, the last three are particularly at risk for WMSDs according to job physical demands (Kisi & Kayastha, 2024). Roofers, for instance, repetitively expose themselves to awkward postures, heavy loads, and working on uneven surfaces, leading to repetition injuries and chronic musculoskeletal pain. Residential roofers spend over 75% of their work time on non-neutral postures such as crawling, squatting, and kneeling (Dutta et al. 2020). These repetitive movements on sloping surfaces are a significant cause of the high incidence of WMSDs among roofers (Breloff et al. 2019a; Wang et al. 2017). Kneeling postures, which are commonly adopted by roofers, have been identified as significant risk factors for knee disorders (Xu et al. 2017). It is important to understand the human postural balance control on inclined and elevated surfaces and thus to possibly introduce interventions to prevent and mitigate fall risk. In addition, Awkward postures reduce muscle efficiency, resulting in higher muscle activation and overload, hence raising the risk of injury (Kaushik & Charpe, 2008). Insufficient recovery time in these positions can lead to overexertion injuries or loss of balance (Hofer et al. 2011).

A stable posture occurs when the body's center of gravity (COG) remains within the base of support (BOS), which is defined by the area between the feet. Equilibrium in static stability is maintained when the vertical ground reaction force COP aligns with the COG within the BOS (Frames, 2013). Any deviation beyond this area may result in a compensatory step or loss of balance. Limits of Stability (LOS), also referred to as Functional Stability Limits (FSL), define the maximum distance an individual can shift their COG in any direction without stepping, grasping, or losing balance (Holbein & Redfern, 1997).

Postural control during work on sloped surfaces relies heavily on foot mechanics, with surface inclination playing a crucial role in stability maintenance. As slope angles increase, CoP movement also increases, presenting greater challenges to balance (Wu et al., 2018). Research suggests that CoP shifts forward when standing on inclined surfaces, and as the bevel angle grows, this effect becomes more pronounced (Wu et al., 2018). Similar findings highlight the impact of varying inclinations on muscle activation, particularly in the lower extremities, which can contribute to fatigue and injury risks (Madeleine et al., 2008; Menant et al., 2009). This study emphasizes the role of foot mechanics in postural stability and provides a basis for future studies investigating adaptive strategies for working on inclined surfaces.

1.2 Problem Statement

Wang et al. (2017) examined the effects of roof slope, working techniques, and pace on low back disorders and found significant associations. Similarly, Breloff et al. (2019b) investigated lower extremity kinematics in roofers walking on cross-slope surfaces, linking these movements to increased MSD risk. Additionally, Lee et al. (2017) explored the feasibility of wearable sensors for monitoring physiological responses such as heart rate and metabolic expenditure in roofers. While these studies contribute to understanding the risk, factors associated with roofing tasks, they largely focus on whole-body kinematics and muscle strain rather than CoP movement across specific foot zones under different postures.

Past research on CoP has mainly addressed postural stability in normal standing conditions (Stodółka et al. 2020; Wu et al. 2018). Teranishi et al. (2013) contrasted CoP trajectory for different standing postures but did not examine localized CoP movement between foot zones (e.g., left heel, right heel, midfoot, forefoot). This is significant as postural stability is not only determined by the overall CoP path but also by localized pressure distribution over foot areas. Dynamic loading studies have explored plantar pressure distribution before and after prolonged walking, and this has demonstrated trends towards greater heel loading and reduced toe function (Stolwijk et al. 2010; Fourchet et al. 2011). However, these studies do not accurately represent the static, yet strenuous postures adopted by construction workers, particularly roofers.

Although pressure and IMU sensors' data are individually established tools in biomechanics research, the methodological novelty of this study lies specifically in their data integration application with ANOVA. This integration uniquely enables detailed foot-region specific CoP analysis during simulated roofing tasks on sloped surfaces which is a scenario not extensively explored in previous ergonomics research. By providing localized insights into foot biomechanics under these controlled conditions, the study offers practical implications for targeted footwear design and fall prevention strategies.

This study aims to bridge the identified research gap by utilising wearable pressure-sensing insoles (e.g. Xsensor) to analyse CoP movement across specific foot zones for novice roofers performing simulated fall in various standing postures. For this study, 'novice roofers' are defined as individuals with no prior roofing experience (Wade & Davis, 2005) or with less than three months of work experience in roofing tasks. The research had the following hypothesis.

Null Hypothesis (H_0): There is no significant difference in the mean distance that the COP travels from its average position to the point of falling, regardless of the standing posture adopted or the foot zone involved.

Alternative Hypothesis (H_1): The mean distance that the COP travels from its average position to the point of falling varies significantly depending on the standing posture and foot zone.

2. METHODOLOGY

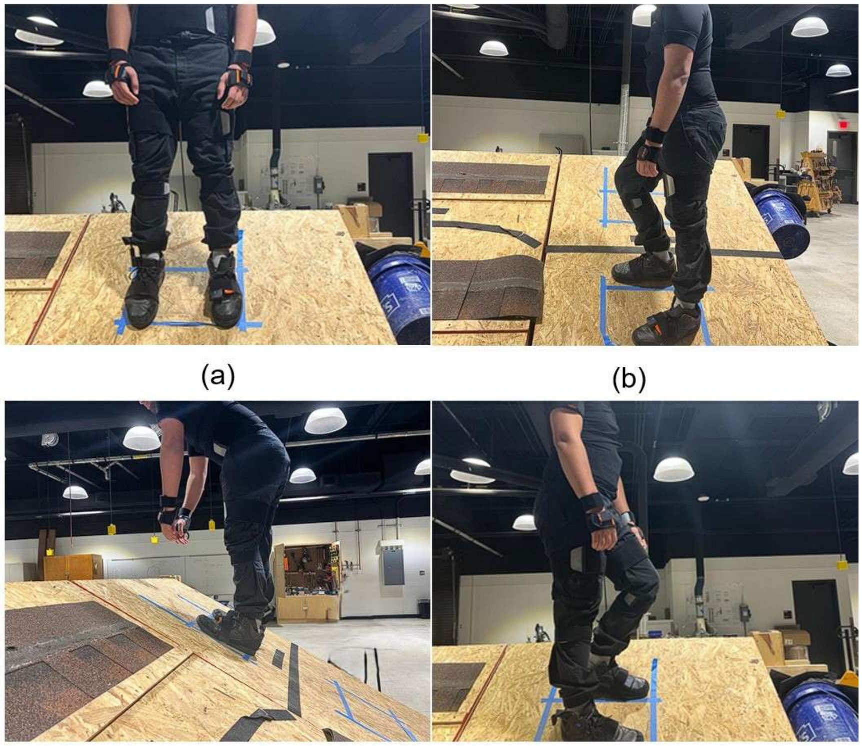
The research study was designed to collect plantar foot pressure data while monitoring the participants movement using IMU sensors. The participant was equipped with a suit and 17 Movella MVN IMU motion sensors. The participant was also equipped with XSens foot pressure sensors on both their feet to measure their foot pressure. The IMU sensors were calibrated using the MVN Analyze Pro software before data collection was started. The participants were given a brief about the experimental setting and activities to perform on flat surface and 30-degree sloped surface. Since this is a pilot study, the research team themselves volunteered as participants.

The participants were asked to perform standing posture on the flat surface and a 30-degree slope surface that simulates the roofing tasks. A 24in * 24in box was marked on the floor and 30-degree slope surface to ensure all participants had same distance between their feet. Four novice participants performed the activity on both the surface. The participants performed the posture Facing Downward (FD) (Fig. 1a), Facing Right (FR) (Fig. 1b), Facing Upward (FU) (Fig 1c) and Facing Left (FL) (Fig. 1d) on both the surfaces for 15 seconds while repeating the same posture 3 times. The participants repeated this session 4 times and were given 1-minute rest in between each session to eliminate the fatigue factor. After the participant performed standing posture, the participant was asked to simulate a fall on each direction.

The participant first performed standing posture on a flat surface, then the participant simulated fall on flat surface. They were asked to rest for 5-minutes before performing the standing posture on a 30-degree slope. Lastly, the participant was asked to simulate fall on a 30-degree sloped surface.

2.1 Data Analysis

The data analysis process began with exporting the raw data from the Xsensor Intelligent Insoles using the Xsensor Pro Foot and Gait software as shown in figure 2 into CSV format. The data was carefully segmented based on timestamps to separate the standing periods in each posture (FU, FL, FD, FR) from the simulated fall events.



(a) (b) (c) (d)

Figure 1: Participants performing posture (a) Facing Downwards (b) Facing Right (c) Facing Upward (d) Facing Left on a 30-degree slope.

For more detailed analysis, the data was sliced to isolate measurements from specific foot regions: left and right heel, midfoot, metatarsal, and toe areas. The same was performed for both standing and falling conditions across both the flat surface (0 degrees) and the 30-degree sloped surface. From the standing data, the mean CoP position was calculated from all 12 repetitions (4 sessions with 3 repetitions each) for each posture and slope condition. This provided a baseline measurement for comparison. The data from the sensors were given in terms of coordinates (CoP Column, CoP Row).

To precisely identify the fall events, MVN Analyze Pro software was used and the animation review to determine the exact timestamp when a participant's fall action occurred. A fall was defined as the moment when either foot lost contact with the ground as shown in figure 2(a)(b)(c)(d). Once these timestamps, they were matched with the corresponding Xsensor pressure data, accounting for its 75 Hz sampling frequency. The cumulative distance traveled by the CoP during only the simulated fall action was calculated and measured from the mean CoP position established during the standing trials. The distance calculated was measured in terms of how many units did the CoP coordinate moved during the fall action.
All data processing was performed using Python programming. The results for each participant were accumulated for each foot zone, each standing posture, and the respective falling action into a single Excel file for further analysis. The final statistical analysis consisted of two-way and three-way ANOVA tests. These tests used zone, posture, and slope as independent variables, with the CoP distance movement during falls as the dependent variable. This helped to determine which factors significantly affected stability during the simulated roofing tasks. The Xsensor Pro Foot and Gait software was utilized throughout the analysis for data extraction, initial processing, and visualization of the pressure patterns across different conditions.

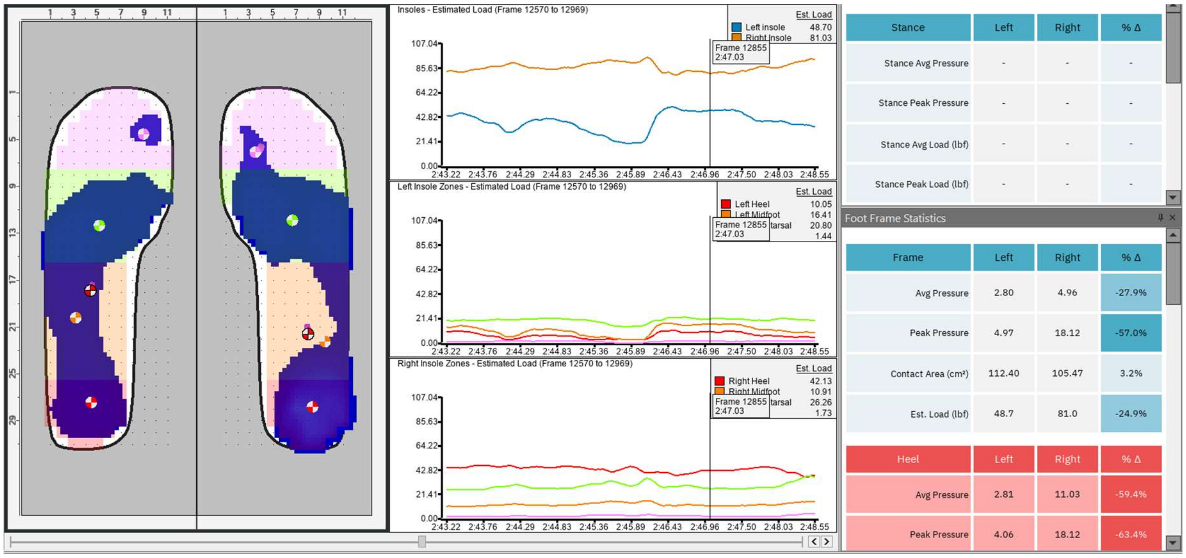


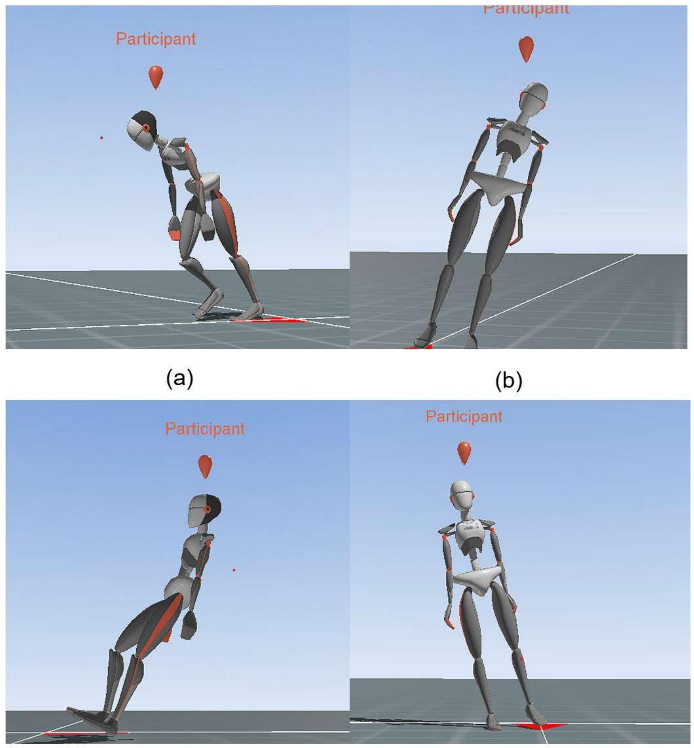
Figure 2: Screenshot of Xsensor Pro Foot and Gait Software

3. RESULTS AND DISCUSSION

This study examined how foot zones (heel, metatarsal, mid-foot and toe), slope (0 and 30-degree) and standing posture (FU, FD, FL and FR) affect the CoP movement during a simulated roofing standing posture. Data were analyzed separately for flat surface and 30-degree slope as well as in a combined dataset while taking their mean standing data from their respective posture and slope as the point of reference. Data was collected from four participants under both flat (0°) and 30° slope conditions, with 12 repetitions per standing posture for each slope. Due to technical issues, the dataset from one participant for the 30° condition was excluded from the analysis. This sample size of three and four for different slope is consistent with prior pilot studies where meaningful biomechanical insights were obtained even from a single participant (Seo et al., 2014) and where similar instances of data loss did not preclude robust analysis (Bennett et al., 2023).

Three way ANOVA of the dataset as the zone, slope and posture as the independent variable and the cumulative movement distance of the CoP in the action of fall revealed that the foot zone ($F=4.08$, $p=0.008$) and slope ($F=5.31$. $p=0.022$) have significant effect on the distance travelled by the CoP. Also, there was no significant effect of posture ($F=1.19$, $p=0.315$) and that the interaction between each of the variable had no significant effect on the CoP movement.

The figure 4 shows the main effect plot of the zone and slope on the CoP movement. From the plot it can be clearly seen that the midfoot (2.36 units) and toe(2.55 units) zones had significantly higher movements compared to that at heel (1.41 units) and metatarsal (1.22). Also, when the slope increased from 0 to 30, the movement of CoP also siginificnatly increased from an average of 1.6 units to 2.18 units.



(a) (b)

(c) (d)

Figure 3: Definition of 'Fall' action on different postures as see in MVN Analyze Pro (a) Facing down the slope (FD) (b) Facing left on the slope (FL) (c) Facing up the slope (FU) and (d) Facing right on the slope

When looking at flat surface only, midfoot (2.1 units) had significantly (p=0.038) higher movement compared to other zones as shown in figure 4.When moving to 30 degrees slope midfoot's movement increased to 2.51 units but the most significant zone shifted from midfoot to toe with an average movment of 3.2 units as shown in figure 5.

Table 1: Analysis of Variance of Posture, Zone and Slope in relation movement of CoP

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Posture	3	13.97	4.656	1.19	0.315
Zone	3	47.82	15.941	4.08	0.008
Slope	1	20.75	20.748	5.31	0.022
Posture*Zone	9	62.59	6.954	1.78	0.076
Posture*Slope	3	11.18	3.727	0.95	0.416
Zone*Slope	3	11.02	3.673	0.94	0.423
Posture*Zone*Slope	9	25.64	2.849	0.73	0.681
Error	156	609.19	3.905		
Total	187	803.69			

Moreover, when both the slope conditions were analyzed together, foot zone (F= 4.08, p=0.008) and the slope itself (F=5.31, p = 0.022) were significant predictors for movement of CoP as shown in Table 1. While the posture (F=1.19, p=0.315) and its interactions with slope (F= 0.95, p=0.416) and posture (F= 1.78, p= 0.076) were not significant enough. As shown in Table 1, participants exhibit larger displacement in CoP movement on 30-degree slope compare to flat surface. This demonstrates that the slope condition is a significant factor in influencing stability. Figure 3 strengthens the cause depicting the incline posing greater instability by portraying the average CoP displacement under both the slope conditions. The midfoot and toe region again has the highest CoP displacement compared to heel and metatarsal, emphasizing their contribution towards stability.

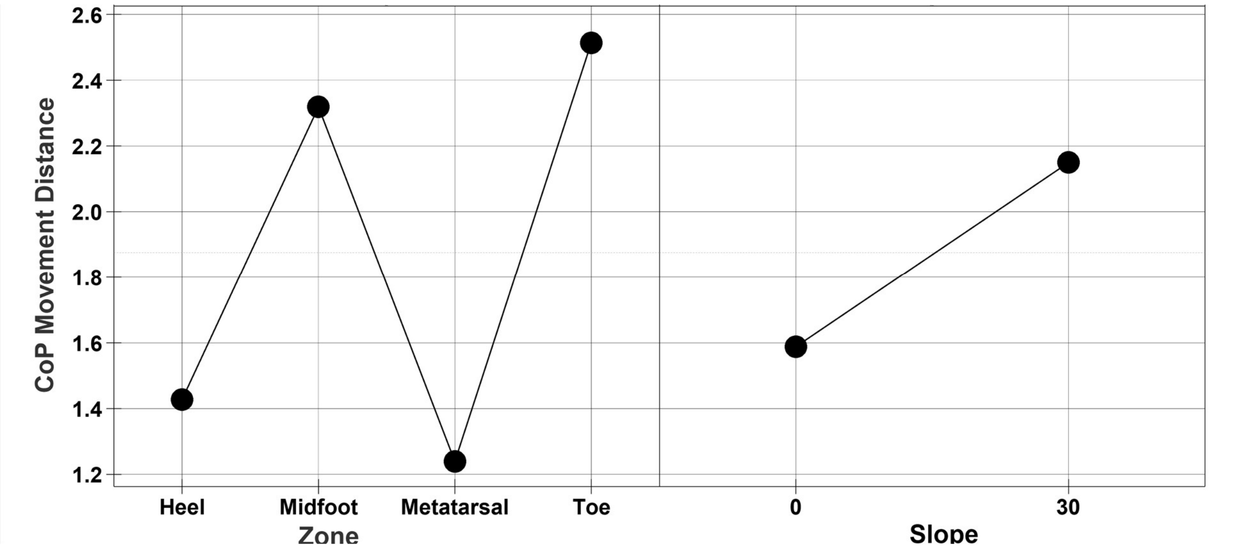


Figure 4: Main effect plot of Distance of Movement of CoP on both surfaces combined

CoP displacement—a measure of how far pressure shifts from a stable baseline—increased by 36% on steep slopes versus flat surfaces, indicating heightened instability This aligns with studies showing CoP motion amplifies with steeper slopes due to reduced functional stability boundaries (Dutt-Mazumder et al., 2016). Notably, body posture (leaning forward, sideways, etc.) had no significant effect on CoP dynamics, contradicting assumptions that posture adjustments alone mitigate fall risks (Matjačić et al., 2020). Instead, slope angle dominated instability patterns, mirroring findings where ankle mechanics and foot pressure distribution—not voluntary postural strategies—dictated balance recovery on inclined surfaces.

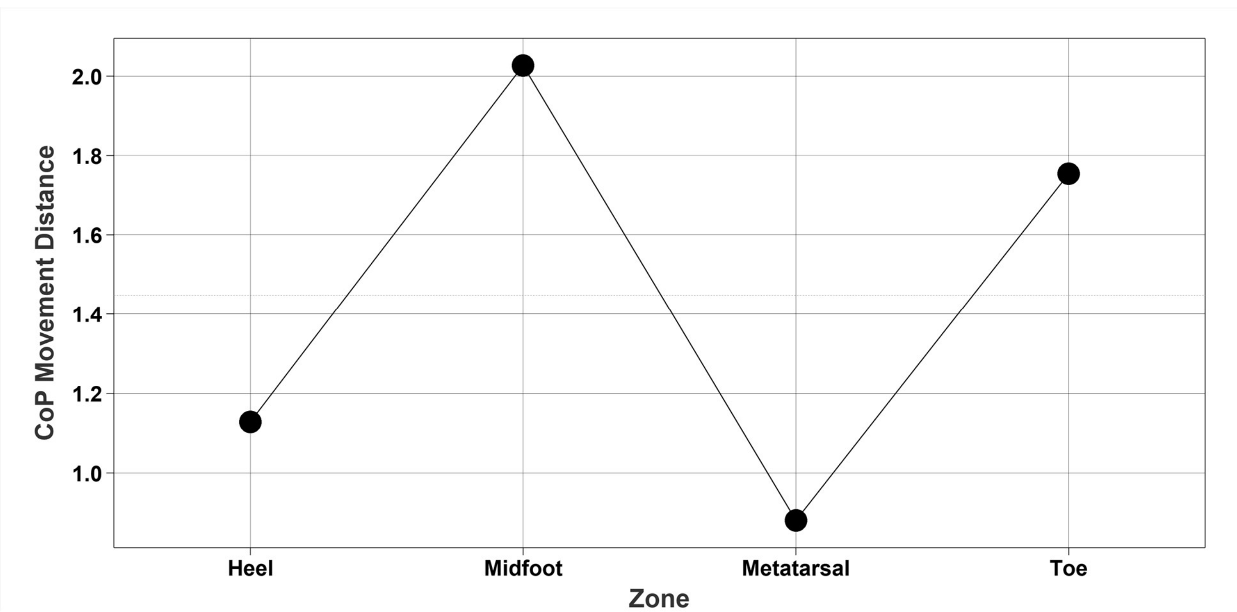


Figure 5 Main effect plot of Distance of Movement of CoP on Flat Surface

The study shows that roofers' balance depends most on midfoot and toe pressure shifts during slips, not body posture, with 30-degree slopes causing 36% higher instability than flat surfaces. This matches Wu et al. (2018), who found steeper slopes increase CoP movement due to gravity pulling weight forward. However, unlike Teranishi et al. (2013), posture adjustments (e.g., facing up/down) didn't reduce risks here, meaning safety rules focused on "safe postures" may miss the mark. Instead, interventions should target footwear redesign—like adding toe grips or arch supports—to mimic adaptations seen in experienced roofers, who showed smaller midfoot/toe CoP shifts (Breloff et al., 2019a).

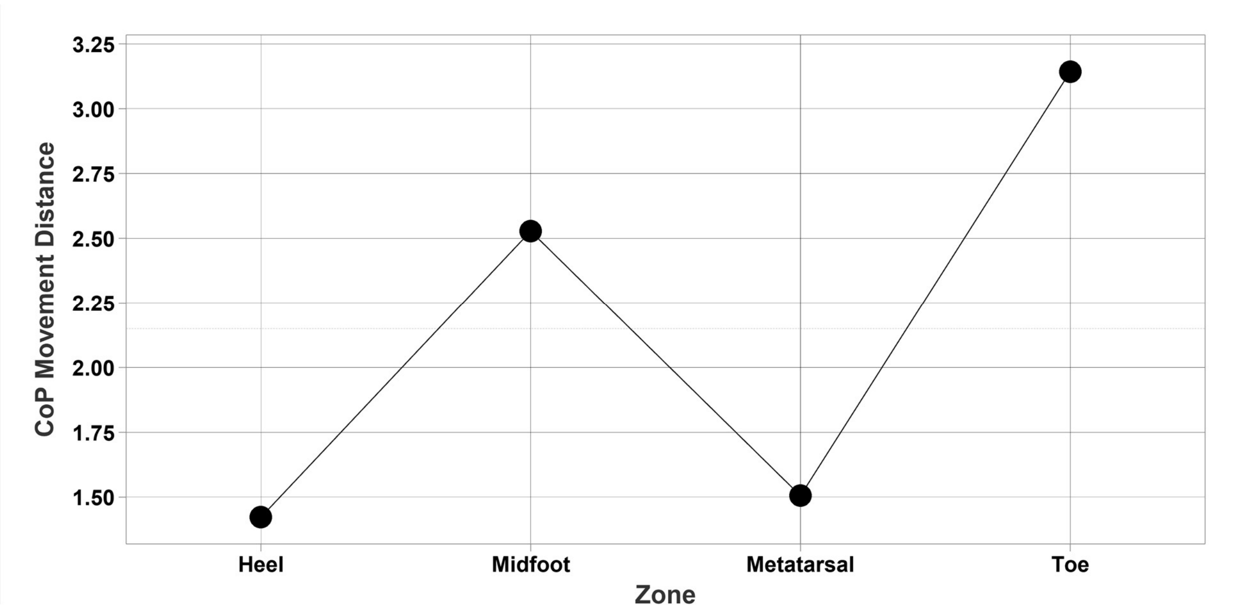


Figure 6: Main effect plot of Distance of Movement of CoP on 30-degree slope

4. CONCLUSION AND FUTURE STUDIES

The findings of this study emphasize the critical role of movement of CoP in different foot zones and slope in postural stability during roofing tasks for novice roofers. The toe and midfoot regions showed highest CoP movement, suggesting that these regions are most engaged in balance recovery and maintenance. Because foot zone was a consistent predictor of CoP displacement across all conditions, roofers can benefit from stability training that enhances control in these foot regions.

The 30-degree inclination caused more CoP movement than the flat surface, confirming that sloped surfaces put a higher risk of instability. The necessity for proper design of fall prevention methods specific to workers who perform tasks in sloped surface e.g., improved footwear incorporating improved grip and special training to improve balance recovery strategies is higher than in the general context. On the contrary, body orientation did not significantly influence movement of the CoP, meaning that foot mechanics and slope conditions are more relevant than body position in maintaining a stability. This finding suggests that prevention of falls training should focus more on foot placement and weight transfer than on postural adjustments.

To sum up, this study provides new evidence regarding posture control on sloped surfaces, and emphasizes the necessity of stricter safety measures, professional training programs, and ergonomic footwear to prevent fall risks for roofers. This research also opens the door for future studies and adding other variables like Base of support, Center of gravity and center of mass to determine the most relevant stable positions in dynamic scenarios. This research can be expanded by addition of more participants specially experienced roofers to understand the way the biomechanics of their postural stability.

5. LIMITATIONS

This pilot study has several notable limitations. First, only four participants were included, and due to technical issues, data from one participant was lost for the 30° slope condition limiting the effective analysis to three individuals. Consequently, the findings are preliminary, and a larger sample size would help to make the results more robust and generalizable. Second, the participants were not experienced roofers; they were from a similar demographic and exclusively right-foot dominant. As experienced roofers may have adapted balance strategies that result in distinct CoP patterns, this limitation may reduce the biomechanical validity of the findings. Third, the experiment was conducted in a controlled environment using only a 30° slope, which may not fully replicate the diversity and complexity of real-life roofing scenarios. Another limitation of this study is that falls were simulated in a controlled setting, which may not fully capture the dynamics of naturally occurring falls. Future research will aim to expand the sample size, recruit professional roofers, and investigate multiple slope conditions to obtain a more comprehensive understanding of CoP dynamics in real-world settings.

ACKNOWLEDGEMENT

The authors would like to acknowledge all the participants who participated in this study were volunteers. The authors would also like to acknowledge the use of ChatGPT-4.0 and Grammarly in language assistance and checking grammar of this paper. ChatGPT-4.0 was also used for coding assistance for data analysis.

REFERENCES

Aumann, K., & Galinsky, E. (2009). The state of health in the American workforce: Does having an effective workplace matter. New York, NY: Families and Work Institute.Bennett, S. T., Han, W., Mahmud, D., Adamczyk, P. G., Dai, F., Wehner, M., Veeramani, D., & Zhu, Z. (2023). *Usability and biomechanical testing of passive exoskeletons for construction workers: A field-based pilot study.* Buildings, 13(3), 822.

BLS (Bureau of Labor Statistics). (2019). Census of Fatal Occupational Injuries: Table 1. Fatal Occupational Injuries by Event or Exposure, All United States. Available online: https://www.bls.gov/news.release/pdf/cfoi.pdf (accessed on 10 January 2025).

BLS (Bureau of Labor Statistics). (2023). National Census of Fatal Occupational Injuries in 2022. Available online: https://www.bls.gov/news.release/pdf/cfoi.pdf (accessed on 6 January 2025).

Breloff, S. P., Dutta, A., Dai, F., Sinsel, E. W., Warren, C. M., Ning, X., & Wu, J. Z. (2019). Assessing work-related risk factors for musculoskeletal knee disorders in construction roofing tasks. Applied Ergonomics, 81, 102901.

Breloff, T., Knapik, G. G., & Marras, W. S. (2019a). Knee musculoskeletal disorders and roof slope: Risk factors in sloped kneeling work. Applied Ergonomics, 82, 102948.

Dulay, M. (2015). Biomechanical analysis of residential roofing tasks: The impact of roof slope. International Journal of Occupational Safety and Ergonomics, 21(3), 307-315.

Dutt-Mazumder, A., Slobounov, S. M., Challis, J. H., & Newell, K. M. (2016). Postural Stability Margins as a Function of Support Surface Slopes. PloS one, 11(10), e0164913. https://doi.org/10.1371/journal.pone.0164913

Dutta, A., Breloff, S. P., Dai, F., Sinsel, E. W., Warren, C. M., Carey, R. E., & Wu, J. Z. (2020). Effects of working posture and roof slope on activation of lower limb muscles during shingle installation. Ergonomics, 63(9), 1182-1193.

Fourchet, F., Horobeanu, C., Loepelt, H., Taiar, R., & Millet, G. P. (2011). The effects of fatigue on plantar pressure distribution in walking. Gait & Posture, 33(3), 437–439.

Frames, C., Soangra, R., & Lockhart, T. E. (2013). Assessment of postural stability using inertial measurement unit on inclined surfaces in healthy adults. Biomedical sciences instrumentation, 49, 234

Hofer, J.K., R. Gejo, M.H. Mcgarry, and T.Q. Lee. (2011). “Effects on Tibiofemoral Biomechanics from Kneeling.” Clinical Biomechanics, 26(6), 605–611. http://doi.org/10.1016/j.clinbiomech.2011.01.016.

Holbein, M. A., & Redfern, M. S. (1997). Functional stability limits while holding loads in various positions. International journal of industrial ergonomics, 19(5), 387–395. https://doi.org/10.1016/s0169-

8141(96)00023-6
Kaushik, V., & Charpe, N. A. (2008). Effect of body posture on stress experienced by worker. Studies on Home and Community Science, 2(1), 1-5.
Kayastha, R., & Kisi, K. (2024). Assessing Factors Affecting Fall Accidents among Hispanic Construction Workers: Integrating Safety Insights into BIM for Enhanced Life Cycle Management. Buildings, 14(9), 3017.
Kisi, K. P., & Kayastha, R. (2024). Analysis of musculoskeletal pains and productivity impacts among Hispanic construction workers. Heliyon, 10(1).
Lee, W., Lin, K. Y., Seto, E., & Migliaccio, G. C. (2017). Wearable sensors for monitoring on-duty and off-duty worker physiological status and activities in construction. Automation in Construction, 83, 341-353.
Matjačić, Z., Zadravec, M., & Olenšek, A. (2020). Biomechanics of in-stance balancing responses following outward-directed perturbation to the pelvis during very slow treadmill walking show complex and well-orchestrated reaction of central nervous system. Frontiers in Bioengineering and Biotechnology, 8, 884. https://doi.org/10.3389/fbioe.2020.00884
Menant, J. C., Steele, J. R., Menz, H. B., Munro, B. J., & Lord, S. R. (2009). Effects of walking surfaces and footwear on temporo-spatial gait parameters in young and older people. Gait & posture, 29(3), 392–397. https://doi.org/10.1016/j.gaitpost.2008.10.057
Phillips, C., Main, C., Buck, R., Aylward, M., Wynne-Jones, G., & Farr, A. (2008). Prioritising pain in policy making: the need for a whole systems perspective. Health Policy, 88(2-3), 166-175.
Seo, J., Starbuck, R., Han, S., Lee, S., & Armstrong, T. J. (2014). *Dynamic biomechanical analysis for construction tasks using motion data from vision-based motion capture approaches.* Computing in Civil and Building Engineering. ASCE.Stodółka, J., Blach, W., Vodicar, J., & Maćkała, K. (2020). The characteristics of feet center of pressure trajectory during quiet standing. Applied Sciences, 10(8), 2940.
Stolwijk, N. M., Duysens, J., Louwerens, J. W., & Keijsers, N. L. (2010). Plantar pressure changes after long-distance walking. Medicine and Science in Sports and Exercise, 42(12), 2264–2272.
Teranishi, T., Sakurai, H., Ohtsuka, K., Yamada, M., Tsuzuki, A., Miyasaka, H., & Kondo, I. (2013). Relationship between feet position and anterior-posterior center of pressure (COP) location. Journal of Physical Therapy Science, 25(1), 41-43.
Valero, E.; Sivanathan, A.; Bosché, F.; Abdel-Wahab, M. (2016). Musculoskeletal disorders in construction: A review and a novel system for activity tracking with body area network. Applied Ergonomics, 54, 120–130.
Wade, C., & Davis, J. (2005). Experience on an elevated inclined surface and postural control. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 49*(1), 1311–1314. https://doi.org/10.1177/154193120504901410
Wang, D., Dai, F., Ning, X., Dong, R. G., & Wu, J. Z. (2017). Assessing work-related risk factors on low back disorders among roofing workers. Journal of Construction Engineering and Management, 143(7), 04017026.
Wang, D., Dai, F., Ning, X., Dong, R. G., & Wu, J. Z. (2017). Assessing work-related risk factors on low back disorders among roofing workers. Journal of Construction Engineering and Management, 143(7), 04017026.
Wang, K., Zeng, X., Li, J., Guo, Y., & Wang, Z. (2024). The prevalence and risk factors of work-related musculoskeletal disorders among nurses in China: A systematic review and meta-analysis. International Journal of Nursing Studies, 104826.
Wu, L., Luo, W., Zhang, Q., & Xiong, C. (2018, July). A Study of Static Standing Balance Control based on Center of Pressure. In 2018 3rd International Conference on Advanced Robotics and Mechatronics (ICARM) (pp. 431-436). IEEE.
Xu, H., Jampala, S., Bloswick, D., Zhao, J., & Merryweather, A. (2017). Evaluation of knee joint forces during kneeling work with different kneepads. Applied Ergonomics, 58, 308-313.