REDUCING RISK OF PRESSURE SORES: EFFECTS OF WATCH PROMPTS AND ALARM AVOIDANCE ON WHEELCHAIR PUSH-UPS

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People who use wheelchairs are at risk for developing pressure sores. Regular pressure relief, in the form of a wheelchair push-up, is one way to reduce the likelihood of pressure sores. We examined the effects of antecedent (i.e., instructions, audible prompts) and consequent (i.e., alarm avoidance) events on wheelchair push-ups, using a multiple baseline analysis with 2 participants with spina bifida. Results suggest that the combined procedure was more effective than either antecedent or consequent events alone, and there is some evidence suggesting maintenance of effects over time.

DESCRIPTORS: pressure sores, prevention, physical disabilities, prompts, avoidance

Pressure sores occur when blood supply to skin tissue is interrupted by prolonged pressure between a bony prominence, such as those next to the buttocks, and an external surface, such as a wheelchair seat or bed (Barton & Barton, 1981). Over 1 million Americans develop pressure sores each year (Brody, 1986), with over half of those who use wheelchairs eventually developing a pressure sore (Sugarman, 1985). Medical treatment for healing a single pressure sore can cost over $30,000 (Krouskop, Noble, Garber, & Spencer, 1983), with a total annual cost of over $3 billion in the United States alone (Pinchcofsky-Devin & Kaminski, 1986). Dinsdale (1974) estimates that insurance companies spend over 25% of their spinal cord injury-related medical expenses for pressure sore treatment.

Physical complications from pressure sores include infection, dehydration, anemia, and electrolyte imbalance (Shea, 1975). Pressure sores also produce pain, disfigurement, lengthy periods of medical treatment, and hospitalization (Grundy & Silver, 1984). Because medical treatment requires prolonged bed rest, persons with pressure sores typically have less contact with family and friends and disrupted employment or job loss.

Behaviors associated with reducing the risk of pressure sores include performing regular pressure relief (Merbitz, King, Bleiberg, & Grip, 1985), doing frequent skin inspections (Mayo Clinic, 1983), practicing regular hygiene (Roberts, Dinsdale, Matthews, & Cole, 1969), and eating nutritious meals (Pinchcofsky-Devin & Kaminski, 1986). Regular pressure relief, in the form of wheelchair push-ups, is widely regarded as a primary deterrent to pressure sores (Fisher & Patterson, 1983; Fordyce & Simons, 1968). Although most rehabilitation programs recommend push-ups, no data are available on natural levels of compliance. Evaluations of the effects of promoting performance of prescribed push-ups often lack methodological rigor or empirical analysis (Cumming, Tompkins, Jones, & Margolis, 1986; Rosenberg & Lach, 1985).

Two earlier studies provided a methodological foundation for the present work. In a measurement advance, Merbitz et al. (1985) developed a portable computerized device for continuously monitoring the frequency and duration of participants' weight shifts. They provided participants with written and oral feedback on their previous day's performance

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of avoiding an alarm by doing a push-up every 30 min. Results showed the intervention increased push-ups to a prescribed criterion for 1 participant and produced variable and temporary effects for the 2nd. An earlier intervention study (Malament, Dunn, & Davis, 1975) examined the effects of an automated alarm that sounded when wheelchair users failed to do a 4-s wheelchair push-up every 10 min. Results suggested that the intervention increased wheelchair push-ups to the prescribed criterion. Although there was an increase in pressure-relief behavior, maintenance of the target behavior was not well documented, in that the length of the follow-up assessment interval averaged only 5.5 hr for both participants.

The present study extends earlier work by analyzing the previous contributions of consequent (i.e., alarm avoidance) events and examines the use of antecedent (i.e., audio prompt) events on wheelchair push-ups.

METHOD

Participants and Settings

Participants were two 11-year-old youths with spina bifida, which results from birth with an open spine. In severe cases spina bifida causes either paraplegia or paraparesis. Enrolled in the study at the same time, both youths signed a consent form to participate. Teri weighed 92 lbs (41.4 kg) and scored 78 on the Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983), indicating a low to normal range of intellectual functioning. Peter weighed 70 lbs (31.5 kg) and scored 84 on the Wechsler Intelligence Scale for Children (Wechsler, 1974), also reflecting a low to normal range of intellectual functioning.

Both participants used a wheelchair as their primary means of locomotion. Because neither had skin sensation on their buttocks or adjacent skin areas, they were without sensory information about prolonged skin pressure. Physical therapists and nurses identified both as being at risk for developing pressure sores, although neither had a history of serious pressure sores. Prior to the study, both subjects were observed to determine whether their arm strength allowed them to lift off their wheelchair for at least 5 s.

Both participants lived and attended school at a residential treatment facility for children and adolescents with developmental disabilities. After Session 18, Peter left the facility and returned to his home in another city. He attended a neighborhood grade school for the remainder of the study.

Recording and Calibration of the Behavior of Wheelchair Lifts

An adaptation of the automatic recording device developed by Merbitz et al. (1985) was used to measure the frequency and duration of wheelchair push-ups, weight shifts, and periods of prolonged sitting. The device used a vinyl air bladder (29 by 36 cm), filled with approximately 450 cc of air, that was placed under the participant's wheelchair cushion. When a weight greater than 20 kg rested on (or was taken off) the cushion, a corresponding increase or decrease in air pressure flowed through plastic tubing (0.96 cm) to a smaller (8 by 12 cm) vinyl air bladder. Thus, when a person sat on the wheelchair cushion, air from the large bladder flowed to the smaller bladder, inflating it and raising a lever that activated two microswitches.

The microswitches had electrical leads connected to an alarm and a modified Radio Shack TRS-80® pocket computer. The computer was capable of continuously measuring the frequency and duration of wheelchair push-ups and time spent sitting on the wheelchair cushion. Each wheelchair push-up was recorded along with the time of occurrence, into computer memory for later retrieval. The computer, microswitches, lever, and small vinyl air bladder were enclosed in a metal box (8 by 13 by 26 cm) attached under the wheelchair frame.

Each day's wheelchair push-up data were divided into 30-min intervals. Raters scored each interval as either appropriate or inappropriate. An interval was scored as appropriate whenever it contained at least one wheelchair push-up that exceeded 3 s. An interval was scored as inappropriate if no wheelchair push-ups had been performed, or if push-ups during the interval were less than 3 s in duration. Intervals in which the participant was out of his or her wheelchair seat for over 30 s, such as to use the bed or toilet, were not scored.

The computers were calibrated 24 times during the study to assess the consistency of the automated recording of wheelchair push-ups. To calibrate the computer, a researcher independently recorded the exact time and duration of all wheelchair push-ups during at least one 30-min interval. The frequency and duration of observed wheelchair push-ups were compared to the computer's printout for reliability. On two reliability checks, computer malfunctions were identified, because there was no correspondence between the computer printout and direct observations. These reliability checks occurred after unusually long (3-day) periods between data collection (Sessions 39, 40, and 41 and Sessions 61, 62, and 63 for Peter). Data for these six sessions were discarded. Reliability observations conducted for Peter's remaining sessions averaged 100% agreement between human and computer scoring. Similarly, all of Teri's reliability observations averaged 100% between human and computer scoring agreement.

Reliability of scoring computer printout tapes was also measured. Duplicate printouts were made and scored independently by a second observer. Total reliability was calculated by dividing the total number of agreements by the total number of agreements and disagreements and multiplying by 100. Reliability checks of these permanent products were conducted during each condition. Overall reliability for printout scoring was 95%, ranging from 78% to 100%.

The computer and alarm were serviced (AA batteries were replaced) and data collected three times each week. The experimenters used the participant's digital watch to reset the clocks on the computer and alarm each time that data were retrieved. This ensured synchronization of all electronic devices. The time difference between the computer and the watch averaged ±2 s per 24-hr period, and the time difference between the watch and the programmable alarm averaged ±20 s per 24-hr period. The longest time between data retrievals was approximately 92 hr, with an average of about 56 hr.

Procedure

The complete intervention, known as "Beep 'n' Lift," included instructions, prompting with a watch beeper, and alarm avoidance.

Instructions. After viewing pictures of pressure sores, the participants were provided a rationale for doing wheelchair push-ups. This was followed by brief instructions in performing a wheelchair push-up. Participants were instructed to place each hand on the wheelchair armrests or wheels and to extend both elbows to approximately 180°, resulting in the buttocks lifting off the cushion. Next, the experimenter modeled wheelchair push-ups for the participant. Then, the participant imitated the model. After the participant had demonstrated three successive appropriate wheelchair push-ups, this portion of the training was considered complete. The participant was then asked to repeat the instructions to the experimenter. Clarification was provided, as needed, and all questions were addressed. These instructions lasted approximately 45 min.

Prompting with watch beeper. After initial instructions, each participant was given a Casio W-700® programmable watch (cost about $30) that emitted a 30 to 35 dB beep every half-hour. The participant was told that whenever the watch beeped, he or she should do a wheelchair push-up for at least 3 s. The watch beeper was then sounded several times to familiarize the participant with the sound. After the participant was given the watch, several practice push-ups (consisting of sounding the watch beep followed by the participant lifting and slowly counting one-thousand-one, one-thousand-two, one-thousand-three) were initiated. The participant was then told to remember the phrase "Beep 'n' Lift" as a mediating stimulus for doing a wheelchair push-up after each watch beep.

Alarm avoidance. The final procedural element involved avoidance of an alarm (Sidman, 1966; Skinner, 1965). This component, located under the participant's wheelchair seat, used a programmable alarm that emitted a pulsating 86-dB noise for 6 s. The alarm met federal safety standards for noise exposure (Hammer, 1976). After any 30-min interval in which the participant did not do a wheelchair push-up of at least 3 s, the alarm sounded. Performing a push-up reset the alarm and the noise was avoided. As part of the instructional session, the experimenter sounded the alarm and explained that the alarm could be avoided by doing a push-up every half-hour. Once the alarm began to sound, the participant could not escape the 6-s noise by doing a push-up. The prototype alarm, constructed specifically for this research, cost about $100. The alarm was powered by four AA alkaline batteries. Batteries were replaced every 2 or 3 days during servicing and cost approximately $5 per week.

Experimental Design

A multiple baseline design across participants was used to analyze the effects of the Beep 'n' Lift intervention on appropriate wheelchair push-ups. Alternating experimental conditions within participants were used to test the effectiveness of various intervention components. The design allowed extensive measures of generalization across settings, because both participants attended school and leisure activities in the community.

For Teri and Peter there was a series of varying conditions including:

Baseline. Before baseline, a seat belt had held the participant tightly to his or her wheelchair. On the first day of baseline, participants were told to loosen their seat belts approximately 3 in. This allowed them to do weight shifts or push-ups as needed. Each had previously been taught to do wheelchair push-ups by physical therapy staff and reported knowing the importance of doing them.

Beep 'n' Lift. This condition consisted of providing instructions about how to perform wheelchair push-ups, audio prompting of wheelchair push-ups using the watch beeper, and alarm avoidance.

Alarm avoidance only. In this condition the watch beeper was turned off, and no audible prompt was heard. The programmable alarm sounded, however, following any interval in which an appropriate push-up did not occur.

Prompting with beeper only. This condition used only the watch with beeper to prompt wheelchair push-ups. The programmable alarm remained attached to the wheelchair, but it was disengaged without the participant's knowledge.

Follow-up. The Beep 'n' Lift procedures were continued for 1 month after Session 72. During follow-up, batteries in the programmable alarm were regularly replaced, but no data were collected. This servicing was performed by an appointed person in each participant's setting. After 1 month, the computer was again turned on without either participant's knowledge, and data were collected for the next 3 days.

Observation of Skin Condition

Two nurses, who received prior training in observing and scoring pressure sores, independently checked participants for pressure sores before the study began and before each change of experimental condition. They used standard protocols for scoring pressure sores that included written specifications and illustrated models for varying severity of sores (Shea, 1975). Data consisted of independent ratings (0 = no pressure sore, 4 = very severe pressure sore) based on the observation of the participant's buttocks and adjacent skin area. Interobserver agreement on the presence and severity of pressure sores was assessed by dividing the total number of agreements by the total number of agreements plus disagreements, multiplied by 100. Reliability was 100% in all conditions.

Social Validation

A social validation procedure was used to assess the appropriateness of the intervention from the participant's perspective and the significance of the intervention's effects from the perspective of experts in the field of rehabilitation medicine (Wolf, 1978).

Following the study, participants were asked if they would recommend the Beep 'n' Lift intervention to a friend who has problems with pressure sores. Each participant then rated the acceptability of the watch prompt and the alarm consequence using a modified 7-point Likert-type scale. The scale ranged from a −3 (very unacceptable) to a +3 (very acceptable), with 0 being a neutral point. Each number on the 7-point scale was also paired with a written description that portrayed the numeric values. The ratings were then averaged to provide overall scores.

A panel of 6 rehabilitation professionals (consisting of 2 physiatrists, 2 occupational therapists, and 2 physical therapists) was told of the procedure's costs, viewed data collected in this study, and were asked if they would prescribe Beep 'n' Lift for someone at risk for developing a pressure sore. Using a similar 7-point Likert-type scale, they also rated the effectiveness of wheelchair push-ups as a means of pressure relief.

RESULTS

Frequency of Wheelchair Push-Ups

Figure 1 presents the percentage of 30-min intervals during which participants completed wheelchair push-ups of at least 3 s in duration. On average, Teri performed appropriate wheelchair push-ups during 23% of baseline observation intervals. She increased appropriate wheelchair push-ups to a mean of 88% during the first Beep 'n' Lift condition. In the alarm avoidance only intervention, appropriate intervals decreased to a mean of 52%. When the Beep 'n' Lift condition was reinstated, push-ups returned to a mean of 89%. A reversal to the alarm avoidance only condition resulted in a decrease in the average percentage of intervals with appropriate push-ups to 40%. When the Beep 'n' Lift condition was again reinstated, appropriate lifts increased to an average of 75%. (Between Sessions 50 and 55, Teri was on vacation with her family. The Beep 'n' Lift procedures were discontinued during this 6-day period.) In the prompting with beeper only condition, appropriate intervals averaged 65%. In the final implementation of the Beep 'n' Lift condition, appropriate wheelchair push-ups increased to a mean of 79%. Appropriate wheelchair push-ups occurred in 68% of the intervals during the 3-day follow-up observations that occurred 1 month later.

During baseline, Peter did appropriate wheelchair push-ups during 22% of the observed intervals. During the first Beep 'n' Lift condition, lifts increased to an average of 55%. In the prompting with beeper only condition, intervals with appropriate wheelchair push-ups decreased to 37%. When the Beep 'n' Lift condition was reinstated, there was an increase to a mean of 64%. During a reversal to the prompting with beeper only condition, lifts occurred during an average of 38% of the intervals. In a permanent return to the Beep 'n' Lift condition, intervals with appropriate wheelchair push-ups increased to 75%. During the 3-day follow-up, appropriate wheelchair push-ups occurred during an average of 45% of intervals observed.

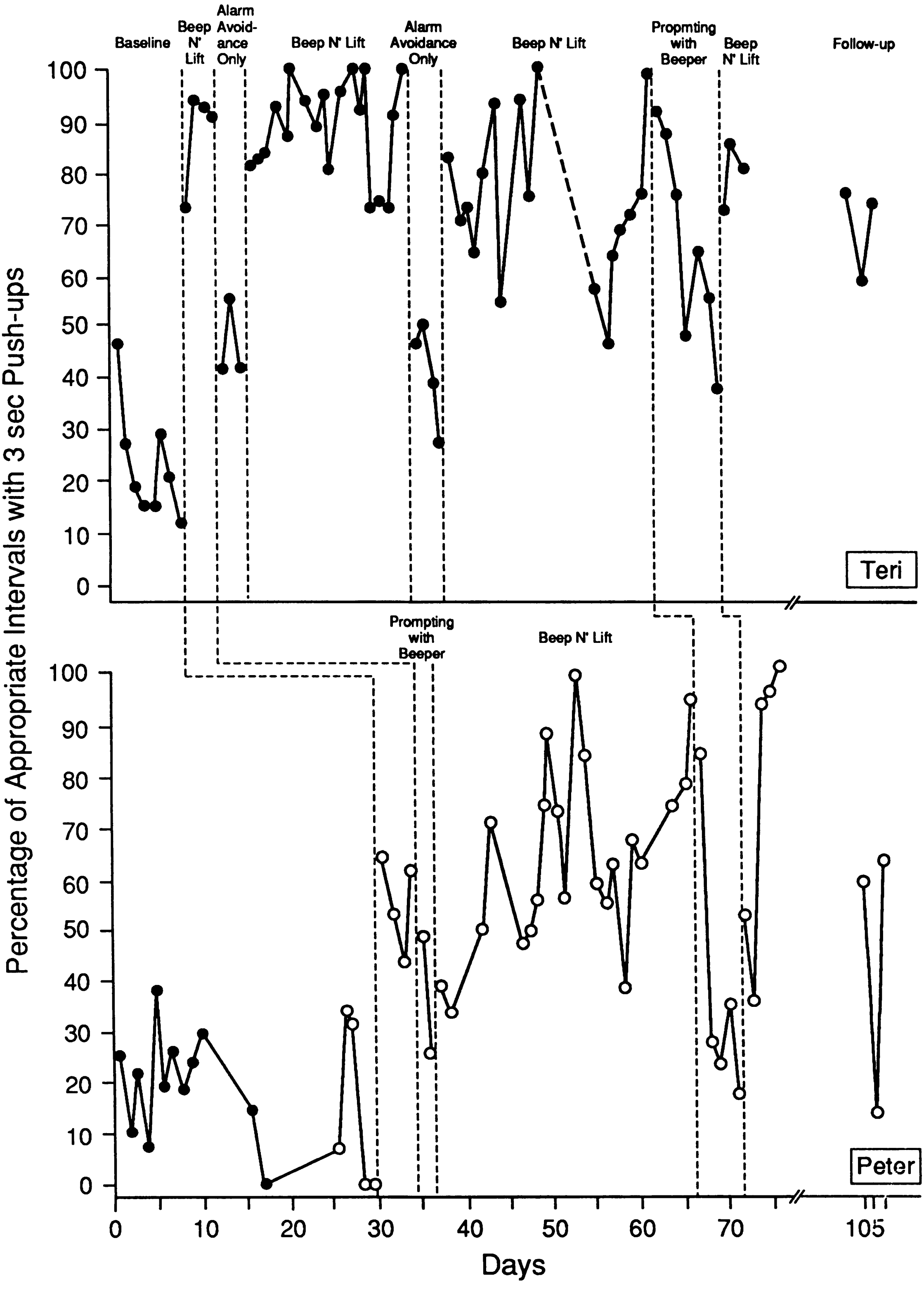
Skin Condition Data

When observed before baseline, neither participant had a pressure sore. Further skin inspections conducted before each condition change and after follow-up indicated that no pressure sores were present. On one skin condition check following Session 17, Peter was observed to have had a rash on his upper thighs as a result of dampness caused by urinary incontinence. Teri was also observed to have a similar rash following Session 76 and after follow-up data had been collected.

Consumer Ratings Data

Both participants indicated that they would recommend the Beep 'n' Lift program to a friend who has problems with pressure sores. They also rated the watch prompt as being very acceptable ($M = +3$) and the alarm consequence as moderately unacceptable ($M = -2$). Both said that they were embarrassed when the alarm sounded.

Physical medicine and rehabilitation physicians on the panel said that they would be very willing ($M = +3$) to prescribe Beep 'n' Lift for someone at risk for developing a pressure sore, based on the intervention's costs and benefits. Physical and occupational therapists rated regular wheelchair push-


Baseline
Beep N' Lift
Alarm Avoid-ance Only
Beep N' Lift
Alarm Avoidance Only
Beep N' Lift
Propmting with Beeper
Beep N' Lift
Follow-up
Teri
Prompting with Beeper
Beep N' Lift
Peter
Percentage of Appropriate Intervals with 3 sec Push-ups
Days
0
10
20
30
40
50
60
70
80
90
100
105

ups as a moderately effective ($M = +2$) means of pressure relief.

DISCUSSION

This experiment investigated the effects of a multicomponent intervention that used prompting and avoidance procedures to increase wheelchair push-ups. The average percentage of intervals with appropriate wheelchair push-ups was 3.2 times higher than baseline during Beep 'n' Lift conditions. Results suggest that the combination of instructions, prompts, and avoidance procedures was effective in producing and maintaining appropriate wheelchair push-ups.

As part of this investigation, we examined the relative effectiveness of various intervention components. When the alarm avoidance component was eliminated (during the prompting with beeper only condition), the average percentage of appropriate intervals was nearly twice the baseline levels but only two thirds as effective as the complete intervention. Similarly, when the prompt was eliminated (during the alarm avoidance only condition), the average percentage of appropriate intervals was over twice the baseline level but was only approximately half as effective as the complete Beep 'n' Lift intervention. Apparent downward trends for both the prompting with beeper only and avoidance only conditions further call into question the sufficiency of either component when used alone.

Consensus has not been attained on how long and how often wheelchair push-ups should be done (Cumming et al., 1986; Fisher & Patterson, 1983; Malament et al., 1975). The duration and frequency of appropriate wheelchair push-ups used in this study (3 s or more every 30 min) have been recommended by Merbitz et al. (1985). The marked increases to relatively high and stable levels of compliance and the absence of observed skin breakdown suggest that these effects are of probable clinical significance. Future research should be conducted with participants who have a history of severe pressure sores to demonstrate further the efficacy of this intervention.

Many biological (body build, body weight, bone structure, and skin resilience), environmental (wheelchair cushion types), and behavioral (proper eating, hygiene, and pressure relief habits) factors affect the probability of developing or preventing a pressure sore (Jones & Millman, 1986; Warner & Hall, 1986). Accordingly, it is difficult to assess the treatment validity of the Beep 'n' Lift intervention alone. Subsequent research studies should examine the effects of compliance with this behavioral prescription for wheelchair lifts (perhaps as produced by Beep 'n' Lift) on long-term outcomes, such as the incidence of pressure sores and related treatment costs (Epstein & Cluss, 1982; Finney, Friman, Rapoff, & Christophersen, 1985). Outcome studies examining these effects in combination with the other biological, environmental, and behavioral factors would be particularly valuable.

Several additional issues merit further research and development. First, the Beep 'n' Lift intervention used a number of electronic components that had to be synchronized to maintain the relationship between the behavior of wheelchair push-ups and antecedent and consequent aspects of the intervention. Future research should address the development of a simpler assessment methodology that requires less calibration and a more reliable and less expensive alarm unit for the avoidance component.

Second, future research should also test the generality of the effects of the Beep 'n' Lift intervention with a more diverse population of people with disabilities. Research with adults with physical disabilities who are living independently, people with limited use of the upper body for doing push-ups, and nursing home residents who are frequently

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Figure 1. The percentage of 30-min intervals that participants did appropriate wheelchair push-ups, lifting off of the wheelchair cushion for 3 s or more. The closed circles indicate an institutional setting, and the open circles indicate the home setting.

bedridden would likely yield new methodological challenges and variations in procedures.

Finally, the question of long-term compliance produced by the Beep 'n' Lift intervention also needs to be addressed. Results of maintenance of effects in this study were inconclusive, because Teri appears to be maintaining her push-ups, whereas Peter's appropriate push-up rate declined during follow-up. Future research on long-term preventive behaviors to reduce medical risks is important, because maintenance with short-term treatment and prevention regimens has been only moderately successful (Meichenbaum & Turk, 1987; Sackett & Snow, 1979). From a prevention viewpoint, wheelchair push-ups should be maintained by those at risk for developing pressure sores for the rest of their lives.

This study has important implications in view of the scope and severity of pressure sores, as well as the tragic loss of potential for the majority of wheelchair users who get them sometime in their lives. Behavioral principles designed to encourage a simple response—regular wheelchair lifts—may contribute to pressure sore prevention. Such applications may reduce needless medical costs, increase productivity among wheelchair users, and extend opportunities for continued mobility and personal freedom.

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