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Are knee savers and knee pads a viable intervention to reduce lower extremity musculoskeletal disorder risk in residential roofers?

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ABSTRACT

One factor commonly associated with musculoskeletal disorder risk is extreme postures. To lessen this risk, extreme postures should be reduced using proactive and prevention-focused methods. The effect of combinations of two interventions, knee pads and knee savers, on lower extremity kinematics during deep or near full flexion kneeling on differently sloped surfaces was analyzed. Nine male subjects were requested to keep a typical resting posture while kneeling on a sloped roofing simulator with and without knee pads and knee savers. Three-dimensional peak knee kinematics were recording using a motion capture system. The kinematic data were analyzed with a two-way—4(intervention) X 3(slope)—repeated measure analysis of variance (ANOVA). It was observed that knee pads did not alter lower extremity kinematics in a way that may reduce musculoskeletal injury risk, but they do provide comfort. Knee savers did statistically significantly reduce peak lower extremity kinematics, however these changes were small and it is uncertain if the changes will reduce musculoskeletal injury risk. This study has provided initial data that supports the use of knee savers as a potential intervention to reduce musculoskeletal disorder risk due to lower extremity joint angles on a sloped surface, nonetheless, further testing involving other musculoskeletal disorder risk factors is needed prior to a conclusive recommendation.

1. Introduction

Musculoskeletal disorders (MSD) are a major problem in the construction sector and roofers have the fourth highest incident rate of work-related MSD among occupations in the all construction sector (BLS, 2017). Although many different factors contribute to MSD risk, awkward postures are generally accepted as a major contributor to the development of MSD among construction workers (Council, 2001). This is most likely due to the unique work environment (sloped rooftops), and roofers can potentially spend more than 75% of their working time either in crawling, squatting, stooping, or kneeling postures (Wang et al., 2015, 2017). As one common factor associated with MSD risk is extreme posture, it is advantageous to look for simple and helpful interventions that may alleviate some of the awkward postures encountered by roofers during their work day on a sloped surface.

Due to the nature of affixing coverings—shingles/tar paper/tiles/etc.—roofers are often required to be in awkward kneeling and stooping postures. Therefore, most MSD that are reported by roofers tend to be located in the lower back and lower extremities (Holmström and Engholm, 2003). The cumulative effects of these awkward postures, combined with repetitive motions, may not only lead to low back pain, but also can increase the musculoskeletal loading in the lower extremities; factors leading to the initiation and acceleration of osteoarthritis (Wang et al., 2015, 2017). When roofers are burdened with MSD, roof workers may face work limitations, missed work, and/or reduced physical functioning, leading to premature departure from the workforce (Welch et al., 2008, 2009, 2010). Musculoskeletal disorders among roofers have been far from adequately studied, partially due to the lack of available technologies required for the measurement and evaluation of MSD risk factors at the job site. While it might be difficult to change the nature of the roofing task, experimenting with interventions that already claim to lessen MSD risk on level surfaces and determine how

Abbreviations: NO, No intervention; KP, Knee Pads; KS, Knee Savers; BO, Both interventions; MSD, Musculoskeletal disorders.

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they elicit a biomechanical change on a sloped surface is an excellent place to start. While numerous studies and protective wearable interventions exist to reduce musculoskeletal injury risk for construction workers, very few, if any, exist specifically for roofers.

Roofers spend most of their time in a kneeling posture while affixing a roof covering. Kneeling is an extreme posture that can increase the likelihood of developing an MSD—such as knee-joint inflammation, bursitis, and osteoarthritis (Manninen et al., 2002; Myllymäki et al., 1993; Pollard et al., 2011; Sharrard, 1963)—and has been connected with discomfort in the knee represented by numbness and tingling in the lower legs (Chung et al., 2005; Reid et al., 2010). While kneeling has been extensively studied following arthroplasty (Abo-Alhol et al., 2014; Barnes et al., 2011; Hanson et al., 2007; Lee, 2014; Moynihan et al., 2010) and it is common in other work environments such as mining, plumbing, carpentry, electrical work, floor and carpet laying (Gallagher et al., 2009; Jensen et al., 2010; Tennant et al., 2015), no information could be found regarding the effects of kneeling on a sloped surface. That said, some of the existing guidelines suggest using mechanical devices during roofing and knee pads while kneeling (Spielholz et al., 2006).

There are two wearable devices tested in this study—knee pads (KP) and knee savers (KS). Knee pads are commonly used by several different construction occupations that require kneeling during the working task while KS are not. There are many different styles of KP (Pollard et al., 2011; Porter et al., 2010; Xu et al., 2017) and the KP design can modify the knee joint forces (Xu et al., 2017). These wearable devices do influence knee flexion (Pollard et al., 2011) and decrease pressure at the patellar tendon and tibial tubercle (Porter et al., 2010) when working on level surfaces.

Knee savers are devices that are placed on the posterior aspect of the shank and contacts the posterior aspect of the thigh during deep-flexion squatting. The device was primarily developed as an ergonomic aid to lessen the knee injury risk during deep flexion of the knee and has been extensively used by catchers in baseball and softball (Stone et al., 2017). Most of the knee saver studies included female athletes and did not find any significant change in lower extremity sagittal plane knee kinematics with and without the intervention (Stone et al., 2014, 2014b, 2017). A study comparing deep and shallow flexion of baseball catchers demonstrated that the use of KS decreases knee flexion in deep flexing catchers, albeit not statistically significantly (Gray et al., 2015). On the surface, it might seem KS would not be a beneficial intervention for any work place which includes a task that requires kneeling. There are several factors to consider; first, catchers do not kneel, they squat, so the use of KS during deep or near full kneeling could decrease large extreme knee kinematics. Second, all tests were conducted on a level surface, therefore, when on a sloped surface, the KS may engage with the posterior aspect of the thigh more readily than on a level surface.

Based on data examining the effectiveness of KP and KS, it is completely unknown if the benefits of these devices while on a level surface will translate onto a sloped working environment. It is nearly impossible to create a 'golden' solution to the MSD issue because MSD are dependent on the response of the individual worker—physical and psychological—to the demands of the job. Nevertheless, there is strong evidence that all occupational musculoskeletal injuries are biomechanical in nature (Kumar, 2001). Consequently, concerted efforts to identify the specific factors contributing to the development of an MSD in different jobs and work environments are needed. To that end, the purpose of this study was to determine if a knee pads and/or knee savers are able to reduce knee MSD risk in a roofing environment. This will be done by measuring the joint kinematics of individuals without intervention, and with the aid of KP, KS or both during a roofing task on a sloped surface. It is hypothesized the addition of wearable devices will alter resting kneeling kinematics in individuals on a sloped surface.

2. Methods

Subjects were asked to adopt an upright resting posture at three different pitches of a roofing simulator. This posture was selected to ensure the knee saver was in contact with the posterior aspect of the thigh. Nine young male subjects (height: 180.6 ± 6.1 cm, weight: 99.7 ± 27.6 kg, age: 26.1 ± 5.6 years) with no roofing experience participated in the study. All subjects were healthy adult males, as 97% of roofers are male. Post-hoc power analysis (G*Power, Franz Faul, Germany) on all the outcomes and the results ranges from 1.0 (ankle flexion) to 0.125 (ankle abduction). Subjects did not have diagnosed musculoskeletal or neurological disorders—such as stroke or head trauma, Parkinson's disease, diabetic neuropathy, dementia, or visual impairment uncorrectable by lenses—which would influence the outcome of the study. The protocol was approved by the National Institute for Occupational Safety and Health's (NIOSH) Institutional Review Board (IRB) and subjects read and completed informed consent.

Subjects came to the NIOSH biomechanics laboratory for one testing day and were outfitted with eighty-two 9 mm diameter retro-reflective motion capture markers (Fig. 1). Kinematic data were collected using 14 MX Vicon cameras (Vicon Inc., Oxford, England) at a sample rate of 100 Hz. Trajectory data were filtered in Visual 3D (C-Motion, Germantown, Maryland), using a 4th order Butterworth filter with a 6 Hz cut off. The marker set has six degrees of freedom and uses tracking markers located away from joints combined with a static joint calibration to provide full 3D tracking of body segments. The use of tracking markers located away from joints increases marker visibility and decreases marker detachment during dynamic activities. Kinematics were calculated with the local coordinate system of one segment oriented relative to the local coordinate system of a second segment and the joint angles are represented as the relative orientation between the two segments (Robertson et al., 2013). Though full body kinematics were collected, only lower extremity data are presented in the current study.

As there is no standard recommended procedure for body position when installing shingles on a sloped surface, the researchers chose a kneeling posture. All data were collected while the subjects were in a deep or full flexion static upright kneeling posture on a roof simulator (Fig. 2). This posture was selected because it allowed interaction of the posterior shank and thigh with the KS. This is a 'resting posture' roofers might assume when not installing shingles. In an active working posture, the knee flexion decreased and the thigh did not contact the shank.

The roof simulator could be locked into three different (0°, 15°, and 30°) angles (Fig. 3). These three angles were selected as a baseline (0°), a shallow sloped roof surface (15°) and a steep, but walkable sloped roof surface (30°). Two different wearable devices were tested to determine their effectiveness in reduction MSD risk on a sloped roof surface—knee pads and knee savers (Fig. 4). Subjects were outfitted per manufactures recommendations with four different combinations of wearable devices—no wearable assist device (NO), knee pads only (KP), knee savers only (KS), and both knee pads and knee savers (BO), (Fig. 5). Along with the three different slopes from the roof simulator, subjects were tested in 12 different combinations. The order of the devices and slope were randomized.

Data were collected after the subject was set in the deep-kneeling posture. Five trials of 5 s in each of the 12 configurations were collected to determine how the wearable devices influenced kneeling kinematics while on a roof surface. Subjects were allowed no acclimation time on the sloped surface, and kinematic data were collected immediately after the subjects were comfortable in the kneeling posture. This was done to capture the kinematic change that occurs when individuals are first introduced to the various wearables. Subjects were given several rest breaks throughout the testing protocol. In between trials, subjects were able to relax after data were collected and the subjects indicated to the researchers when they were ready to assume the testing posture once again. On average, the subjects waited 15–20 s between trials. In between conditions—slope or wearable—the amount

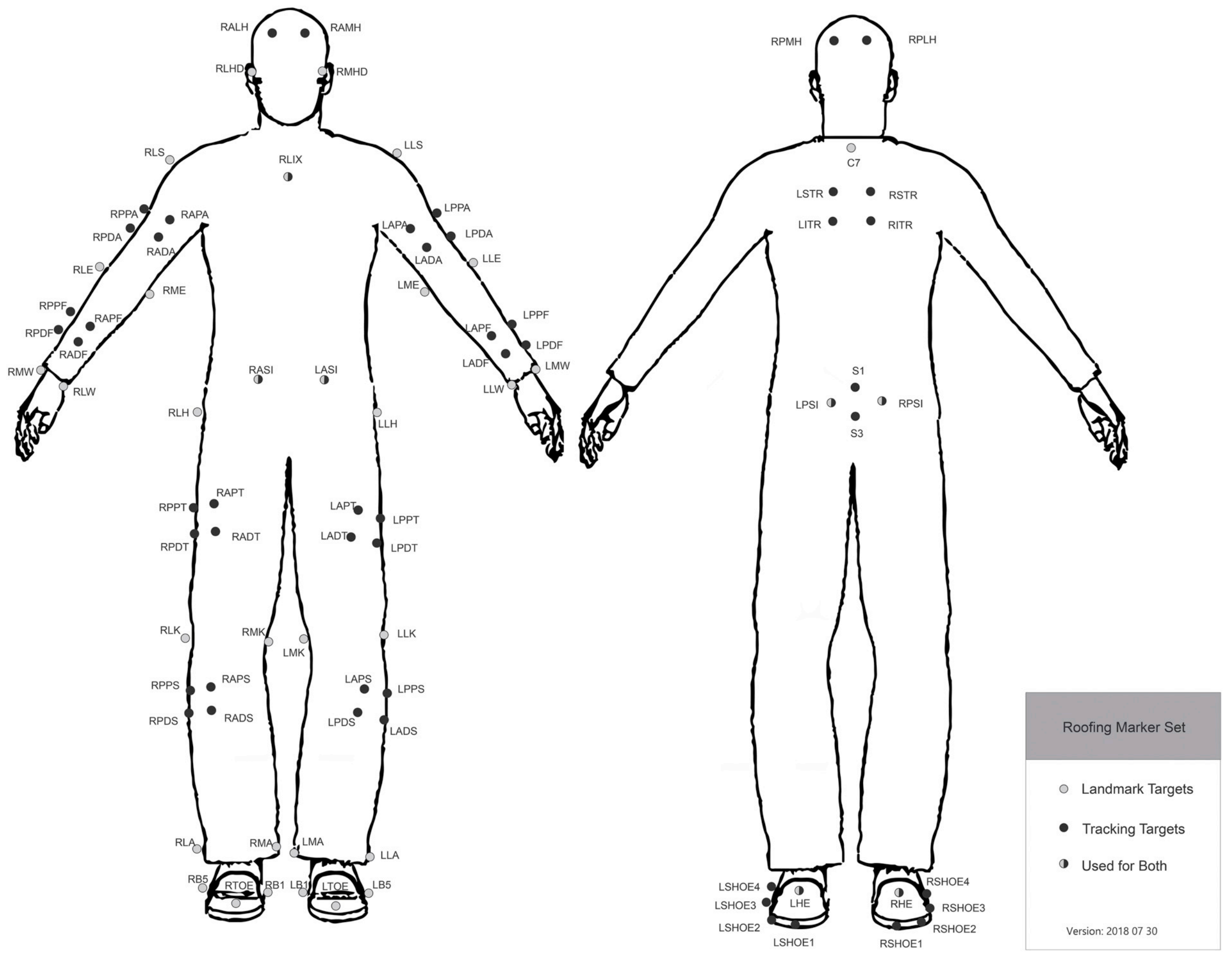

Fig. 1. Retro-reflective marker set utilized for recording human motion.

of time would vary from 2 to 5 min to either change the wearable or slope from one condition to another.

Outcome measures for this study were the three-dimensional kinematics (sagittal, frontal, and transverse) peak lower extremity angles (ankle, knee, and hip), for each combination of roof angle and wearable device, calculated in Visual 3D. The data left and right lower extremity data were first averaged, then ensemble averages were calculated for each subject. The kinematics were analyzed with a two-way—4(intervention) X 3(slope)—repeated measure analysis of variance (ANOVA). Mauchly's Test of Sphericity was used to determine the sphericity of the data. If Mauchly's Test showed the data were spheric, then no correction was needed. If Mauchly's Test indicated sphericity was violated, the Greenhouse-Geisser correction was used if epsilon was less than 0.75 and the Huyhn-Feldt correction was used if epsilon was greater than 0.75. Fisher's least significant difference (LSD) post-hoc pairwise comparisons were used to determine specific differences between conditions. Data analysis was completed using SPSS v25 (IBM Corp. Armonk, NY) and *p*-values were set to 0.05.

3. Results

As hypothesized, the introduction of a sloped surface and the wearable interventions considerably altered lower extremity full flexion kneeling kinematics compared to zero degree slope and no intervention deep kneeling. Of the nine outcome variables analyzed, four were significantly changed with the introduction of the sloped surface and seven were significantly changed with the introduction of a wearable device. The results highlighting the differences are in Tables 1 and 2 and the comparison of intervention influence of the kinematics can be found in Fig. 6 through 8, while Figs. 9 and 10 show significant main effect differences.

3.1. Sagittal

Ankle peak angles did not have a significant interaction between slope and intervention ($p = 0.164$). Significant main effects for slope ($p \leq 0.001$) and intervention ($p = 0.009$) were present. Slope post-hoc pairwise comparisons revealed zero degree slope ankle plantar flexion (21.13°±6.58°)—mean ± standard deviation—was significantly different than ankle dorsiflexion at 15° (2.23°±3.10°) and 30° (15.77°±1.91°) slopes. Also, ankle dorsiflexion at the 15° slope (2.23°±3.10°) was significantly larger than at the 30° slope (15.77°±1.91°). KS intervention dorsiflexion (2.35°±12.74°) was significantly different than BO intervention plantarflexion (5.42°±19.00°).

Knee peak angles did not have a significant interaction between slope and intervention ($p = 0.150$). Significant main effects for intervention ($p \leq 0.001$) were present. Intervention post-hoc pairwise comparisons revealed NO intervention knee flexion (145.26°±0.74°) was significantly larger than KS intervention knee flexion (140.57°±0.24°) and BO intervention (140.58°±0.89°). It was also shown that KP intervention knee flexion (144.96°±1.07°) was significantly larger than KS intervention (140.57°±0.24°) and BO (140.58°±0.89°) knee flexion.

Hip peak angles did not have a significant interaction between slope and intervention ($p = 0.073$). Significant main effects for slope ($p \leq 0.001$) and intervention ($p \leq 0.001$) were observed. Slope post-hoc pairwise comparisons revealed that 0° slope hip flexion (32.66°±4.07°) was significantly smaller than hip flexion on both 15° (49.70°±4.94°)

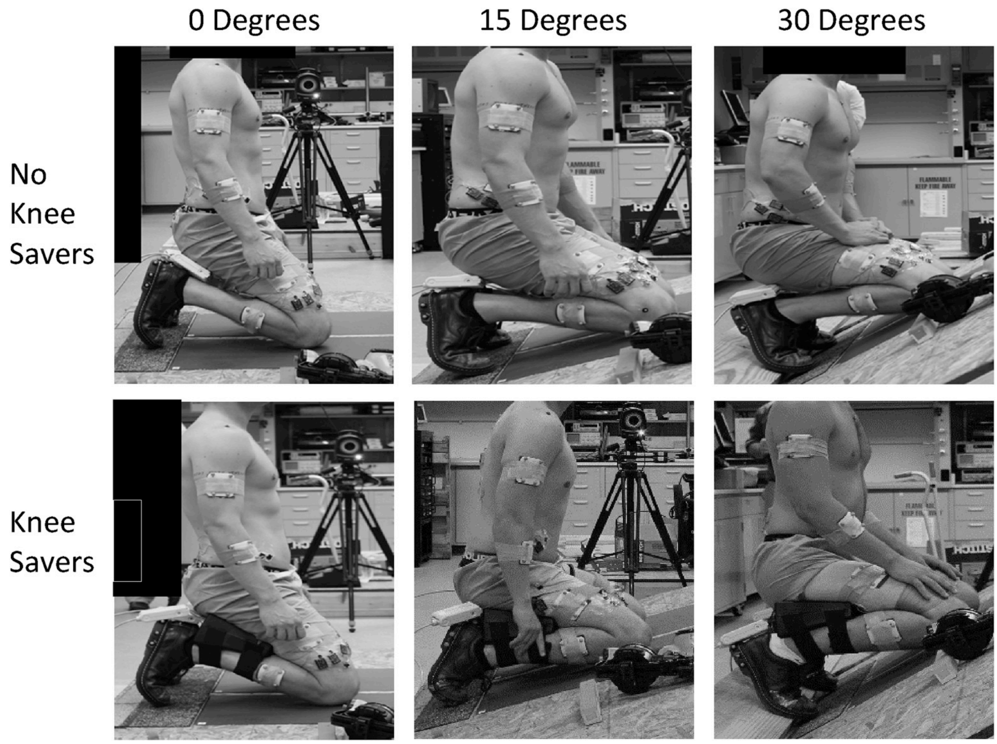

Fig. 2. A subject in full/deep flexion resting posture on three different slopes: First column is 0°, second column is 15°, and third column is 30°. The first row the subjects do not have knee savers and the second row, the subjects are wearing knee savers.

and 30° (50.13°±5.87°) slopes. Intervention post-hoc pairwise comparisons indicated NO intervention hip flexion (46.72°±10.42°) was significantly smaller than KP intervention hip flexion (50.25°±8.21°) and significantly larger than KS intervention (38.22°±7.79°) and BO intervention (41.45°±6.39°) hip flexion. Additionally KP intervention hip flexion (50.25°±8.21°) was significantly larger than KS intervention (38.22°±7.79°) and BO intervention (41.45°±6.39°).

3.2. Frontal

Ankle peak angles did not have a significant interaction between slope and intervention ($p = 0.377$). Main effects of intervention were not significant ($p = 0.702$). Significant main effects for slope ($p = 0.001$) were present. Slope post-hoc pairwise comparisons revealed ankle inversion at zero degrees (7.12°±0.92°) was significantly different than ankle eversion (2.14°±1.36°) at 30°. It is noteworthy that ankle inversion at zero degrees (7.12°±0.92°) was trending to be significantly larger than ankle inversion (1.50°±1.83°) on a 15° slope ($p = 0.052$).

Knee peak angles did not have a significant interaction between slope and intervention ($p = 0.685$). Significant main effects for intervention ($p \leq 0.001$) were present. Intervention post-hoc pairwise comparisons revealed the NO intervention condition abduction (0.64°±0.17°) was significantly different than BO intervention adduction (2.13°±0.31°). BO intervention adduction (2.13°±0.31°) was significantly larger than KP intervention knee adduction (0.13°±0.24°) and KS intervention knee adduction (0.12°±0.56°). Furthermore NO intervention condition abduction (0.64°±0.17°) was trending toward significantly different KP intervention knee adduction (0.13°±0.24°) with $p = 0.053$.

Hip peak angles did not have a significant interaction between slope and intervention ($p = 0.485$). Main effects for slope ($p = 0.499$) and intervention ($p = 0.382$) were not significant.

3.3. Transverse

Ankle peak angles did not have a significant interaction between slope and intervention ($p = 0.544$). Significant main effects for intervention ($p \leq 0.001$) were present. Intervention post-hoc pairwise comparisons revealed NO intervention external rotation (8.72°±1.36°) was significantly smaller than KS intervention (15.18°±1.83°) and BO intervention (13.00°±0.65°) external rotation.

Knee peak angles did not have a significant interaction between slope and intervention ($p = 0.406$). Significant main effects for intervention ($p \leq 0.001$) were present. Intervention post-hoc pairwise comparisons revealed NO intervention internal rotation (6.52°±0.68°) was significantly different than KS intervention (0.41°±1.95°) and BO intervention (1.07°±0.50°) external rotation. Also, KP intervention internal rotation (5.00°±1.74°) was significantly different than KS intervention (0.41°±1.95°) and BO intervention (1.07°±0.50°) external rotation.

Hip peak angles did not have a significant interaction between slope and intervention ($p = 0.105$). Significant main effects for slope ($p = 0.014$) and intervention ($p \leq 0.001$) were present. Slope post-hoc pairwise comparisons revealed zero degree hip internal rotation (9.31°±2.69°) was significantly smaller than hip internal rotation (14.57°±1.90°) at the 30° slope. Intervention post-hoc pairwise comparisons revealed NO intervention hip internal rotation (13.40°±3.80°) was significantly larger than KS intervention hip internal rotation (9.79°±2.73°). Additionally, KP intervention internal rotation (14.67°±0.82°) was significantly larger than KS intervention hip (9.79°±2.73°) and (11.07°±1.49°) BO intervention internal rotation.

4. Discussion

In this study, it was determined how the inclusion of different combinations of two interventions, knee pads and knee savers, can alter three-dimensional lower extremity kinematics during the resting posture in roofing when deep or near full flexion kneeling occurs while on different sloped surfaces. Overall, the addition of the interventions significantly altered all the lower extremity kinematics in the sagittal and transverse planes, and also the knee kinematics in the frontal plane. Deep or near full kneeling on a sloped surface is a common action by

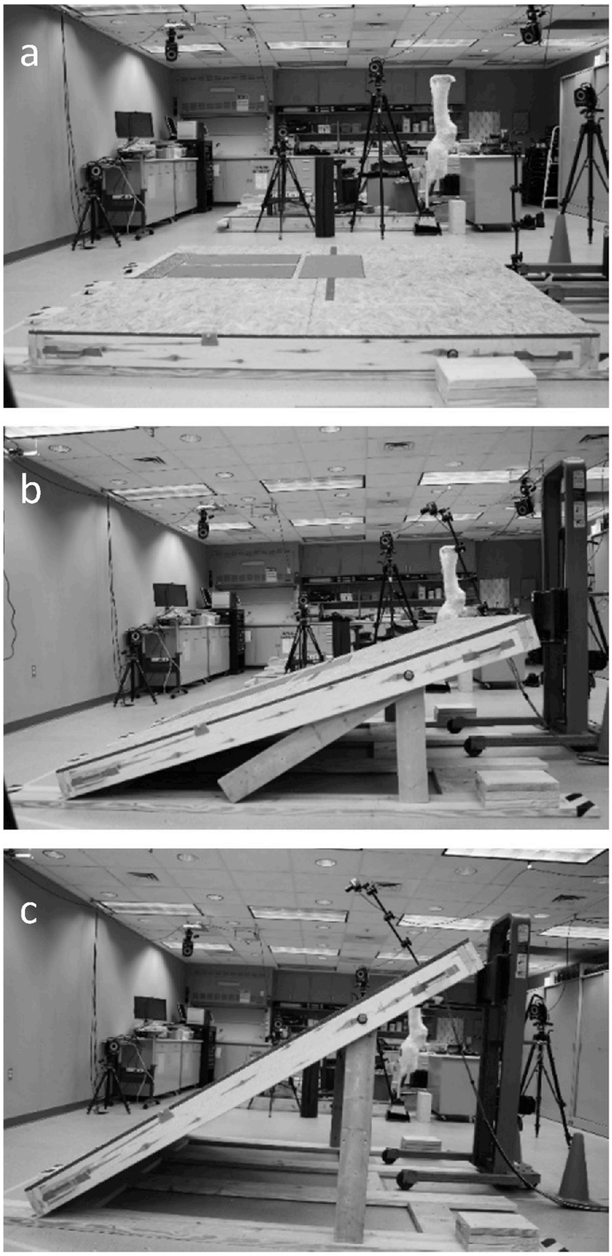

Fig. 3. Roof Simulator set at three different slopes: (a) 0°, (b) 15°, (c) 30°.

Fig. 4. A) Knee Pads. (B) Knee Savers. The two wearable devices tested in the current study to determine the effectiveness of reducing MSDs in sloped roofing work.

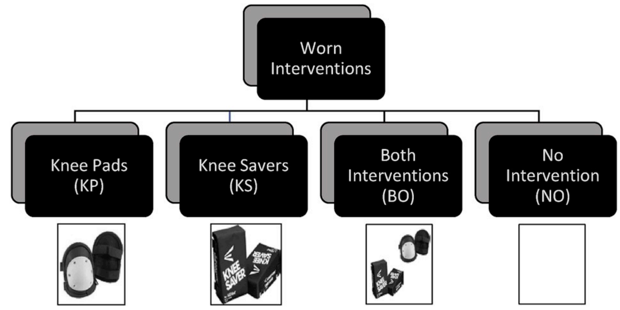

Fig. 5. Four different combinations of wearable interventions that were tested in the current study.

Table 1
Depicts statistical significant ($p \leq 0.05$) changes in the various testing conditions. † indicates statistical significance.

		Interaction	Main Effect Slope	Main Effect Intervention
Sagittal	Ankle		†	†
	Knee			†
	Hip		†	†
Frontal	Ankle		†	
	Knee			†
	Hip			
Transverse	Ankle			†
	Knee			†
	Hip		†	†

Table 2
Indicates how the intervention changed peak kinematics compared to no intervention. ↑ indicates the peak kinematics increased compared to no intervention and ↓ demonstrates the peak kinematics decreased compared to no intervention.

		Knee Pads	Knee Savers	Both
Sagittal	Ankle			
	Knee	↓	↓	↓
	Hip	↑	↓	↓
Frontal	Ankle		↓	↓
	Knee			↑
	Hip	↑	↓	↓
Transverse	Ankle	↑	↑	↑
	Knee	↓	↓	↓
	Hip	↓	↓	↓

residential roofers. This is the first study to quantify the lower extremity kinematic changes due to wearable interventions during this activity.

4.1. *Interaction*

The connection between the interventions and slope on the effect of the lower extremity kinematics is an essential one in relation to MSD risk caused by extreme and awkward postures. The current study did not find any interactions between the two factors (interventions and slope). This suggests that a changing slope does not diminish any enhancements achieved with the use of the interventions. As many different pitches of roof are present in the residential sector, this is an important finding that during deep knee flexion, regardless of the slope of the roof, influence from a wearable intervention should provide similar advantages.

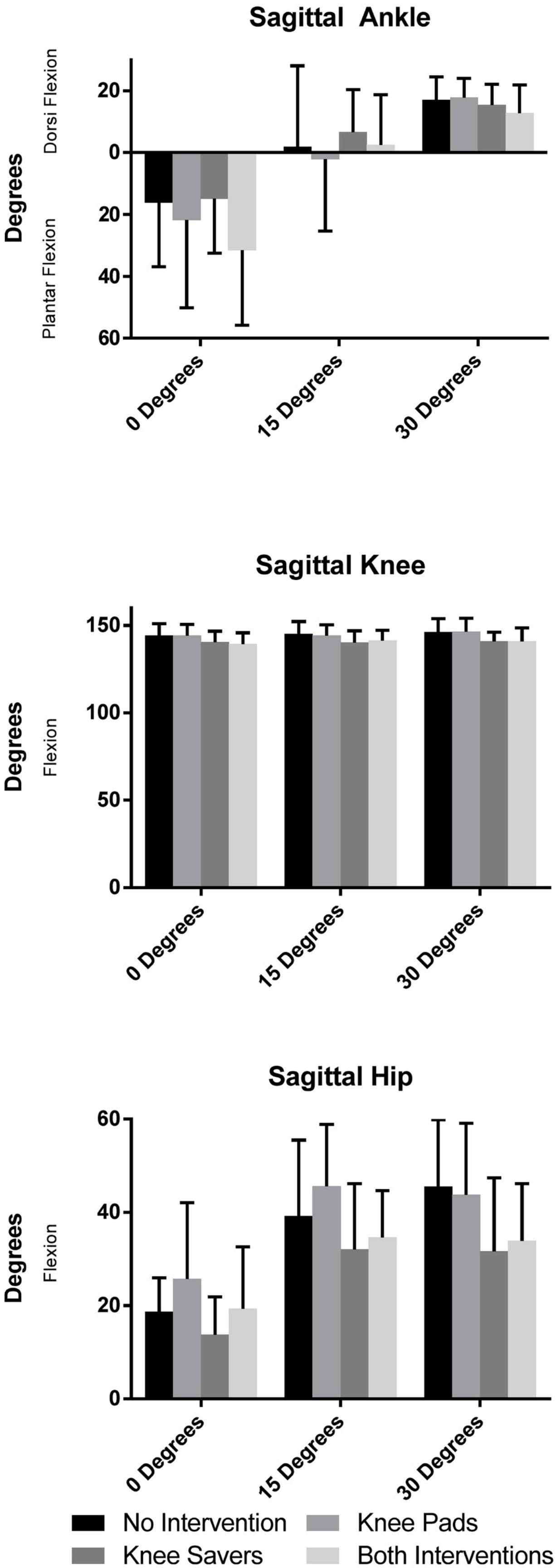

Fig. 6. Sagittal inter-subject lower extremity peak angles.

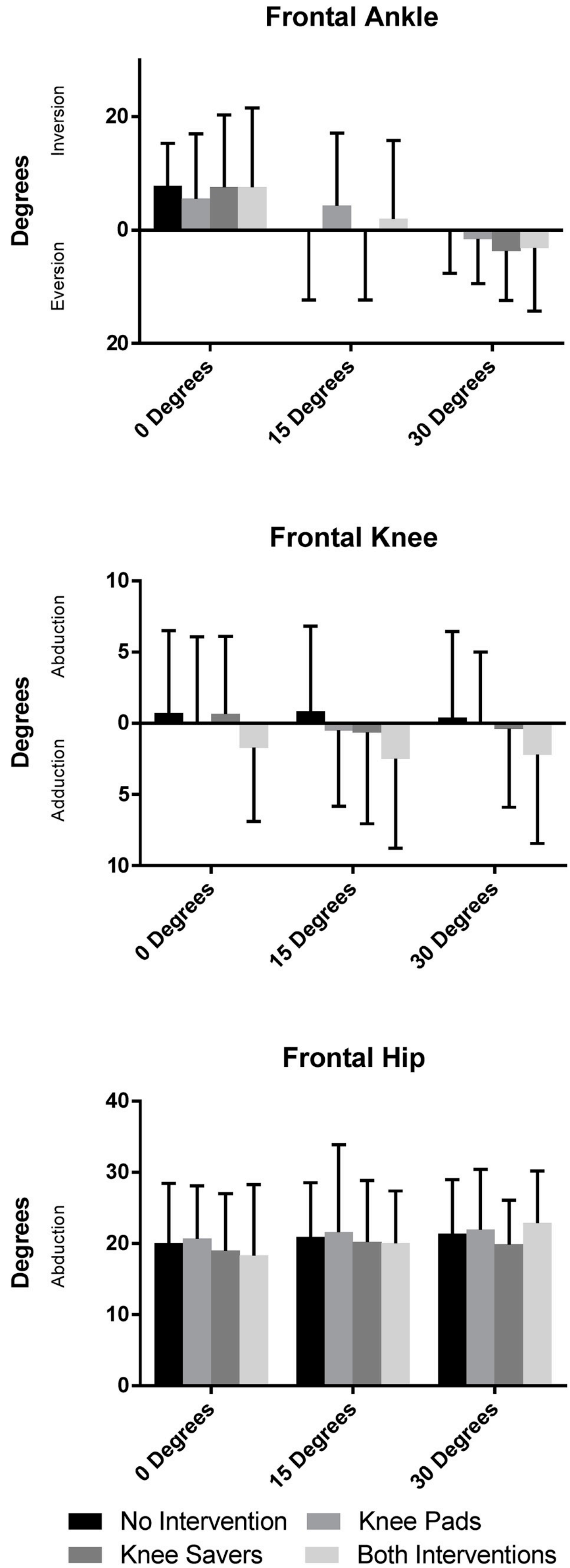

Fig. 7. Frontal inter-subject lower extremity peak angles.

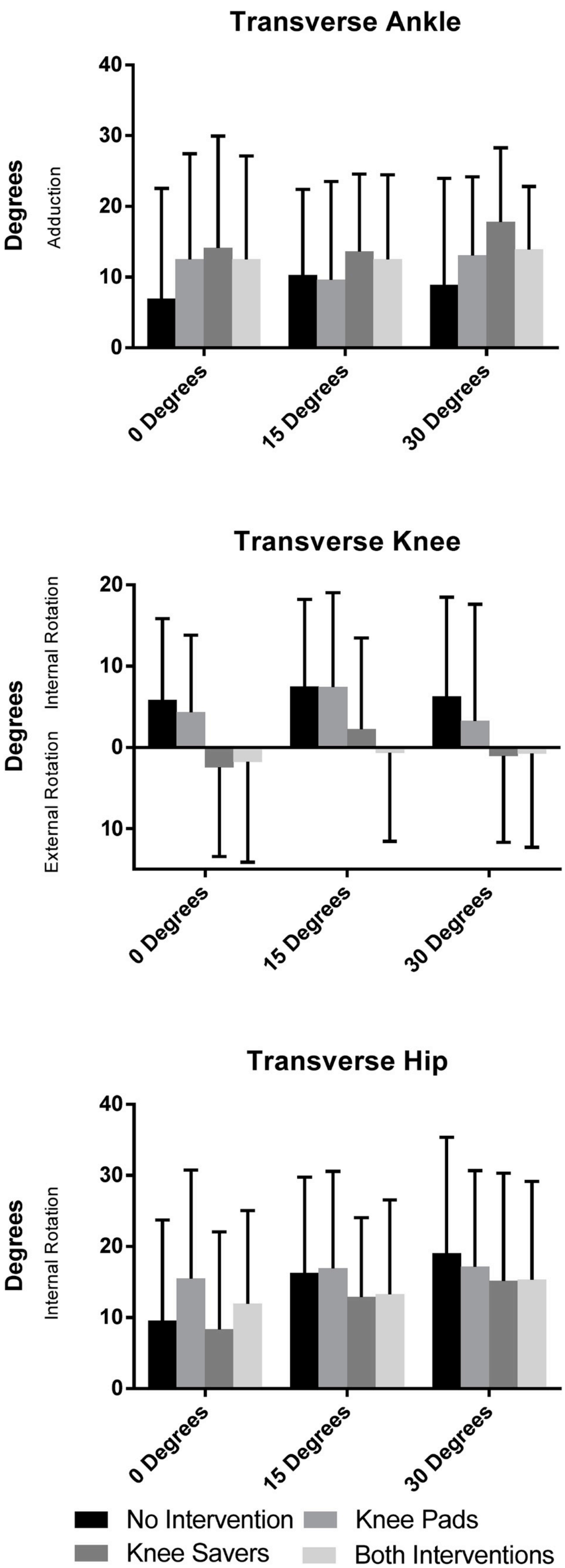

Fig. 8. Transverse inter-subject lower extremity peak angles.

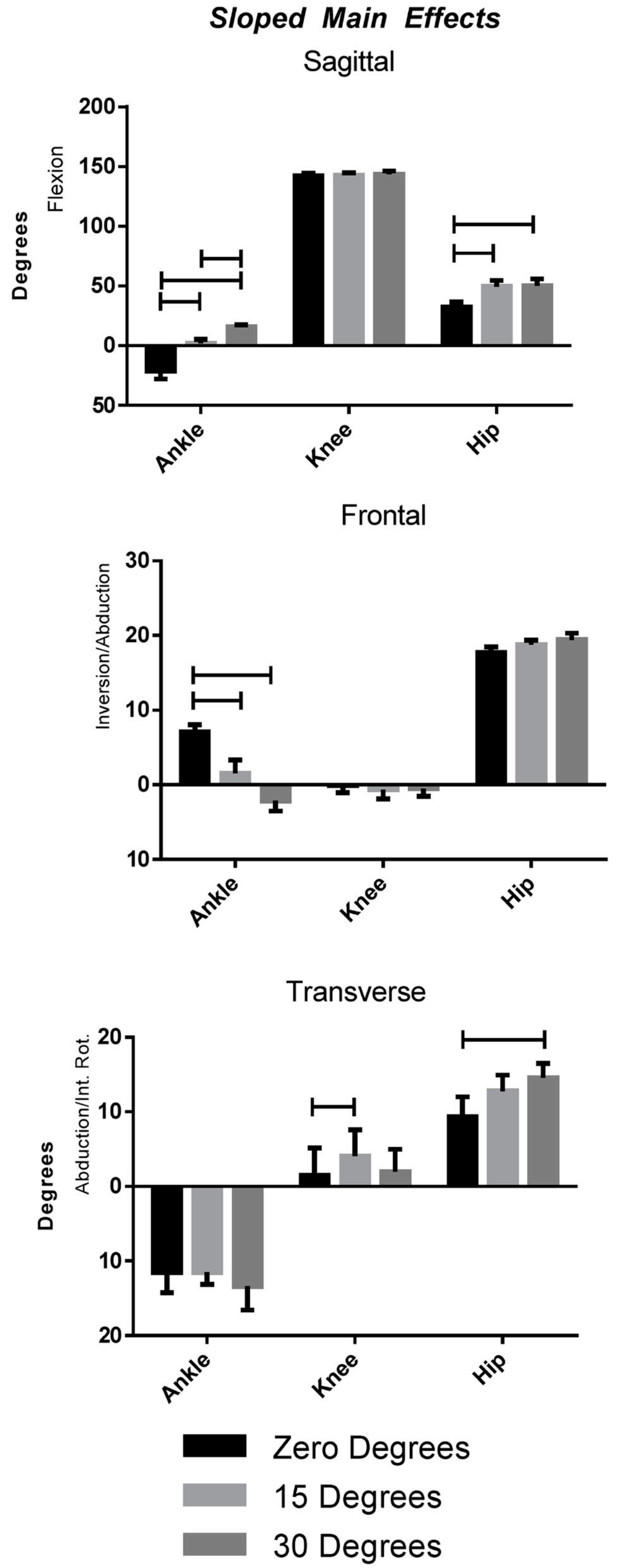

Fig. 9. Slope main effects.

4.2. Slope

While the effect of slope is not easily controlled in an actual residential roof environment, it is important to consider how the slope has an impact on lower extremity kinematics. The current study observed changes in the lower extremity kinematics due in different sloped

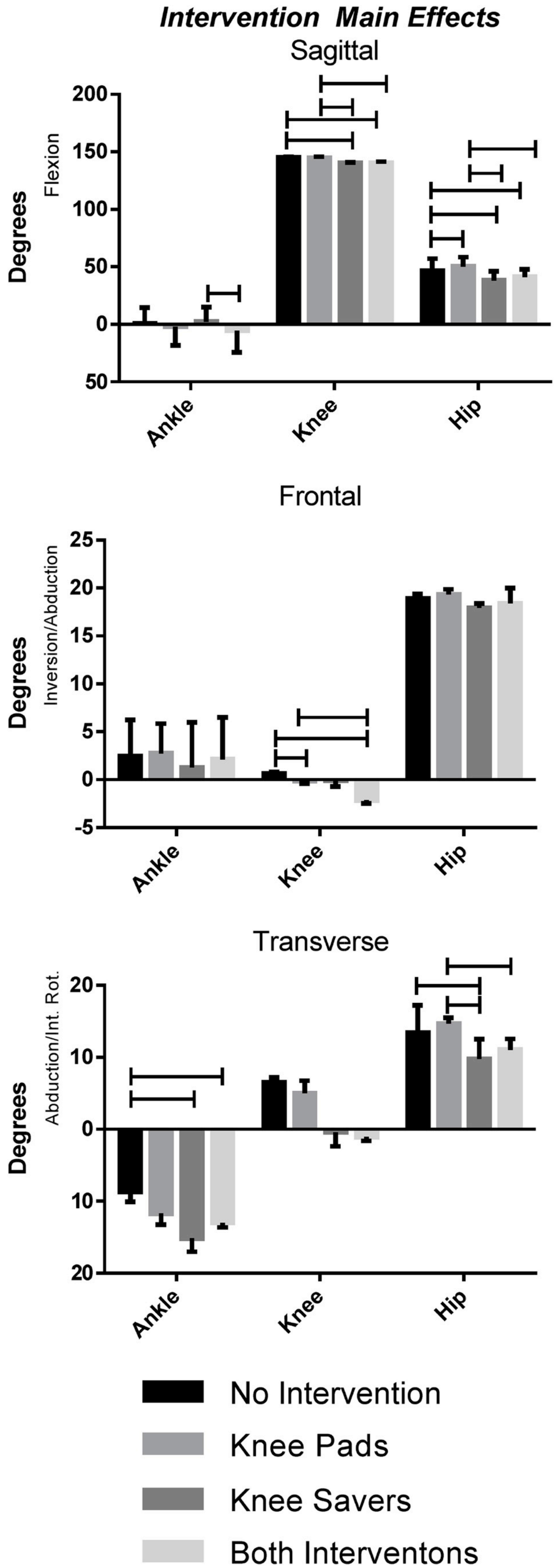

Fig. 10. Intervention main effects.

surfaces. This is similar to other studies that have investigated sloped gait (Breloff et al., 2019; Damavandi et al., 2010; Dixon and Pearsall, 2010; Dixon et al., 2011; Lay et al., 2006; Redfern and DiPasquale, 1997; Wannop et al., 2014). What was interesting was that most of the changes in the lower extremity were in the ankle and hip, not the knee (Fig. 9). This suggests that an intervention which focuses on the knee kinematic changes, as a means to reduce MSD risk, may not be the highest priority for kneeling work in a sloped environment. For example, severe ankle stress and imbalance was reported while kneeling on a 30° slope and increased hip osteoarthritis risk can be associated with kneeling (Jensen, 2008; Wang et al., 2017).

4.3. *Intervention*

In the current study, several examples were observed wherein the inclusion of an intervention statistically significantly decreased the peak angle during that condition, which was different than what was observed in previous KS studies (Gray et al., 2015; Stone et al., 2014, 2014b, 2017). For example, knee flexion angle did not have any significant differences for all three sloped conditions, however with the addition of a single intervention (KP or KS) caused a reduction in deep knee flexion during resting compared to no intervention. Hip flexion was increased as the slope increased, nevertheless, the addition of either the KS or BO interventions reduced hip flexion compared to NO intervention, which is a positive result and in part confirms the hypothesis of this study. Similarly, hip internal rotation increased as the sloped increased, and with the addition of the KS or BO interventions, the internal rotation posture was reduced. Finally, peak knee rotations were statistically significantly smaller with the KS and BO interventions compared to NO intervention. It is uncertain what causes MSD risk from extreme postures but larger than usual knee moments and forces are a product of extreme flexion angles during kneeling (Mikosz et al., 1988; Morrison, 1970; Nagura et al., 2002; Schipplein and Andriacchi, 1991; Seireg and Arvikar, 1975), the medial and lateral tibiofemoral and patellofemoral contact pressure increases as knee flexion gets larger (Hofer et al., 2011; Lee, 2014) and repetitive kneeling has been linked to knee osteoarthritis (Coggon et al., 2000; Cooper et al., 1994; Hofer et al., 2011). Therefore any strategy that has the ability to reduce large or extreme joint angles can be considered to potentially reduce lower extremity MSD risk. The addition of the two interventions in the current study exhibited an ability to alleviate extreme posture in several of the lower extremity kinematics and thus is a positive finding of this study.

That said, in one instance, ankle external rotation, the addition of the tested interventions statistically significantly increased this angle compared to the NO intervention. It is important to consider any changes that might increase MSD risk, by increasing the extreme posture, when considering the usefulness of an intervention. Additionally, knee frontal plane posture statistically significantly changed from adduction posture with the KS and BO interventions to an abduction posture with NO intervention. As the magnitudes of both the adduction and abduction posture are small, it is likely that this change would not influence lower extremity MSD risk in roofers.

4.4. *Limitations*

One possible limitation in this study is the use of non-roofers. The use of novice individuals is acceptable because it allowed for the observation of how extreme postures influence individuals when they first encounter a sloped working environment. Furthermore, this study only used young subjects, though working roofers have a larger age range. This is an adequate choice, as the majority of roofing injuries are suffered by roofers in the age range from 18 to 24 years (BLS, 2017). Additionally, this study only investigated one ergonomic risk factor (awkward postures) and how the interventions will alleviate this risk. The effectiveness of these interventions need to still be evaluated with respect to the other ergonomic risk factors such as: repetition, pace of work, static postures, contact stress, large forces, extreme temperatures and duration.

4.5. Potential implication for KP and KS as interventions to reduce MSD risk on sloped surfaces

This study explored the possibility of using KP and/or KS as potential wearable interventions to reduce MSD risk in residential roofers who spend a large amount of their working time kneeling. KP only significantly changed lower extremity kinematics in two instances compared to no interaction, so as an intervention to reduce MSD risk from extreme postures on a sloped surface, KP are not an ideal solution. However, KP have been shown to reduce knee joint forces (Pollard et al., 2011) and it is largely accepted that KP provide comfort and make kneeling easier. The second intervention in the current study was KS, and several realizations were made regarding the use of KS and its ability to reduce MSD risk in kneeling individuals on a sloped surface. First, the KS is only 'active' during deep flexion kneeling, what was called a 'resting posture' in the current study. The data did show that KS did reduce peak angles while in this resting posture, however it is unclear how often or for how long roofers will adopt this posture in a real-life work environment. Second, although the data yielded statistically significant results, the tangible change in posture was approximately five degrees. Due to the small magnitude of the statistically significant changes, it is unclear if these changes represent a clinically important transformation in minimizing MSD risk due to extreme postures. This is the case as MSD are reliant on the physical and psychological reactions of the individual worker to the physical demands of the job. Finally, more testing regarding KS use, such as walking with KS, adorning the KS, and quantifying time and frequency roofers are in the resting posture in the sloped environment are needed. The data in this current study suggest a potential clinically important change with KS use on a sloped surface, but more work is needed before a definitive conclusion of their use in this sloped roof environment.

4.6. Future work with KS

The mechanisms which prompt MSD are not well defined, and given that several different factors are strongly believed to stimulate MSD, the testing of any wearable device must be comprehensive and consider all possible factors of increased MSD risk. Therefore, future studies investigating the effectiveness of the knee pads and knee savers interventions to reduce MSD risk should include other ergonomic factors that are associated with roofing such as: repetition, pace of work, static postures, contact stress, large forces, extreme temperatures and duration. Additionally, further studies into the effectiveness of knee savers on a sloped surface can investigate if wearing that device in an alternate location—such as closer to the knee or closer to the ankle—than the manufacturer's suggestion might boost usefulness of that device in sloped environments. Furthermore, additional considerations for safety must be tested with the KS intervention to ensure the roofers are not placed at any increased falling risk, even though they may have a reduced MSD risk.

5. Conclusion

The purpose of this study was to determine if KP and/or KS were able to reduce extreme posture and thus alleviating some MSD risk in roofers working in a sloped environment. The current study observed that KP did not change lower extremity kinematics, thus are not an ideal intervention for MSD, however they do increase comfort and have been shown to reduce knee forces. KS was determined to be active only during a deep flexion posture and it is uncertain how often roofers use this posture. KS was shown to reduce extreme posture in the lower extremity, however the magnitudes of these changes were small and it is unclear if the statistically significant change will lead to an actual reduction in MSD risk on a sloped surface. This study has provided initial data that supports the use of KS as a potential intervention to reduce MSD risk due to lower extremity joint angles on a sloped surface, nonetheless further testing involving other MSD risk factors is needed.

Disclaimer

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, Centers for Disease Control and Prevention.

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We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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