Optimal numbers and locations of wearable sensors to enhance the performance of classification models that differentiate injurious versus non-injurious transfers

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Purpose Low back pain (LBP) is a cause of disability resulting in activity limitation in working age population (Hoy et al., 2014). In particular, patient transfers are known as a common task causing LBP in healthcare providers (Henriques et al., 2019). The National Institute for Occupational Safety and Health (NIOSH) defined a safety criterion to help reduce a risk of LBP during lifting or transferring, where a compressive force at a disc between L5 and S1 (Fc) should be smaller than 3.4 kN to be non-injurious activities (NIOSH, 1981). We simulated patient transfers from bed to wheelchair to develop support vector machine algorithms that differentiate injurious versus non injurious transfers. Then we examined how the model performance was affected by numbers and locations of wearable sensors placed on body segments. **Method** Sixteen healthy young adults participated simulations of patient transfers from bed to wheelchair. Trials were acquired with different patient body weights and transfer methods. Trials were also acquired with and without a mechanical lift. During trials, kinematics of a body was recorded with eight motion capture cameras (Vero v2.2, VICON, Oxford, UK) and used to calculate the Fc, and with IMU sensors (Xsens Dot, Xsens Technologies, Enschede, The Netherlands) placed on body segments (waist, both arms and forearms, both thighs and shins) and used to extract features (x-, y-, z-axis of mean and variance accelerations, velocities, angular velocities) from a time window of 0.2s at 0.3s prior to the moment of peak Fc. A radial basis function kernel support vector machine in LIBSVM (Chang & Lin, 2011) was then used to create classification models that differentiate injurious versus non-injurious patient transfers using the extracted features. The model performance was then examined with various combinations of the number and location of IMU sensors. **Results and Discussion** Overall, our classification models provided good accuracy (over 85%) (Figure 1). The model performance was maximized with two sensors placed on each wrist, providing 98.2% of accuracy. Our study presents the feasibility of wearable sensors in detecting injurious patient transfers from bed to wheelchair, providing a template for prevention of low back injury in older adults working as caregivers during lifting or transfers.

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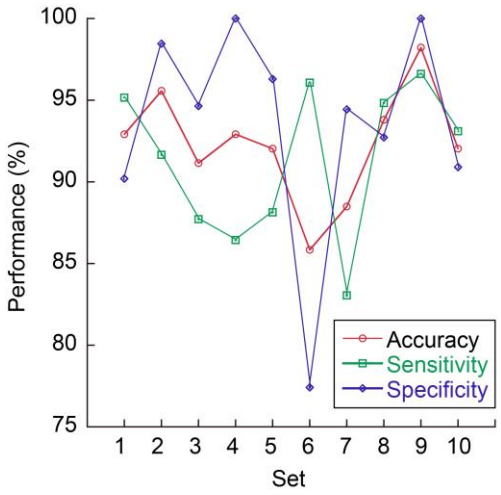

Set	Sensor location
Set 1	Waist + both arms and forearms + both thighs and shins
Set 2	waist + both arms and forearms
Set 3	waist + both thighs and shins
Set 4	waist + both arms
Set 5	waist + both thighs
Set 6	both arms and forearms
Set 7	both thighs and shins
Set 8	both thighs
Set 9	both arms
Set 10	waist

Figure 1 Performance of support vector machine algorithms depending on the number and location of sensors