Project Title:	Waistband Enabled Construction Workers Low Back Health Monitoring System
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Project ID:	CICR/01/15
Research Institution:	The Hong Kong Polytechnic University
Subject Area:	Construction Safety and Health

Objective

1. To compare the differences in lumbar biomechanics during three typical rebar tying postures: stooping, one-legged kneeling, and squatting;
2. To develop a wearable sensor-based real-time motion capture system for measuring ergonomic movements of workers while workers are performing construction tasks;
3. To design ergonomic motion capturing and warning algorithms to alert workers when their trunk inclination angles or holding time are beyond acceptable thresholds;
4. To improve the proposed motion warning system based on a field test and front-line practitioners' suggestions;
5. To develop a data-driven method for personalized recommendation of trunk holding time, and examining the effect of the method in a field test.

Background

In general, work-related physical postures and holding time have been proven to be statistically significant risk factors for musculoskeletal disorders (WMSDs), especially regarding lower back pain. Compared to other industries, heavy manual operations in the construction domain are universal and inevitable, exposing workers in various trades to danger at work, regardless of different individuals, environments or countries. Repetitive or awkward postures like stooping, squatting and kneeling, frequently confronted by operational workers, can cause overexertion in the spine and the muscle of the back and neck. Maintaining similar working postures for a long period of time is another common cause of WMSDs around lower back and neck. Both ergonomically hazardous postures and insecure holding time are major risk factors for construction workers and should be taken as major concerns in WMSDs prevention.

Amongst 15 typical work tasks in construction, 7 tasks (i.e. flooring, roofing, framing, plumbing, masonry, concrete pouring and drywall installing) hold a WMSDs incidence rate of more than 50%, with a nearly 80% prevalence in flooring. Previous applications of Inertial Measurement Units (IMUs) in injury risk assessment indicate they help reconstruct human postures and record holding time in a more precise and reliable way so this could be a more practical and effective wearable sensor based personalized healthcare solutions for workers' WMSDs prevention.

Methodology

- Comparing the differences in lumbar biomechanics during three typical rebar tying postures: stooping, one-legged kneeling, and squatting.
- Developing a wearable sensor-based real-time motion capture system by IMU sensors via Bluetooth technology, and sending motion warnings; and cloud databased for motion data storage.
- Conducting field experiments to validate the practical utility and reliability of the proposed WIMU-based motion warning system.

Results and Findings

Findings in comparing the differences in lumbar biomechanics during three typical rebar tying postures: stooping, one-legged kneeling, and squatting

1. Lumbar segment exhibited larger range of movements in flexion and lateral bending during rebar tying, whereas thoracic spine showed greater range of movements for axial rotation during rebar tying.
2. Rebar tying demanded large lumbar flexion (approximately 60-65°) irrespective of the working posture. The lumbar flexion angles exceeded the recommended limits (60°) suggested by ISO 11226:2000 for static working postures.
3. Rebar tying tasks required the participants to work over a moderate range of lumbar lateral bending (25-30° including left and right side range of movements) and axial rotation (15-20° including clockwise and anti-clockwise range of movements).

Findings in development of a wearable sensor-based real-time motion capture system

1. The proposed personal protective equipment can help on-site workers recognize hazardous postures without disturbing their operations and some gradually change previous ergonomically hazardous operational patterns by interacting with the real-time warning system.
2. The IMU sensor was redesigned to be embedded into the reflective safety vest so that potential sensor damages can be prevented.
3. The ergonomic rule for postural hazard warning was not practical and did not consider individual differences among different workers so personalized recommendation of trunk holding time to an individual worker was proposed.
4. The holding time values were separated into normal ones and far from normal ones and the duration of the alarm sound was reset to around 0.5s so that it would not disturb an individual's normal performance. The field test provided positive support for applying worker-centric self-management based on data-driven personalized healthcare with recommendations on holding time.

Recommendations

- All the tested postures involve extensive lumbar bending while one-legged kneeling has an additional disadvantage of asymmetrical trunk posture. Prolonged working in these postures may explain the high prevalence of LBDs in rebar workers.
- Postural training and education should be provided to emphasize the importance and techniques of postural variations.
- The rebar tying task can be scheduled in between other less physically demanding activities so as to minimize back and leg muscles fatigue secondary to prolonged postures.
- Construction project managers should use workers' daily postural scores from the system to identify individuals with high ergonomic risk level, meanwhile improving workplace to reduce environmental ergonomic hazards.