Electrogoniometric Feedback: Its Effect on Genu Recurvatum in Stroke

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ABSTRACT. Morris ME, Matyas TA, Bach TM, Goldie PA: Electrogoniometric feedback its effect on genu recurvatum in stroke. Arch Phys Med Rehabil 1992;73:1147-54.

• The purpose of this study was to determine the effect of combining electrogoniometric feedback with contemporary physical therapy procedures for treatment of genu recurvatum following stroke. Twenty-six patients suffering knee hyperextension resulting from cerebrovascular disorders were allocated to either a control group or an experimental group. Both groups received treatment for knee hyperextension during two consecutive phases. During phase I the control group received physical therapy and the experimental group received electrogoniometric feedback as an adjunct to physical therapy. In phase II both groups received physical therapy alone. Each phase lasted four weeks, during which time patients were treated 45 minutes daily, five days every week. Subjects in the experimental group showed greater reduction in knee hyperextension. This was particularly evident in phase II when the difference between groups for reduction in knee hyperextension reached statistical significance ($U = 40$, $p = 0.011$). These results suggest that the addition of electrogoniometric feedback to standard physical therapy enhanced the effectiveness of treatment for genu recurvatum in stroke.

KEY WORDS: Biofeedback; Cerebrovascular disorders; Gait; Hemiplegia; Motor skills; Physical therapy; Rehabilitation

Genu recurvatum, defined as extension of the affected knee beyond the neutral anatomical position during the stance phase of gait, is a frequent and disabling consequence of stroke. Despite the finding that 40% to 68% of stroke patients suffer from knee hyperextension[1-4] little attempt has been made to evaluate the outcome of physical therapy treatment or to compare the effectiveness of different management approaches. Recently the importance of feedback in motor retraining has been emphasised[5] and electrogoniometric feedback has emerged as one method that shows considerable promise for movement disorders such as genu recurvatum.[6-8] This investigation examined the effect of electrogoniometric feedback on knee hyperextension during rehabilitation following cerebrovascular accident (CVA).

Several causes of genu recurvatum have been identified. These include spasticity of the quadriceps and calf muscles and contracture of the tendo Achilles.[9] In addition, some stroke patients with quadriceps weakness appear to hyperextend the knee as a compensatory strategy, in order to achieve leg stability.[10] Although knee hyperextension can arise from disturbances in the force or timing of activation of individual muscles, the movement disorder is frequently characterized by abnormal activity in a number of lower limb muscles. Quadriceps spasticity in conjunction with calf weakness, hip contracture associated with calf spasticity, and quadriceps spasticity accompanied by calf spasticity are well documented causes of genu recurvatum.[2,11] The net result is an anterior shift in the line of action of the ground reaction force during the stance phase of gait, which increases the moment of force producing knee hyperextension. Usually the cruciate, collateral, and oblique popliteal ligaments, menisci, posterior capsule of the knee joint and the hamstrings and gastrocnemius muscles offer passive resistance to knee hyperextension.[9] However, repeated hyperextension forces acting on these structures can lead to soft tissue damage that perpetuates and exacerbates the problem.

Because genu recurvatum has the potential to become a chronic deteriorating problem,[9] adequate management during rehabilitation is essential. A major focus of physical therapy for genu recurvatum is enhancement of the gait pattern and prevention of secondary complications. Studies have shown that the peak amplitude of knee hyperextension (PKH) can range as high as 22° in stroke patients.[3,4,6,12] Such residual gait deviations can lead to high energy costs of walking[6,13] and pain during ambulation.[3] When movement rehabilitation techniques fail to prevent disabling secondary problems, management with expensive aids and orthoses[14] or even surgery[15] may become necessary.

Physical therapy techniques proposed for treatment of genu recurvatum include manual facilitation,[16-19] orthotics,[9,20,21] neuro-developmental therapy,[22] sensory stimu-

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lation,[22] techniques derived from the principles of motor learning and motor control,[5] and biofeedback.[6-8] However excluding biofeedback, only two studies have reported the effect of these interventions on knee hyperextension in adult hemiplegia.

Bogardh and Richards[6] found few significant changes with conventional physical therapy that focussed on retraining hip movement in order to improve knee hyperextension. Treatment incorporated verbal feedback, visual feedback using a mirror, whole-part practice and manual guidance, and was provided for 13 weeks on average. Although a reduction in the PKH was evident for five of the nine patients tested, only four were able to eliminate the problem. Similarly, Trueblood and associates[16] failed to find strong or lasting changes following a ten minute treatment session that aimed to improve knee control via pelvic facilitation. Given the growing evidence that motor learning is task specific,[23] it seems likely that one factor that reduced the effect in both of these studies was the selection of proximal techniques that relied on generalization of training from the pelvis or hip to the knee, rather than methods directed specifically toward knee control. Moreover, in the study by Trueblood low practice duration could have restricted the opportunity for motor skill learning.

ELECTROGONIOMETRIC FEEDBACK FOR GENU RECURVATUM

Biofeedback has long been used in gait retraining[24,25] and two major types of biofeedback have been advocated for stroke rehabilitation. Historically, electrogoniometric feedback (EMG) was widely used,[24] although recently it has been acknowledged that its usefulness is limited to training isolated muscles without reference to goal directed actions.[26] In contrast, electrogoniometric feedback, also known as joint angle or positional feedback, has become the focus of increased attention, particularly when the goal of intervention is the regulation of movement patterns, range of motion, or body position.[25] One of the advantages of joint angle feedback is easy incorporation during practice of daily tasks in a functional context, such as moving from sitting to standing, standing, and walking.

An early single case study by Koheil and colleagues[7] compared the effect of traditional physical therapy with electrogoniometric feedback for genu recurvatum. Traditional intervention incorporated weight shifting exercises, gait training using an ankle-foot orthosis, and mat exercises for hip and pelvic control. Electrogoniometric feedback was used as an adjunct to physical therapy. Results showed little change during baseline or physical therapy phases. However, there was a dramatic reduction in incidence of hyperextension errors during physical therapy plus feedback training with only a small degree of regression at the final baseline test.

Likewise, Hogue and McCandles[3] found positive results when joint angle feedback was used for 13 patients with genu recurvatum resulting from stroke, head injury, or multiple sclerosis. All patients reduced the frequency of hyperextension errors with feedback and the difference between pretest and posttest scores was statistically significant. Unfortunately the study was limited by a failure to include a control group or within subject controls; therefore, the contribution of nonspecific treatment effects and natural recovery confounded the results. Failure to control for maturation or practice effects was also evident in the recent study by Bassaglia and coworkers.[8] Despite this limitation, these investigators concluded that electrogoniometric feedback enabled chronic stroke patients to reduce the frequency of hyperextension errors and the effect was maintained for up to one year after intervention.

Although only a few studies have reported the effects of electrogoniometric feedback for genu recurvatum in stroke (and these studies contain significant methodological limitations) the modality has been used extensively in neurological rehabilitation. A review of the literature reveals wide use for various conditions in adults and children, including equinus deformities of the foot, excessive knee flexion during gait, head position and trunk alignment disorders, hip dissociation, and wrist and elbow dysfunction.[26-30] By demonstrating that electrogoniometric feedback is effective for enhancing control in a diverse range of movement disorders, these studies provide further support for use of the method generally, and its potential use for genu recurvatum.

The motor control literature also provides some theoretical support for the efficacy of this treatment modality. It is generally agreed that feedback plays a key role during motor skill learning.[31-32] From an information processing perspective it has been suggested that feedback facilitates skill acquisition by enhancing error detection and correction mechanisms, by guiding the learner towards the desired response, by providing associations between stimuli and responses, or by motivating the patient to practice more attentively and more frequently.[23,24,27] It is possible that electrogoniometric feedback, by providing concurrent auditory information on knee hyperextension error during gait, enables the patient to learn more effective movement patterns.

To summarize, there is some theoretical evidence and clinical support for the use of electrogoniometric feedback for genu recurvatum in stroke. However, this evidence is largely based on studies with chronic patients, small samples, and few controls. Because a large proportion of resources are allocated to rehabilitation of acute stroke patients, the purpose of this study was to evaluate the effect of electrogoniometric feedback during the first four months following CVA.

METHOD

Subjects

Twenty-six stroke patients who demonstrated knee hyperextension during the stance phase of gait were recruited from Royal Talbot Hospital and Mount Royal Hospital in Victoria, Australia. Inclusion criteria required that patients had suffered a cerebrovascular accident (CVA) up to four months previously, were medically stable, and able to pro-

Table 1: Demographic Profile of Sample

	Control	Experimental	Total
Age (years)			
Age range	48-73	33-74	33-74
Mean and SD	64.2 ± 10.3	64.4 ± 11.9	64.2 ± 11.9
Duration post-CVA (days)			
Range	21-148	15-86	15-148
Mean and SD*	79.0 ± 41	45.0 ± 23	62.0 ± 37
Gender			
Female	5	9	14
Male	8	4	12
Type of lesion			
Infarct	9	9	18
Haemorrhage	4	4	8

vide informed consent. To be included, patients also had to demonstrate ability to safely walk ten meters four times without aids or orthoses.

Exclusion criteria included prior history of neurological conditions, surgery poststroke, and inability to hear the feedback signal. Auditory response to feedback was tested by the senior physiotherapy clinician who held the knee angle monitor next to the affect knee with the patient standing, looking directly ahead. The clinician slowly moved the axes of the monitor through the flexion and hyperextension range and the patient indicated verbally or via gesture when he or she could hear the auditory signal. Subjects who did not detect the auditory signal every time it was activated were excluded from the study.

Of the 286 CVA patients admitted to the two rehabilitation units during the testing period, 27 fulfilled the selection criteria. One patient did not continue due to early discharge. The final sample comprised 26 subjects aged between 33 years and 74 years with a mean age of 64 years. The demographic profile of the sample is presented in table 1.

The selection process consisted of several phases. Patients were initially screened on admission to the rehabilitation unit. A senior physical therapy clinician checked the medical record on admission to ensure that selection criteria were fulfilled. Subsequently visual screening for genu recurvatum was conducted independently by the senior clinician and the physiotherapist to whom the patient had been assigned for treatment. If both therapists agreed that knee hyperextension was present and warranted physical therapy, the researcher was immediately contacted. Within one week the researcher confirmed knee hyperextension using electrogoniometry. Agreement between clinicians' and researcher's diagnoses of genu recurvatum resulted in 90% of cases being included in the study. When there was disagreement the subject was excluded.

Stroke patients who failed to demonstrate genu recurvatum on admission yet fulfilled all other selection criteria were retested on a weekly basis until four months after CVA. Weekly testing for inclusion was necessary because many stroke patients were unable to walk at the time of admission and because genu recurvatum frequently developed later in the recovery process due to progressive stretching of the knee joint capsule and ligaments.

Apparatus

The PKH was measured using an electrogoniometer incorporated in the knee feedback monitor (fig 1). The electrogoniometer comprised a rotary potentiometer (10kΩ rated 1% to 2% linearity) mounted over the center of a polycentric apparatus attached to tibial and femoral struts. The electrogoniometer was designed to allow, in a limited way, the polycentric behavior of the knee joint during gait via a system of springs around the axis of rotation. During data collection the auditory feedback was disabled. In order to determine swing and stance components of gait, footswitch data was simultaneously collected. A TEAC R-61 FM cassette recorder was connected to the knee feedback monitor via coaxial cables so that PKH data could be stored on tapes. Data was digitized using a Digital[a] PDP 11 computer in conjunction with data acquisition software[b].

Gait recovery, velocity, and temporal asymmetry were also measured in order to detect general changes in gait quality and function not specifically related to knee hyperextension. Gait recovery was measured on the gait subcomponent of the Motor Assessment Scale (MAS)[33] (table 2), a functional recovery scale that has established reliability[33] as well as concurrent validity.[34] For the purposes of this study patients were allocated a zero score on the MAS if they were unable to maintain hip extension during standing on the affected leg, as they stepped forward with the unaffected leg (table 2).

Gait velocity and asymmetry were measured using a commercially available Clinical Stride Analyzer[c]. The system consisted of a set of footswitches worn as insoles, a start-stop controller, a recorder and an IBM[d] compatible microcomputer system. Velocity of gait has been used as an outcome variable in many studies of hemiplegic gait.[35-37] As

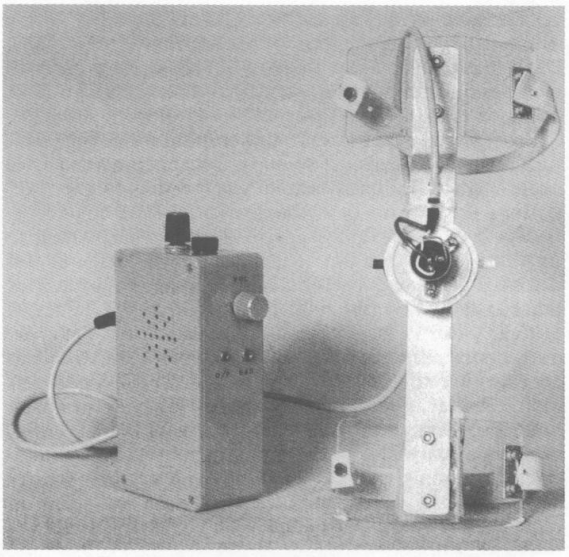

Fig 1—Electrogoniometric feedback monitor.

Table 2: Gait Component of the Motor Assessment Scale

1. Stands on affected leg and steps forward with other leg. (Weight-bearing hip must be extended. Therapist may give standby help.)
2. Walks with standby help from one person.
3. Walks 3 meters alone or using any aid but with no standby help.
4. Walks 5 meters with no aid in 15 seconds.
5. Walks 10 meters with no aid, turns around, picks up a small sandbag from the floor, and walks back in 25 seconds. (May use either hand.)
6. Walks up and down 4 steps with or without an aid but without holding on to the rail 3 times in 35 seconds.

Excerpt from Carr and colleagues.[33]

well as predicting the stage of motor recovery following stroke,[35-37] it has high interrater and retest reliability.[38] Gait asymmetry provided a measure of the quality of movement.[35,38]

Procedure

Subjects were allocated to either a control group, which received standard physical therapy, or an experimental group, which received electrogoniometric feedback as an adjunct to physical therapy. Group allocation was performed by a senior hospital physiotherapist not participating in the study so that the researcher, who measured the patients, was blind to group allocation. The clinician allocated subjects to groups by tossing a coin. Random allocation was used for the first 20 patients. Stratification was used for the remaining six to ensure that groups were matched with respect to age, side of lesion, severity of genu recurvatum, and stage of gait recovery. Table 3 shows means and standard deviations for the matched variables.

The study comprised two treatment phases. During phase I, the control group received standard physical therapy and the experimental group received electrogoniometric feedback as an adjunct to physical therapy. During phase II both groups received standard physical therapy. The knee monitor was not used in phase II in order to evaluate transfer of training to performance without feedback.

Each treatment phase was four weeks duration. The literature review revealed that some researchers provided knee angle feedback for one week,[7] others for up to four weeks.[3] Because this was the first clinical trial for knee angle feedback using a control group design, it seemed appropriate to select the longer duration, to maximize the opportunity for detecting a therapeutic effect. In accordance with standard practice at the hospitals selected, clinicians were requested to treat patients for 45 minutes a day, five days a week during both phases. A minimum of 30 minutes per day was allocated to retraining gait and knee control. Dosage sheets indicated that clinicians adhered quite closely to the guidelines. The mean total treatment time was 27.0 ± 11.6 minutes. On average 29.3 ± 11.3 minutes per session was allocated to training gait and knee movement in the control group and 24.6 ± 12.0 minutes per session was spent on these tasks for the experimental group.

Standard physical therapy treatment was based on the Motor Relearning Programme (MRP)[5] and incorporated the use of instruction, explanation, demonstration, manual guidance, verbal feedback, visual feedback, and whole-part practice. In addition to physical practice, patients mentally rehearsed movements and actions. Emphasis was placed on use of cognitive functions in the early stages of learning, progressing to practice at an automatic level. Patients were guided to practice at their highest level of performance with tasks being continually modified and progressed.[5] Stereotyped and abnormal synergistic activity was discouraged.[5]

The MRP was chosen for intervention because it was one of the standard physical therapy methods used for stroke rehabilitation at the hospitals selected. It provided operationally defined treatment protocols, which included clear guidelines for gait retraining. Moreover, it was thought that electrogoniometric feedback would complement the method well because both approaches are based on principles derived from motor learning theory. Physiotherapists had been instructed in the MRP in their undergraduate education and participated in a training session prior to the study.

The experimental group received electrogoniometric feedback during standing and gait training throughout phase I. Auditory feedback on knee hyperextension was provided by a knee angle monitor that consisted of a sensor (an electrogoniometer) that detected angular position, a signal conditioner, a voltage comparator, and a tone generator that produced the auditory signal (fig 1). When the patient hyperextended the knee the auditory signal was activated; the pitch of the signal was proportional to hyperextension angle. In addition to the hyperextension tone, a fixed high frequency warning signal sounded when knee flexion exceeded 75° flexion to discourage over compensation with excessive knee flexion. Consequently, during normal gait the auditory signals remained silent.

Patients were measured prior to intervention (Test 1), at the end of phase I (Test 2), and at the end of phase II (Test 3). Measures of knee hyperextension, gait recovery, velocity, and single limb support asymmetry were obtained at each test. All measurements were obtained in the clinical setting, which eliminated the disadvantage of requiring stroke patients to travel away from their familiar environment. The measurement procedure for each test was identical. In each case the patient performed four 10-meter walking trials with a two minute rest period between each trial. In the first trial temporal gait data was collected. In the subsequent trials the angular displacement of the knee was recorded. Data was sampled from the middle six meters of

Table 3: Matched Variables: Prestest Values

Variable	Pretest Values	
	Control Group	Experimental Group
Subject number	13	13
Hyperextension (degrees)	−4.4 ± 1.2*	−4.2 ± 1.5*
Motor recovery (MAS)	0.9 ± 1.2*	0.9 ± 1.3*
Age (years)	64.3 ± 8.9*	64.4 ± 11.9*
Side CVA	6 left, 8 right	8 left, 5 right

* Mean and standard deviation values.

each gait trial. Patients were permitted to walk alone or with supervision of their therapist; orthoses and walking aids were not allowed. One hour prior to testing, a senior clinician who had been tested for interrater reliability on the MAS[33] scored patients on the gait component of the scale.

Statistical Analysis

A series of planned comparisons were devised to address the major questions. Comparisons aimed to establish whether the two groups differed at the pretest; whether the experimental group showed greater gains than the control group from Test 1 to Test 2 and from Test 2 to Test 3; and the degree of improvement in the control group across both treatment phases. Due to apparent threats to the assumptions of homogeneity of variance and covariance, nonparametric tests were used for statistical analysis. The Mann-Whitney test was used for between groups comparisons and the Wilcoxon signed rank test was used for the within group comparisons.

Peak amplitude of knee hyperextension was derived by averaging the maximum stance phase hyperextension angle for the affected leg, for consecutive gait cycles. The mean was obtained from data from all gait cycles measured during the middle six meters of each gait trial.

The symmetry of gait was derived by calculating the difference between single limb support duration on the unaffected leg and affected leg and was expressed as a percentage of the gait cycle (%GC). A score of zero indicated perfect symmetry. Positive values indicated that more time was spent on the unaffected leg and negative values indicated greater time on the affected leg.

RESULTS

Knee Hyperextension

The severity of knee hyperextension, as measured by its PKH progressively improved in both groups during the study. Figure 2 indicates that during phase I the experimental group showed a trend toward greater reduction in PKH compared to the control group. Reduction in PKH for experimental subjects was 3.1 ± 3.0° (mean and standard deviation values) compared to 2.4 ± 4.2° for control subjects, although this difference was not statistically significant ($U = 66$, $df = 24$, $p = 0.173$). However, during phase II mean reduction in PKH for the experimental group was 1.7 ± 1.8° compared to only 0.4 ± 3.1° for the control group. Statistical analysis confirmed that during phase II the difference between groups was statistically significant ($U = 40$, $df = 24$, $p = 0.011$).

Gait Recovery

The median gait score for the pretest was zero for both groups, which indicated that most patients were unable to maintain extension of the affected leg as they stepped forward with the unaffected leg (table 2). At the end of phase I, gait recovery was significantly better in the experimental group ($U = 39$, $df = 24$, $p = 0.007$). By the end of this first phase, the median MAS score for the experimental group was three compared to only two in the control group. The majority of subjects in the experimental group could walk three meters without standby help, whereas most of the control group subjects still required standby help from one person. The two groups showed similar rates of improvement during phase II, with median increments of one unit on the MAS. At the end of the second phase the majority of experimental group subjects were able to walk five meters in 15 seconds with no aid, thereby scoring four on the MAS. Most of the control group subjects still required standby help to walk three meters, hence scored three (table 2). Nevertheless, the improvement on the MAS during phase II was not statistically different between groups.

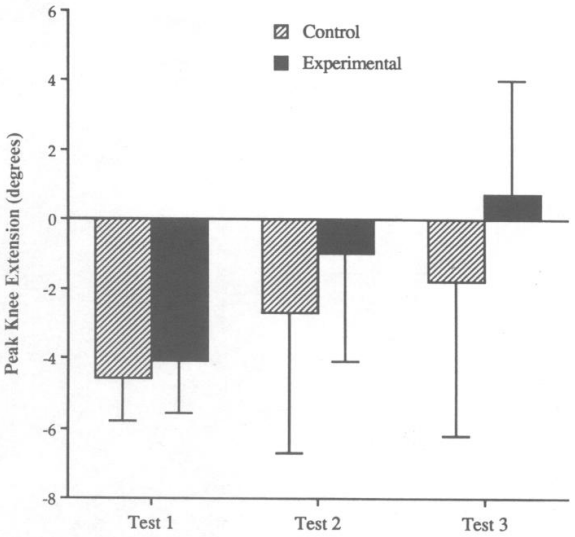

Fig 2—Means and standard deviations for peak knee extension at the pretest (Test 1), at four weeks (Test 2) and at eight weeks (Test 3). Values less than zero indicate knee hyperextension.

Gait Velocity

Figure 3 shows that velocity of walking steadily improved across both treatment phases although there were not statistically significant differences between groups for either phase. In phase I mean gait velocity for the experimental group improved by 6.3 ± 10.2m/min compared to 0.8 ± 12.5m/min in the control group. During phase II the experimental group showed a mean improvement of 8.2 ± 9.9m/min compared to 5.8 ± 11.2m/min for the control group.

Gait Asymmetry

Figure 4 shows the group means for single limb support (SLS) asymmetry, expressed as a percentage of the gait cycle. Figure 4 shows that the control group were more asym-

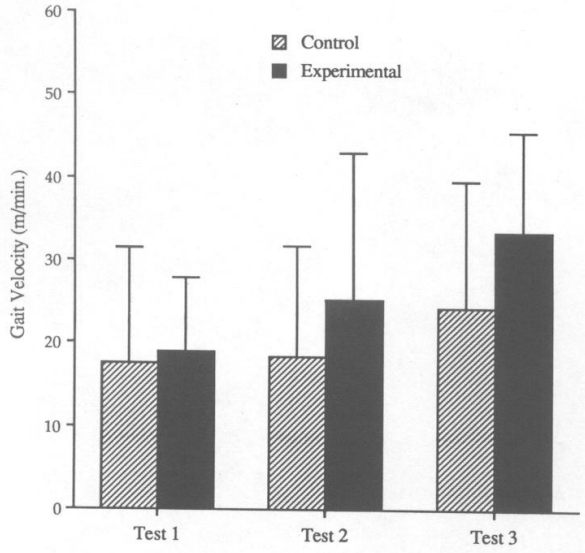

Fig 3—Means and standard deviations for gait velocity at the pretest (Test 1), at four weeks (Test 2) and at eight weeks (Test 3).

metrical than the experimental group at the pretest and at the subsequent tests, although the difference between groups was not statistically significant. Symmetry improved in both groups during the initial training phase then regressed marginally during the final treatment phase. In the first treatment phase, SLS asymmetry improved by 2.7 ± 11.7%GC in the experimental group compared to 6.1 ± 11.9%GC in the control group. In the second treatment phase gait asymmetry regressed marginally in the experimental group (0.4 ± 16.5%GC) compared to 2.4 ± 12.1% regression in the control group.

DISCUSSION

The results indicate that patients who used the knee feedback monitor reduced knee hyperextension to a greater extent than patients in the control group. Of importance, genu recurvatum improved in both groups during both treatment phases although the experimental group showed a greater rate of improvement. Although there was a trend toward greater reduction in PKH for the experimental group during phase I, the difference between groups did not reach statistical significance in the first treatment phase. The experimental group advantage was mainly evident in phase II, when subjects who had previously received electrogoniometric feedback showed greater gains and the difference between groups was statistically significant. These results provide some support for the hypothesis that use of electrogoniometric feedback enhanced treatment effectiveness.

The finding that the full effect of knee angle feedback was not apparent until phase II when PKH improvements were statistically significant can be interpreted in a number of ways. It could be suggested that during phase I, the feedback effect was present but masked, and the phase I results underrepresented the ability of patients in the experimental group to control knee hyperextension. Alternative explanations include that faster natural recovery in the experimental group or nonspecific treatment effects were responsible for the observed changes.

Convincing evidence can be put forward in support of the first explanation. During phase I the experimental group subjects used the knee angle monitor throughout each physical therapy session. They were not provided with an opportunity for supervised feedback-free practice. However the test at the end of each phase required them to walk without the monitor. Patients may have experienced some difficulty transferring from feedback dependent conditions of training to feedback-free conditions of measurement. Given the results of studies on transfer of training and specificity in motor learning,[23] it seems likely that this would have adversely affected their phase I results. Patients in the control group did not experience such an effect because conditions of training were similar to conditions of testing.

Alternatively, it might be argued that enhanced knee control in the experimental group was due to accelerated general recovery rather than use of the knee angle monitor. The MAS results, which provide an indication of overall gait recovery, showed significantly greater gains for the feedback group during phase I. Therefore a post hoc procedure[39] was used to match the two groups for rate of improvement on the MAS during the first treatment phase. Four experimental group subjects and four control group subjects with extreme scores on the MAS during phase I were selectively deleted in order to achieve comparable rates of recovery in the two groups, as indexed by the MAS. Follow-

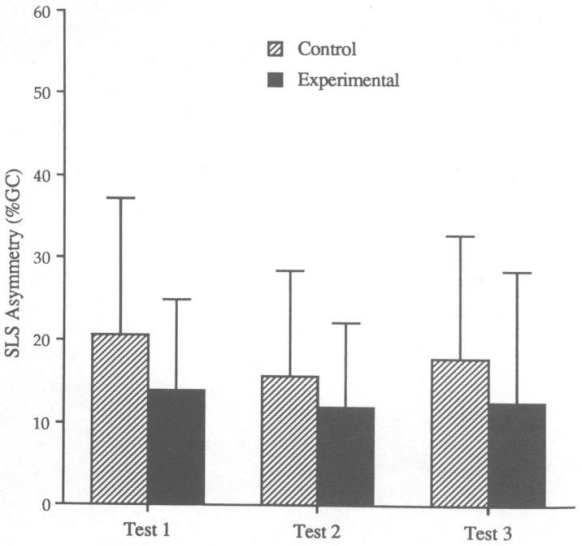

Fig 4—Means and standard deviations for single limb support (SLS) asymmetry at the pretest (Test 1), at four weeks (Test 2), and at eight weeks (Test 3).

ing post hoc matching for rates of general recovery the PKH changes obtained in the two groups were reanalyzed. The experimental group still showed greater ability to control knee hyperextension and the statistically significant difference between groups for PKH during phase II was retained ($U = 15$, $df = 16$, $p = 0.012$). Thus it is unlikely that the superior PKH outcome for the experimental subjects can be attributed to a faster natural recovery in the experimental group.

However, whether this superiority was due to the specific effects of electrogoniometric feedback or to nonspecific treatment effects requires some consideration. Only the experimental group used the monitor. Just wearing the device provided auditory and cutaneous information that might have affected knee control, or enhanced interest and motivation amongst patients and therapists. Some investigators suggest that feedback could play an energizing role by making the task seem more interesting, by keeping the person alert, and by encouraging them to set higher performance goals.[24,32] However, these are likely to be transient performance effects that subside when feedback is withdrawn.[32] If the results were due to motivational and attentional aspects of feedback, then a differential result should have been obtained for improvement in PKH for phase I, when the experimental group received feedback but dissipated during phase II when feedback was withheld. The results were contrary to these predictions, therefore it seems unlikely that these factors could account for the observed changes.

Although both groups showed apparent improvements in gait velocity and gait asymmetry during the course of the study, the differences between groups on these changes did not reach statistical significance. Substantial intersubject variability may have contributed to the nonsignificant results. Even so, there was a trend toward greater improvement in gait velocity in the experimental group during both treatment phases (fig 3). Although the knee monitor directed patients to focus their attention on knee hyperextension, this did not appear to occur at the expense of walking speed or gait asymmetry. Both groups showed negligible changes in temporal asymmetry. In phase I asymmetry diminished by approximately 2% in the experimental group and 6% in the control group. In phase II asymmetry increased marginally, less than 1% in the experimental group and approximately 2% in the control group (fig 4).

Our controlled group study supported the findings of previous investigations[3,8] that use of an electrogoniometric feedback monitor enhances the effectiveness of treatment for knee hyperextension during the early stages of motor recovery. Whether it is also valuable in the case of stroke patients whose condition is chronic remains to be determined. Moreover it is not yet clear whether patients with genu recurvatum due to particular causes (eg, paresis, spasticity, or contracture) will benefit more from this approach than others. Because the method addresses the kinematics of the disorder rather than its underlying cause, it is potentially suitable for the treatment of knee hyperextension arising from a wide range of factors. However, some practical limitations need to be considered. For example, it seems unlikely that the method would be effective for patients with perceptual or cognitive problems who are unable to perceive or interpret the feedback signal, or concentrate for long enough to learn from the information provided. These factors could be taken into account when assessing suitability for electrogoniometric feedback training.

A final point to emphasize is that knee hyperextension improved in both groups over the duration of the study, even though the experimental group improved at a greater rate. Given that genu recurvatum has been described as a chronic, perpetuating problem which tends to begin with a disorder of small magnitude that exacerbates over time,[9,20] the finding that both groups improved is clinically significant. This suggests that the motor learning approach used during standard physical therapy was effective for curtailing progression of the disorder, although the addition of electrogoniometric feedback to these procedures further enhanced treatment outcome.

Although the exact mechanisms that produced the effect require further clarification, the use of a monitor that provided auditory feedback on knee hyperextension enhanced the effectiveness of treatment of genu recurvatum following stroke.

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