Comparing Fatigue, Physical Activity, and Posture among Nurses in Two Staffing Models

Mark C. Schall Jr. [1], Howard Chen [2], Nathan Fethke [2]

[1] *Auburn University,* [2] *University of Iowa*

The high variability and complexity of patient care needs have led to the development of various nurse staffing models. While "pod nursing" has been observed to result in favorable outcomes such as improved patient access, professional communication, and job satisfaction among nurses, the effects of pod nursing on important metrics related to nurse health have not been previously reported. This study compared self-reported estimates of fatigue and directly measured estimates of physical activity and exposure to non-neutral working postures of the trunk and upper arms obtained from registered nurses working in a pod nursing model to estimates obtained from registered nurses working in a total patient care (TPC) model. Results suggested that nurses working in the pod model had similar exposures to nurses working in the TPC model. Consistent with previous work, nurses were observed to spend a small percentage of work time performing moderate or greater intensity physical activity.

INTRODUCTION

Nursing personnel report a high prevalence of pain and other symptoms consistent with work-related musculoskeletal disorders (MSDs), especially of the low back and shoulders (Alexopoulos, Burdorf, & Kalokerinou, 2006; June & Cho, 2011; Karahan, Kav, Abbasoglu, & Dogan, 2009; Long, Bogossian, & Johnston, 2013; Lövgren, Gustavsson, Melin, & Rudman, 2014). According to the Bureau of Labor Statistics (BLS, 2013), nursing assistants and registered nurses had the second and fifth highest number of nonfatal occupational injuries and illnesses involving days-away-from-work and MSDs, respectively, among all occupations in 2012. 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. These conditions contribute to undesirable consequences such as early retirement, preventable disability, and nurse turnover (De Castro, 2006).

Biomechanically-demanding work tasks such as lifting and transferring patients often require that nurses work in non-neutral postures (Byrns, Reeder, Jin, & Pachis, 2004; Dennerlein et al., 2012; Sonja Freitag et al., 2012; S. Freitag et al., 2014). Working in non-neutral postures has been associated with an increased risk of MSDs of the back and shoulder in many occupations, including nursing (da Costa & Vieira, 2010; Miranda, Viikari-Juntura, Martikainen, Takala, & Riihimäki, 2001; Silverstein et al., 2008; Silverstein et al., 2006; Svendsen, Bonde, Mathiassen, Stengaard-Pedersen, & Frich, 2004; Susanne Wulff Svendsen et al., 2004). Demanding work tasks may also lead to increased fatigue and high levels of occupational physical activity that may threaten nurse health and safety (Han, Trinkoff, & Geiger-Brown, 2014; Holtermann et al., 2012; Smith-Miller, Shaw-Kokot, Curro, & Jones, 2014).

In an effort to improve patient outcomes and nurse work conditions, many U.S. hospitals have begun adjusting the way that nurses are assigned to patients and deliver care. Traditionally, hospitals use a "total patient care" (TPC) model where a single nurse is assigned to several patients that may be spread throughout one or multiple units. In contrast, in "pod nursing", nurses work as a team in a particular physical area of the hospital to better serve patients (Kalisch & Schoville, 2012). While pod nursing has been observed to result in favorable nurse outcomes such as improved patient access, professional communication, job satisfaction, and reduced overtime work (Friese et al., 2014; Hall & Doran, 2004; Kalisch & Schoville, 2012; Pizzingrilli & Christensen, 2014), no prior study has evaluated the effects of pod nursing on self-reported fatigue and directly measured estimates of physical activity and exposure to non-neutral working postures.

The objective of this study was, therefore, to compare levels of self-reported fatigue, directly measured physical activity, and directly measured exposure to non-neutral working postures of the trunk and upper arms among a convenience sample of registered nurses assigned to two different nurse staffing models. We tested the hypothesis that registered nurses working in a pod nursing model would experience less fatigue, and be exposed to less occupational physical activity and exposure to non-neutral working postures in comparison to nurses working in a TPC model.

METHODS

Participants

A convenience sample of 36 healthy, female registered nurses (mean age=30.8 years, SD=10.1; mean body mass index [BMI]=24.1 kg/m^2, SD=4.4) was recruited from two medical surgical inpatient units at the University of Iowa Hospitals and Clinics. One unit used a pod nursing model and one unit used a TPC model. All nurses worked a 12 hour shift except for three participants; two worked for 8 hours and one worked for 11 hours. Twenty-one participants (11 pod nurses) worked day shifts (starting at 7 am) and 15 participants (7 pod nurses) worked night shifts (starting at 7pm).

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.

Fatigue

Fatigue, a feeling of physical tiredness and lack of energy, was self-reported by participants using the Daily Fatigue Impact Scale (D-FIS) at the conclusion of their work shift (Fisk & Doble, 2002). The D-FIS is a validated instrument designed to measure subjective daily fatigue. The D-FIS is composed of 8 items investigating 3 dimensions of fatigue (cognitive, psychological, and physical). Each item is scored on 5-point Likert scale with item scores ranging from 0-4. The total D-FIS score is calculated as the sum of the ordinal scores obtained for each item and has a total possible range of 0-32. A lower score represents less fatigue. The D-FIS has been used extensively to assess the impacts of fatigue on health-related quality of life in a number of clinical populations (Benito-León et al., 2007; Martinez-Martin et al., 2006).

Physical Activity

Estimates of physical activity were obtained using a wGT3X-BT physical activity monitor (Actigraph, Pensacola, Florida, USA) worn over the right hip (the anterior superior iliac spine) on an elastic belt. The wGT3X-BT has a dynamic range of ±8 G and is band limited with a frequency response from 0.25-2.5 Hz (John & Freedson, 2012). Activity "counts" at each data sample were summed across non-overlapping epochs of one minute to attain counts/min. Finally, the counts/min at each epoch was categorized into different intensities of physical activity. Definitions from Freedson et al. (1998) were used to categorize physical activity as "sedentary" (0-100 counts/min), "light" (101-1952 counts/min), "moderate" (1953-5724 counts/min), vigorous (5725-9498 counts/min), and "very vigorous" (>9498 counts/min). For each participant and sensor, the total number of minutes assigned to each physical activity category across the full sampling duration was calculated. The proportions of time in each physical activity category were used as the exposure variables.

Posture

Estimates of trunk inclination (flexion/extension), lateral inclination (lateral bending), and upper arm elevation (either forward flexion or abduction of the upper arm) were obtained using three ArduIMU+ V3 inertial measurement units (IMUs). Each IMU was a small wireless, battery-powered unit that measures and stores acceleration (triaxial, +/- 8 g) and angular velocity (triaxial, +/- 2000 ° s-1). One IMU was secured to the posterior torso at approximately the level of the 4th thoracic vertebral body and the additional IMUs were secured to the lateral aspect of the upper arms, approximately one-half the distance between the lateral epicondyle and the acromion, bilaterally. The raw acceleration data streams from each IMU were sampled at 50 Hz and the data was stored to an on-board flash memory card. A combination of custom LabVIEW (version 2014, National Instruments Inc., Austin, TX) and Matlab (r2014a, The Mathworks, Natick, MA) programs were used to synchronize the data from each device (using time stamps recorded with the data) and to process the raw acceleration information to posture estimates.

A custom complementary weighting algorithm developed in MATLAB (r2014a, The MathWorks, Inc., Natick, MA) was used to convert the raw data streams of acceleration and angular velocity to estimates of trunk inclination and upper arm elevation as in previous studies (Schall Jr, Fethke, Chen, & Gerr, 2015; Schall Jr, Fethke, Chen, & Kitzmann, 2014). The complementary weighting algorithm approach was used in lieu of a solely accelerometer-based approach as accelerometer-based estimates have been observed to be less accurate during complex, dynamic movement (Amasay, Zodrow, Kincl, Hess, & Karduna, 2009; Brodie, Walmsley, & Page, 2008; Godwin, Agnew, & Stevenson, 2009; Hansson, Asterland, Holmer, & Skerfving, 2001).

Exposure variables used to describe posture included selected percentiles (10th, 50th, 90th) of the amplitude probability distribution function (APDF) and variables describing 'extreme' postures such as percent time with the trunk flexed >45° and upper arms elevated >60° (Jansen, Morgenstern, & Burdorf, 2004; Punnett, Fine, Keyserling, Herrin, & Chaffin, 1991; Putz-Anderson et al., 1997). Peak inclination and elevation levels were defined as those values associated with the 90th percentile of the APDF while static levels were defined as those associated with the 10th percentile of the APDF (Jonsson, 1982). Negative values denote trunk extension or left lateral bending.

Statistical Analysis

Means and standard deviations (SD) were calculated for each exposure variable (fatigue, physical activity, and posture) by nursing model. Independent samples t-tests (2-tailed) were used to compare the exposure variables between the unit types. Each comparison was evaluated for statistical significance using a *p*-value of 0.05.

RESULTS

Physical activity data were successfully obtained for all participants. Instrumentation failure led to the loss of one participant's trunk data, two participant's right upper arm data, and one participant's left upper arm data. No statistically significant differences were observed between the pod nursing and TPC models for all of the exposure variables (Table 1).

In general, a small percentage of work time was spent performing moderate physical activity across all participants (7.95%) and none of the participants had any vigorous or very vigorous levels of physical activity. On average, participants spent 90.9% of their work time in a neutral trunk position (>-15° - 45°), 94.4% of their work time with the left arm elevated less than 60°, and 96.6% of their work time with the right arm elevated less than 60°.

Table 1. Mean (SD) of physical activity, fatigue, and trunk inclination and upper arm elevation estimates by unit model.

Exposure Variable	TPC	Pod	*p*
Physical activity			
Sedentary (% time)	30.9 (6.1)	29.7 (7.9)	0.61
Light (% time)	60.6 (5.8)	63.1 (6.9)	0.25
Moderate (% time)	8.5 (7.2)	7.2 (3.7)	0.31
Fatigue (D-FIS)	5.0 (5.2)	6.5 (5.0)	0.38
Trunk inclination angle			
APDF 10th (°)	-5.0 (7.1)	-4.4 (5.7)	0.80
APDF 50th (°)	10.1 (6.2)	10.6 (6.1)	0.79
APDF 90th (°)	36.1 (6.3)	35.4 (9.5)	0.80
< -15° (% time)	3.7 (4.0)	3.4 (2.9)	0.79
> -15 - 45° (% time)	90.4 (4.6)	90.3 (4.7)	0.93
> 45° (% time)	5.9 (3.3)	6.3 (4.7)	0.73
Lateral inclination angle			
APDF 10th (°)	-9.0 (2.9)	-8.4 (4.4)	0.65
APDF 50th (°)	-0.7 (2.9)	0.1 (3.6)	0.50
APDF 90th (°)	7.4 (3.7)	8.3 (3.0)	0.48
< -15° (% time)	3.5 (1.9)	4.2 (3.3)	0.44
> -15 - 15° (% time)	92.9 (3.0)	91.9 (3.4)	0.38
> 15° (% time)	3.7 (2.8)	3.9 (2.6)	0.79
Left arm elevation			
APDF 10th (°)	8.0 (5.0)	8.0 (2.4)	0.99
APDF 50th (°)	22.0 (8.1)	23.5 (4.6)	0.49
APDF 90th (°)	49.0 (10.8)	52.0 (7.0)	0.34
< 15° (% time)	34.6 (14.1)	29.8 (9.2)	0.25
> 15-60° (% time)	59.8 (9.9)	64.4 (7.6)	0.13
> 60° (% time)	5.7 (5.8)	5.8 (3.5)	0.94
Right arm elevation			
APDF 10th (°)	6.9 (5.0)	6.2 (2.3)	0.62
APDF 50th (°)	21.7 (7.3)	21.1 (4.6)	0.78
APDF 90th (°)	46.2 (8.6)	45.7 (6.2)	0.85
< 15° (% time)	34.6 (12.4)	35.3 (9.5)	0.85
> 15-60° (% time)	61.6 (8.8)	61.6 (8.8)	0.99
> 60° (% time)	3.9 (4.7)	3.1 (1.6)	0.54

Note: Negative values = trunk extension or left lateral bending

DISCUSSION

The objective of this study was to compare levels of self-reported fatigue, directly measured physical activity, and directly measured exposure to non-neutral working postures of the trunk and upper arms among a convenience sample of registered nurses assigned to two different staffing models. We tested the hypothesis that registered nurses working in a pod nursing model would experience less fatigue, and be exposed to less occupational physical activity and exposure to non-neutral working postures in comparison to nurses working in a TPC model.

In contrast to our hypothesis, results of this study indicated that registered nurses working in a pod nursing model did not experience less fatigue, and had similar exposure to occupational physical activity and non-neutral working postures in comparison to nurses working in a TPC model. No statistically significant differences were observed between the pod nursing and TPC models for all of the exposure variables obtained in this study.

Although not statistically significant, the nurses in the pod model reported more fatigue, on average, than the nurses in the TPC model. This result was unexpected and suggests that pod nursing may lead to increased occupational physical activity despite less dispersion in the location of patients.

Consistent with previous work by Arias et al. (2012) and Umokuru et al. (2013), nurses were observed to spend a very small proportion of their work time performing moderate or vigorous levels of physical activity. In fact, no vigorous or very vigorous levels of physical activity were measured among nurses in this study. These results provide further evidence that physical activity at work contributes very little to the total amounts of moderate and vigorous intensity activity levels recommended for protection against cardiovascular diseases among nurses (Haskell et al., 2007; Umukoro et al., 2013).

Nurses in this study were also observed to spend a very small percentage of work time in extreme trunk and upper arm postures (those defined as >45° trunk inclination; >15° lateral inclination; >60° upper arm elevation). In comparison to previous work by Hodder et al. (2010) who observed that long-term care nurses spent 25% of their time with the trunk flexed beyond 30°, nurses in this study were observed to only spend 18% of their work time with the trunk flexed beyond 30° (following re-analysis to examine the percentage of time with trunk flexed >30°; not shown in Table 1). Differences in trunk flexion estimates may be partially explained by the use of the complementary weighting algorithm that is theoretically more accurate for estimating exposure during dynamic movements and differences in the location of the IMU worn by participants.

Limitations of this study include the use of proprietary activity counts and use of data from a single work shift for all participants. Physical activity counts and their associated cut points have recently been identified as being an imperfect form of summarizing physical activity (Freedson, Bowles, Troiano, & Haskell, 2012; Thiese, 2014). More appropriate exposure estimates such as the metabolic equivalent of a task (MET) may provide more accurate estimates of physical activity than activity counts (Hildebrand, Van Hees, Hansen, & Ekelund, 2014). Further assessment of the data obtained in this study is planned using these methods.

Additionally, this study did not assess several important job stressors associated with MSDs among nurses including physical workload (e.g., high forces during manual patient handling), mental workload (e.g., information overload), time pressure, and emotional workload (De Castro, 2006; Hoonakker et al., 2011; Kiekkas et al., 2008). Biomechanical risk due to manual material handling and/or sudden, unexpected loads, in particular, may contribute to the high prevalence of MSDs among nurses. Future research evaluating nurse staffing models should consider the effects of high physical loading among nursing personnel, especially when nurses are working in non-neutral postures.

ACKNOWLEDGEMENTS

This research was supported by a pilot project grant from the Healthier Workforce Center for Excellence (HWCE) at the University of Iowa. The HWCE is supported by Cooperative Agreement No. U19OH008858 from the Centers for Disease Control and Prevention (CDC) / National Institute for Occupational Safety and Health (NIOSH). The contents are solely the responsibility of the author(s) and do not necessarily represent the official views of the CDC, NIOSH, or the HWCE. The authors thank Martha Blondin, Laura Cullen, Marcia Gingerich, Grace Matthews, LouAnn Montgomery, Tamara Sebolt, and Karen Stenger for assistance recruiting participants for this study.

REFERENCES

Alexopoulos, E. C., Burdorf, A., & Kalokerinou, A. (2006). A comparative analysis on musculoskeletal disorders between Greek and Dutch nursing personnel. *International archives of occupational and environmental health, 79*(1), 82-88.

Amasay, T., Zodrow, K., Kincl, L., Hess, J., & Karduna, A. (2009). Validation of tri-axial accelerometer for the calculation of elevation angles. *International Journal of Industrial Ergonomics, 39*(5), 783-789.

Arias, O. E., Umukoro, P. E., Stofell, S., Dennerlein, J. T., & Sorensen, G. (2012). *Association between Trunk Flexion and Physical Activity in Patient Care Unit Workers.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

Benito-León, J., Martínez-Martín, P., Frades, B., Martínez-Ginés, M., De Andrés, C., Meca-Lallana, J., et al. (2007). Impact of fatigue in multiple sclerosis: the Fatigue Impact Scale for Daily Use (D-FIS). *Multiple Sclerosis*.

Brodie, M. A., Walmsley, A., & Page, W. (2008). Dynamic accuracy of inertial measurement units during simple pendulum motion. *Comput Methods Biomech Biomed Engin, 11*(3), 235-242.

Byrns, G., Reeder, G., Jin, G., & Pachis, K. (2004). Risk factors for work-related low back pain in registered nurses, and potential obstacles in using mechanical lifting devices. *Journal of occupational and environmental hygiene, 1*(1), 11-21.

da Costa, B. R., & Vieira, E. R. (2010). Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. *Am J Ind Med, 53*(3), 285-323.

De Castro, A. (2006). Handle with Care®: The American Nurses Association's Campaign to Address Work-Related Musculoskeletal Disorders. *Orthopaedic Nursing, 25*(6), 356-365.

Dennerlein, J. T., Hopcia, K., Sembajwe, G., Kenwood, C., Stoddard, A. M., Tveito, T. H., et al. (2012). Ergonomic practices within patient care units are associated with musculoskeletal pain and limitations. *American journal of industrial medicine, 55*(2), 107-116.

Fisk, J. D., & Doble, S. E. (2002). Construction and validation of a fatigue impact scale for daily administration (D-FIS). *Quality of Life Research, 11*(3), 263-272.

Freedson, P., Bowles, H. R., Troiano, R., & Haskell, W. (2012). Assessment of physical activity using wearable monitors: recommendations for monitor calibration and use in the field. *Medicine and science in sports and exercise, 44*(1 Suppl 1), S1.

Freitag, S., Fincke-Junod, I., Seddouki, R., Dulon, M., Hermanns, I., Kersten, J. F., et al. (2012). Frequent bending—an underestimated burden in nursing professions. *Annals of occupational hygiene*, mes002.

Freitag, S., Seddouki, R., Dulon, M., Kersten, J. F., Larsson, T. J., & Nienhaus, A. (2014). The effect of working position on trunk posture and exertion for routine nursing tasks: an experimental study. *Ann Occup Hyg, 58*(3), 317-325.

Friese, C. R., Grunawalt, M. J. C., Bhullar, S., Bihlmeyer, M. K., Chang, R., & Wood, M. W. (2014). Pod Nursing on a Medical/Surgical Unit: Implementation and Outcomes Evaluation. *The Journal of nursing administration, 44*(4), 207.

Godwin, A., Agnew, M., & Stevenson, J. (2009). Accuracy of inertial motion sensors in static, quasistatic, and complex dynamic motion. *Journal of biomechanical engineering, 131*(11), 114501.

Hall, L. M., & Doran, D. (2004). Nurse staffing, care delivery model, and patient care quality. *Journal of Nursing Care Quality, 19*(1), 27-33.

Han, K., Trinkoff, A., & Geiger-Brown, J. (2014). Factors associated with work-related fatigue and recovery in hospital nurses working 12-hour shifts. *Workplace health & safety, 62*(10), 409-414.

Hansson, G., Asterland, P., Holmer, N.-G., & Skerfving, S. (2001). Validity and reliability of triaxial accelerometers for inclinometry in posture analysis. *Medical and Biological Engineering and Computing, 39*(4), 405-413.

Haskell, W. L., Lee, I.-M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., et al. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation, 116*(9), 1081.

Hildebrand, M., Van Hees, V. T., Hansen, B. H., & Ekelund, U. (2014). Age-group comparability of raw accelerometer output from wrist-and hip-worn monitors. *Med Sci Sport Exerc, 46*, 1816-1824.

Hodder, J. N., Holmes, M. W., & Keir, P. J. (2010). Continuous assessment of work activities and posture in long-term care nurses. *Ergonomics, 53*(9), 1097-1107.

Holtermann, A., Burr, H., Hansen, J. V., Krause, N., Søgaard, K., & Mortensen, O. S. (2012). Occupational physical activity and mortality among Danish workers. *International archives of occupational and environmental health, 85*(3), 305-310.

Hoonakker, P., Carayon, P., Gurses, A. P., Brown, R., Khunlertkit, A., McGuire, K., et al. (2011). Measuring workload of ICU nurses with a questionnaire survey: the NASA Task Load Index (TLX). *IIE transactions on healthcare systems engineering, 1*(2), 131-143.

Jansen, J., Morgenstern, H., & Burdorf, A. (2004). Dose-response relations between occupational exposures to physical and psychosocial factors and the risk of low back pain. *Occupational and Environmental Medicine, 61*(12), 972-979.

John, D., & Freedson, P. (2012). ActiGraph and Actical physical activity monitors: a peek under the hood. *Medicine and science in sports and exercise, 44*(1 Suppl 1), S86.

Jonsson, B. (1982). Measurement and evaluation of local muscular strain in the shoulder during constrained work. *Journal of human ergology*.

June, K. J., & Cho, S. H. (2011). Low back pain and work-related factors among nurses in intensive care units. *Journal of Clinical Nursing, 20*(3-4), 479-487.

Kalisch, B., & Schoville, R. (2012). It takes a team. *AJN The American Journal of Nursing, 112*(10), 50-54.

Karahan, A., Kav, S., Abbasoglu, A., & Dogan, N. (2009). Low back pain: prevalence and associated risk factors among hospital staff. *Journal of advanced nursing, 65*(3), 516-524.

Kiekkas, P., Sakellaropoulos, G. C., Brokalaki, H., Manolis, E., Samios, A., Skartsani, C., et al. (2008). Association between nursing workload and mortality of intensive care unit patients. *Journal of Nursing Scholarship, 40*(4), 385-390.

Long, M. H., Bogossian, F. E., & Johnston, V. (2013). The Prevalence of Work-Related Neck, Shoulder, and Upper Back Musculoskeletal Disorders among Midwives, Nurses, and Physicians A Systematic Review. *Workplace health & safety, 61*(5), 223-229.

Lövgren, M., Gustavsson, P., Melin, B., & Rudman, A. (2014). Neck/shoulder and back pain in new graduate nurses: A growth mixture modeling analysis. *International journal of nursing studies, 51*(4), 625-639.

Martinez-Martin, P., Catalan, M. J., Benito-Leon, J., Moreno, A. O., Zamarbide, I., Cubo, E., et al. (2006). Impact of fatigue in Parkinson's disease: the Fatigue Impact Scale for Daily Use (D-FIS). *Quality of Life Research, 15*(4), 597-606.

Miranda, H., Viikari-Juntura, E., Martikainen, R., Takala, E., & Riihimäki, H. (2001). A prospective study of work related factors and physical exercise as predictors of shoulder pain. *Occupational and Environmental Medicine, 58*(8), 528-534.

Pizzingrilli, B., & Christensen, D. (2014). Staff perceptions of pod nursing on an acute mental health unit. *Journal of Nursing Education and Practice, 4*(12), p88.

Punnett, L., Fine, L. J., Keyserling, W. M., Herrin, G. D., & Chaffin, D. B. (1991). Back disorders and nonneutral trunk postures of automobile assembly workers. *Scandinavian journal of work, environment & health*, 337-346.

Putz-Anderson, V., Bernard, B. P., Burt, S. E., Cole, L. L., Fairfield-Estill, C., Fine, L. J., et al. (1997). Musculoskeletal disorders and workplace factors. *National Institute for Occupational Safety and Health (NIOSH)*.

Schall Jr, M. C., Fethke, N. B., Chen, H., & Gerr, F. (2015). A comparison of instrumentation methods to estimate thoracolumbar motion in field-based occupational studies. *Applied Ergonomics, 48*, 224-231.

Schall Jr, M. C., Fethke, N. B., Chen, H., & Kitzmann, A. S. (2014). A Comparison of Examination Equipment Used During Common Clinical Ophthalmologic Tasks. *IIE Transactions on Occupational Ergonomics and Human Factors, 2*(2), 105-117.

Silverstein, B. A., Bao, S. S., Fan, Z. J., Howard, N., Smith, C., Spielholz, P., et al. (2008). Rotator cuff syndrome: personal, work-related psychosocial and physical load factors. *Journal of Occupational and Environmental Medicine, 50*(9), 1062-1076.

Silverstein, B. A., Viikari-Juntura, E., Fan, Z. J., Bonauto, D. K., Bao, S., & Smith, C. (2006). Natural course of nontraumatic rotator cuff tendinitis and shoulder symptoms in a working population. *Scandinavian journal of work, environment & health*, 99-108.

Smith-Miller, C. A., Shaw-Kokot, J., Curro, B., & Jones, C. B. (2014). An Integrative Review: Fatigue Among Nurses in Acute Care Settings. *Journal of Nursing Administration, 44*(9), 487-494.

Svendsen, S. W., Bonde, J. P., Mathiassen, S. E., Stengaard-Pedersen, K., & Frich, L. H. (2004). Work related shoulder disorders: quantitative exposure-response relations with reference to arm posture. *Occup Environ Med, 61*(10), 844-853.

Svendsen, S. W., Gelineck, J., Mathiassen, S. E., Bonde, J. P., Frich, L. H., Stengaard-Pedersen, K., et al. (2004). Work above shoulder level and degenerative alterations of the rotator cuff tendons: a magnetic resonance imaging study. *Arthritis & Rheumatism, 50*(10), 3314-3322.

Thiese, M. (2014). Important differences in accelerometer cut points for quantifying physical activity in a nested occupational cohort. *J Exerc Sports Orthop, 1*(1), 12.

Umukoro, P. E., Arias, O. E., Stoffel, S. D., Hopcia, K., Sorensen, G., & Dennerlein, J. T. (2013). Physical Activity at Work Contributes Little to Patient Care Workers' Weekly Totals. *Journal of Occupational and Environmental Medicine, 55*, S63-S68.