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Working postures and physical activity among registered nurses

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ABSTRACT

Nurses report a high prevalence of musculoskeletal discomfort, particularly of the low back and neck/shoulder. This study characterized the full-shift upper arm and trunk postures and movement velocities of registered nurses using inertial measurement units (IMUs). Intensity of occupational physical activity (PA) was also ascertained using a waist-worn PA monitor and using the raw acceleration data from each IMU. Results indicated that nurses spent a relatively small proportion of their work time with the arms or trunk in extreme postures, but had few opportunities for rest and recovery in comparison to several other occupational groups. Comparisons between nurses in different PA groups suggested that using a combination of accelerometers secured to several body locations may provide more representative estimates of physical demands than a single, waist-worn PA monitor. The findings indicate a need for continued field-based research with larger sample sizes to facilitate the development of maximally effective intervention strategies.

1. Introduction

A high prevalence of work-related musculoskeletal disorders (MSDs) has been observed among nursing personnel in all settings of patient care, including hospitals, long-term care, and home health care (Alexopoulos et al., 2003, 2006; Bernal et al., 2015; Caruso and Waters, 2008; Choobineh et al., 2006; Davis and Kotowski, 2015; Karahan et al., 2009; Long et al., 2013, 2012; Lorusso et al., 2007; Reed et al., 2014; Smedley et al., 2003; Trinkoff et al., 2002; Waters et al., 2006). Disabling low back and neck/shoulder pain, in particular, is reported more frequently by nurses than by several other occupational groups (Corona et al., 2004; Harcombe et al., 2014, 2009). In 2012, for example, nursing assistants and registered nurses reported the second and fifth highest quantity of nonfatal occupational injuries and illnesses involving days-away-from-work and MSDs, respectively, among all occupations in the United States (BLS, 2013). The low back was injured in 56.2% of the nursing assistant cases and 51.4% of the registered nurses cases, while the shoulder was injured in 12.6% of the cases in both groups.

Working in non-neutral postures has been associated with an increased risk of MSDs of the low back and neck/shoulder in many occupations, including nursing (Bernal et al., 2015; Davis and Kotowski, 2015; Karahan et al., 2009; Long et al., 2013, 2012; Lorusso et al., 2007; Reed et al., 2014; Waters et al., 2006). While several studies have characterized the trunk postures of nurses working full shifts using direct measurement methods (Arias et al., 2012; Freitag et al., 2007, 2012; Hodder et al., 2010), the working postures and movement velocities of the upper arms of nurses have not been previously reported. Characterizations of the upper arm postures and movement velocities of nurses are needed to develop maximally effective intervention strategies intended to mitigate MSD risk factors.

Complementary to exposure to non-neutral working postures, high intensity occupational physical activity (PA) may contribute to several chronic health conditions, including MSDs (Harari et al., 2015; Heneweer et al., 2009, 2011; Holtermann et al., 2010, 2012a,b; Sitthipornvorakul et al., 2011). While regular, high intensity leisure-time PA is generally considered beneficial to overall health (Haskell et al., 2007; Warburton et al., 2006), and many workplace interventions that focus on achieving "adequate" PA levels result in some benefit (e.g., Anderson et al., 2009; Conn et al., 2009; Rongen et al., 2013), opposing effects of occupational and leisure-time PA have been observed in several other studies (i.e. high intensity PA outside of work appears to be beneficial while high intensity PA at work appears to be harmful; Holtermann, 2012b, Hu et al., 2013). The complex (and seemingly opposing) relationship between occupational and leisure-time PA on adverse

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health outcomes is further magnified by a reliance on self-reported PA estimates.

Low to moderate agreement between self-reported and objectively measured PA estimates has been observed to result in poor predictions of morbidity and health risk (Ekblom et al., 2015; Helmerhorst et al., 2012). Patient care workers, in particular, have been observed to report seven times the number of minutes of moderate or greater intensity PA that they complete during a work week in comparison to direct measurements obtained with a waist-worn PA monitor (Umukoro et al., 2013). One potential reason for the incongruity is that the monitors used to measure PA are typically worn at the waist and may not be sensitive to physically demanding upper body work (e.g., extremes of posture during patient transfers; Matthews et al., 2012). Consistent with this theory is the observation that nursing personnel report their work to be more strenuous the more often they work in non-neutral positions (Freitag et al., 2014).

In light of the lack of information on the upper arm postures and movement velocities, and because of the large discrepancy in self-reported and direct measurements of PA obtained from nurses, we conducted a study to assess the full-shift postures and movement velocities of the upper arms and trunk among nurses using inertial measurement units (IMUs). Simultaneous measurement of PA was accomplished using a waist-worn PA monitor and acceleration data obtained from each IMU to evaluate the relationship between occupational PA and postural demands among nurses in greater detail than what is currently available in the scientific literature.

2. Methods

2.1. Participants and study design

Thirty-six female registered nurses (age = 30.8 ± 10.1 years; body mass index = 24.1 ± 4.4 kg/m^2) were recruited via informational meetings, email advertisements, and word of mouth from two medical surgical inpatient units at the University of Iowa Hospitals and Clinics. Each nurse worked a full, 12 h work shift except for two who worked for 8 h and one who worked for 11 h. Twenty-one nurses worked day shifts (starting at 7 am) and 15 nurses worked night shifts (starting at 7 pm). Participants self-reported 1) no history of physician-diagnosed MSDs in the neck/shoulder or back regions, 2) no neck/shoulder or back pain two weeks prior to enrollment, and 3) no history of neurodegenerative disease (e.g., Parkinson's disease). All participants were right-hand dominant. All study procedures were approved by the University of Iowa Institutional Review Board and the University of Iowa Hospitals and Clinics Nursing Review Committee. Informed consent was obtained prior to participation.

2.2. Direct measurements of posture, movement velocity, and rest/recovery

Angular displacement waveforms of upper arm elevation (defined as either forward flexion or abduction of the shoulder relative to gravity) and trunk flexion/extension were estimated using three inertial measurement units (ArduIMU v3, 3D Robotics Inc., Berkeley, CA). Each IMU was a small (45 × 65 × 35 mm), wireless, battery-powered unit that measured and stored acceleration (triaxial, ±8 g) and angular velocity (triaxial, ±2000° s^{-1}) information. One IMU was secured to the lateral aspect of each upper arm approximately one-half the distance between the lateral epicondyle and the acromion and one IMU was secured to the posterior trunk at approximately the 4th thoracic vertebral body. The IMU data streams were sampled at 50 Hz and stored to on-board flash memory.

The raw accelerometer and gyroscope information obtained from each IMU was processed using a custom complementary weighting algorithm developed in MATLAB (r2014a, The MathWorks, Inc., Natick, MA). The complementary weighting algorithm approach was used in lieu of a solely accelerometer-based approach, as accelerometer-based estimates have been observed to have poor accuracy during complex, dynamic movements (Amasay et al., 2009; Brodie et al., 2008; Godwin et al., 2009; Hansson et al., 2001). Details of the complementary weighting algorithm are described elsewhere (Schall Jr et al., 2015a; Schall et al., 2014). Previous analysis of the complementary weighting algorithm has indicated that the approach has good accuracy and repeatability when used with IMUs similar to those employed in the current study (Schall et al., 2015b). Specifically, sample-to-sample root mean square differences of 5.4° for the trunk and 8.5° for the upper arm have been observed in comparison to a "gold-standard" optical motion capture system. Estimates of mean angular displacement and angular displacement variation (difference between the 90th and 10th percentiles of angular displacement) were also observed to change roughly 2° on average per 8 h of data collection in a previous study (Schall et al., 2015b).

Exposure metrics used to describe posture, movement velocity, and rest/recovery in this study included: selected percentiles (10th, 50th, 90th, and the difference between 90th and 10th) of the amplitude probability distribution function (APDF; Jonsson, 1982); variables describing 'extreme' postures, such as percent time with the trunk flexed ≥45° and/or the upper arms elevated ≥60° (Jansen et al., 2004; Punnett et al., 1991; Putz-Anderson et al., 1997); the proportion of time working with high (≥90° s^{-1}) and low (<5° s^{-1}) angular velocities; and variables describing the occurrence of 'rest' and 'recovery' as in previous studies (Douphrate et al., 2012; Kazmierczak et al., 2005; Wahlstrom et al., 2010). 'Rest' was defined as having the trunk or upper arm in a neutral posture (<20°) and moving with an angular velocity of <5° s^{-1}. 'Recovery' periods were defined as the number of times per minute of substantial periods (≥3 s) in a neutral posture.

2.3. Direct measurements of physical activity

Raw acceleration information obtained from each IMU and a wGT3X-BT PA monitor (ActiGraph, Pensacola, Florida, USA; triaxial, ±8 G, 50 Hz sampling rate) worn over the right hip (anterior superior iliac spine) was used to directly measure PA. Specifically, a custom MATLAB (r2014a, The MathWorks, Natick, MA) program was used to convert the raw acceleration information obtained from each participant and each of the sensors from units of gravity (i.e., g) to metabolic equivalents (METs) that express the energy cost of physical activities. The raw acceleration values were converted into an omnidirectional measure of acceleration by calculating the vector magnitude of the three accelerometer axes and then subtracting the value of gravity (g), after which, negative values were rounded up to zero (Hildebrand et al., 2014). The resulting value has been referred to as the Euclidian norm minus one (ENMO) (van Hees et al., 2013). Data were then further reduced by calculating the average acceleration values per 1-s epoch and then averaging the 1-s epoch values over 1-min intervals. The resulting acceleration averages per 1-min epoch were implemented into a regression equation to predict METs based on the relationship between acceleration and oxygen consumption (VO_2) (Hildebrand et al., 2014). Standard definitions were used to categorize PA as "light" (≤3.0 METs) or "moderate" (>3.0 METs) intensity activity.

Complete PA information was obtained from the waist-worn wGT3X-BT monitor for all participants. Instrumentation failure led to the loss of PA information from the IMUs on one participant's trunk, three participants' right upper arm, and three participants'