RESEARCH ARTICLE

Combining Workstation Design and Performance Management to Increase Ergonomically Correct Computer Typing Postures

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ABSTRACT. The effects of workstation changes and a performance management (PM) package on seven typing postures were examined for seven office workers. Workstation adjustments were implemented first. Two participants increased five safe postures by 50% or more. The effects of a PM package on postures that did not improve by 50% were then examined

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using a multiple baseline design across participants. The PM package included information, feedback, and praise. Composite percent safe scores for postures targeted in the PM package increased for all seven participants, with increases ranging from 54% to 80%. Results suggest that it is beneficial to combine ergonomic design and performance management in office ergonomic programs.

KEYWORDS. Office ergonomics, performance management, behavior-based safety

Each year in the United States thousands of workers report work-related musculoskeletal disorders (MSDs). According to a survey by the Bureau of Labor Statistics (United States Department of Labor [USDOL], 2005), MSD injuries and illnesses account for more than one third of the total lost worktime cases reported in private industry, which, according to the Occupational Safety and Health Administration (Occupational Safety and Health Administration [OSHA], 2004), amounts to more than 600,000 cases. Employers pay approximately $15–18 billion annually in direct workers' compensation costs and another $60 billion in indirect costs related to these injuries and illnesses (OSHA, 2004). The prevention of MSD injuries and illnesses would be clearly beneficial to both the health and well-being of workers and to the national economy.

The incidence of MSDs in computerized workstation environments is rising, no doubt due to increasing computer use (Bergqvist, Wogast, Nilsson, & Voss, 1995; McLean, Tingley, Scott, & Rickards, 2001). The U.S. Occupational Safety and Health Administration estimates that 90% of all U.S. office workers now use computers and 40% work on their computers at least 4 hours a day (OSHA, 1999). Ergonomic experts warn that the risk of discomfort increases by using the computer as little as 1 hour a day. And the risk of injury is nine times greater for those who spend 4 hours a day using the computer than it is for those who spend 1 hour per day (Revelle, 2000).

As a result of technological advancements, many office workers no longer need to leave their desks to perform many time-inefficient tasks of the past, such as copying documents, sending and receiving mail, and filing. Consequently, computer terminal workers now face prolonged periods of sustained seated postures (McLean et al., 2001). If unsafe, these prolonged postures can affect the lower back, the upper limbs, and neck and place workers at risk for MSDs (Nelson & Silverstein, 1998; Sauter &

Schleifer, 1991). Similarly, repetitive keyboard and mouse use places workers at risk of muscle, tendon, and nerve damage (Gerr, Marcus, & Monteilh, 2004; Marcus, 1996).

Evidence supporting a causal link between highly repetitive work and neck and neck-shoulder MSDs is documented in a review of over 600 epidemiological studies by the National Institute for Occupational Safety and Health (National Institute for Occupational Safety and Health [NIOSH], 2000), and the National Academy of Sciences (NAS) (USDOL, 1998). The risk of injury is compounded when workers use computer workstations that impede or prevent safe postures. While the link between repetitive work and neck-shoulder MSDs has been established, it is not yet known if adjusting the computer workstation to fit a worker is sufficient to bring about lasting postural change and, consequently, reduced risk of developing MSDs.

ERGONOMICS

Ergonomics literally means the natural law or system of work (Grandjean, 1988; Grimaldi & Simonds, 1989) and takes the total physiological and psychological demands of the job on the worker into consideration (Plog, Niland, & Quinlan, 1996). Ideally, the practice of ergonomics relies on a process that (a) tailors empirically derived interventions to specific circumstances, (b) continues to assess the effectiveness of interventions in the face of changing workplace and worker factors, and (c) evaluates new interventions (NAS, 2001).

Practically speaking, however, applied ergonomics usually does not include ongoing evaluation and assessment of interventions but stops once the intervention is in place. For example, many workplace ergonomic efforts have focused only on individual workstation components such as the keyboard, monitor, work surface, or chair (Robertson & Courtney, 2001). This is not surprising because much of the scientific research in office ergonomics has also focused on the effects of individual workstation components, for example, monitor placement (Psihogios, Sommerich, Mirka, & Moon, 2001), keyboard design (Hedge, Morimoto, & McCrobie, 1999; Swanson, Galinsky, Cole, Pan, & Sauter, 1997), desk height (Bhatnager, Drury, & Schiro, 1985), and chairs (Fredericks & Butts, 2006; Shute & Starr, 1984).

Even though ergonomic research tends to be narrowly focused on individual workstation components, the research does support a link between these components and posture. Green, Briggs, and Wrigley (1991) found that working postures are directly related to the workstation, and effective adjustment of the equipment is often required before correct postures can occur. Also, in a review of 43 articles, Smith, Karsh, and Moro (1999) concluded that ergonomic interventions appear to have positive effects on musculoskeletal discomfort, injury incidence, and body posture.

The most commonly reported outcomes in the office ergonomic literature, however, are based on employee self-reports from questionnaires (Cole, Wells, & The Worksite Upper Extremity Research Group, 2002; Sauter & Schleifer, 1991; Swanson et al., 1997). The literature is noticeably silent on whether self-reported postural changes correlate with actual postural changes. Thus, objective confirmation of the link between workstation components and postures is called for. Additionally, it is not known whether adjusting the computer workstation is sufficient to bring about lasting postural change.

Although ergonomic workstations enable correct postures, they do not guarantee that they will occur. Even the best designed tools and workstations are frequently misused even after employees receive well-designed ergonomics training (Perdue, 1999). Thus, ergonomic redesign may have to be supplemented by behavioral change strategies.

BEHAVIORAL APPLICATIONS

Over the past 30 years behavioral interventions have gained visibility and credibility as a method for improving safe behavior in the workplace (for reviews, see Grindle, Dickinson, & Boettcher, 2000; and Sulzer-Azaroff & Austin, 2000). In a study that focused on reducing the risk of cumulative trauma disorders among keyboard operators, Blake-McCann and Sulzer-Azaroff (1996) used a behavioral approach that combined training, self-monitoring, feedback, goal-setting, and reinforcement to increase correct posture and correct hand-wrist position. Dramatic increases in the percentages of correct postures and neutral hand-wrist positions occurred for all participants.

Alavosius and Sulzer-Azaroff (1990) used behavioral change strategies to increase the safe lifting and transferring of patients by nursing staff. A multiple baseline design across participants and behaviors was used to evaluate the effects of written instructions combined with no feedback, intermittent feedback, or continuous feedback. Written instructions led to slight and very brief improvements. Marked improvements were noted after feedback was introduced, with the continuous feedback producing more rapid acquisition. Maintenance of targeted safe behaviors continued even after feedback was discontinued.

COMBINING ERGONOMICS AND PERFORMANCE MANAGEMENT

Both workstation design and performance management have been shown to increase safe working postures. Together, they might provide the most efficient and effective improvement strategy. Workstation design creates physical environments that provide opportunities for working safely and may affect some postures for some individuals, but may not be maximally effective because such changes do not provide ongoing behavioral supports. On the other hand, performance management can increase safe postures, but effects are likely to be limited if workstations impede safe postures. The purpose of this study was to first evaluate whether workstation design based on ergonomic assessments would improve safe typing postures and then to assess whether a performance management (PM) package consisting of training, graphic feedback, and praise would enhance the effects of workstation design for postures that did not improve substantially. To assess long-term effects, follow-up measures were obtained periodically for up to 10 months after the end of the study.

METHOD

Participants and Setting

Participants were seven female full-time administrative staff employees at a midwestern university. Prior to the study, these employees had requested or had been referred to the third author (a faculty member in the university's department of occupational therapy) for an office ergonomic assessment. None of the participants was experiencing acute work-related pain, nor did any have any medically diagnosed MSDs.

The study was conducted at participants' offices. Participants were observed as they performed normal duties, including computer-related tasks at their individual workstations. Computer-related tasks included keyboarding, using the mouse, composing work on the computer, and entering data from copy.

DEPENDENT VARIABLES

Physical Dimensions of the Workstation

Physical dimensions of the computer workstation that could affect safe postures were measured at the start of the study. These measures were taken to document extra-experimental changes to the workstation that might have influenced the worker's posture. For example, chair height can influence leg position, feet position, hand-wrist position when typing, and head-neck position when looking at a computer monitor. Thus, if a new chair had been purchased during the study, its height could have affected these dependent variables and confounded the effects of the ergonomic assessments and PM package.

Five variables were measured: chair height, monitor distance and angle from the user's eye, keyboard height and slope, mouse height and slope of the mouse tray, and desk height. During the study, no extra-experimental changes were made to the workstations that influenced these measures. Some changes were made as a result of the ergonomic assessments; however, these changes were documented and assessed as part of the independent variable.

User-Computer Interface

Safety dimensions related to the user-computer (UC) interface were measured to determine whether the UC interface actually changed as a result of the ergonomic assessments, and also to determine whether the PM package would increase and maintain safe postures despite UC interface problems. Nine workstation UC interface variables, divided into four categories, were scored as safe or unsafe.

Chair. (1) User's feet rested comfortably on the floor or footrest while the upper body was high enough to work comfortably at the workstation.

Monitor. (2) Directly in front of and centered on the user; (3) user's eyes were in line with a point 2 to 3 inches below the top of the monitor; (4) the distance of the monitor from the user's eyes was at least 18 inches; and (5), if the user wore bifocal lenses or progressive lenses, the monitor was tilted backward slightly so that she could see the screen without tilting her head.

Keyboard. (6) Directly in front of and centered on the user; (7) below the user's elbow height when the user was seated; and (8) sloped away from the user.

Mouse. (9) Either on a flat surface that was 1 to 2 inches above the keyboard and moveable, or on a mouse tray that was on the same level as the keyboard and sloped away from the user to keep her hand and wrist in a neutral position.

A percent safe score was calculated for the UC interface by dividing the number of workstation variables scored as safe by the number of workstation variables scored as safe plus unsafe, and then multiplying the quotient by 100.

Postures

Seven postures linked to MSD incidence from extended periods of office work (NIOSH, 2000; USDOL, 1998) were observed. Postures were considered safe only when they met all of the criteria contained in the following definitions:

Hand-wrist position (Typing). Wrist flat (not bent up or down) and straight (not bent right or left) when keyboarding or using the mouse.
Head-neck position. Head in a vertical position such that the neck is aligned with the back and facing forward.
Shoulder position. Upper arms tucked close to the body and hanging relaxed, not extended out to the side, forward or backward, and not raised up or hunched.
Back position. Lower back (lumbar) in a supported and reclined posture producing an angle of the back and thigh between 100 and 110 degrees.
Arm position. Upper arms and elbows close to the body when keyboarding or using the mouse (the inside angle of elbow should be between 90 and 120 degrees).
Leg position. Knees bent forming an angle between 90 and 120 degrees.
Feet position. Both feet flat on the floor or foot rest.

Composite percent safe scores across postures for each participant for each session served as the main dependent variable. If any posture improved by at least 50 percentage points over baseline during the ergonomic assessment phase, then two composite percent safe scores were calculated (retroactively) for the participant: one across postures that improved by at least 50% during the ergonomic assessment phase, and one across postures that did not improve by 50% and hence were targeted in the PM package. If no postures improved by 50%, then only one composite percent safe score served as the dependent variable for the participant: a composite percent safe score across all seven postures. In addition, a percent safe score was calculated for each posture for each participant in each session. Due to space limitations these latter data are not included in the article but are available from the first author.

OBSERVATION PROCEDURES

The first author and an undergraduate research assistant were observers. Participants were aware when the observers were present because the observers had to stand close enough to the participants to view all of the above dependent variables, and other observation systems were not logistically or economically feasible. While this observation procedure might have resulted in reactivity, it was used throughout the study, including baseline, and thus was a constant variable in all phases.

Observers recorded the dependent variables using the safety observation checklist in the appendix. Each participant was observed daily for approximately 10 minutes. Observation sessions were scheduled at a time that was convenient for the participant and were rescheduled as needed. UC interface was measured for approximately 50% of the sessions. When the UC interface was measured, it was done at the beginning of the observation session before the postures. The seven postures were scored as “safe,” “unsafe,” or “not performed,” using a 10s whole interval time sampling procedure. Each posture was observed for 10s, followed by a 5s record period. A given posture was scored safe if, and only if, it occurred throughout the entire interval without interruption; otherwise it was scored as unsafe. A portable cassette player was used to sound beeps to cue the appropriate observation and recording behaviors.

INTEROBSERVER AGREEMENT

Interobserver agreement (IOA) assessments were conducted for 81 sessions (33% of all sessions). During IOA sessions, the first author and a research assistant completed the observation checklist independently. To ensure that both observers were observing at the same time, the first author announced when to begin the UC interface measurement. To ensure that each posture observation was synchronized, both observers used the same portable cassette player fitted with an adapter for two headsets. The cassette sounded beeps to cue the appropriate observation and recording procedures. An agreement was defined as any occurrence in which both observers scored the posture the same way (safe or unsafe). Interobserver agreement was calculated as follows: the number of agreements divided by the number of agreements plus disagreements multiplied by 100.

Interobserver agreement was 100% for the UC interface. For the postures, IOA averaged 98.07% per session across the seven postures (range: 97–99%).

EXPERIMENTAL PROCEDURES AND DESIGN

Baseline

Participants were observed daily for 1–2 weeks. They received no instructions or feedback. Office ergonomic assessments, described next, were conducted on the last day of the baseline condition.

Occupational Therapy Ergonomic Evaluation

Occupational Therapy (OT) students enrolled in a senior-level undergraduate course (Occupational Therapy in Work Settings) conducted ergonomic assessments under the supervision of the third author, who was the course instructor. Students attended a training session conducted by the first and third authors during a regularly scheduled class session approximately 1 week before the assessments. The training consisted of two basic components: (a) review of the office ergonomic assessment protocol and checklist, and (b) demonstration and practice of measurement and workstation adjustment procedures.

The third author randomly assigned the participants to OT student groups for the assessment. During the assessment, students interviewed the participant, evaluated the workstation, made recommendations for improvement, and documented their measures and observations using an ergonomic assessment checklist.

Recommendations were classified as “quick fix,” “moderate,” or “optimal” based on cost and ease of implementation. When possible, quick-fix (on-the-spot) changes were made to the workstation during the assessment. Examples of on-the-spot changes include (a) repositioning the computer monitor to be directly in front of user, (b) collapsing the keyboard legs to lower the keyboard, and (c) adjusting the chair angle. All recommendations and/or adjustments made to the workstation conformed to scientifically established standards (e.g., Hedge, 2002a, 2002b; Revelle, 2000; Washington Industrial Safety and Health Administration [WISHA], 2000; 3M Corporation, 1998). Participants were asked and encouraged to share concerns and suggestions during the assessment. Assessment duration ranged from 45 to 90 minutes.

After the on-site assessment, students reviewed the data, developed recommendations, and compiled a final written report. The first and third authors met with the students and discussed their observations and recommendations. The third author reviewed and verified the final reports and the first author distributed them to participants approximately 2 weeks after the assessment.

The ergonomic assessments were conducted at the same time for all participants due to constraints imposed by class requirements. After the on-site assessments, participants were observed daily for 2–3 weeks during the *OT Ergonomic Evaluation* phase. Participants remained in this phase until they had received and reviewed the assessment reports so that the authors could account for any behavior changes that might have resulted from the written reports.

Performance Management Package

The PM package was implemented only for postures that did not appreciably increase as the result of workstation adjustments or the written assessment report. Appreciable improvements were defined as an average increase of at least 50 percentage points above baseline. Postures that improved appreciably, while not targeted as part of the PM package, continued to be measured during this phase in order to determine whether they would maintain.

Although Cohen's *d* statistic (Cohen, 1992) was calculated for increases in safety scores, a decision was made to define an appreciable increase in terms of a 50% increase in percentage points rather than in terms of a medium or large effect size based on Cohen's *d* statistic. The 50% increase was viewed as being a more stringent criterion, better reflecting practical significance. For example, in the current study, the head-neck position of P1 increased from an average of 6.9% in baseline to an average of 19.1% in the ergonomic phase after the monitor angle was adjusted. According to Cohen's *d* statistic, this was a large effect size (d = 1.01). However, P1 was still performing unsafely in 80.9% of the observation intervals, leaving the participant at risk for head-neck problems.

The PM package included ergonomic information (written and pictorial), graphic feedback, and praise. A multiple baseline across participants design was used to assess the effects of the PM package. The PM package phase lasted 2–3 weeks for each participant.

Information and demonstration. The first author presented written and pictorial information illustrating correct ergonomic postures to participants individually at their workstations prior to the start of the first session in the PM package phase. All information was based on established standards (e.g., Hedge, 2002a, 2002b; Revelle, 2000; WISHA, 2000; 3M Corporation, 1998) but did not include the definitions used by the observers. Information was presented only for those postures that had not changed by at least 50% as a result of the workstation adjustments. After reviewing the information, participants were asked to demonstrate the safe postures at their workstations. Participants were given a copy of the information sheets for reference.

Feedback and praise. At the start of each observation session during the PM package condition, the first author presented graphic feedback to the participant on the targeted postures. The feedback showed the participant's percent safe score for each posture up to that point in time, including baseline. Praise was provided for those postures that had improved from the previous session. For example, the first author would say, "Your safe feet position has improved considerably from yesterday's session, and overall during the course of the study. That's great!"

Poststudy Follow-Up

Follow-up observation sessions were conducted for four participants (Ps 1, 3, 4, and 6) approximately 4 months after the end of the study to examine if a participant's safe postures had maintained. Thereafter, follow-up sessions were conducted monthly for three participants (Ps 1, 3, and 6) for another 6 months. The PM package was withdrawn during this period, while workstation changes made during the ergonomic assessment phase were not removed.

INDEPENDENT VARIABLE INTEGRITY

Three measures of independent variable integrity were calculated. Percentage of compliance with the office ergonomic assessment protocol by OT students was calculated by counting the actual number of sections completed on the office ergonomic assessment checklist and dividing it by the total number of sections on the checklist, and then multiplying by 100. Percent compliance was 100%. Percentage of compliance with the information and demonstration procedures was measured by observing the participant's ability to demonstrate the safe ergonomic postures after the presentation of pictorial information, and was documented on the information sheet by the first author. Percent compliance was 100%. Percentage of feedback compliance was calculated by counting the number of feedback graphs that were initialed by participants, dividing that number by the total number of sessions in which feedback was planned, and then multiplying by 100. Percent compliance was 100%.

RESULTS

Figures 1 and 2 show the composite percent safe scores for Ps 1, 3, 6, and 4, and Ps 5, 2, and 7, respectively. Two composite percent safe scores are displayed for Ps 1 and 6; one for postures that improved by 50 or more percentage points during the OT evaluation phase and thus were not subjected to the PM package (represented by open circles "o"), and one for postures that did not improve by 50 percentage points and thus were included in the PM package phase (represented by closed circles "●"). Only one composite score is displayed for the other participants because none of their postures improved by 50 percentage points or more during the OT evaluation phase. The UC interface percent safe scores are represented by the "+" on the graphs.

Baseline

During baseline, composite safety scores were low for all participants, ranging from an average of 3.3% to 13.5%, with an overall average across participants of 7.7%.

Occupational Therapy Ergonomic Evaluation

Occupational therapy students adjusted the workstations of three participants (Ps 1, 3, and 6). Approximately 1 week after the assessment, P4 responded to recommendations made during the assessment by relocating her computer monitor so that it was positioned directly in front of her body. Table 1 summarizes the changes that were made to the workstations, the resulting increases in the UC interface percent safe score, and

FIGURE 1. Composite percent safe scores for Ps 1, 3, 6, & 4. A “+” is the user-computer interface percent safe score. For Ps 1 and 6, a “o” indicates the scores for postures that increased appreciably due to ergonomic adjustments and a “●” indicates the scores for postures targeted in the PM package. The arrow identifies when Ps received the ergonomic report. P1 through P7 refer to poststudy follow-up observations that occurred 4 to 10 months after the study.

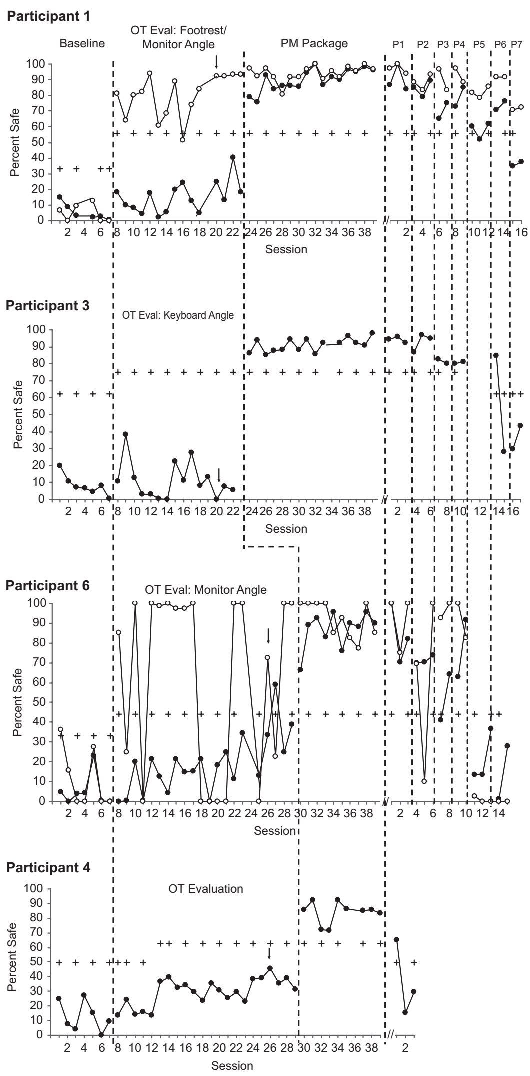

FIGURE 2. Composite percent safe scores for Ps 5, 2, & 7. A "+" is the user-computer interface percent safe score. The arrow identifies when Ps received the ergonomic report.

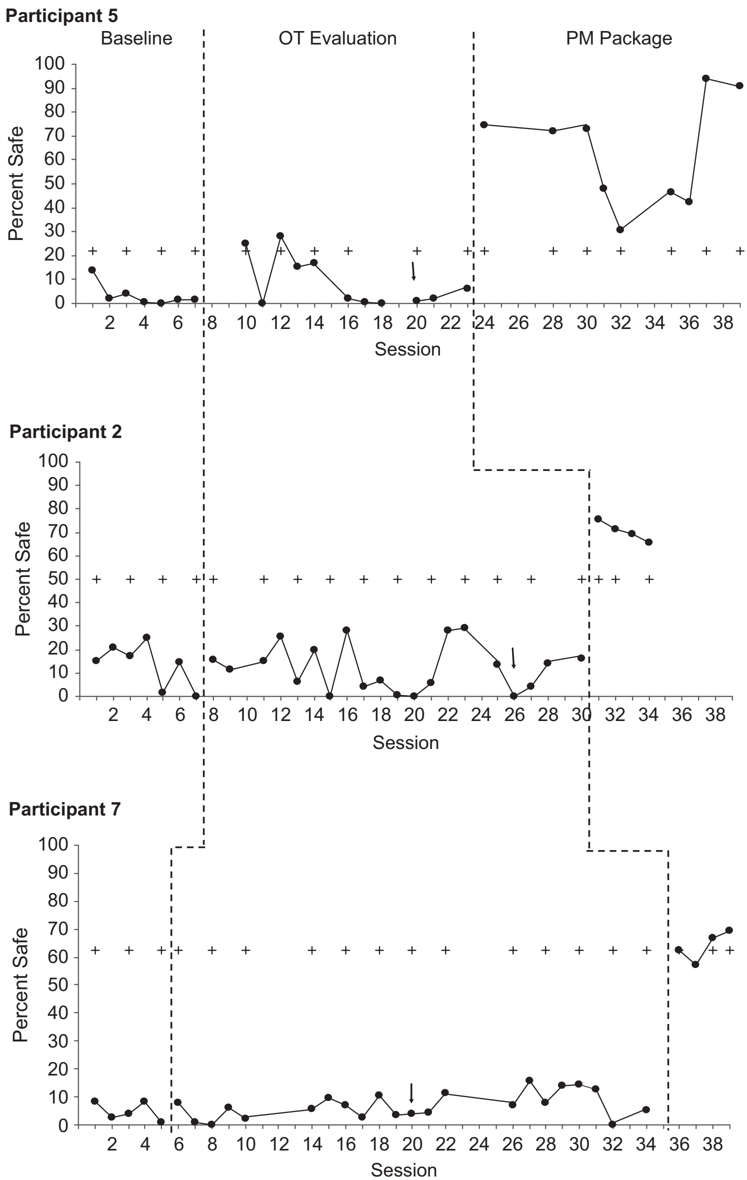

TABLE 1. Effects of OT ergonomic assessments

Participant	Workstation Changes	UC Interface Increase	Postures Improved by at least 50%
1	Footrests added Monitor angle modified	23.0%	Back, Leg, Feet
3	Keyboard angle	12.5%	None
4	Monitor centered on user	12.5%	None
6	Monitor angle adjusted Footrest use discussed	11.0%	Leg, Feet

the postures that increased by an average of 50% or more during the OT evaluation phase due to the adjustments.

Results were mixed in terms of UC interface safety and safe postures. For P1, the addition of footrests and the monitor angle adjustment increased the UC interface percent safe score from 33% to 56%. In terms of increases in percentage points, substantial improvements were observed for (a) back position (55.5% improvement), (b) leg position (85.6% improvement), and (c) feet position (84.6% improvement). The improvements most likely resulted from the addition of the footrests. Prior to having footrests, P1 would tuck her feet behind her and rest them on the base of her chair. She would also lean forward in her chair. The monitor angle was also adjusted during the assessment but only relatively small improvements in percentage points were observed in head-neck position (12.2%, $d = 1.01$), even though larger improvements were expected (Green et al., 1991; Psihogios et al., 2001).

The composite percent safe score for the three postures (back, leg, and feet) rose from an average of 4.9% during baseline to an average of 80.1% during the ergonomic evaluation phase ($d = 6.45$). The PM package was not implemented for these postures because they increased substantially as a result of the workstation adjustments.

For P3, the keyboard angle was adjusted during the ergonomic assessment so that it was parallel to the floor by collapsing the keyboard legs, thereby increasing the UC percent safe score from 62.5% to 75%. This adjustment was expected to improve the hand-wrist and arm positions of the participant (Green et al., 1991; Hedge, 2002b; Hedge et al., 1999). In fact, the percent safe scores for these positions decreased from an average of 3.2% to 0% (hand-wrist) and 3.2% to 1% (arm) after the keyboard adjustment.

During the ergonomic assessment, the OT students recommended that P4 move the computer monitor so that she did not have to turn her head to view it. About one week later, P4 relocated the monitor so that it was directly in front of her body. This change increased the UC interface percent safe score from 50% to 62.5%. Fairly large to moderate increases above baseline were observed in head-neck (48.2% improvement, d = 2.01), shoulder (26.1% improvement, d = 0.85), and back (34.8% improvement, d = 1.30) after the monitor was relocated. None of the increases, however, met the percentage point increase criterion for an appreciable increase.

During the ergonomic assessment for P6, the OT students discussed footrest use and adjusted the computer monitor angle. The monitor adjustment increased the UC interface percent safe score from 33% to 44%. After the assessment, substantial improvements were observed for leg (50% improvement) and feet (51.2% improvement). Minimal improvements in safe head-neck position (3.4%, d = 0.50) resulted after the monitor angle was adjusted. The composite percent safe score for leg and feet rose from an average of 11.4% during baseline to an average of 65.8% during the ergonomic evaluation phase (d = 1.38).

To summarize, changes were made to four workstations (Ps 1, 3, 4, and 6) during the OT ergonomic assessments. These changes resulted in large percentage point improvements in five postures: three for P1 (back, leg, and feet) and two for P6 (leg and feet). These postures were not targeted in the PM package phase as a result, but the composite safe scores for these postures were monitored to determine whether they would be maintained.

Performance Management Package

Overall, safe postures increased substantially for all participants during the PM package phase. Table 2 displays the postures that were targeted during the PM package phase for each participant, the average composite percent safe score for these postures during the ergonomic evaluation phase and the PM package phase, and the increase in percentage points. Effect sizes for the increases are also included.

During the ergonomic evaluation phase, average composite safety scores ranged from 8.8% to 29.6% across participants. During the PM package phase, they ranged from 63.5% to 91%. Average increases in

TABLE 2. Increases in composite percent safe scores from the OT evaluation to the PM package phase

Participant	Targeted Postures	Ergonomic Mean	PM Mean	% Increase	Cohen's *d*
1	Hand-Wrist, Head-Neck, Shoulder, Arm	15.0	89.9	74.9	8.67
2	Hand-Wrist, Head-Neck, Shoulder, Back, Arm Leg, Feet	12.1	70.4	58.3	6.25
3	Hand-Wrist, Head-Neck, Shoulder, Back, Arm Leg, Feet	10.9	91.0	80.1	9.76
4	Hand-Wrist, Head-Neck, Shoulder, Back, Arm Leg, Feet	29.6	83.9	54.3	6.14
5	Hand-Wrist, Head-Neck, Shoulder, Back, Arm Leg, Feet	8.8	63.5	54.7	3.24
6	Hand-Wrist, Head-Neck, Shoulder, Back, Arm	18.7	86.6	67.9	5.13
7	Hand-Wrist, Head-Neck, Shoulder, Back, Arm Leg, Feet	9.2	63.9	54.7	11.45

percentage points ranged from 54.3% to 80.1%, with effect sizes ranging from 3.24 to 11.45. These changes occurred despite the fact that the UC interface percent safe scores remained constant across the two phases.

Table 3 displays the average increases in percentage points from the ergonomic evaluation phase to the PM package phase for each posture for each participant. Every targeted posture for every participant increased, although the degree of change varied across participants and postures.

As indicated earlier, modifications were made to the workstations of four participants (Ps 1, 3, 4, and 6). As measured by increases in percentage points, these modifications appreciably increased the safety scores of five postures by two participants (P1: back, leg, and feet; P6: leg and feet) but had only moderate effects, small effects, or no effect on other postures that were expected to increase as a result of the adjustments. Of interest is the extent to which the PM package influenced these postures.

Table 4 displays the workstation changes that did not have the anticipated effects and the related postures that were expected to appreciably increase as a result of those changes but did not. Also displayed are the

TABLE 3. Increases in percentage points from the OT evaluation phase to the PM package phase

Participant	Hand-Wrist	Head-Neck	Shoulder	Back	Arm	Leg	Feet
1	90.8	68.7	58.7	N/A	88.3	N/A	N/A
2	71.7	57.4	65.0	51.1	65.2	54.0	45.4
3	83.7	84.1	83.6	87.1	82.7	78.5	65.4
4	70.2	35.6	31.2	16.2	83.6	73.1	73.1
5	80.7	58.8	51.8	37.2	75.8	32.7	42.8
6	85.1	74.0	62.9	34.7	85.9	N/A	N/A
7	70.8	58.0	54.0	50.5	76.7	39.8	39.2

Note: N/A indicates that the behavior was not targeted in the PM package phase.

TABLE 4. Percent safe scores for postures expected to increase substantially by workstation changes

Participant	Workstation Changes	Posture	Baseline Mean	Ergonomic Mean	PM Package Mean
1	Monitor angle	Head-Neck	6.9	19.1	87.8
3	Keyboard angle	Hand-Wrist	3.2	0.0	83.7
		Arm	3.2	1.0	83.7
4	Monitor centered	Head-Neck	7.2	55.4	91.0
		Shoulder	33.5	59.6	90.8
		Back	46.7	81.5	97.7
6	Monitor angle	Head-Neck	1.1	7.5	81.5

means for the percent safe scores for each of the postures during each phase. Table 5 displays the average increases in percentage points from the baseline phase to the ergonomic evaluation phase and from the ergonomic phase to the PM package phase for each of these postures, along with Cohen's d. The PM package substantially improved the percent safe scores for postures that were not affected much by the workstation changes (P1: head-neck; P3: hand-wrist and arm; and P6: head-neck) and augmented the safety scores for postures that were moderately affected (P4: head-neck, shoulder, and back). Average increases for the former percent safe scores ranged from 68.7 to 83.7 percentage points, with d scores ranging from 4.07 to 11.92. Average increases for the latter percent safe scores ranged from 16.2 to 35.6 percentage points, with d scores ranging from 1.46 to 1.85.

TABLE 5. Percentage increases for postures expected to increase substantially by workstation changes

Participant	Workstation Changes	Posture	Baseline to Ergonomic		Ergonomic to PM	
			% Change*	Cohen's *d*	% Change*	Cohen's *d*
1	Monitor angle	Head-Neck	12.2	1.01	68.7	5.48
3	Keyboard angle	Hand-Wrist	–3.2	0.77	83.7	10.76
		Arm	–2.2	0.39	82.7	11.92
4	Monitor centered	Head-Neck	48.2	2.01	35.6	1.46
		Shoulder	26.1	0.85	31.2	1.47
		Back	34.8	1.30	16.2	1.85
6	Monitor angle	Head-Neck	6.4	0.50	74.0	4.07

*All changes are increases except where indicated.

Finally, it should be noted that the composite safety scores for postures that increased appreciably during the ergonomic evaluation phase, and hence were not targeted in the PM package (P1: back, leg, and feet; P6: leg and feet), remained high during this period of time.

Poststudy Follow-Up

Approximately 4 months after the end of the study (and after termination of the PM package), poststudy follow-up observation sessions were conducted for four participants (Ps 1, 3, 4, and 6) and monthly for another 5–6 months for three of the four participants (Ps 1, 3, and 6). These data are displayed in Figure 1. Although the safety scores for P1 and P3 remained relatively high for 7 months, they trended downward across the follow-up period. Safety scores trended downward for the other two follow-up participants as well (P4 and P6). The composite safety scores for the postures targeted by the PM package, denoted by the closed circles on Figure 1, were considerably lower during follow-up sessions than during the PM package intervention sessions, and reverted to or were trending toward baseline levels.

DISCUSSION

Physical changes were made to four workstations during the OT ergonomic assessments. These changes resulted in substantial improvements in five postures by two participants. Overall, there were substantial improvements in safe postures during the PM package phase, although individual trends varied. Poststudy observations indicated that safe postures decreased over time when the PM package was withdrawn.

Occupational Therapy Ergonomic Assessment Effects

Adjusting the computer workstation to fit the worker was not sufficient to bring about major changes in most safety-related postures. “Quick-fix” workstation changes did, however, improve five postures appreciably for two participants and because of that, it was not necessary to target them in the more labor-intensive PM package.

Ergonomic assessments substantially improved back, leg, and feet positions for P1, and leg and feet positions for P6. All three improvements by P1 likely resulted from the addition of a footrest to her work area. Similarly, P6’s two postural improvements likely resulted from discussions regarding correct footrest use during the ergonomic assessment. Prior to the assessment, P6 used the footrest incorrectly, whereas, after the assessment, she used it correctly. These results are consistent with ergonomic studies of the effects of footrests (e.g., Hedge, 2002a; Sauter & Schleifer, 1991).

On the other hand, some postures that were expected to appreciably improve as a result of the workstation changes did not. For example, although studies indicate that changing the angle of the computer monitor should greatly improve the user’s head-neck position (Green et al., 1991; Psihogios et al., 2001), it did not alter these positions appreciably for P1 or P6, as displayed in Tables 4 and 5. Similarly, keyboard adjustments were expected to improve hand-wrist and arm positions for P3 (Green et al., 1991; Hedge, 2002b; Hedge et al., 1999) but did not. In fact, as also displayed in Tables 4 and 5, these postures were slightly less safe after the keyboard adjustments. These data indicate that when workstations are changed, it is important to monitor whether those changes actually do bring about the desired postural changes.

Although all participants were given a written report of their ergonomic assessment that included a variety of recommendations to improve their workstation arrangement, none of the written recommendations was implemented. This suggests that such reports may not be sufficient to get employees to alter their workstations.

It is not clear why workstation changes substantially improved some postures (back, leg, and feet positions for P1; and leg and feet positions for P6) but not others. One possible reason may be found in P1's answer to the question: were there any strategies that you used to help you keep the safest posture? She stated, "the main one was that it feels better to sit with my feet on the footrest; . . . it relieves pressure from my back." From a behavioral perspective, this participant's response can be interpreted using the concept of the motivating operation (MO). An MO is an environmental event, operation, or stimulus condition that has two simultaneous functions. First, it alters the effectiveness of certain other events as reinforcers or punishers. Second, it alters the immediate frequency of behaviors associated with those reinforcing or punishing events (Michael, 2004). In the present analysis, pain (described as "pressure in my back") would be the MO that increases the reinforcing effectiveness of pain termination and increases the likelihood of any behavior (or posture) that has resulted in pain reduction—that is, "it feels better to sit with my feet on the footrest."

Building upon the concept of the MO, and as proposed by Blake-McCann and Sulzer-Azaroff (1996), several external factors, including the footrest, may have served as cues for correct posture. Stated another way, the footrest may have functioned as a discriminative stimulus (S^D). An S^D is defined as a stimulus that alters the current frequency of behavior because of a historical relation between the presence of that stimulus and the differential availability of an effective reinforcer for that behavior (Michael, 2002). In the current example, when the S^D (footrest) is present, the reinforcer (pain termination) is available. It is important to note that it is the combined effect of the MO and the S^D that may be controlling the participant's behavior; referred to as the S^D evocative effect (Michael, 2004). In the present case, when the participant felt pressure in her back (MO), it was more likely that seeing the footrest (S^D) would evoke placing her feet on the footrest (behavior) because doing so had resulted in pain reduction (reinforcer) in the past. On the other hand, moving her feet off the footrest would be punished by an increase in discomfort.

An additional explanation for the dramatic increase in safe back, leg, and feet position is that the components of these positions consist primarily of static gross motor behaviors. McFall (1977) indicated that gross motor behaviors are more salient and easier to discriminate than other behaviors.

Performance Management Effects

Overall, substantial and dramatic improvements in safety performance were observed after the implementation of the PM package for postures identified as in need of improvement. These improvements resulted from increases in each and every posture targeted: 44 postures across seven participants were targeted, and each increased substantially as a result of the PM package.

The PM package augmented changes in postures that were altered, but not substantially, by workstation changes, indicating that behavioral supports were necessary to achieve optimal improvements. Also, the dramatic improvements in safe postures during the PM package phase when the UC interface was often quite low indicate that the safe postures occurred despite less than adequate computer workstations. These results clearly suggest that a PM package that includes information, feedback, and reinforcement could enhance traditional office ergonomic programs—programs that typically do not include management systems to encourage or support employees to continue to engage in ergonomically sound work practices (Perdue, 1999).

The most dramatic improvements were seen in hand-wrist position and arm position. These two positions were unsafe for all participants during both baseline and the OT evaluation phase. After the introduction of the PM package, both positions improved appreciably and were maintained throughout the phase. This finding is consistent with the results from the Blake-McCann and Sulzer-Azaroff (1996) study, in which they stated, "the intensive feedback package did appear necessary in producing optimal change in hand-wrist position" (p. 288).

Leg and feet positions also improved dramatically for P4. Both averaged 0% safe during baseline and 0.6% safe during the OT evaluation phase. During the PM package phase, average safety scores for both positions increased to 73.7%.

The data in the preceding two paragraphs suggest that certain postures are more amenable to change than others, and the size of postural changes for certain postures may vary from person to person. Thus, it is important to assess how safety programs affect each posture for each employee.

Five postures were not targeted by the PM package because they improved by at least 50 percentage points or more during the ergonomic evaluation phase: back, leg, and feet for P1; and leg and feet for P6. The composite percent safe scores for these postures remained high during this phase even though participants did not receive information, feedback, or praise about these postures. It is not clear why the percent safe scores for these postures remained high. As indicated earlier, it may be that reduced discomfort resulting from footrest use continued to positively affect these postures. It may also be that the percent safe scores remained high because of measurement reactivity or generalization of the effects of the information, feedback, and praise that were provided for the other postures during this phase. However, P1 was not aware that back, leg, and feet were being measured, and P6 was not aware that leg and feet were being measured; participants received ergonomic training, feedback, and praise only for postures that did not appreciably improve when workstation changes were made.

Poststudy Follow-Up

Composite percent safe scores for two of the four follow-up participants (P1 and P3) remained above baseline levels for 7 months after the end of the study. However, all of the scores were trending down, including those for P1 and P3. Some scores reversed to baseline levels before the follow-up ended.

It is interesting to note that the composite safety scores for the five postures that increased appreciably during the OT ergonomic evaluation phase decreased over time, even though the work station changes were still in place (as indicated by the UC interface percent safe score). The percent safe scores for the postures targeted by the PM package also decreased, but only after the PM package was withdrawn. The fact that these latter percent safe scores stayed as high as they did for as long as they did is somewhat surprising and may have been due to measurement reactivity.

Regardless, the decreased percent safe scores at the end of follow-up suggest that (a) increases in postural safety that result from workstation adjustments may last for a while but are likely to be temporary, and (b) ongoing behavioral supports are likely to be necessary to sustain safe work practices—that is, gains are not going to persist in the absence of those behavioral supports. Thus, it is very important to institutionalize those behavioral supports so the gains will be maintained (Sigurdsson & Austin, 2006).

It should be noted that if follow-up data had been collected for only 4 or 5 months after the study had ended, different conclusions might well have been reached. Thus, the follow-up data indicate that it is very important to monitor the long-term effects of safety improvement efforts, something touted but not often done in ergonomic interventions.

STRENGTHS AND WEAKNESSES

One of the major strengths of the study was that it was conducted in an actual work setting. Participants were observed as they worked and were influenced by environmental variables at their individual workstations. Thus, there was no question as to whether the results of the interventions would generalize to an actual work environment.

Another important strength was the individual data. These data revealed that the workstation changes affected different participants differently. In addition, the individual data revealed that the PM package dramatically improved safe postures for each participant, despite less than adequate computer workstations.

Similarly, measurement of the seven postures for each individual was a strength. These data revealed that neither the ergonomic assessments nor the PM package affected all postures the same way, indicating, as others have noted in the past, that some postures appear to be more amenable to change than others.

Another strength of the study was the inclusion of the ergonomic evaluation phase. This permitted evaluation of workstation changes alone. Also, postures that increased appreciably due to workstation changes were not targeted by the more labor-intensive PM package. On the other hand, caution should be exercised when generalizing the results of the PM package to other settings and when comparing the results to other behavior-based safety studies, in that most studies do not isolate or target only behaviors and postures that require improvement. Thus, the mean increases seen in this study are likely to be larger than those in other settings and studies that target all critical safe behaviors and postures.

One weakness was the fact that participants were aware that they were being observed during sessions. The safety scores of participants, thus, may have been inflated due to measurement reactivity (Rohn, 2002). Measurement reactivity may have been responsible for the relatively long maintenance of high percent safe scores during the poststudy follow-up as well. On the other hand, the same observation procedures were used throughout the entire study, including baseline, thus increases observed during the intervention phases are not likely to be due to measurement reactivity.

Another weakness was the fact that senior OT students conducted the office ergonomic assessments. The OT students completed the assessments with varying levels of competency, completed the assessments during only one meeting, and were not ergonomic experts hired by the organization. This may have reduced the consistency with which the ergonomic assessments were administered. On the other hand, similar to the OT students, in many organizations, personnel who conduct ergonomic assessments do not have prior knowledge of an employee's work arrangement. Furthermore, these personnel usually have limited control over scarce resources (i.e., money) and may not be able to implement elaborate recommendations readily. Thus, ergonomic safety specialists must often overcome organizational constraints and develop creative, low-cost, or no-cost ergonomic solutions. This was also true of the OT students in the present study.

An additional weakness of the study was the lack of any ergonomically correct—that is, 100% safe according to UC interface criteria—workstations. Thus, it was not possible to examine whether someone working at a 100% safe workstation would assume a 100% safe posture. However, results from other studies in which completely safe workstations were arranged suggest that individuals remain unsafe even under these conditions (Alvero & Austin, 2004; Rohn, 2002).

FUTURE RESEARCH AND IMPLICATIONS

Although the current findings suggest that workstation adjustments alone were not sufficient to bring about dramatic postural changes, future research should be conducted in an effort to confirm these results. In the present study, the workstation changes were limited to minor adjustments. Studies should be conducted in which personnel are able to make substantial equipment changes to the computer workstations. Additionally, researchers should investigate the effects of working at a 100% safe workstation.

In the present study, all workstation adjustments were treated equally, but in terms of postural changes that they produced, they were not all equal. Thus, researchers should examine the relative postural changes produced by specific equipment changes. For example, researchers could examine the relative postural change produced by changing the monitor angle or adding a footrest versus changing the keyboard or desk height.

Future researchers should also investigate the effects of other environmental factors—for example, clothing—on safe postures. As a case in point, P6 would engage in unsafe leg and feet positions only when wearing pants and casual clothing; when wearing skirts or dresses, her leg and feet positions were safe. When casually dressed, she would sit on her foot as she worked at her computer. Engaging in this unsafe lower body position also affected other postural components, namely back position and to a lesser degree shoulder position and head-neck position.

In this study, the first author served as the agent of change when the PM package was implemented. As a result, though the PM package did not cost the organization much, it was not continued after the first author withdrew from the organization. Thus, long-lasting safety gains did not occur. In an effort to both promote a safety culture and keep program costs low, future researchers should examine the effects of an employee "buddy" system in which employees team up to be the primary change agents for each other, comparing such a system to a more management-driven system.

The practical implications of this and future research could aid practitioners in their attempts to more effectively implement office ergonomic programs and behavior-based safety processes. The results suggest that organizations should adopt behavioral technology to enhance and support their ergonomic programs. It is important to recognize that ergonomic interventions provide the opportunity for employees to work safely, and thus they should not be replaced by behavioral interventions. Rather, behavioral interventions should be used to ensure that tools and equipment are used correctly. Just as, or even more, importantly, however, is that the results show that safety improvements, even those that result from workstation changes, may not persist in the absence of behavioral supports. Thus, once again, these results point out the importance of imbedding behavioral supports within a system or safety culture in organizations in order to achieve real and lasting safety benefits (Geller, 1996; McSween, 1995).

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APPENDIX

Safety Observation Checklist

PARTICIPANT # __________SESSION # ______DATE: __________OBSERVER: ____________(RELIABILITY OBSERVER __________)

WORKSTATION VARIABLES Š PHYSICAL DIMENSIONS										
HEIGHT	Keyboard		Mouse		Monitor*		Chair		Desk	
ANGLE	Keyboard		Mouse		Monitor					

* - distance from userÕs eye to monitor

WORKSTATION VARIABLES Š USER-COMPUTER INTERFACE	(+ = SAFE / - = UNSAFE)		
COMPONENT	**DESCRIPTION**	**SAFE**	
CHAIR	UserÕs feet rest on floor or footrest and upper body is high enough to work comfortably	+	-
MONITOR	Positioned directly in front of and centered on user	+	-
	UserÕs eyes should be in line with a point 2-3 inches below top of monitor	+	-
	Distance from userÕs eye to monitor at least 18 inches	+	-
	Angle relevant for bifocal userÕs: tilted backwards slightly so user can see screen w/out tilting head	+	-
KEYBOARD	Positioned in front of and centered on user	+	-
	Height is below userÕs seated elbow height	+	-
	Sloped away from user Š tilted downward	+	-
MOUSE	On a flat surface that 1-2 inches above keyboard and moveable, OR	+	-
	On same level as keyboard: sloped away from user Š tilted downward	+	-

BEHAVIOR + = PERFORMED SAFELY / - = PERFORMED UNSAFELY / X = NOT PERFORMED

TYPING

INTERVALS		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	% S
Hand-Wrist Position Wrists flat (not bent up or down) and straight (not bent right or left)	0	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
	2	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	

POSTURE

INTERVALS		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	% S
Head/Neck Position Head in vertical position such that the neck aligned with back; head facing forward	0	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
	2	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
Shoulder Position Upper arms close to body & relaxed, not extended; shoulders not hunched or raised	0	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
	2	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
Back Supported Lower back supported reclined posture; angle of the back & thigh approx. 100 Š 110 degrees	0	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
	2	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
Arm Position Arms & elbows close to body; inside elbow angle 90-120 degree	0	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
	2	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
Leg Position Knees bent forming an angle between 90 Š 120 degrees	0	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
	2	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
Both Feet Flat on Floor Both feet are flat on the floor or footrest (ball of foot and heel should be touching)	0	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	
	2	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	+ - X	

Interval duration = 10min.