Phase Level Assessment of Ergonomic Intervention Effectiveness in Reducing Knee Musculoskeletal Disorder Risks during Residential Roof Shingle Installation

***** Dataset *****

Introductory Information

The prevalence of knee musculoskeletal disorders (MSDs) among roofers due to ergonomically unfavorable kneeling postures during shingle installation is a well-recognized concern. While knee-saving interventions like knee savers (KSs) and knee pads (KPs) have shown potential to reduce MSD risks, their effectiveness across different phases of shingle installation remains unknown. The objective of this study is to assess how interventions of KSs and KPs alleviate risks of MSDs in the knees during various phases of shingle installation. These phases encompass (1) reaching for shingles, (2) placing shingles, (3) grabbing a nail gun, (4) moving to the first nailing position, (5) nailing shingles, (6) replacing the nail gun, and (7) returning to an upright position. To collect data, nine male participants simulated the shingle installation task on a slope-adjustable roof platform (0°, 15°, and 30° slopes) under four intervention conditions: no intervention (NO), with KPs only (KP), with KSs only (KS), and with both KPs and KSs (BO) in a laboratory setting. Knee parameters including maximum flexion, abduction, adduction, and internal/external rotations were measured at all phases to assess intervention impacts through statistical analysis.

Methods Collection

- Overview:
  - Knee joint rotation data (kinematics) were collected by conducting experiments involving human subjects.
  - The research protocol was approved by the Institutional Review Boards (IRB) of the National Institute for Occupational Safety and Health (NIOSH).
- Instruments:
  - The knee kinematic data (segment endpoint data from motion capture system) were collected using a VICON optical motion capture system with 14 MX Vicon cameras.
  - 42 retroreflective motion capture markers were placed bilaterally on the participant's hip joints, thighs, knee joints, shanks, ankles, toes, heels, and feet.

- A 1.2 ×1.6 m custom-made adjustable wood platform was used to mimic the residential roof surface for shingle installation. The slope of the roof platform can be adjusted from 0º to 30°.
- A pair of generic off-the-shelf knee pads and a pair of knee savers were used as interventions during the test to assess their impacts.
- A pneumatic nail gun weighing 2.5 kg was used by the participants to simulate the roof shingle installation in the experiments.
- Shingles with a dimension of 0.91×0.30 (m) and a weight of 1.1 kg per piece were used in the experiments.

- Procedure:
  - The experiment was conducted in the biomechanics laboratory at the National Institute for Occupational Safety and Health (NIOSH).
  - Participants were requested to perform simulated shingle installation tasks on the roof simulator.
  - Each participant completed the simulated shingle installation task on the roof simulator at three different slope angles—0°, 15°, and 30° under four different intervention conditions—no wearable assist device (NO), knee pads only (KP), knee savers only (KS), and both knee pads and knee savers (BO), leading to 12 combinations. For each combination, five trials were recorded.
- Data Processing:
  - By using the coordinates of the recorded markers, five knee rotations were obtained.
  - From these data points, the maximum of five knee rotations (flexion, abduction, adduction, internal rotation, and external rotation) for each phase were computed for both left and right knees on each roof slope under each intervention condition.
  - The calculated five maximum knee joint rotation angles, the roof slope, and the intervention conditions were used for phase-level assessment.

Citations

1. S.P. Breloff, A. Dutta, F. Dai, E.W. Sinsel, C.M. Warren, X. Ning, J.Z. Wu, Assessing work-related risk factors for musculoskeletal knee disorders in construction roofing tasks, Applied Ergonomics 81 (2019). https://doi.org/10.1016/j.apergo.2019.102901.
2. S.P. Breloff, E. W. Sinsel, A. Dutta, R. E. Carey, C. M. Warren, F. Dai, S. Ning, and J. Z. Wu, Are knee savers and knee pads a viable intervention to reduce lower extremity musculoskeletal

disorder risk in residential roofers? International Journal of Industrial Ergonomics 74 (2019). https://doi.org/10.1016/j.ergon.2019.102868.

3. Zerin N, Breloff SP, Dai F, Carey RE, Warren CM, Moore KD, Hawke AL, Sinsel EW, and Wu JZ. Phase Level Assessment of Ergonomic Intervention Effectiveness in Reducing Knee Musculoskeletal Disorder Risks during Residential Roof Shingle Installation. American Journal of Industrial Medicine. 2025 1-13. In Press. https://doi.org/10.1002/ajim.23701

Acknowledgements

This research was funded by the National Occupational Research Agenda (NORA) Construction Sector of the National Institute for Occupational Safety and Health, project number 939051J. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC). Mention of any company or product does not constitute endorsement by NIOSH/CDC.

Authors

Nazia Zerin (nz00006@mix.wvu.edu)

Scott P. Breloff (lqz0@cdc.gov)

Fei Dai (fei.dai@mail.wvu.edu)

Robert E. Carey (ohn7@cdc.gov)

Christopher M. Warren (cpw4@cdc.gov)

Kevin D. Moore (qcp5@cdc.gov)

Ashley L. Hawke (ptt3@cdc.gov)

Erik Sinsel (eur2@cdc.gov)

John Z. Wu (ozw8@cdc.gov)

Contact

Physical Effects Research Branch (PERB), Health Effects Laboratory Division (HELD), National Institute for Occupational Safety and Health, 1095 Willowdale Rd., Morgantown, WV 26505