Motor Imagery for Gait Rehabilitation in Post-Stroke Hemiparesis

Background and Purpose. Reports have described the contribution of motor imagery (MI) practice for improving upper-extremity functions in patients with hemiparesis following stroke. The purpose of this case report is to describe the use of MI practice to attempt to improve walking in an individual with hemiparesis. Case Description. A 69-year-old man with left hemiparesis received MI gait practice for 6 weeks. Intervention focused on task-oriented gait and on impairments of the affected lower limb. Preintervention, midterm, postintervention, and follow-up measurements of temporal-distance stride parameters and sagittal kinematics of the knee joint were taken. Main Outcomes. At 6 weeks postintervention, the patient had a 23% increase in gait speed and a 13% reduction in double-support time. An increase in range of motion of the knees also was observed. No changes in gait symmetry were noted. Discussion. The outcomes suggest that MI may be useful for the enhancement of walking ability in patients following stroke. Because improvement was mainly in temporal-distance gait variables and knee movement, imagery practice probably should focus on its specific impairments during gait in order to affect the performance of the paretic lower extremity. [Dickstein R, Dunsky A, Marcovitz E. Motor imagery for gait rehabilitation in post-stroke hemiparesis. *Phys Ther.* 2004;84:1167–1177.]

Key Words: *Gait, Hemiparesis, Mental practice, Motor imagery, Stroke.*

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When hemiparesis due to stroke reduces a patient's ability to walk, recovery of walking ability is generally accomplished around 11 weeks after the stroke,[1] although the plateau may be reached earlier or later.[1,2] Nevertheless, walking after a stroke is often impaired and restricted to short distances.[2,3] The average walking speed of people with hemiparesis is lower than that of people without known pathology or impairments, with values ranging from 0.23 to 0.73 m/s, depending on the severity of the hemiparesis.[3] Characteristically for these individuals, stride length and cadence are lower than normal, and a greater proportion of the gait cycle is occupied by double-support and stance-phase duration of both lower extremities (particularly of the unaffected lower extremity), as compared with people without hemiparesis.[3–5] Gait impairments of patients with hemiparesis at the chronic stage have frequently been described by temporal, spatial, kinematic, and kinetic variables. Straightforward relationships have been demonstrated between the these variables and reduction in walking speed as well as functional disability.[3] Consequently, patients' independence in moving about the home or in the community often is compromised, constituting a major social handicap.[6]

Physical therapy provided for patients with hemiparesis in the weeks following their strokes frequently consists of exercise therapy based on neuromuscular re-education,[2] as well as on the practice of prewalking functional tasks such as transfer activities, weight shifts in sitting or standing, and the maintenance of unassisted stance.[7–9] Walking practice is usually limited in time (practiced once or twice a day for only a few minutes) and space (within institutional confines). Recent evidence has highlighted the importance of intensive practice of the walking task itself,[10–12] as well as the need to adjust the conditions of walking practice (eg, walking surface, environment), to the life conditions of the individual.[13–17]

This evidence is congruent with ecological viewpoints that consider environmental and task constraints as vital components of motor planning and learning.[18] Unfortunately, the incorporation of intensive and frequent gait practice into physical therapy for patients following stroke, whether in rehabilitation centers or later at home, is often unrealistic because of the costs. In addition, in our experience, the disabilities caused by the hemiparesis, together with the ensuing safety limitations, prevent many patients from practicing walking by themselves and may contribute to a further decline in their walking ability and to overall physical deterioration.

Gait performance may be enhanced by use of motor imagery in the mental practice of motor tasks in people with hemiparesis following a stroke.

The possibility of enhancing gait performance in this group of patients through the nonhazardous, intensive self-practice of gait activities in their own homes may be realized through the use of motor imagery (MI) in the mental practice of walking tasks. Motor imagery is considered to be a cognitive task[18,19] that takes place without known immediate stimulus antecedents. Individuals engaged in such imagery are consciously aware of it and are able to report the contents of the imagined acts or scenes.[20] It can be applied through external (mainly visual) imagery in which a person views himself or herself from the perspective of an external observer, as if watching a home movie. It also can be applied through internal imagery (mainly kinesthetic), in which the individual imagines being inside his or her own body experiencing those sensations that might be expected in the actual situation.[21] Research has shown that different people may make better use of one form of imagery than another.[22–25]

Mental practice or *mental rehearsal* refers to the systematic application of imagery techniques for improving output. Mental practice using MI techniques is commonly applied in sports psychology.[26,27] Its effects have been demonstrated in enhancing speed,[18,28] muscle force,[29] and movement execution[30,31] and in an increase in electromyographic activity in muscles that participate in

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the imaged task.[18,32] In addition, a positive correlation has been reported between autonomic changes such as breathing and heart rate and intensity of practice.[33]

Recent brain imaging, such as positron emission tomography and functional magnetic resonance imaging, has further strengthened the validity of data obtained using mental practice with imagery procedures for the enhancement of motor learning. For example, the results of a study on an early and a late phase of learning of a sequence of foot movements revealed a similar pattern of changes in neuronal activity, regardless of whether the movements were practiced physically or with MI.[34]

Kosslyn and colleagues[35] claim that, because of the close relationship between cognitive brain mechanisms and the enhancement of neural activity in specific brain areas, as revealed by neuro-imaging studies, imagery is now becoming one of the best understood higher cognitive functions. The notion that neuronal circuits involved in the production of movements may be activated in patients with hemiparesis who are unable to physically perform such movements constitutes the basis for introducing these techniques into neurological rehabilitation (see Jackson et al[36] for a recent review).

Thus far, however, few studies have documented the application of mental practice with MI to the motor rehabilitation of patients following stroke, and those that did so applied the intervention only to the affected upper extremity. In one such study,[37] mental practice was found to be effective in improving line tracing in 3 subjects with hemiparesis during active rehabilitation. In another study,[38] 13 patients with stable motor deficits in their upper arm improved their scores on the Fugl-Meyer Assessment of Sensorimotor Impairment and the Action Research Arm Test after mentally practicing arm movements. It is noteworthy that patients who practiced real arm movements via occupational therapy combined with MI improved more than did those who received occupational therapy alone.[38] Likewise, a case report of a combined program of physical therapy and MI for a patient with hemiparesis who had an infarct 5 months earlier pointed to a reduction in impairment and an improvement in arm function.[39] In a recent study, Malouin and colleagues[40] demonstrated the beneficial effects of MI for patients with hemiparesis in enhancing their loading of the affected lower extremity when standing up and sitting down, although that skill improvement was not translated to movement speed.

The paucity of experimental studies examining the effect of these techniques on walking ability and the potential merits of MI practice in enhancing the motor performance of patients with hemiparesis after stroke highlight the need to further investigate the contribution of MI practice to functioning in patients following stroke. As part of a large-scale experimental study aimed toward this end, the following case report describes our experience in implementing MI practice for improving the gait performance of one community-dwelling individual with hemiparesis due to stroke.

Case Description

MW was a 69-year-old man with left hemiparesis following a first single unilateral stroke in the right parietal lobe and corona radiata, which occurred 100 days previously. MW had lived at home for 27 days following 73 days in a rehabilitation center. Prior to the stroke, he had been an independent retired community dweller.

Upon an appeal by the researcher (RD) to individuals who had been discharged from the rehabilitation setting, MW was the first volunteer who satisfied inclusion criteria for participation in the experiment. These criteria were that the individual had to be living at home following a first unilateral stroke that took place at least 90 days prior to enrollment. Capacity for independent indoor ambulation also was required. MW then signed an informed consent statement, in accordance with the guidelines of the institutional ethical review board, outlining his rights as a subject.

MW was shown to have normal communication and cognitive skills, as measured by the Folstein Mini-Mental State Examination,[41] with his score of 28 falling within the normal range. His score of 90 on the Barthel Index,[42] which is a basic activities of daily living scale with a maximum score of 100, was due to the assistance he needed in bathing and in dressing. He used a plastic ankle-foot orthosis (AFO) for outdoor ambulation and walked with the aid of a cane. Despite walking at a slow pace with an obvious asymmetrical pattern, he was able to traverse a distance of 10 m independently using neither the AFO nor the walking aid.

The Motor Imagery Questionnaire (MIQ), which is extensively used in sports,[43,44] was modified to test MW's ability to imagine prior to his engagement in MI intervention. The original MIQ was designed specifically to measure the mental practice of movements and contains 18 tasks for measuring visual and kinesthetic mental practice ability. The questionnaire incorporates a variety of relatively simple upper-extremity, lower-extremity, and whole-body movements. For each movement, participants are first asked to assume a standard starting position and then to execute the movement. After returning to the starting position, the execution of the movement is imagined. Finally, the individual rates the difficulty experienced in imagining the movements on a 7-point Likert scale, ranging from 1 ("easy to imagine") to 7 ("difficult to imagine"). The best attainable score is 18, and the worst obtainable score is 126. A positive relationship between scores on the MIQ and measurements of motor performance has been reported[44]; yet, the indication of optimal candidacy for MI practice has not been established. Internal consistency (Cronbach alpha) of .87 and .91 were reported for the visual and kinesthetic subscales of the MIQ, respectively; test-retest reliability (Pearson correlation coefficient) was .83 for each subscale.[44]

The modifications made in the original questionnaire were done with the permission of the developer of the instrument (C Hall, personal communication). Modifications included the elimination of 10 tasks that were unrealistic for performance (eg, "Jump straight up in the air as high as possible with both arms extended above the head"), leaving 8 tasks in the modified version. Reliability of that modified version was not estimated. MW rated the difficulty of both the visual and the kinesthetic imagery tasks that were required by the questionnaire as "very easy." Accordingly, his imagery ability was scored as the highest of the 7 possible scores.

The patient management consisted of 5 gait examination and evaluation (testing) sessions and a 6-week intervention (treatment) period. Testing was conducted in the rehabilitation center, whereas practice sessions were carried out at MW's home.

Testing

Schedule. MW was tested 5 times: (1) 2 weeks prior to the beginning of MI practice, (2) 1 day before the first practice session, (3) 3 weeks after starting MI practice (midterm evaluation), (4) 6 weeks after starting MI practice, at the end of the intervention period (postintervention evaluation), and (5) 6 weeks after practice termination (follow-up evaluation). The time period between the first and second evaluations was considered to be pretreatment and the period between the postintervention evaluation and the follow-up evaluation was considered to be posttreatment (retention).

Measurements. Testing took place while MW was walking with his regular walking shoes without the AFO and without the use of a cane. Observational gait analysis was performed with the Tinetti ambulation scale.[45] The interrater reliability of the scale is estimated to be .85, and scores are positively correlated with stride length ($r=.62$–$.68$) and single-leg support time ($r=.59$–$.64$).[46] The test has a sensitivity of 70% and a specificity of 52% to predict falling.[47] Walking speed was measured with a stopwatch while MW was walking independently at a self-selected speed along a straight 10-m path. Temporal step parameters were measured and sagittal-plane kinematic data (Ariel Performance Analysis System*) of the knee were obtained during each of the 5 testing sessions. The reported accuracy of angular measurements obtained with the Ariel Performance Analysis System in adults without known pathology or impairments is ±1 degree,[48–50] and the reported accuracy of linear data is 1.3, 4.6, and 3.1 mm along the x, y, and z axes, respectively (see Klein and DeHaven[50] for specific details). All testing was performed with the same dark sport shoes and clothes, with reflective markers fixed at the greater trochanter, lateral tibiofemoral notch, and lateral malleolus[51] on each lower extremity. Data collection at 60 Hz was done with 2 digital video cameras (JVC 9500†) positioned at 50 degrees relative to the plane of progression at a distance of 2.5 m from the calibrated 1.5- × 1.5-m filming area. It included at least 3 back-and-forth trials, with MW walking independently at his self-selected speed along a straight 6-m path.

Criterion measurements. Because gait speed has repeatedly been shown to be the cardinal variable for measuring functional gait,[3,52–56] speed was the major variable of interest. Step and stride length, as well as cadence, were used as complementary measurements. Given that prolonged double support is a marker of slow gait, with improvement being characterized by its shortening,[52] the duration of double support also was recorded during each testing session. *Symmetry*, defined as the ratio between the duration of single support on each lower extremity, was calculated to supplement temporal information. The Tinetti gait score was selected as an additional parameter that may shed light on gait aspects caught by an observer's eye rather than by a camera. Approaching normal values of the sagittal-plane knee angle was further considered as indication of an intervention-related improvement; therefore, the kinematics of both knees were measured during each testing session. Knee angles at initial contact, mid-stance, toe-off, and mid-swing were determined offline via frame-by-frame observational analysis. *Initial contact* was defined as the time point of first contact between the foot and the floor, *mid-stance* was defined as the time point in single-leg stance when the thigh of the contralateral swinging limb is parallel to the thigh of the stance limb, *toe-off* was defined as the time point when the last toe leaves the ground, and *mid-swing* was determined by the time point of mid-stance of the contralateral limb.

Intervention

Schedule. All practice sessions were conducted by the same professional (AD), who holds a master's degree in physical education and has previous experience in the

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* Ariel Dynamics Inc, 6 Alicante St, Trabuco Canyon, CA 92679.

† JVC Company of America, 41 Slater Dr, Elmwood Park, NJ 07407.

Table 1.
Time Schedule and Major Tasks That Were Practiced

Week	Task
First	Familiarization with motor imagery practice. Practicing imagery gait in the living room, emphasizing imagery experience, using all sensory modalities. Examples: "Try to imagine the scene of the pictures on the wall as if you are watching it in reality." "Try to use your imagery ability to hear the sound of your footsteps on the floor."
Second	Practice of missing components (impairments) in gait performance of the paretic lower extremity, focusing on knee flexion during swing, on heel contact during stance, and on the timed application of propulsive force during push-off. Examples: "Try to 'see' your left knee flex as high as your right knee." "Try to feel your left knee flex as high as your right knee." "During each step, price to lifting your leg, try to feel that your foot is strongly pushing backward toward the floor."
Third	Practice continued as in second week, with additional emphasis on loading of the affected side during stance and on increasing gait speed. Examples: "In each step, feel that you somewhat extend the time you stand on your paretic leg, at the same time you move your unaffected leg further ahead." "Imagine that you are walking faster than your current tempo." "Feel that you move each of your feet farther ahead."
Fourth	Further gait practice, focused on integrating the prior practiced components into the step cycle and on increasing symmetry and gait velocity. Examples: "Try to 'see' both of your legs making the same movements." "Feel each foot going up the same height as the other." "In each step, feel your forefoot is strongly pushing against the floor prior to 'take off.'"
Fifth and sixth	Imagery practice of walking with the desired gait pattern toward meaningful targets within as well as outside the individual's home. Practice involved walking as fast as possible on different terrains, such as carpets, roads, and grass. Examples: "Imagine that you are walking on a sidewalk at normal speed, just as you used to walk before the stroke." "While walking in the street, try to feel the same self-confidence that you always had."

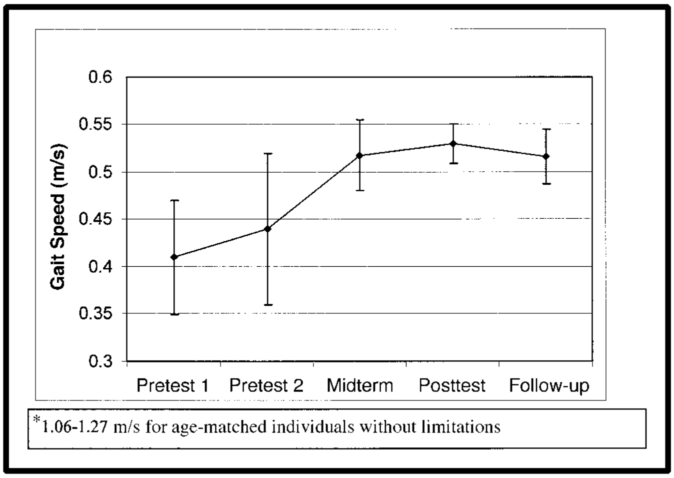
administration of MI techniques in mental practice. Fifteen-minute treatment sessions were held 3 times a week for 6 weeks. This time frame was chosen because according to our experience the majority of gait rehabilitation programs last 4 to 8 weeks and because substantial improvement has been demonstrated after 3 weeks of imagery practice.[38,57]

Contents. Based on MW's responses to the MIQ, we determined that he was able to use both kinesthetic and visual forms of imagery equally well. Therefore, internal as well as external imagery scenes were applied in his intervention protocol. The 2 main goals were: (1) to facilitate movement and posture of the affected lower extremity during gait by focusing on specific impairments and (2) to enhance functional walking within his own environment. Specific impairments chosen as targets for intervention were forefoot initial contact and deficient push-off during stance, as well as reduced knee flexion during swing. Concomitantly, imagery practice was directed toward improving speed and symmetry and toward negotiating walking routes indoors and outdoors (eg, public buildings, uneven terrains).

The first 4 weeks of the intervention period focused on the amelioration of specific gait impairments and on improving speed and symmetry, whereas more attention was devoted during the last 2 weeks to the performance of functional task-oriented gait activities. Timing, sequencing, and spacing of the MI practice activities were based on established principles taken from the motor learning discipline and on reports of the application of these principles to stroke rehabilitation.[58–60] Accordingly, MI exercises were applied randomly rather than in blocks, and explicit information on the nature of the task was provided prior to performance. Additionally, the gait was practiced under variable circumstances with only intermittent or minimum oral feedback presented during practice.

Each practice session was composed of: (1) deep muscle relaxation (1–2 minutes),[57] (2) the provision of explicit information on task characteristics and environmental circumstances (1–2 minutes),[61] (3) imaging of walking activity from an external perspective (3–8 minutes),[25] (4) imaging of walking activity from an internal perspective (3–8 minutes),[25] and (5) refocusing of attention on the immediate surroundings and on genuine body position (1 minute).

The content of each MI practice session was adjusted to the performance level of MW at that particular point in time and was modified during the 6-week treatment period in accordance with changes in walking performance. Reinforcement was applied through imagery of feelings of confidence in gait performance and of successful accomplishment of the practiced tasks. That is, the trainer encouraged feelings of safety, calmness, and satisfaction during as well as after completion of the imagery gait. No physical intervention was applied during treatment. An outline of the major tasks that were practiced each week is provided in Table 1.



*1.06-1.27 m/s for age-matched individuals without limitations

Figure 1.
Patient's gait speed. *Data from: Oberg T, Karsznia A, Oberg K. Basic gait parameters: reference data for normal subjects, 10–79 years of age. *J Rehabil Res Dev.* 1993;30:210–223; and Von Schroeder HP, Coutts RD, Lyden PD, et al. Gait parameters following stroke: a practical assessment. *J Rehabil Res Dev.* 1995;32:25–31.

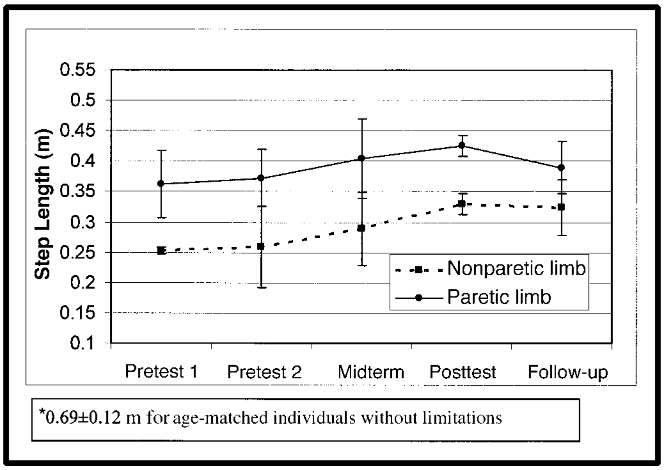
Outcomes

Temporospatial Parameters

The patient's gait speed was faster following imagery practice (Fig. 1). The increase was highest at the postintervention evaluation (20.4% above the second baseline level), with substantial gains maintained at the follow-up evaluation.

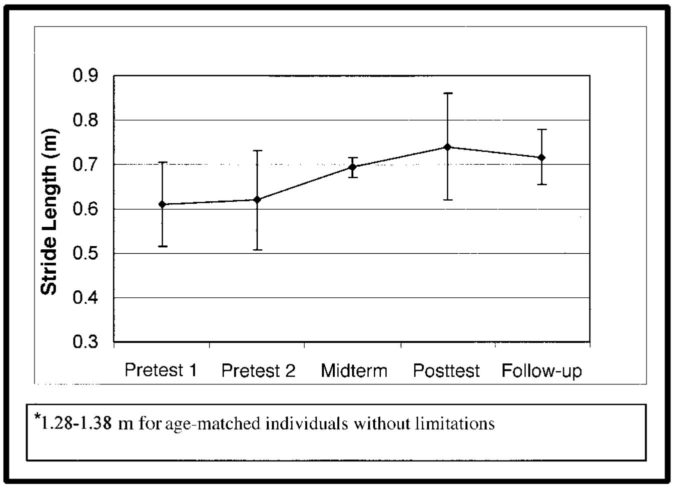
Step lengths of both the paretic and nonparetic lower extremities were below the normal range during baseline sessions and increased with imagery practice (Fig. 2), as evidenced by the 19.4% increase in stride length from the second baseline measurement to the postintervention evaluation (Fig. 3). Gains in step length were partially maintained at follow-up. The cadence of MW was substantially lower than the cadence of aged-matched individuals without impairments (Fig. 4). Despite variability in baseline cadence, the highest gains (9%) were noted at the midterm evaluation. These gains were only marginally maintained at follow-up.

Duration of absolute and relative double-support periods is depicted in Figure 5. A decrease in double support can be seen at the midterm and postintervention evaluations, with some of these gains lost at follow-up. The absolute decrease in double-support duration was more enhanced than the relative (percentage of the gait cycle) decrease. This difference became pronounced in values obtained during the follow-up evaluation, where the relative values almost reverted to preintervention levels, while the absolute values remained lower than at preintervention.



*0.69±0.12 m for age-matched individuals without limitations

Figure 2.
Patient's step length (paretic limb versus nonparetic limb). *Data from: Winter DA. *Biomechanics and Motor Control of Human Gait: Normal, Elderly and Pathological.* Waterloo, Ontario, Canada: Waterloo Biomechanics; 1991.



*1.28-1.38 m for age-matched individuals without limitations

Figure 3.
Patient's stride length. *Data from: Oberg T, Karsznia A, Oberg K. Basic gait parameters: reference data for normal subjects, 10–79 years of age. *J Rehabil Res Dev.* 1993;30:210–223; Von Schroeder HP, Coutts RD, Lyden PD, et al. Gait parameters following stroke: a practical assessment. *J Rehabil Res Dev.* 1995;32:25–31; and Winter DA. *Biomechanics and Motor Control of Human Gait: Normal, Elderly and Pathological.* Waterloo, Ontario, Canada: Waterloo Biomechanics; 1991.

Symmetry between single support on the nonparetic extremity versus the paretic extremity was 1.4 on the pretest and on all subsequent tests, including the follow-up evaluation. These results indicate a lack of improvement. Similarly, observational analysis of MW's unassisted gait yielded a score of 8/12 on the Tinetti ambulation scale[45] during all 5 testing sessions.

Kinematic Data

Kinematic data obtained at initial contact, mid-stance, toe-off, and mid-swing during each of the evaluation

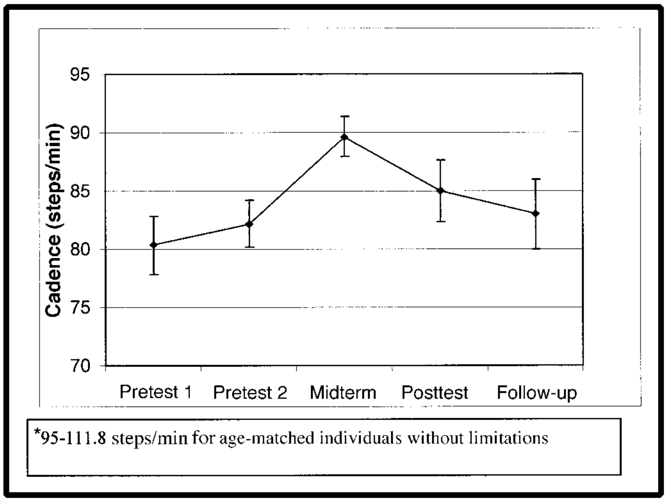


Figure 4.
Patient's cadence. *Data from: Von Schroeder HP, Coutts RD, Lyden PD, et al. Gait parameters following stroke: a practical assessment. *J Rehabil Res Dev.* 1995;32:25–31; and Winter DA. *Biomechanics and Motor Control of Human Gait: Normal, Elderly and Pathological.* Waterloo, Ontario, Canada: Waterloo Biomechanics; 1991.

sessions are presented in Table 2. Percentage of improvement between the second baseline and the postintervention evaluation is presented in the far-right column of the table. The improvement at the knee joints was expressed by additional extension upon initial contact (eg, 176° and 174° at midterm, as compared with 171° and 167° at the second baseline, on the paretic and nonparetic sides, respectively), by additional extension at mid-stance, and by more enhanced flexion at toe-off and mid-swing.

Data describing the total range of motion of the knee (ie, the difference between the maximal extension angle and the maximal flexion angle) are provided in Figure 6. Following practice, the patient had a net increase in range of motion of the paretic knee as well as on the nonparetic knee, with gains partially maintained at follow-up. Nevertheless, the range of motion on the paretic side was substantially limited in comparison with the unaffected side. Furthermore, the range of motion on the unaffected side at follow-up also was somewhat reduced in comparison with normal values.

MW was highly motivated throughout the intervention period and was present at all sessions. From the third week on, he reported on increase in self-confidence during gait and resumed part of the outdoor ambulatory activities that he used to do prior to his stroke.

Discussion

The purpose of this case report was to describe the implementation of MI practice for improving walking performance in one individual with hemiparesis. The increase in gait speed observed in the patient is encouraging and warrants further study.

The temporospatial gait characteristics indicate that cadence was especially adversely affected by the stroke and that the improvement in gait speed was due mainly to an increase in stride length and, to a lesser extent, to an increase in cadence (as demonstrated by the increase of 19.4% and 3.4% from the second baseline to postintervention evaluation for stride length and cadence, respectively). Furthermore, the increase in cadence was almost lost at the 6-week follow-up, whereas gains in step length of the unaffected lower extremity were almost completely preserved at follow-up.

In previous MI studies,[62,63] chronometry was used for controlling temporal parameters. Perhaps controlling and enhancing cadence could have been facilitated by the similar use of a metronome in the current work, and such use is recommended for future studies. The shortening of the period of double support also is positive, indicating that MW became capable of reducing his safety limits for the benefits of faster gait. Note that a relative decrease in the double-support period was less pronounced than the absolute decrease due to the general reduction in the duration of the gait cycle.

Despite these apparent gains, the gait symmetry showed no improvement, nor was any change noted in scores on the Tinetti ambulation scale. This clinical scale examines aspects of gait that are not usually quantifiable by measurement instruments. A score lower than 9 out of 12 indicates the risk of a fall.[45] MW received a score of 8 due to poor symmetry, insufficient left foot clearance, and marked unilateral trunk sway, none of which were satisfactorily improved by MI practice.

Presumably, MI intervention, as applied here, did not sufficiently modify the asymmetry that is an inherent feature of hemiparesis. The practice of gait as a unit activity was followed by improvement in functional gait and speed, with concurrent changes made by both lower extremities. The patient's asymmetrical gait pattern remained. It is worth noting that MW's imagery was focused on an asymmetrical gait pattern throughout mental practice, as he acknowledged being unable to imagine his own walking in a symmetrical fashion. Perhaps the alleviation of this specific disorder demands more vigorous MI practice for specific impaired functions of the paretic lower limb as well as for symmetrical gait. More research is needed to clarify this issue.

Regarding the range of motion of the knee joint, the most prominent observations were the increases in knee extension at initial contact and in knee flexion during swing. Both changes may have enabled the swing limb to

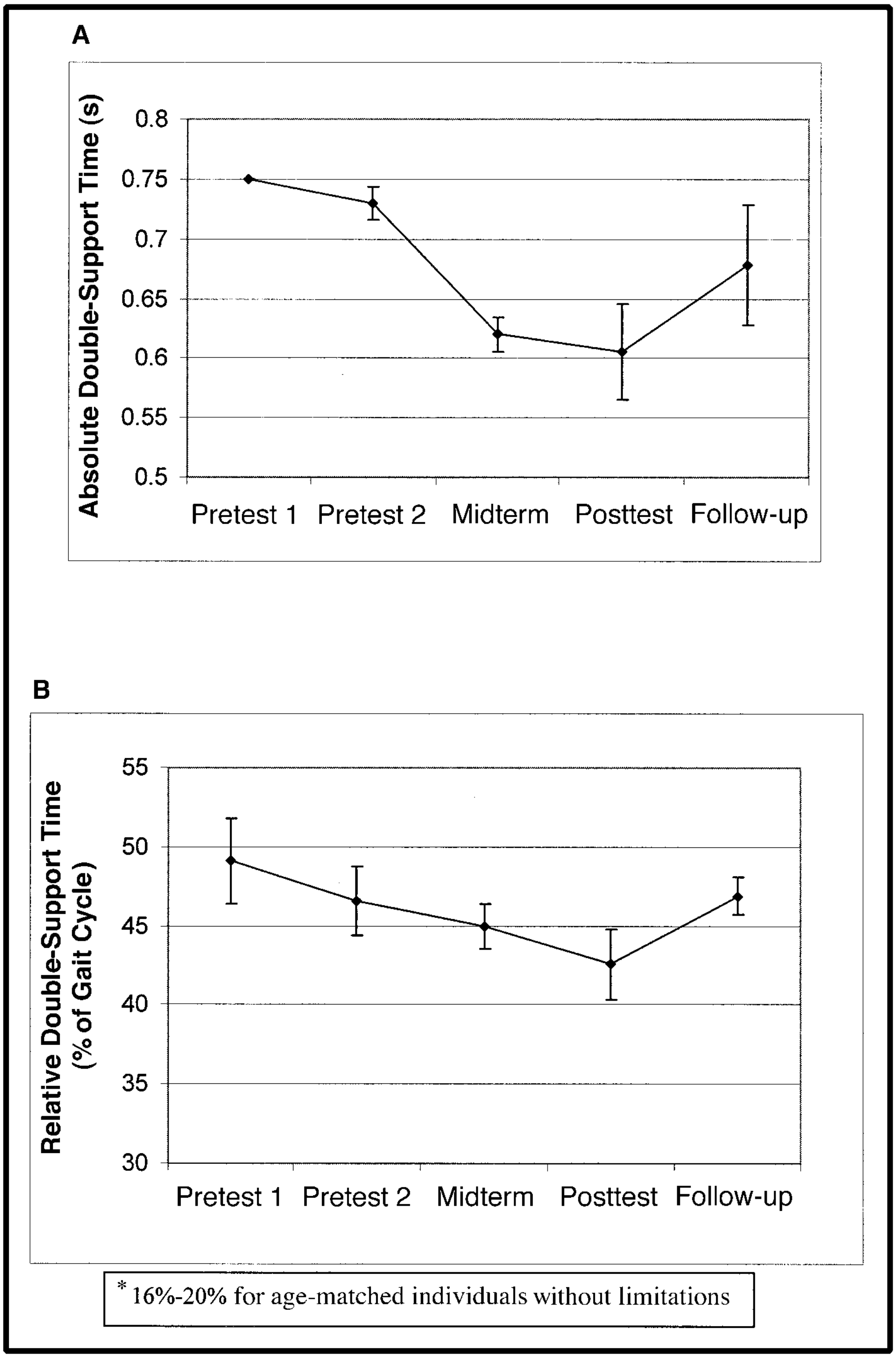


Figure 5.
Changes in (A) patient's absolute double-support time (in seconds) (double-support time=[time between right initial contact and left toe-off] + [time between left initial contact and right toe-off]) and (B) patient's relative double-support time (percentage of gait cycle). *Data from: Winter DA. *Biomechanics and Motor Control of Human Gait: Normal, Elderly and Pathological*. Waterloo, Ontario, Canada: Waterloo Biomechanics; 1991.

traverse a larger arc prior to initial contact, thus increasing step length. The comment of MW's spouse that his dragging of the paretic lower extremity decreased following the intervention is in line with the improvement in flexion during swing. MW, himself, supported this notion, declaring that following MI intervention, he paid more attention to the events of single stance and swing of the affected lower limb.

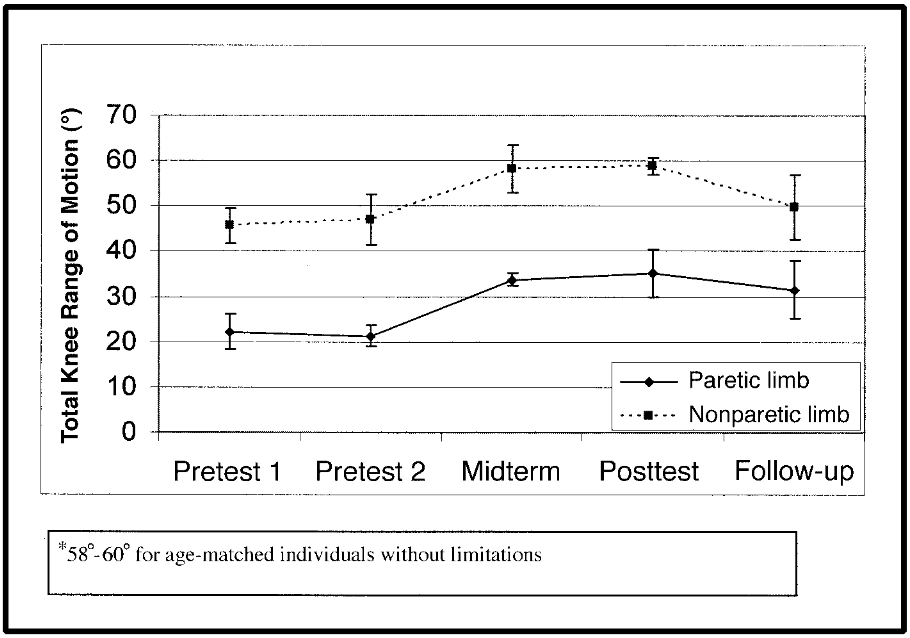
In conclusion, the information provided by this case report points to a potential contribution of MI practice to gait speed, with these gains partially extending beyond the practice period. The bilateral effects seen here may be a function of the level of intervention entailed by this approach, insofar as it demands the execution of a cognitive task and presumably encompasses the planning and mental rehearsal of the entire

Table 2.
Sagittal-Plane Angle (in Degrees) of the Knee Joints in Each Testing Session at 4 Critical Time Points of the Gait Cycle (Full Extension=180°)

	Normal Values[a]	Pretest 1	Pretest 2	Midterm	Posttest	Follow-up	Change (%) Pretest 2-Posttest[b]
Initial contact	173.5						
Paretic limb		172.1	171.3	176.3	175.8	177.0	2.6
Nonparetic limb		165.5	166.9	174.0	175.8	173.3	5.3
Mid-stance	163–171						
Paretic limb		159.8	159.9	164.6	162.1	165.7	1.3
Nonparetic limb		168.4	166.8	167.1	170.6	167.5	2.3
Toe-off	144–150						
Paretic limb		156.2	154.4	146.5	143.5	148.3	−7.1
Nonparetic limb		123.6	125.3	122.3	125.6	127.4	0.2
Mid-swing	116–118						
Paretic limb		149.9	150.5	142.5	140.5	145.5	−6.3
Nonparetic limb		119.9	119.9	115.9	117.0	123.5	−2.4

[a] From: Winter DA. *Biomechanics and Motor Control of Human Gait: Normal, Elderly and Pathological.* Waterloo, Ontario, Canada: Waterloo Biomechanics; 1991.

[b] A positive change denotes increase in extension; a negative change denotes an increase in flexion.



*58°-60° for age-matched individuals without limitations

Figure 6.
Patient's total knee range of motion (paretic limb versus nonparetic limb). *Data from: Winter DA. *Biomechanics and Motor Control of Human Gait: Normal, Elderly and Pathological*. Waterloo, Ontario, Canada: Waterloo Biomechanics; 1991.

gait task. Perhaps greater benefits could be gained by more heavily focusing on imagery for impairments of the affected side. Further research is needed to better highlight the benefits of this approach and the desired focus of intervention.

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