2. Materials and Methods

2.1 Participants

Seven healthy males (age: 24.3 ± 7.7 yrs, height: 1.81 ± 0.07 m, weight: 91.5 ± 10.0 kg) with no prior roofing experience participated in this study. Healthy was defined as no musculoskeletal injuries, neurological disorders, or visual impairments that could not be corrected by lenses. The National Institute for Occupational Safety and Health's (NIOSH) Institutional Review Board (IRB) reviewed and approved the study protocol and subjects read and completed informed consent prior to data collection.

2.2 Experimental Set-up & Procedures

Participants came to the NIOSH biomechanics laboratory, where anthropometrics were recorded, and 46 retro-reflective motion capture markers (9mm) were placed on the pelvis and lower extremities. The data in this study is a subset of a larger study, eighteen of the aforementioned 46 markers were used in this investigation (Figure 1 and 2). Marker trajectories were collected using 14 MX Vicon cameras (Vicon Inc., Oxford, England), sampling at a rate of 100 Hz.

Data were collected on a 1.2 x 1.6 m custom-handmade roofing simulator, which could be adjusted to no pitch (0°) or a 15° pitch (Breloff et al., 2020; Breloff et al., 2019). Subjects were asked to mimic the installation of three roof shingles in two conditions: 1) a conventional bent over standing posture with no roof pitch (0°) and 2) a kneeling posture with a 15° roof pitch (Breloff et al., 2019). The installation of the roof shingles followed the procedure form Breloff (2019) and Dutta (2020). Three trials were recorded for each condition. Ample rest was given between trials to avoid muscle fatigue and viscoelastic creep.

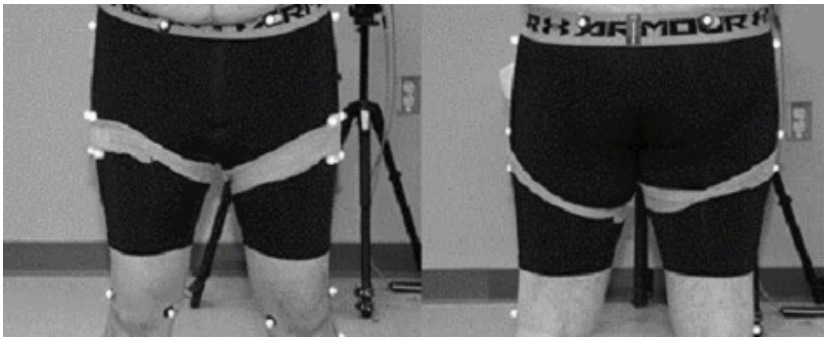
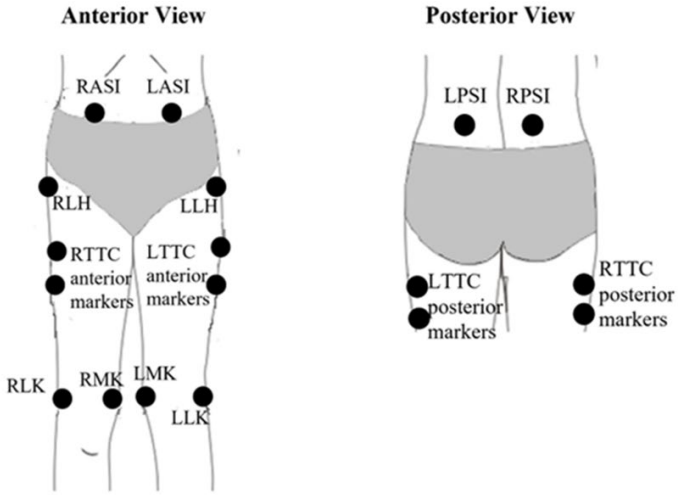
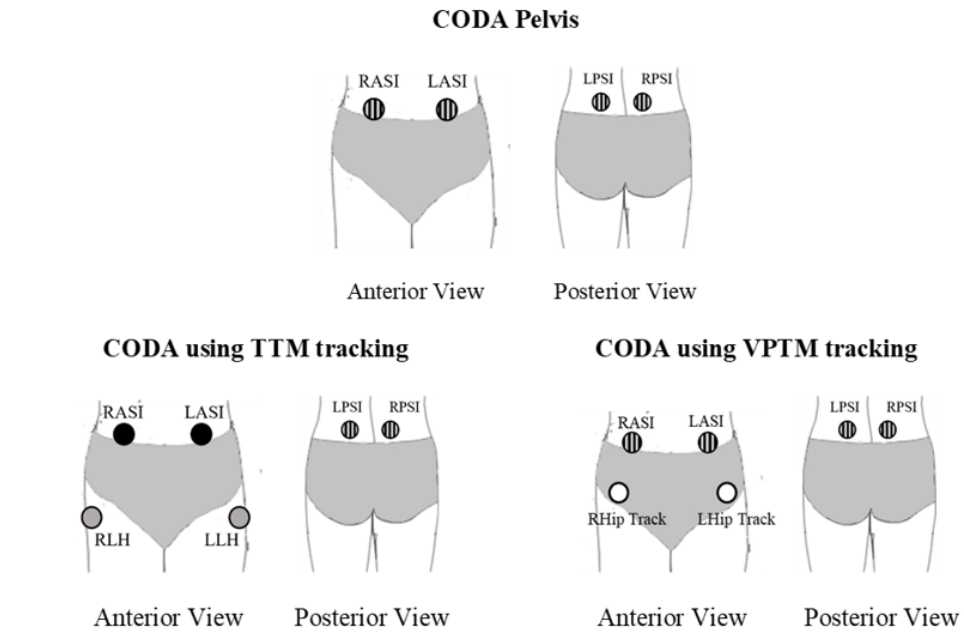


Fig. 1. Marker set, consisting of 18 retroreflective markers, applied to subject's pelvis and lower extremities.



Abbreviation	Description
R/LASI	Right / left anterior superior iliac spine
R/LPSI	Right / left posterior superior iliac spine
R/LLH	Right / left trochanter
R/LTTC	Right / left thigh four marker cluster (tracking)
R/LLK	Right / left lateral epicondyle (femur)
R/LMK	Right / left medial epicondyle (femur)

Fig. 2. Placement of the 18 markers located on the pelvis and thigh that were used to create segments and compute joint kinematics.



Marker	Marker Type
●	Anatomical
●	Tracking
●	Anatomical and Tracking
○	Virtual Tracking

Abbreviation	Description
R/LASI	Right / left anterior superior iliac spine
R/LPSI	Right / left posterior superior iliac spine
R/LLH	Right / left trochanter
R/LHip Track	Right / left virtual tracking marker created for VPTM

Fig. 3. The CODA pelvis maker set used for anatomical purposes and the TTM and VPTM tracking marker configurations applied to the CODA pelvis.

2.3.4 Hip Kinematics

The right and left hip joint angles were calculated using the pelvis as the reference and the right and left thigh segments as the parent, respectively. All joint angle rotations were computed as three-dimensional Euler angles and an X-Y-Z Cardan sequence. All thigh segment and hip

computations were identical for the TTM and VPTM configurations to prevent any kinematic differences from arising that were not related to the tracking configurations themselves.

References

Breloff, S.P., Carey, R.C., Dutta, A., Sinsel, E.W., Warren, C. M., Dai, F., Wu, J.Z., 2020. Kneeling trunk kinematics during simulated sloped roof shingle installation. International Journal of Industrial Ergonomics, 77, 102945.

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Dutta, A., Breloff, S. P., Dai, F., Sinsel, E. W., Warren, C. M., Wu, J. Z., 2020. Identifying Potentially Risky Phases Leading to Knee Musculoskeletal Disorders during Shingle Installation Operations. Journal of Construction Engineering and Management, 146(3), 04019118.