Advances in Usability Evaluation

Part I

Advances in Human Factors and Ergonomics Series

Series Editors

Gavriel Salvendy
Professor Emeritus
School of Industrial Engineering
Purdue University

Chair Professor & Head
Dept. of Industrial Engineering
Tsinghua Univ., P.R. China

Waldemar Karwowski
Professor & Chair
Industrial Engineering and
Management Systems
University of Central Florida
Orlando, Florida, U.S.A.

3rd International Conference on Applied Human Factors and Ergonomics (AHFE) 2010

Advances in Applied Digital Human Modeling
Vincent G. Duffy

Advances in Cognitive Ergonomics
David Kaber and Guy Boy

Advances in Cross-Cultural Decision Making
Dylan D. Schmorrow and Denise M. Nicholson

Advances in Ergonomics Modeling and Usability Evaluation
Halimahtun Khalid, Alan Hedge, and Tareq Z. Ahram

Advances in Human Factors and Ergonomics in Healthcare
Vincent G. Duffy

Advances in Human Factors, Ergonomics, and Safety in Manufacturing and Service Industries
Waldemar Karwowski and Gavriel Salvendy

Advances in Occupational, Social, and Organizational Ergonomics
Peter Vink and Jussi Kantola

Advances in Understanding Human Performance: Neuroergonomics, Human Factors Design, and Special Populations
Tadeusz Marek, Waldemar Karwowski, and Valerie Rice

4th International Conference on Applied Human Factors and Ergonomics (AHFE) 2012

Advances in Affective and Pleasurable Design
Yong Gu Ji

Advances in Applied Human Modeling and Simulation
Vincent G. Duffy

Advances in Cognitive Engineering and Neuroergonomics
Kay M. Stanney and Kelly S. Hale

Advances in Design for Cross-Cultural Activities Part I
Dylan D. Schmorrow and Denise M. Nicholson

Advances in Design for Cross-Cultural Activities Part II
Denise M. Nicholson and Dylan D. Schmorrow

Advances in Ergonomics in Manufacturing
Stefan Trzcielinski and Waldemar Karwowski

Advances in Human Aspects of Aviation
Steven J. Landry

Advances in Human Aspects of Healthcare
Vincent G. Duffy

Advances in Human Aspects of Road and Rail Transportation
Neville A. Stanton

Advances in Human Factors and Ergonomics, 2012-14 Volume Set: Proceedings of the 4th AHFE Conference 21-25 July 2012
Gavriel Salvendy and Waldemar Karwowski

Advances in the Human Side of Service Engineering
James C. Spohrer and Louis E. Freund

Advances in Physical Ergonomics and Safety
Tareq Z. Ahram and Waldemar Karwowski

Advances in Social and Organizational Factors
Peter Vink

Advances in Usability Evaluation Part I
Marcelo M. Soares and Francisco Rebelo

Advances in Usability Evaluation Part II
Francisco Rebelo and Marcelo M. Soares

CHAPTER 16

Reducing Ergonomic Injuries for Librarians Using a Participatory Approach

Lu Yuan

Southeastern Louisiana University
Hammond, USA
Lu.Yuan@selu.edu

ABSTRACT

This study utilized a participatory ergonomics approach to examine the ergonomic hazards and to reduce musculoskeletal symptoms for librarians in the East Baton Rouge Parish Main Library. A total of 39 employees from 9 different divisions in the Library participated in the study. The results of pre- and post-training ergonomics knowledge tests indicate significant improvement of librarians' understanding of ergonomics principles, whereas the questionnaire responses for both 2-month-post- and 8-month-post- the ergonomics training compared against those before the training have shown positive improvements in the majority of musculoskeletal symptom presence and severity, computer workstation, manual material handling, and perceived control over the work environment. With the identification of ergonomic hazards through RULA (Rapid Upper Limb Assessment) and REBA (Rapid Entire Body Assessment) observations as well as focus group discussions, the study findings accomplish the project's overall objective of assisting librarians to improve ergonomics in the workplace. The results of this study provide foundation for future long-term study of participatory ergonomics to reduce musculoskeletal injuries and disorders for librarians and other service sector workers.

Keywords: participatory ergonomics, librarians, musculoskeletal symptom

1 INTRODUCTION

Technological advancement has shaped the work environment in libraries dramatically since the 1990s. Intensive or long-term use of computers and other electronic tools has become more and more popular in all public service areas and technical operations, particularly cataloging. This has caused librarians to use awkward postures of the head, neck, and upper extremities and to endure increased pressures on the soft tissues against external workstation surfaces. On the other hand, librarians are still involved in extensive and repetitive handling of books, boxes, and other materials, where they usually have to exert excessive strength during different activities and maintain sustained static posture during prolonged holding (Thibodeau and Melamut, 1995).

Both these typical aspects of library work expose librarians to a relatively wider range and higher level of ergonomic hazards than "standard" office-type work does, as they have produced enormous risk and stress on librarians (Chao, 2001). For example, Mansfield and Armstrong (1997) reported that the average yearly numbers of injuries and traumatic musculoskeletal disorders (MSDs) at the Library of Congress whose yearly average was 4917 staff during 1991-1995, are 229 and 47, respectively. These injuries and disorders have caused an average yearly $946,284 workers' compensation cost during that five-year span.

It seems there is a great need to address ergonomic issues within the library environment. Although there is a growing body of literature discussing ergonomics and libraries found in books, journals, and internet sources, there is currently no systematic process to determine needs and evaluate interventions (Tepper, 1996). Rather, the majority of relevant ergonomic research focuses on the examination of hazards in the "standard" office environment. Libraries spend a great amount of time planning the hardware and software implementations of electronic information services, but the human factors and ergonomics are often overlooked (Thibodeau and Melamut, 1995). Thus, it is imperative to explore effective and efficient research methodologies to identify, analyze, and control ergonomic hazards during library work.

One method for introducing and implementing ergonomics is to use the concept of participatory ergonomics, which originated from discussions between Drs. Kageyu Noro and Kazutaka Kogi in Singapore in 1983 (Imada, 1991). As the word "participatory" indicates, this specific concept constitutes the use of participative techniques and various forms of participation in the workplace (Vink and Wilson, 2003). Wilson (1995) defined participatory ergonomics as "the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals."

The objective of the present study was to utilize a participatory ergonomics approach to reduce musculoskeletal injuries and disorders for librarians in the East Baton Rouge Parish Main Library. Specifically, the study was designed to: provide training of the basic concepts and principles of ergonomics to librarians; identify the ergonomic hazards associated with typical library work; and introduce and then

apply the participatory ergonomics approach to mitigate the ergonomic hazards within the library environment.

2 METHODS

Figure 1 illustrates a simplified diagram outlining the participatory ergonomics process used in this study. It should be noted that *evaluation* is one of the most crucial elements involved in the entire research process. Variables that were evaluated are connected to relevant measures within each step using different methods.

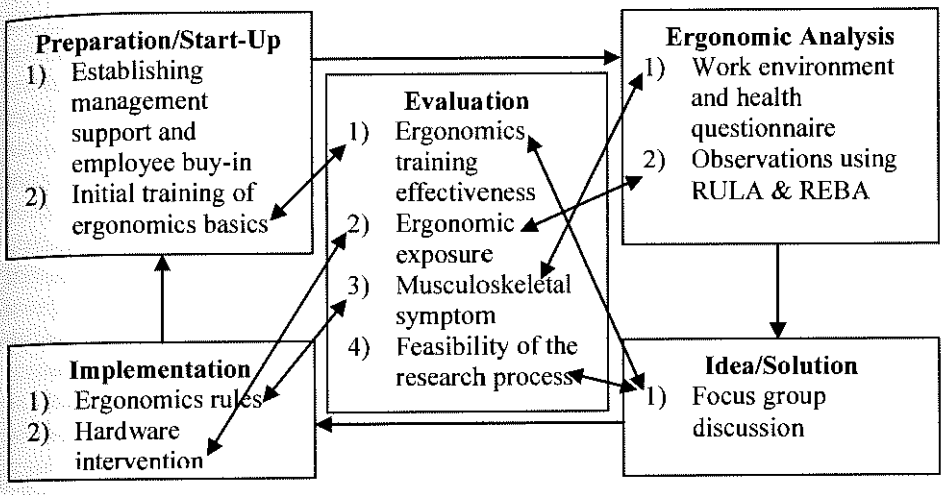

Figure 1 A simplified diagram of the participatory ergonomics process in this study

Details about preparation/start-up, ergonomics training, and work environment and health questionnaire are available in Yuan and Culberson (2011).

2.1 Observations Using RULA & REBA

RULA (Rapid Upper Limb Assessment) was used to assess working postures and required muscle use and force exertion for computer usage of the library work (Lueder and Corlett, 1996; McAtamney and Corlett, 1993). For the manual material handling activities during library work, REBA (Rapid Entire Body Assessment) was used to estimate the risks of entire-body injuries and disorders (Hignett and McAtamney, 2000).

A total of approximately 20 hours of RULA and REBA observations were conducted on representative samples of the library work before the ergonomics training (10 hours in total), 2 months after the training (5 hours), and 8 months after (5 hours). Typical library work tasks/activities that were observed by RULA include: labeling, stamping, and lining books and cataloging books in the Technical

Service Department; answering phone calls in the Reference Division; Checking in/out books in the Circulation Division; and by REBA include: unloading boxes of books and other materials and categorizing in the Shipping/Handling Office of the Circulation Division.

2.2 Focus Group Discussion

Focus group interviews and/or meetings have been employed in many participatory ergonomics research projects (Pehkonen, Takala, and Ketola, et al., 2009). This technique uses a scripted brainstorming method to solicit questions and answers from a group of people representing a wide range of employment. In this study, the employee representatives from different divisions in the Library were invited to participate in the focus group discussion. During the one-hour meeting, the attendees were asked questions about their work activities, safety and health concerns, ergonomic exposures, hazard control, and opinions on the feasibility of the study.

2.3 Implemention of Ergonomics Rules and Hardware

Based on the previous steps of the research process where ergonomic hazards and risk factors have been identified and assessed through ergonomics training, the work environment and health questionnaires, observations, and focus group discussions, the researcher explored some handy posters or brochures illustrating ergonomics rules through consultation with the Barbre Ergonomics Consulting and Training (2011) and Experteyes (2011). Permission has been granted to distribute three ergonomics brochures including Stretches (from Barbre Ergonomics), and Workstation Ergonomics and Manual Handling and Storage (from Experteyes) to the study participants.

It was expected that better ergonomically-designed equipment, typically an ergonomic chair, would be recommended through both observations and focus group discussions. The upper management of the Library under study was supportive regarding expenses for reasonable requests. However, since the Library was in a process of getting a new building at the end of this study, the Director has preferred to make the investment for ergonomic workstation at a later stage.

2.4 Evaluation

Evaluation of the study includes both comparison of intermediate effects before and after the participatory ergonomics intervention and examination of the feasibility of the participatory approach. The effects of the intervention were measured through pre-post-differences in mean scores for ergonomics training test, work environment and health questionnaire, RULA and REBA observations.

The feasibility of the research process was assessed by focus group discussions and satisfaction surveys. At the end of the focus group discussions, the attendees were asked such questions as general opinions about the process, benefits of the

project, difficulties with the approach, and barriers in the implementation, etc. to assess feasibility. To measure the success of the intervention, a survey was distributed to the study participants at the end of the intervention phase. Satisfaction with the arrangements of the project, flow of information, implemented changes, support from the management, and support from researcher was evaluated on a five-point scale (1 = very dissatisfied, 2 = fairly dissatisfied, 3 = undecided, 4 = fairly satisfied, 5 = very satisfied).

2.5 Data Analysis

Differences in the average scores of pre- and post- training ergonomics knowledge tests were examined using paired t-tests. Changes in the responses of work environment and health questionnaire, especially the presence and severity of musculoskeletal symptoms, workstation postures, manual material handling experience, and perceived control of the work, were calculated and then summed across librarians to determine the proportion of subjects' responses in each of the three classifications ("improved", "worsened", or "no change"). A McNemar non-parametric test was used to evaluate the statistical significance of the observed changes ("improved" vs. "worsened") for comparisons of two-month-post- VS. pre-training, eight-month-post- VS. pre- training, and eight-month-post- VS. two-month-post- training, respectively. The one-way ANOVA was used to examine the differences in the average RULA and REBA scores at different stages of the research process, including before ergonomics training, 2 months after the training, and 8 months after. The focus group discussion notes were analyzed qualitatively, whereas a descriptive statistics was presented to summarize the satisfaction survey results.

Data were analyzed using PASW (also known as SPSS) Statistics 18.0. In each of the statistical tests described above, the level of significance required to reject the null hypotheses was established at $p < 0.05$.

3 RESULTS

3.1 Demographics of the Study Population

Thirty nine employees representing nine different divisions participated in the study. There were 28 females and 11 males. The average age for the sample population was 43.3 years (range 22 to 72). The subjects have been in their profession for an average of 13.2 years (range 0.4 to 45 years), and they have been working in the East Baton Rouge Parish Main Library for an average of 10.0 years (range 0.3 to 36 years). The majority of subjects are full-time employees (89.7% of the total), and the top two job titles that the subjects hold are Librarian Technician/Assistant (41.0%) and Librarian (30.8%).

Six of the 39 subjects did not return their 8-month-post-training questionnaires, which made the total number of questionnaire responses for this round to be 33.

Among those 6 subjects, one person has retired after completing the 2-month-post-training questionnaire, 2 employees have moved to other branch libraries, and the other 3 people could not be located.

3.2 Pre- and Post- Training Ergonomics Knowledge Tests

The average pre-test score was 37.6 (of 100 points), whereas the average post-test score was 76.3. The mean increase was 38.7. The t value of 11.9 (df = 38) was significant at $p < 0.0001$. Thirty four of the 39 subjects have answered the open-ended question in the post-test, of which the most common answers include adjusting monitor and chair height, and removing clutter from desk, etc.

3.3 Work Environment and Health Questionnaire

Two-Month-Post- VS. Pre-

The numbers (proportions) of changes in subjects' overall health rating for the three categories of "improved", "worsened", or "no change" were 6 (15%), 10 (26%), and 23 (59%). The χ^2 value for the McNemar test was 0.56, which did not show a significant difference between "improved" and "worsened" responses (p = 0.45).

There were statistically significantly positive changes in the questionnaire responses to the four specific questions: "break/rest every 2 hours", "hand/wrist positions", "handle more than 50 lbs", and "bend or twist at the waist to handle objects". The changes in other categories of the questionnaire, including the presence and severity of musculoskeletal symptoms and perceived control over the work environment, were not statistically significant; however, there was a trend toward positive improvement.

Eight-Month-Post- VS. Pre-

Subjects responded more "improved" changes 11 (33%) than "worsened" ones 8 (24%) in the overall health rating eight months after the training. The $\chi 2$ value for the McNemar test was 0.21, which did not show a significant difference between "improved" and "worsened" responses (p = 0.65).

There are statistically significantly positive changes in the questionnaire responses to three specific questions: "break/rest every 2 hours", "hand/wrist positions", and "supervisor's willingness to listen to work-related problems". The changes in other categories of the questionnaire were not statistically significant; however, there was a trend toward positive improvement.

Eight-Month-Post- VS. Two-Month-Post-

There were 10 (30%) "improved" and 4 (12%) "worsened" changes, respectively, in subjects' overall health rating between eight-month-post- and two-month-post- training questionnaire responses. However, this difference is not statistically significant ($\chi 2 = 1.79$, p = 0.18).

The net changes in the ratings of the presence and severity of musculoskeletal symptoms tended to fluctuate, and there were negative net changes in the manual material handling experience. Yet, it has shown positive improvement in the

category of computer workstation postures and adjustability. Also, it has been reported that supervisors were more willing to listen to work-related problems and the improvement was statistically significant.

3.4 RULA and REBA

The study did not find any statistically significant differences in the average RULA and REBA scores for the tasks/activities that were observed before and after the ergonomics training. Overall, some typical ergonomic hazards/issues were identified and these include: awkward postures of neck and upper extremities during computer usage and back during material handling, inadequate leg room under desk and work space on desk, improper postures of neck and shoulder and simultaneous computer typing when answering phone calls, and extreme overload on Mondays especially for the Shipping/Handling Office, etc.

3.5 Focus Group Discussion

Twelve subjects from 7 different divisions participated in a total of 3 focus group meetings in February 2011. The important things learned from these meetings include: 1) Heavy lifting, repetition, and sitting at computer for a long period of time are common activities for librarians; 2) There are also health concerns, e.g., customers might be sick and books might also contain viruses and bacteria; 3) Ergonomic furniture should be in place; and 4) Participation in the project was beneficial, and a workstation model during the ergonomics training and ergonomics posters/brochures afterwards would help even more.

3.6 Satisfaction survey

Approximately 85-94% of the subjects felt satisfied or very satisfied with arrangements of project, flow of information, and support from researchers. Only half of the subjects were satisfied with implemented changes and about 27% of the subjects were not so satisfied with support from management; however, there was a general consensus among the majority of those people that they understood the management was waiting to make the investment of ergonomic workstation for the new building that would be broken ground soon.

4 DISCUSSION

The present study utilized a participatory ergonomics approach consisting of ergonomics training, observations, work environment and health questionnaires, focus group discussions, ergonomics brochures to improve ergonomics in the workplace and to reduce musculoskeletal symptoms for librarians in the East Baton Rouge Parish Main Library. The results of ergonomics knowledge tests indicate significant improvement of librarians' understanding of ergonomics principles,

whereas the questionnaire responses for both 2-month-post- and 8-month-post- the ergonomics training compared against those before the training have shown positive improvements in the majority of musculoskeletal symptom presence and severity, computer workstation, manual material handling, and perceived control over the work environment. With the identification of ergonomic hazards through RULA and REBA observations as well as focus group discussions, the study findings accomplish the project's overall objective of enhancing ergonomics in the library environment.

The evaluation of library ergonomics training has not been conducted significantly in previous research studies; however, there have been a few publications depicting office and VDT (Video Display Terminal) ergonomics training evaluation (Bohr, 2000; Ketola, Toivonen, and Hakkanen, et al., 2002; Lewis, Fogleman, and Deeb, et al., 2001; Rizzo, Pelletier, and Chikamoto, 1997; Robertson, Amick III, and DeRango, et al. 2009). In particular, Lewis, Fogleman, and Deeb, et al. (2001) evaluated the effectiveness of a VDT training program through comparing the 170 participants' responses to a musculoskeletal symptom questionnaire before and one year after the program. This study did not have a control group not receiving the training, which used the similar design as the present study. However, both two studies shared the same results in demonstrating the effectiveness of ergonomics training to reduce musculoskeletal symptoms.

Since the post-training questionnaires were handed out both two months and eight months after the training, this study only measured the short-term effects on changes in subjects' work behavior and health status. There are some positive net changes in the presence and severity of musculoskeletal symptoms of major body parts when comparing subjects' responses two months and eight months after the training with those before training, respectively. Yet, the comparison of the responses in between two-month-post- and eight-month-post- training did not show one-way pattern at all. It may seem natural to see the decrease of the influence that participation in this project has produced on the subjects' musculoskeletal symptoms when time passes by, even though there have been positive improvements when compared with those ratings before the training. As 13 subjects have reported medical care for existing symptoms, it was not surprised to not see significant changes in the short-term effects that participating in this project could improve the subjects' health conditions. On the other hand, the responses in "other non-work-related activities" indicate that approximately half of the subjects had prolonged use of home computer, did heavy housework such as painting and mowing, and attended fitness program regularly. All these activities could produce confounding effect in the work-relatedness of musculoskeletal symptoms.

The improvement in subjects' computer usage and other work activities and experience indicates the application of ergonomics principles into their daily work life. Although the training tests only examined the subjects' knowledge of ergonomics, it would be surmised that because of the improving knowledge which could be demonstrated by the increasing test scores, subjects tended to apply ergonomics more often during their regular work activities.

The observational data by RULA and REBA, however, could not confirm any

statistically significant improvements in subjects' workstation posture and behavior. The researcher felt part of the reasons might be that no hardware intervention, primarily installation of the ergonomic workstation, has been implemented, as the Library is waiting on the new building that it will get in a near future. Also, the distribution of ergonomic brochures have been delayed as the management of the Library would like to purchase the license of these brochures and expand the distribution to all of the employees (approximately 500) working in the Library system. It would be interesting to see if there were any significant differences should the new building be in place, which might unduly indicate the necessity and importance of a follow-up study to continuously helping the librarians improve ergonomics in their new work environment.

The management's decision on not considering any significant changes until the new building is in place might also indirectly explain the less satisfaction ratings on support from management in the subjects' exit survey at the end of the project. Nevertheless, the 8-month-post-training questionnaire results indicate that the research participants felt their supervisors were more willing to listen to their work-related problems. In fact, the management was in the process of selecting and testing a variety of chairs that shall be purchased for different workstations and public service areas for the new building. Based on the conversation with the librarians during the focus group discussions and other casual occasions, it seemed that the majority of librarians understood the management's situation and had been anxiously waiting for the new building.

5 CONCLUSIONS

Overall, the study findings accomplish the project's objective of assisting librarians to improve ergonomics in the workplace and to reduce musculoskeletal symptoms in a short term. The present study provides invaluable baseline information about the ergonomic issues in the library environment, beyond which further research effort is warranted to improve the effectiveness of the library ergonomics program.

ACKNOWLEDGMENTS

The author thanks the East Baton Rouge Parish Main Library employees who participated in the research activities. The support from City of Baton Rouge Risk Management Division is greatly appreciated. This study was funded by the NIOSH Southwest Center for Occupational and Environmental Health (SWCOEH) Pilot Projects Research Training Program (Grant 3T42OH008421-0552). The contents in this article are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH. The author would like to thank Gregory Culberson who contributed to data collection.

REFERENCES

"Barbre Ergonomics Consulting and Training." Accessed March 1, 2011, http://www.barbre-ergonomics.com.

Bohr, P.C. 2000. Efficacy of office ergonomics education. *Journal of Occupational Rehabilitation* 10: 243-255.

Chao, S.J. 2001. Library ergonomics in literature: a selected annotated bibliography. *Collection Building* 20: 165-175.

"Experteyes." Accessed March 1, 2011, http://www.experteyes.com.au/.

Hignett S. and L. McAtamney. 2000 Rapid Entire Body Assessment: REBA. *Applied Ergonomics* 30: 201-205.

Imada, A.S. 1991. The rationale and tools of participatory ergonomics. In: *Participatory Ergonomics*, eds. K. Noro and A.S. Imada. London: Taylor & Francis.

Ketola, R., R. Toivonen, and M. Hakkanen, et al. 2002. Effects of ergonomics intervention in work with video display unit. *Scandinavian Journal of Work, Environment & Health* 28: 18-24.

Lewis, R.J., M. Fogleman, and J. Deeb, et al. 2001. Effectiveness of a VDT ergonomics training program. *International Journal of Industrial Ergonomics* 27: 119-131.

Lueder R. and E.N. Corlett. 1996. A proposed RULA for computer users. Proceedings of the Ergonomics Summer Workshop, UC Berkeley Center for Occupational & Environmental Health Continuing Education Program.

Mansfield, J.A. and T.J. Armstrong. 1997. Library of Congress workplace ergonomics program. *American Industrial Hygiene Association Journal* 58: 138-144.

McAtamney L. and E.N. Corlett. 1993. RULA: a survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics* 24: 45-57.

Pehkonen, I., E-P. Takala, and R. Ketola, et al. 2009. Evaluation of a participatory ergonomic intervention process in kitchen work. *Applied Ergonomics* 40: 115-123.

Rizzo, T.H., K.R. Pelletier, and Y. Chikamoto. 1997. Reducing risk factors for cumulative trauma disorders (CTDs): the impact of preventive ergonomic training on knowledge, intentions, and practices related to computer use. *American Journal of Health Promotion* 11: 250-253.

Robertson, M., B.C. Amick III, and K. DeRango, et al. 2009. The effects of an office ergonomics training and chair intervention on worker knowledge, behavior and musculoskeletal risk. *Applied Ergonomics* 40: 124-135.

Tepper, D. 1996. Participatory ergonomics in a university library. Master's Thesis. Ithaca: Connell University.

Thibodeau, P.L. and S.J. Melamut. 1995. Ergonomics in the electronic library. Bull Med Libr Assoc. 83: 322-329.

Vink, P. and J.R. Wilson. 2003. Participatory ergonomics. Proceedings of the XVth Triennial Congress of the International Ergonomics Association and The 7th Joint conference of the Ergonomics Society of Korea/Japan Ergonomics Society, 'Ergonomics in the Digital Age', Seoul, Korea.

Wilson, J.R. 1995. Ergonomics and participation. In. *Evaluation of Human Work: A Practical Ergonomics Methodology, 2nd ed.*, eds. J.R. Wilson and E.N. Corlett. London: Taylor and Francis.

Yuan, L. and G. Culberson. 2011. Effectiveness of a library ergonomics training program. Proceedings of the 55th Annual Meeting of Human Factors and Ergonomics Society, Las Vegas, NV.