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Wheelchair Push-ups: Measuring Pressure Relief Frequency

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ABSTRACT. Merbitz CT, King RB, Bleiberg J, Grip JC: Wheelchair push-ups: measuring pressure relief frequency. Arch Phys Med Rehabil 66:433–439, 1985.

• Ischial pressure sores (PS) are a long-recognized complication of wheelchair confinement, yet teaching spinal-cord patients to establish lift-off behavior habitually and permanently remains a challenge. A new device was developed to record automatically and continuously the wheelchair lift-off behavior of spinal-cord injured patients. Data from seven patients who used the device for between 768 and 1800 hours each are reported. The device was used to monitor longitudinally the behavioral compliance of each individual with prescribed lift-off intervals using standard teaching procedures. Wide variability between patients and within patients over time was found. Experimental interventions including the use of an electronic timer and written and oral feedback of the previous day's data also varied in their effectiveness. Data from one patient who developed a pressure sore while being monitored suggest that there is no simple relationship between lift-off intervals and PS formation.

KEY WORDS: Paraplegia; Pressure; Wheelchairs

Ischial pressure sores (PS) have long been a persistent and serious complication of spinal cord injury (SCI). Such sores are a principal source of morbidity and a primary cause of prolonged hospitalization in this population.[2] To prevent sores, individuals with paraplegia secondary to SCI routinely are taught during rehabilitation to perform pressure-relief lift-offs. This paper presents data collected with a new device which continuously and automatically records lift-off behavior.

The pressure-relief lift-off is simple if the requisite upper body strength and coordination exist. A lift-off training program is considered successful if patients perform the lift-offs at specified intervals routinely for the rest of their lives. Evaluating a teaching program thus implies monitoring behavior during and after training, and following discharge from the hospital. In the past 15 years, at least seven devices designed to facilitate such training have been reported.[1,4,5,8,9,11] Teaching a person to perform the behavior habitually and permanently, however, has remained a challenge.

We have developed a device, the Timer-Logger-Communicator (TLC), which provides automatic, direct measurement of lift-off behavior on a continuous basis for up to 3 days without maintenance. This report focuses on the collection and systematic clinical use of lift-off data using the TLC system.

Subject Characteristics

Patient	Age	Sex	Injury Level	Hours Observed	Skin Status: in hosp.	At D/C	Post D/C
A	25	M	T8 UMN	1032	Intact	Intact	N/A
B	31	M	T6 UMN	948	Intact	Intact	N/A
C	26	M	T12 LMN	1032	GD2	GD2	Healed*
D	22	F	T5 UMN	1800	Intact	Intact	Intact
E	23	M	T12 LMN	768	Intact	Intact	Intact
F	32	F	T6 UMN	1176	Intact	Intact	Intact
G	23	M	T12 UMN	1200	Intact	Intact	Intact

LMN = Lower Motor Neuron. UMN = Upper Motor Neuron. "Hours Observed" = number of hours patient was monitored. GD2 = Grade 2 PS.
* At 6 months, patient C developed a grade 1 PS which subsequently healed.
N/A = Not Available.

MATERIALS AND METHODS

Subjects. Seven newly injured paraplegic SCI patients at a rehabilitation hospital served as subjects in this study (table 1). Data for 13 other subjects are not reported here; eight of these served in pilot phases of the project, during which the apparatus was being refined, and the other five were discharged before a minimum of 750 hours of data had been collected.

Apparatus. The TLC consists of a small, battery-operated "pocket computer" to record data, and a sensor apparatus which reports to the computer whether the subject is seated in the chair. The sensor consists of a large, airtight vinyl bladder placed on the wheelchair sling under the subject's seat cushion, connected by a tube to a smaller vinyl bag. The smaller bag is located in an 8x13x26mm box mounted on a frame of the chair, along with the computer and a lever. A weight of greater than 20kg over the area of the cushion forces air out of the larger bladder into the smaller, moving the lever, which depresses a key to enter the event into the computer. If the weight on the seat is reduced to 14kg, as in a lift-off, a spring returns the lever and enters a second type of event into the computer. The exact time of day of each event is stored by the computer. When the computer is removed from the TLC, the stored data are printed out. For purposes of this study, only lift-offs greater than 3 seconds in duration were counted.

Procedure. Data collection on selected patients began shortly after admission. Patients received standard care, including routine instruction to perform pressure-relief lift-offs every 20 minutes and to inspect their skin for PS daily. Staff logged skin inspections and comments about skin care for patients in the study.

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While the patient slept at night, the TLC was checked and the computer replaced. Print-outs of the data were inspected daily. Routine feedback was provided to patients weekly, unless they responded positively to the offer of more frequent communication. Frequent prolonged episodes without a lift-off prompted researchers to provide additional feedback to the patient and treatment staff. The researcher would attempt to identify with the patient the activity (watching TV, drinking alcohol, having visitors, parties, shopping, etc) during which the prolonged sitting episodes occurred.

Individual clinical interventions, such as more frequent feedback or the use of a timer, are described in the case discussions below.

RESULTS

Four cases illustrating a variety of findings are described:

Case A: Fig 1 displays lift-off behavior on a temporal basis. Each horizontal line represents a day, and may have two states. When the line is low, the patient is seated in the wheelchair. When it is high, the patient is out of the wheelchair. An upward spike represents a lift-off of over 3 seconds. Inspection of the upper part of the record indicates that patient A sat for long periods without a lift-off. Long bouts that did occur were not at a consistent time of day. The lower part of the record covers a period during which experimental interventions were applied. At 5:26 pm on day 40, a Friday, the patient was given an electronic timer which beeped every 30sec to signal him to do lift-offs.[7] Note the dramatic change in his record from irregular intervals and some bursts of lifts, to responding spaced at 30sec intervals. Each weekday, beginning the following Monday, he was given written feedback in the form of a photocopy of the event record, and an experimenter met him most days to discuss his progress. On day 47, the beeper was removed and he began to cue himself using his wristwatch. Note the gradual return of irregularity and bursts. Daily written feedback was continued until day 58, followed by oral feedback only through day 60, after which no feedback was given through discharge on day 66.

While the presentation and withdrawal of the beeper produced a clear and pronounced change in the daily pattern of lift-offs, trends in the frequency of behavior are not apparent in fig 1. Accordingly, frequencies of lift-offs (counts of lifts/minutes spent in the wheelchair) for patient A were plotted on Standard Celeration Charts (SCC),[10] thereby condensing each day of behavior into a single dot (fig 2). Also plotted (as a dash) is the reciprocal of minutes spent in the wheelchair each day. Accordingly, higher dots represent higher lift-off frequencies, while lower dashes represent more time spent in the wheelchair. Thus, the first dot indicates that Tuesday, December 20, patient A lifted at a frequency of .016 lifts/min (1 lift every 62 minutes). Since he was seated for 186 minutes, the dash is placed at .0054 (the reciprocal of 186). Each calendar day is a vertical tic, and vertical dashed lines are Sundays. Days are numbered as on the event record to facilitate comparison. Since all days are represented, the slope (celeration) of a line of best fit is conveniently quantified as count/min/wk.[6]

Fig 2 reveals that during the first two weeks there was considerable day-to-day variability in lift-off frequency, and a clear acceleration (rising trend). During the third week, there is a definite flattening of celeration at the unacceptable rate of about .02 lift-offs/min (one lift-off every 50 minutes). The patient was transferred to another institution (for treatment of

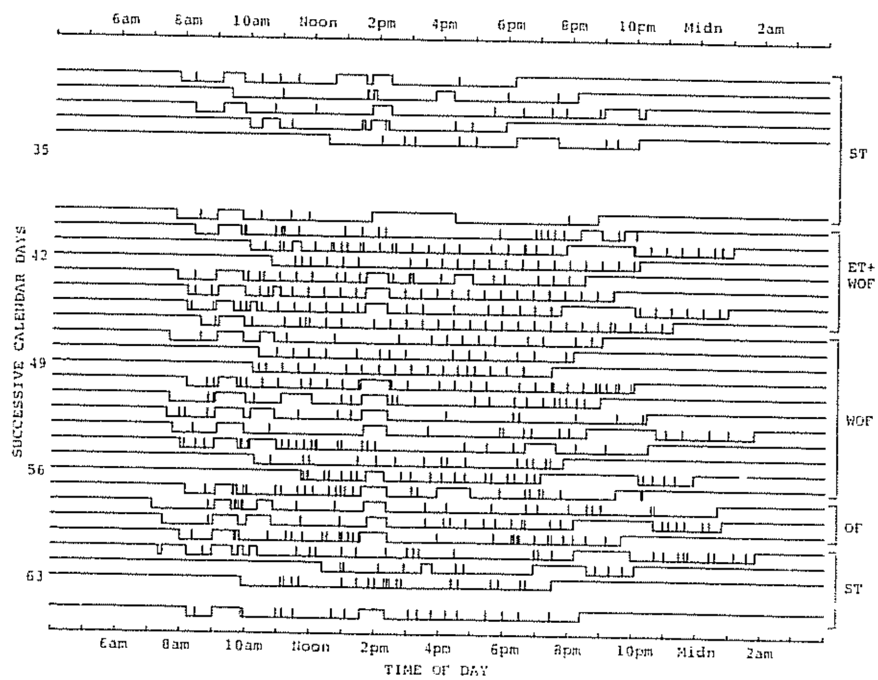

Fig 1—Daily lift-off behavior, patient A. Data trace down indicates patient seated in wheelchair; data trace up indicates patient not seated in chair; upward spike indicates lift-off. Sundays numbered on left; interventions indicated on right: ST=Standard treatment: ET=30′ electronic timer; WOF=Written and oral feedback; OF=Oral feedback only. Patient temporarily discharged days 35 through 38.

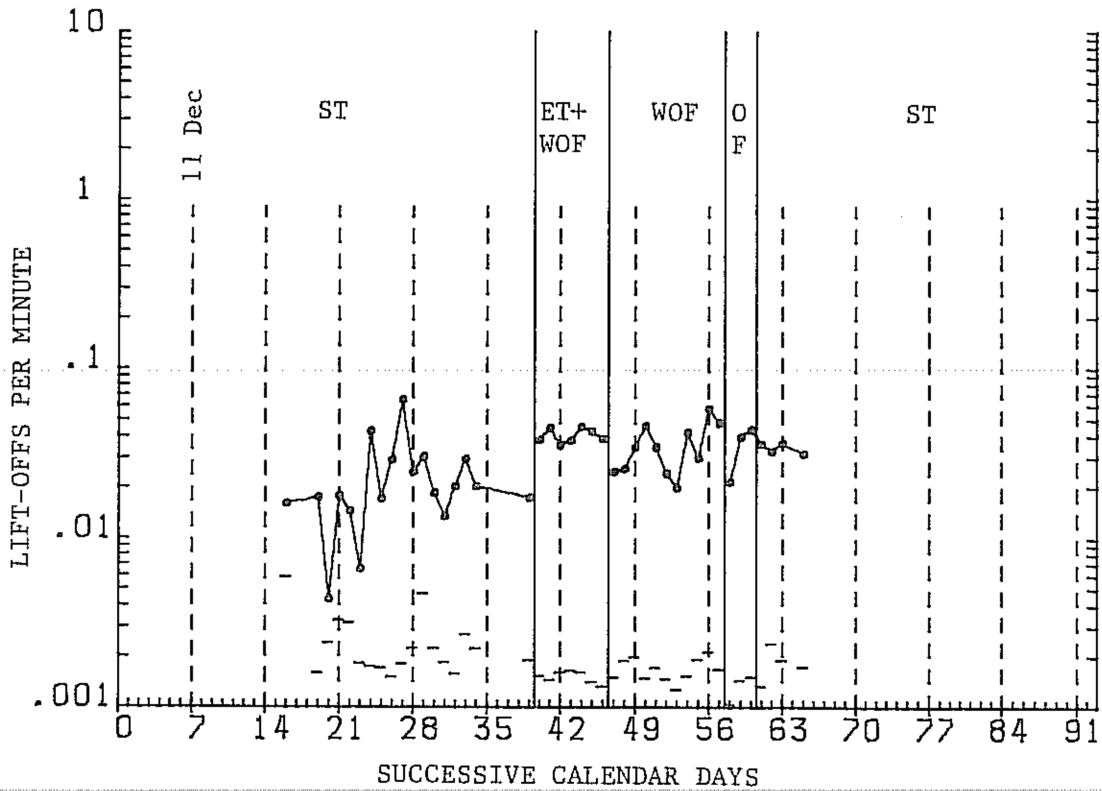

Fig 2—Lift-off frequencies, patient A. Dots are daily lift-off frequencies. Dashes are reciprocal of total minutes spent in the wheelchair. Numbered, vertical dashed lines are Sundays. Day 0 is the Sunday before hospital admission. Intervention codes as in fig 1. Temporarily discharged on days 17-18 and 35-38. No data collected on day 64.

suspected deep vein thrombosis) during days 35 through 38, interrupting data collection. The low lift-off frequencies were still evident on his return (day 39). He then was provided with a 30-minute cycling timer for cueing, as previously indicated.

The dramatic change noted in his event record following introduction of the beeper is also seen in fig 2. Note the step-up in frequency and the decrease in variability while the beeper was in place. When it was clear that the frequencies were stable, the beeper was removed, but written feedback was continued (day 47). There was an immediate drop in frequency, followed by acceleration, then deceleration, then increasing daily variability. By day 54, however, the frequencies had recovered to previous levels even though the pattern of lift-offs within the day remain irregular (fig 1). Patient A reported that he had been cuing himself using his wristwatch during this period. As patient A's discharge was imminent, we elected first to eliminate his written feedback (day 58), and then oral feedback (day 61) to more nearly approximate conditions he would experience after discharge. A dip in frequency is seen on day 58, followed by frequencies around .03 lifts/min (one lift every 33 minutes) before discharge.

Thus, precise and accurate feedback about his lifts, combined with the temporary use of a training device appear to have increased the frequency of patient A's lift-offs to an acceptable level.

Case B: Fig 3 is the SCC for patient B, showing the same timer (ET) and written feedback (WOF) procedures that were applied to patient A. The data reveal at most a temporary effect on lift-offs as a result of the intervention procedures. The behavior, in fact, appears to be deteriorating and irregular toward the end of his stay. This variability over days corresponded to highly variable lift-off intervals within each day. Lift-off frequencies were generally lower during the weekends when he was on pass out of the hospital and higher during the week, a "negative weekend effect." The "3-day weekend" centered on day 63 included Christmas, and the next troublesome day (#71) was January 2.

Case C: Patient C received only standard treatment. He declined regular feedback and refused to count his own lift-offs. Fig 4 displays lift-off behavior during his final month of rehabilitation hospitalization, just prior to the discovery of a PS (day 65). At 4PM on day 64 patient C was informed by his mother that he would be discharged to a nursing home, and his social worker reported that he became very depressed during the conversation. Thus, the data in fig 4 represent a natural history of the development of a PS. However, if the sore was the result simply of the long sitting bout the evening of day 64, it would seem that a sore should have resulted from a similar bout on the morning of day 46 or even on day 53. Clearly, sitting for one interval of this magnitude is not the only factor.

Fig 5 shows no configuration that clearly seems to predict sore occurrence. During days 28 to 54, patient C's lift-off frequency is < 0.05/min on 22 days and ≥ 0.05 on only 5 days. (Note that four of these "good days" are Fridays and the other is a Sunday — a "positive weekend effect.") How-

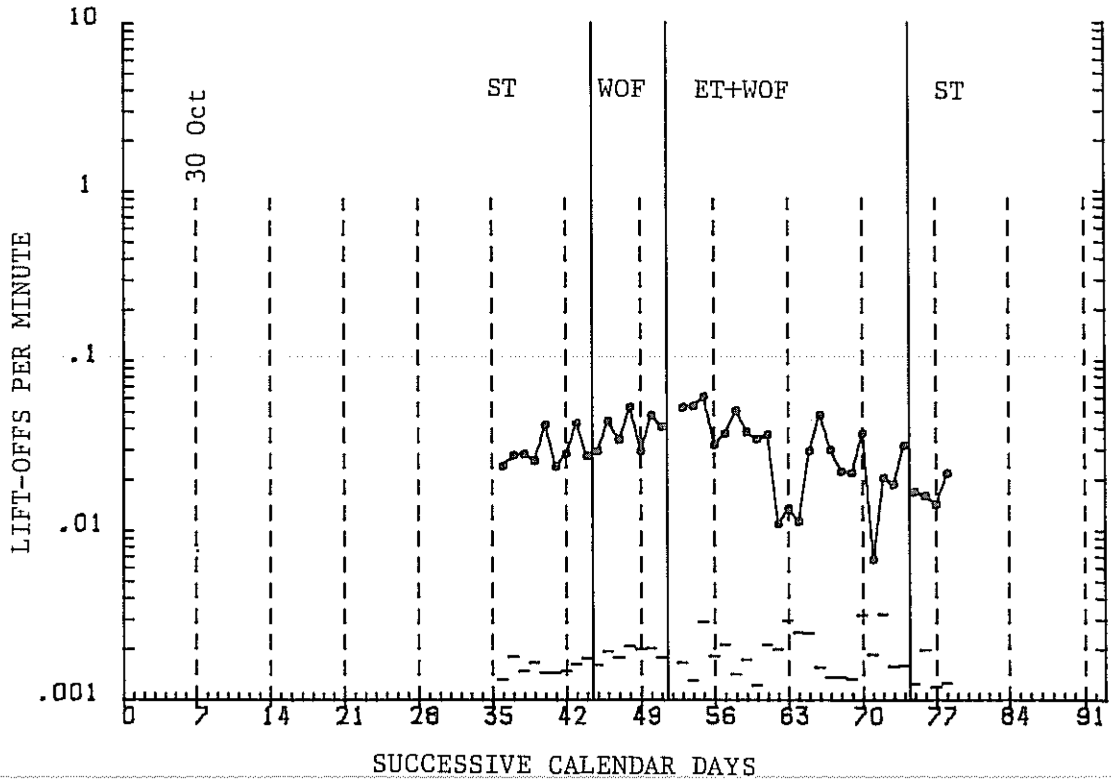

Fig 3—Lift-off frequencies, patient B. Dots are daily lift-off frequencies; dashes are reciprocal of total minutes spent in the wheelchair. Numbered, vertical dashed lines are Sundays. Day 0 is Sunday before hospital admission. Intervention codes as in fig 1. No data day 52 due to equipment failure. Note dips in frequency on most weekends.

ever, the lift-off frequencies on the days immediately before the formation of the sore were generally higher than those in the preceeding 4 weeks. Thus, in this case, neither a single episode of 4 hours duration (day 46) nor frequencies as low as .04 lifts/min for several days produced a sore.

Case D: In some cases, the data recording revealed adequate lift-off performance, and hence no extraordinary interventions were applied. Fig 6 shows the daily lift-off frequency for patient D's hospitalization. Note the acceleration in her data through day 32. Her medical record for this period notes bowel diffi-

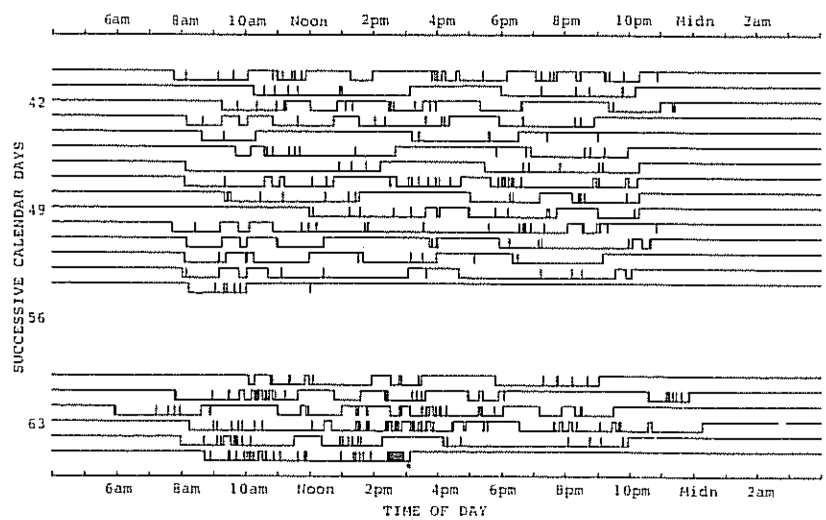

Fig 4—Daily lift-off behavior, patient C. Data trace down indicates patient seated in wheelchair; data trace up indicates patient not in chair; upward spike indicates lift-off. Sundays numbered on left. No experimental intervention. Asterisk indicates discovery of a GDII pressure sore and discontinuance of wheelchair sitting. Patient changed chairs frequently on days 55 through 59, interrupting data collection.

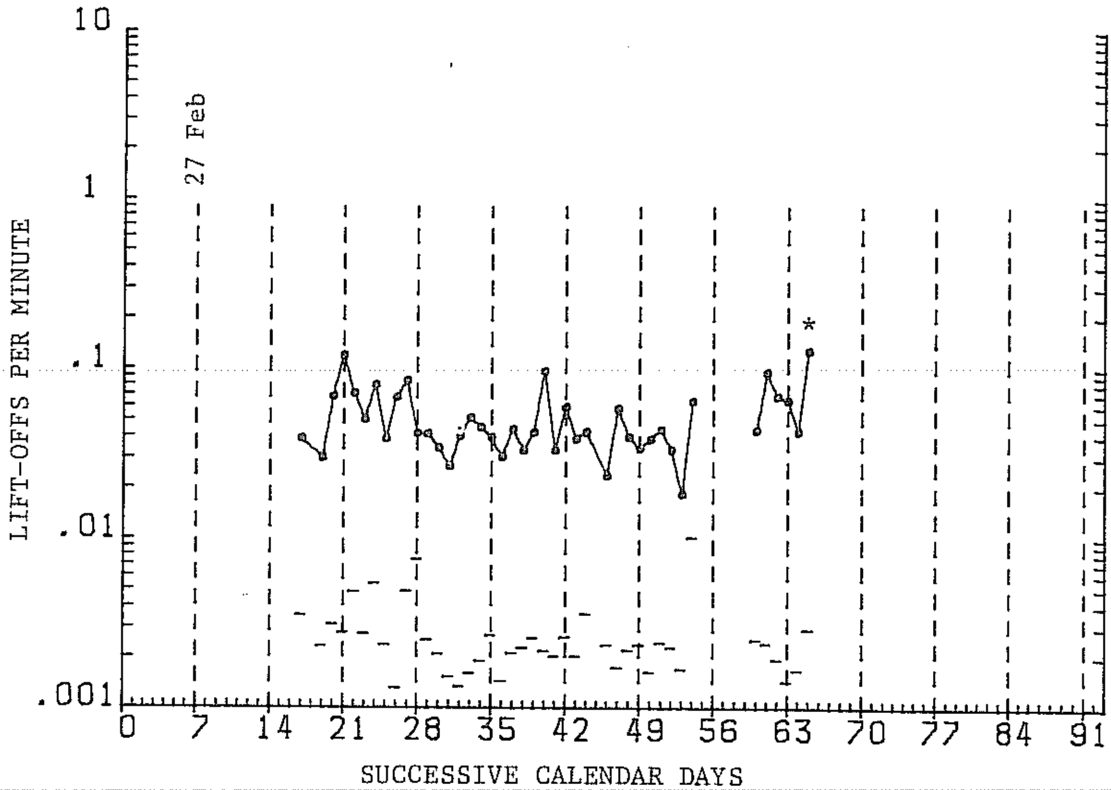

Fig 5—Lift-off frequencies, patient C. Dots are daily lift-off frequencies; dashes are reciprocal of total minutes spent in the wheelchair. Numbered, vertical dashed lines are Sundays. Day 0 is Sunday before hospital admission. No experimental intervention applied. Asterisk indicates discovery of a pressure sore. Patient changed chairs frequently on days 55 through 59, interrupting data collection. Note peaks toward end of most weeks.

culties, back pain, referral for psychologic/psychiatric assistance, and a nerve block. The balance of the data show some variability with a flatter celeration overall.

Cases E, F and G: These patients developed and maintained adequate rates of lift-off behavior during hospitalization. Patient E consistently recorded the highest frequencies: on 20 of 32 days he was monitored, his lift-off frequency averaged at or above 0.1 lift/min. Because lift-off frequencies were judged to be adequate, they received no extraordinary interventions other than brief weekly discussion of their progress. None of these patients developed a sore.

DISCUSSION

The results presented above demonstrate consistent measurement of the pressure-relief lift-off behavior of individuals with paraplegia for the duration of hospitalization and including short (weekend) trips outside the hospital. The event records display daily patterns of activity, so that patient and staff can relate activities (watching TV, etc) to lift-off frequencies, while SCCs provide graphic display of trends in behavior not always evident in the event records.

These procedures function as an assessment tool with new patients, permitting staff to identify patients who do not lift frequently as "at risk," so that treatment may be instituted. Our baseline data demonstrate that initial lift-off patterns vary widely. For patients with adequate initial performance, continous data collection permits monitoring of lift-offs for the duration of hospitalization. These data indicate that lift-off frequencies may wander over a period of weeks, and that even patients with adequate intitial performance may later require intervention. In addition, the measurement system permits routine, inexpensive, and objective experimental analysis of clinical interventions (such as beeper application). Directly tracking a patient's performance through time allows the experimenter or clinician to appropriately and individually titrate intervention procedures.

One issue raised by these data relates to the process of PS formation. Patient C's data show a long period (3 hours) of sitting with no pressure relief the day before the sore was noted. However, he sat for similar periods on other days with no apparent ill effect. These results suggest that while a single episode of prolonged sitting of this magnitude may be necessary for the formation of a sore, it is not always in and of itself sufficient.

A similar question is raised by our finding that patients typically exceed the 20min maximum recommended sitting time. Fisher and Patterson[3] have presented data indicating that their subjects also exceed the routinely prescribed time limits without apparent ill effect. These findings suggest that further investigation of the physiology of PS acquisition is needed. Such investigation may yield an individual prescription of inter-lift-off intervals for a given patient, and a behavioral experimental analysis procedure then could be used to individualize clinical intervention to accomplish the prescribed behavior.

Comparison of these data with those presented in the widely

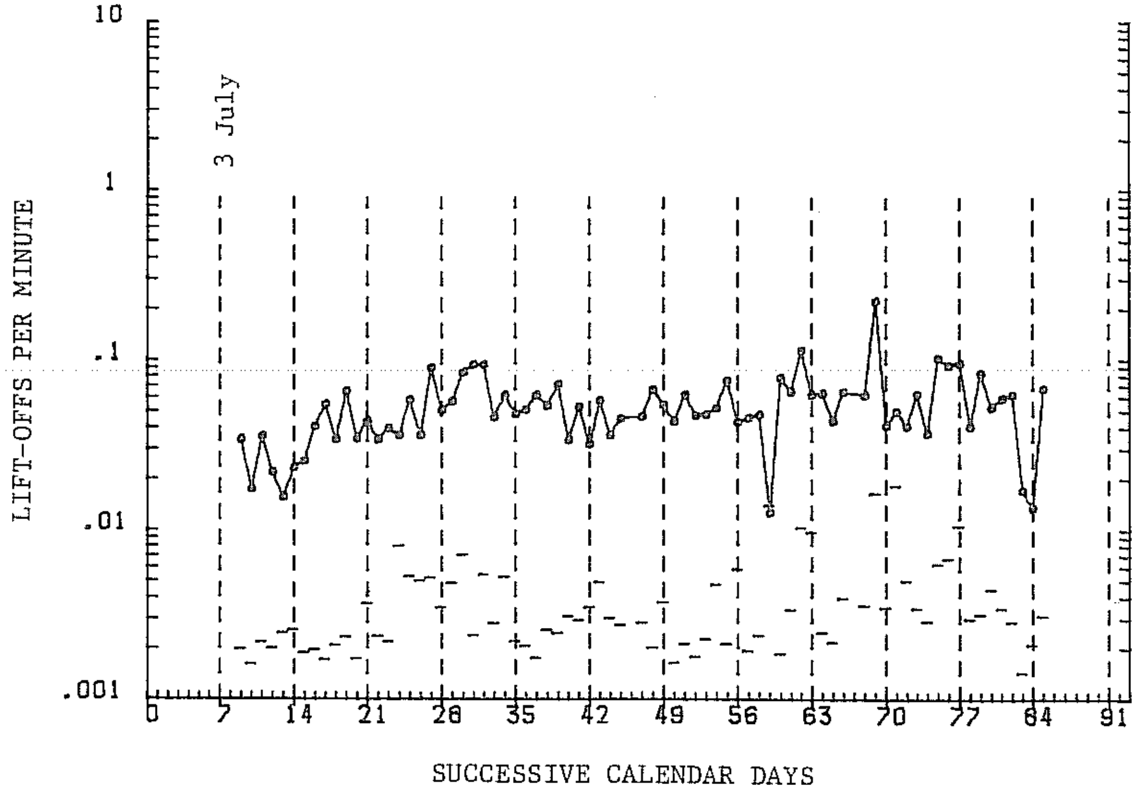

Fig 6—Lift-off frequencies, patient D. Dots are daily lift-off frequencies; dashes are reciprocal of total minutes spent in the wheelchair. Numbered, vertical dashed lines are Sundays. Day 0 is Sunday before hospital admission. No experimental intervention applied.

cited study by Malament's group,[8] on which the present study builds, reveals that their baseline frequencies were generally higher and less variable than ours. Procedural differences between the two studies may account for the range of findings.

The present study focused on establishment of a technology that permits both initial assessment and continuous measurement of an individual's lift-off behavior. Future work is planned to include more systematic explorations of a wider range of interventions, including one similar to the system used by Malament.[8] Also clearly needed is long-term unobtrusive monitoring of behavior after rehabilitation, to assess the desirability of change and need for supportive devices. Malament[8] directed attention to a system that could be removed after training, while the Klein and Fowler[7] device is intended for permanent patient use. Each of these approaches may be appropriate for some individuals. Our results clearly demonstrate the need for measurement and experimental analysis as the basis for developing and clinically applying interventions to prevent PS, and the TLC provides an efficient and economical system for so doing.

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