Use of the Actigraph for Objective Quantification of Hand/Wrist Activity in Repetitive Work

Katharyn A. Grant, Traci L. Galinsky and Peter W. Johnson

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USE OF THE ACTIGRAPH FOR OBJECTIVE QUANTIFICATION OF HAND/WRIST ACTIVITY IN REPETITIVE WORK

Katharyn A. Grant and Traci L. Galinsky
National Institute for Occupational Safety and Health
Division of Biomedical and Behavioral Science
Cincinnati, Ohio

Peter W. Johnson
University of California Ergonomics Laboratory
Richmond, California

ABSTRACT

Valid and reliable measures of hand/wrist activity are needed to address the relationship between work tasks and the development of upper extremity musculoskeletal disorders. The utility of the actigraph for measuring wrist activity in manual work was examined in this study. Ten grocery cashiers and four non-cashier retail workers wore actigraph monitors on both wrists and the left ankle during their normal work activities. Work activities were periodically observed and recorded on videotape. Data recorded by the actigraphs were matched against observational data. The results indicated that actigraphy was effective in detecting significant work-related variations in physical activity in the three limbs studied. Compared to traditional observational procedures, actigraphy represents a cost-effective approach for obtaining objective and quantitative information about the intensity and duration of work over long time periods. Traditional observational procedures, however, are necessary to provide additional information needed for a complete job analysis (e.g., postural data). Continuous activity recordings can be used in conjunction with sampling protocols to examine the relationship between work-related physical activities and musculoskeletal trauma.

INTRODUCTION

Musculoskeletal disorders of the upper extremities have become a leading source of concern among occupational health professionals. Evidence has accumulated which suggests that these disorders are associated with highly repetitive occupational activities, especially those involving high force, extreme joint position, or exposure to vibration (Birbeck and Beer, 1975; Armstrong, 1983). Experimental data do not, however, demonstrate conclusively the extent to which occupational stressors contribute to the development of upper extremity musculoskeletal disorders among exposed workers. One obstacle in performing this type of research concerns the difficulties inherent in quantifying exposures to ergonomic risk factors.

Establishing an association between musculoskeletal disorders and repetitive and forceful manual activities requires empirical methods for estimating the intensity, frequency and duration of human exposures to these work conditions (Hawkins, Jayjock and Lynch, 1992). Three methodologies have been applied to assess exposure to ergonomic hazards: (1) self-report methods (e.g., diaries and questionnaires), (2) observational methods, and (3) direct measurement techniques (Burdorf, 1992). To date, none have proven completely satisfactory for gathering reliable exposure data from a large number of workers. Most investigators agree that application of observational or direct measurement methods increases the quality of ergonomic exposure assessments, yet these methods tend to be costly and time consuming. Indeed, time constraints make it virtually impossible to perform a study in which all subjects are observed and/or monitored for any meaningful length of time. As a result, most researchers measure exposure in a small sample of workers and apply the result to all workers in the same job title or category. Because numerous

sources of variation exist among workers employed in the same job (e.g, anthropometry, individual work habits) job title usually provides only a vague index of the risk factors presented to a worker by a task. As a consequence, real associations between exposures to specific risk factors and the development of upper extremity disorders may remain undetected.

Clearly, an alternative measurement approach which circumvents these problems would enhance efforts to elucidate the relationship between work activities and musculoskeletal injuries. One possibility is actigraphy, or the use of accelerometer-based motion recording systems to continuously record human body movements. Recent advances in micro-electronics have allowed development of miniature, battery-powered systems which can be attached to most sites on the body (wrist, ankle, trunk) and can make continuous recordings for up to 30 days.

Actigraphy has traditionally been used for purposes such as distinguishing sleep and waking states and estimating daily energy expenditure (Redmond and Hegge, 1987). The applicability of the technique could be extended to the quantification of manual work activities in terms of movement frequency, intensity, and duration in order to determine the impact of these factors on musculoskeletal compromise. An advantage of actigraphy is that it can provide objective activity data without the constant attention of an observer, and it precludes the influence of biases which can affect observational and self-report data. Nonetheless, there have been no published studies which have examined the utility of actigraphy for characterizing the nature of repetitive, manual work. Toward that end, the National Institute for Occupational Safety and Health (NIOSH) has undertaken studies to evaluate the use of actigraphy for distinguishing workers exposed to varying levels of hand/wrist activity during their work. This paper describes an assessment based on a recent NIOSH study of workers in the retail food industry.

Retail food workers from two job categories - grocery cashiers and general merchandise clerks - were selected for study. Grocery cashiers handle 300-800 grocery items per hour. Tasks such as scanning and bagging require repetitive hand/arm movements and forceful manual exertions, often combined with awkward wrist, shoulder and trunk postures. By contrast, tasks performed by general merchandise clerks are less stereotyped and require less hand/arm exertion. Their primary job function is to provide customer service, i.e., to help customers locate items in the store, to answer questions, and to handle special customer needs. Whereas cashiers perform most job activities at a fixed location (the checkstand), general merchandise clerks tend to roam about the store, performing light stocking tasks or attending to customers as needed.

The primary goal of the present study was to examine the extent to which physical differences in these two jobs can be reflected in actigraph data. Worker activities were observed and categorized. Data obtained from actigraphs affixed to workers' wrists and ankles were analyzed to determine if variations in activity levels paralleled activity differences demarcated through direct observation and videotape analysis. It was expected that during work periods, wrist activity would be higher among cashiers than among general merchandise clerks, whereas activity recorded from the ankle would be higher among general merchandise clerks than among cashiers. Moreover, within the cashier group, significant variations in wrist activity levels were expected to be attributable to the type of task being performed (i.e., scanning, bagging, tendering money, etc.).

METHOD

Worksites

Data were collected at two medium-sized supermarkets, and one large "combination" store encompassing a full supermarket, a discount store and a pharmacy. All stores were located in the Midwest United States.

Subjects

Ten grocery cashiers (2 men, 8 women) and four general merchandise clerks (all women) participated in this study. Participants ranged in age from 18 to 55 years. All participants were right handed, free of musculoskeletal complaints, and had a minimum of six months experience working in their current job.

Apparatus

Mini Motionlogger Actigraphs designed by Ambulatory Monitoring, Inc. (731 Saw Mill River Rd., Ardsley, New York, 10502) were employed. Each unit weighs 57 grams and is housed in a wireless aluminum enclosure which is secured to the wearer's limb with velcro straps. A piezoceramic motion transducer inside the enclosure produces analog voltage signals in response to accelerations in the X, Y or Z planes. A pulse is produced each time the signal amplitude exceeds a preselected reference threshold. Pulses are summed in an event counter for a preselected epoch length (2 seconds in the present study) and stored in memory. A clock inside the unit is used to control run/stop times and to specify the times at which movement signals are generated.

Two hand-held video cameras were used to record cashiers' work activities on videotape. The cameras' clocks were synchronized with those inside the actigraph units.

Procedure

Each participant wore three units, fastened to the left and right wrist, and the left ankle, for a 3-6 hour monitoring period on a working day. Investigators observed and recorded the work activities of all participants at random intervals throughout each monitoring period. Clerks were observed four times every hour for periods of approximately 5 minutes each. Cashiers were observed continuously for a 15 minute period once every hour, and their work activities were recorded on videotape. Break periods (starting and ending times) were also recorded in a log. (Note: Two cashiers failed to take breaks during the monitoring period). At the completion of each monitoring period, the actigraph units were removed, and data were downloaded to a microcomputer.

RESULTS

Representative data obtained during an eight hour work period from a cashier and from a clerk are displayed in Figures 1a and 1b.

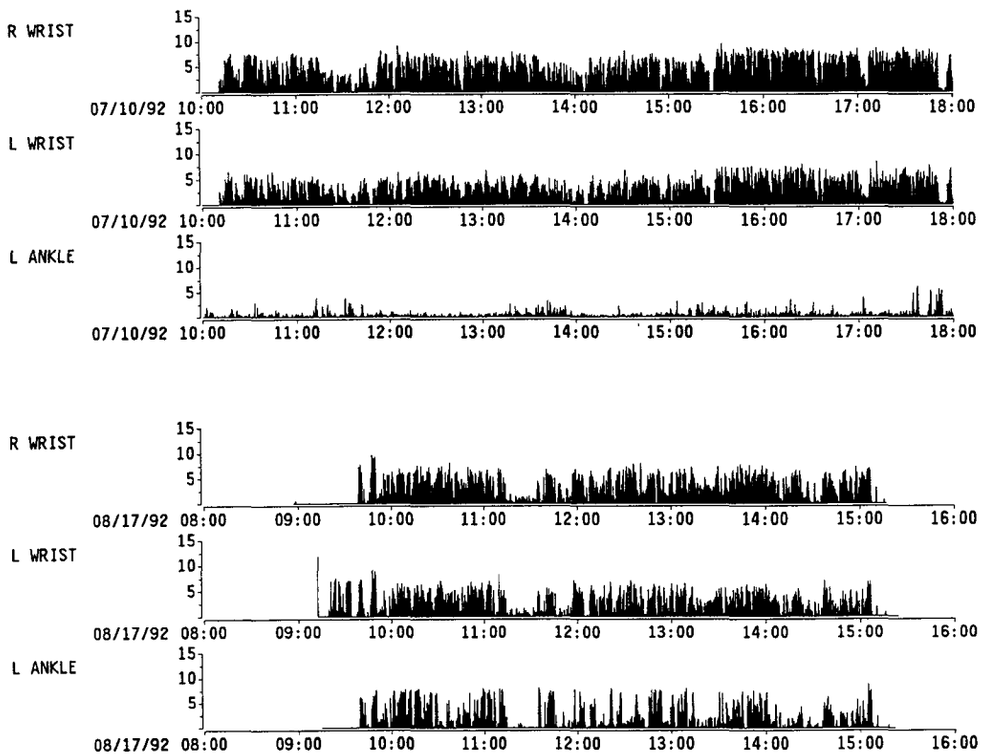

Figure 1. Actigraph data collected from (a) a cashier and (b) a general merchandise clerk

A comparison of these figures reveals clear differences in the patterns of activity recorded from the two workers. The cashier's record displays high levels of wrist activity and low levels of ankle activity, whereas the clerk's record displays moderate levels of wrist activity and high levels of ankle activity.

Mean counts/epoch at each recording site during work and break periods were computed across participants in each job category. These means are plotted in Figure 2.

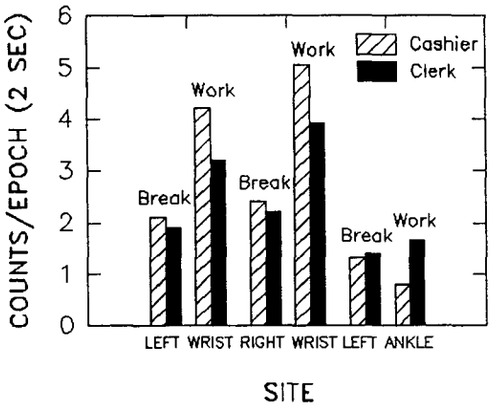

Figure 2. Cashier vs. general merchandise clerk activity comparison

Several effects consistent with expectations were verified by analyses of variance. First, wrist activity levels were significantly higher during work periods than during break periods, F (1,10) = 37.57, p < 0.01 (right wrist), and F (1,10) = 83.99, p < 0.01 (left wrist). Second, dominant (right) wrist activity exceeded nondomdinant (left) wrist activity during work activities, F (1,12) = 13.75, p < 0.01, but there was no significant difference between wrists during break periods, F(1,10) = 3.10, p > 0.05. Third, wrist activity levels were significantly higher among cashiers than clerks during work periods, F (1,10) = 8.22, p < 0.02, while activity levels recorded at the ankle were significantly higher among clerks than cashiers during work periods, F (1,10) = 6.44, p < 0.03. There were no differences in wrist or ankle activity between cashiers and clerks during break periods, F (1,10) = 0.34 (wrists), and F (1,10) < 0.01 (ankle), p > 0.05.

Using data obtained from the grocery cashiers, additional analyses were performed to determine if different job tasks were associated with different levels of activity. Cashier work tasks were classified into five categories: (1) scanning or keying the price of grocery items, (2) bagging groceries, (3) tendering money, (4) waiting for a customer, and (5) miscellaneous (e.g., cleaning the checkstand). Each 2-second epoch of actigraph data was matched with a code to indicate which of the five tasks transpired during that epoch. For each cashier, the mean numbers of activity counts/epoch generated during each type of task were determined. Mean counts/epoch recorded from each site during each type of task were computed across cashiers and are displayed in Figure 3.

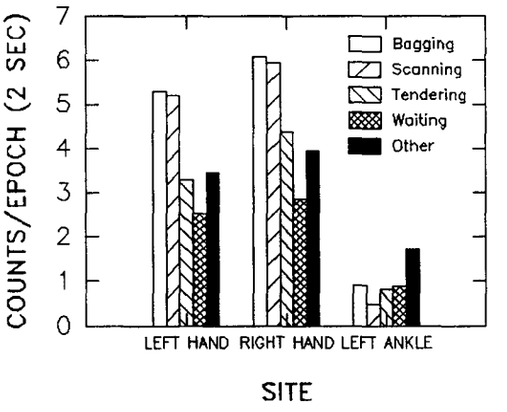

Figure 3. Cashier activity comparison

As shown, activity levels recorded from the ankle were lower than those recorded from the wrists; also, ankle activity did not vary widely in response to changes in task type. Consequently, data recorded from the ankle were excluded from statistical analyses of task influences on activity.

Dominant (right) wrist activity was higher than nondominant (left) wrist activity for all tasks. The main effect of wrist was significant, F (1,9) = 8.18, p < 0.02. This effect was not modified significantly by the task variable, F(4,36) = 1.22, p > 0.05. Rather, an identical pattern of task-related activity differences is apparent for the two wrists. Analysis of variance also confirmed that the main effect of task type was significant, F (4,36) = 24.36, p

< 0.01. Post-hoc comparisons indicated that wrist activity was greatest during scanning and bagging periods. Tendering money and miscellaneous actions were associated with intermediate levels of wrist activity, whereas waiting for customers produced the lowest wrist activity levels.

DISCUSSION

For over a decade, actigraphy has been successfully used to monitor gross changes in physical activity, such as those associated with sleep/wake cycles, etc. (Redmond and Hegge, 1987; Brown, Smolensky, Alonzo and Redman; 1990). This technique has not as yet, however, been utilized to quantify exposure to manual activities implicated in the development of upper extremity musculoskeletal disorders. Accordingly, the present study used the actigraph to examine variations in hand/wrist activity among retail food workers employed in different job tasks. Actigraph patterns in this study were consistent with predictions based on observations of the job tasks. For both groups, overall activity levels were significantly higher during work periods than during break periods. During work periods, wrist activity was significantly higher among cashiers than general merchandise clerks, reflecting the greater involvement of the hand/wrist in cashier work. By contrast, clerks are required to do more walking than cashiers, and this was reflected in the data recorded from workers' ankles. In addition, variations in the types of tasks performed by cashiers were associated with significantly different activity levels.

The results of this study indicate that actigraphy provides some advantages over traditional observational methods for quantifying work-related hand/wrist activity. In most cases, however, observational data describing the qualitative aspects of work activities are needed to supplement the quantitative actigraph data. For example, the actigraph is not sensitive to limb posture, an important contributing factor in the etiology of work-related musculoskeletal disorders. However, limb postures can be observed and coded on a periodic basis using a sampling scheme. By combining sampled data with continuously-recorded actigraph data, the researcher should be able to derive a fairly comprehensive index describing the activities of workers performing different jobs. It is our hope that this approach will facilitate future epidemiological studies of the relationship between work activities and the development of upper extremity musculoskeletal disorders.

REFERENCES

Armstrong, T.J. (1983). An ergonomics guide to carpal tunnel syndrome. Akron, OH: American Industrial Hygiene Association.

Birbeck, M.Q., and Beer, T.C. (1975). Occupation in relation to the carpal tunnel syndrome. Rheumatology and Rehabilitation, 14, 218-221.

Brown, A.C., Smolensky, M.H., D'Alonzo, G.E., and Redman, D.P. (1990). Actigraphy: a means of assessing circadian patterns in human activity. Chronobiology International, 7(2), 125-133.

Burdorf, A. (1992). Exposure assessment of risk factors for disorders of the back in occupational epidemiology. Scandinavian Journal of Work Environment and Health, 18, 1-9.

Hawkins, N.C., Jayjock, M.A., and Lynch, J. (1992). A rationale and framework for establishing the quality of human exposure assessments. American Industrial Hygiene Association Journal, 53(1), 34-41.

Redmond, D.P., and Hegge, F.W. (1987). The design of human activity monitors. In: Scheving, L.E., Halberg, F., and Ehret, C.F. (Eds.), Chronobiology and chronobiological engineering (NATO ASI series, Applied Sciences No. 120). Dordrecht: Martinus Nijhoff.