Gait Characteristics in Multiple Sclerosis: Progressive Changes and Effects of Exercise on Parameters

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This study determines the characteristics of the multiple sclerosis gait, identifies the progressive gait changes associated with this degenerative disease, and determines the effects of an aquatic exercise program on gait parameters. Eleven patients with multiple sclerosis volunteered to participate and were filmed three times during a 10 week period with a Locam camera at 100 frames/s. During the testing period, subjects participated in an aquatic exercise program. In addition, they were rated according to the Kurtzke Scale for Evaluating Disability in Multiple Sclerosis. Results indicated that these patients with MS have shorter stride lengths, slower free speed walking rates, and higher cadence than do persons without MS. Knee and ankle joint rotation were characterized by lower than normal excursion with less vertical lift of the center of gravity and greater trunk lean than normal. Significant correlations between the Kurtzke Scale and gait parameters were indicated for step length and hip and ankle joint excursion. The aquatic exercise program appeared to have had no effect on the studied gait parameters.

KEY WORDS: Exercise therapy; Gait; Multiple sclerosis

Several studies of the kinematic parameters of the normal gait have been reported but few concern pathologic gait. There is little information on the effects of exercise on the parameters of pathologic gait. This study was conducted to (1) determine the characteristics of the multiple sclerosis (MS) gait, (2) identify the progressive gait changes associated with this degenerative disease, and (3) determine the effects of an aquatic exercise program on selected gait parameters.

METHOD

Subjects

The volunteer subjects in this investigation were 11 patients with MS recruited from the local Multiple Sclerosis Association chapter. Two subjects quit the program prior to the final tests. Informed consent and medical permission were prerequisites for participation. Prior to the start of the study the subjects underwent medical evaluations which were administered by two physicians and included a medical history and physical examination. In addition, the subjects were rated according to the Kurtzke Scale for Evaluating Disability in Multiple Sclerosis.

Three filming sessions were scheduled for each subject. Pretest filming was done a week prior to the start of the exercise program. The midtest was given during the fifth week of training, and the posttest was done the week immediately after completion of the exercise program.

Each subject was filmed at 100 frames/s with a Locam 16mm camera equipped with an internal timing device. Subjects were asked to walk a path perpendicular to the camera position, at their normal walking speed. The walking speed was monitored by photo cells. Each filming session was composed of four trials, two right sagittal and two left sagittal views.

The film data were digitized on a sonic digitizer interfaced to a DEC 10 computer; 22 points were digitized for each frame of the walking gait studies. For analytic purposes, a single step was divided into four phases: (1) initial contact, (2) mid support, (3) end of contact, and (4) mid swing. The film frame representing each phase and every second frame between each phase was digitized.

A computer program determined the average right and left side temporal and displacement values and the position of center of gravity. Dempster's values for the determination of the center of gravity were used. Statistical analysis included analysis of variance and product moment correlation (SPSSX computer program).

Exercise Procedure

All subjects participated in 10-week aquatic exercise program consisting of free-style swimming and shallow water calisthenics as described previously. Site for the program was a six-lane instructional swimming facility; water temperature was regulated within a range of 24° to 27.5°.

Three 60-minute exercise sessions were held each week, with training intensity being established at 60% to 75% of the subject's estimated maximal heart rate. Progression of exercise intensity and duration of exercise was based on a subject's feelings of fatigue, physicians' recommendations, and resting.
recovery, and maximal heart rate responses. Changes in muscular strength, fatigue, work, and power induced by this program were previously reported.  

RESULTS

Five men and six women initially participated in this investigation with one woman and one man quitting before completing the final test. The characteristics of the subjects are presented in Table 1. The mean length of time the subjects had had MS was 7.3 ± 2.6 years.

Speed of Walking Cadence

The mean values for the speed at which the subjects walked during the three tests ranged from 63.5 ± 64.5 m/min. The free speed of walking mean values were identical for the pretests and posttests. The mean walking speed was slightly lower than the mean values for the other two tests, but analysis of variance statistics revealed no significant difference. The correlations between free walking speed values and the Kurtzke Scale rating for the three tests were: r = 0.56, pretest; r = -0.60, midtest; and r = -0.70, posttest. The midtest and posttest correlation values were significant (p < 0.05). The subject with a Kurtzke Scale rating of 6 had the greatest deviation from the mean (25 m/s below the group mean walking speed). The two subjects with the lowest Kurtzke Scale rating (rating = 3) averaged 14 m/s above the group mean walking speed.

The cadence (steps per minute) mean values for the subjects during the three trials ranged from 102.8 to 107.3 steps/min. The mean cadence value for the pretest was 4.5 steps/min greater than for the midtest; and 3.0 steps/min greater than for the posttest. An analysis of variance statistic showed no significant differences. The correlations between the cadence values for each test and the Kurtzke Scale rating also were insignificant. The correlation values were r = -0.15 for the pretest; r = -0.39 for the midtest; and r = -0.15 for the posttest.

The cadence mean values for all tests for the male subjects averaged 2.83 steps/min higher than the total group mean cadence values. The women's cadence means averaged 2.4 steps/min lower than the group mean value. Female subjects with Kurtzke Scale ratings of 3 and 4 had higher cadence values than the mean; whereas subjects with ratings of 5 and 6 tended to be lower than the women's group mean. These differences were not evident for the men. Of the two male subjects with scale ratings of 5, one had higher cadence value and one had a lower cadence value than the men's group mean cadence value.

The support time mean values decreased 7 percent with each testing situation. As may be expected, the swing time mean value for the three tests increased with each test. However, there was no significant difference in either the swing or support time percentage values between the three tests. In addition, no significant correlation was detected between the Kurtzke Scale, percentage of support time, and percentage of swing time.

Stride Length

The stride length mean values were 1.20, 1.21, and 1.23 meters respectively for the pre, mid, and posttest. Similar results were indicated between stride length per height ratio mean values. The asymmetry (right step length minus left step length) appeared to decrease between the three tests. However, the differences were insignificant. The correlations between severity (Kurtzke Scale rating) and stride length were r = -0.62 for the pretest; r = -0.65 for the midtest; and r = -0.91 for the posttest. All three correlations were significant (p < 0.05, p < 0.05, p < 0.01). Considering height, the correlation between the Kurtzke Scale rating and stride length per height were r = -0.50, r = -0.55, r = -0.61 for the three tests, respectively. The posttest correlation value was significant (p < 0.05). No significant correlation was detected between the Kurtzke Scale rating and asymmetry on the three tests. The stride length: height (stature) ratio mean values were 74.9 and 67.3 for the men and women, respectively.

Hip Joint

The subjects' excursion angular values of the hip joint during a walking step are shown in Fig 1. The angle of the hip joint was formed between the femur and trunk. Both right and left joint rotation movements were considered in the determination of hip joint movement for each subject.

The angular displacement of the hip joint during the three steps...
Knee Joint

During a walking step, the angular displacement of the knee joint in a subject with MS appears to be more complex than the hip joint angular excursion. Fig 2 shows the knee joint angular displacement for the walking tests. The pattern of knee joint angular displacement increases slightly after contact and decreases during the final stage of the support phase. The greatest angle of knee joint flexion occurred during the swing phase and was followed by almost complete extension. The range of knee joint motion for the support phases were 7.6°, 5.8°, and 8.5° for the pretest, midtest, and posttest, respectively. During the swing phase pretest, the range of motion was 40.0°. This value increased to 41.4° during the midtest and increased to 43.9° during the posttest. No significant difference (ANOVA) was noted between the tests.

Each phase of knee joint angular displacement was correlated with the Kurtzke Scale for each of the tests; none of the correlations was significant.

Ankle Joint

The angle formed between the tibia and the fifth metatarsal was considered the angle of the ankle joint. The displacement of the ankle joint during a walking step for the three tests is shown in fig 3. The range of the ankle joint during the walking step was limited to 9.9° during the pretest, 13.5° during the midtest, and 12.0° during the posttest. There was no significant improvement in the range of motion values between the three tests. The lowest angle (84°) was found during the support phase of walking; while the greatest angular displacement values were found during the walking swing phase. The significant correlations between the different walking step phases of ankle joint rotation and the Kurtzke Scale were pretest mid-support, \( r = -0.66 \) (p < 0.05) and posttest midswing, \( r = -0.72 \) (p < 0.05).

Trunk

The angle of the trunk was measured in terms of degrees from the horizontal axis. Trunk angles ranged from 81.0° to 82.4° during the pretest walking cycle. The range of motion for the midtest trunk angles was 80.0° to 82.1°. Analysis of variance indicated no significant difference between pretest, midtest, and posttest values for walking cycle trunk displacement. In addition, the correlation values between the different phases of the walking cycle and the Kurtzke Scale were insignificant.

Center of Gravity

A computer program utilizing Dempster’s\(^1\) data was used to calculate the position of the center of gravity during the walking cycle. The horizontal and vertical displacement values were calculated for each subject. The horizontal displacement values are reflected in the speed of walking values. The vertical displacement center of gravity values were the highest during the support phase of walking (2.8cm, 3.6cm, and 3.4cm on the pretest, midtest, and posttest, respectively). There were no significant differences among the three tests during any phase of the walking cycle. The correlation coefficient values between the different walking cycle phases and the Kurtzke Scale also were insignificant.

DISCUSSION

The results of this study are based upon a limited number of men and women with MS (n = 11). The gait of the patients studied here was different from the quantitatively analyzed gaits of normal subjects of comparable age reported in the literature. Patients in this study showed decreased stride length,
higher cadence. Hip rotation mean values during the different phases of the gait cycle were slightly lower (within one standard deviation) of the normal hip rotation defined by Murray. However, rotational values for knee and ankle joints were clearly lower (two to three standard deviations) than the normal. The trunk angle was greater and the vertical lift of the center of gravity was less than normal. However, rotational values for knee and ankle joints were clearly lower (two to three standard deviations) than the normal. Murray and co-workers⁷,⁸ found the stride length to average 89% of body stature for men at free walking speeds and 82% of body stature for women at free walking speeds. In the current study, mean values were 74% for the men and 67% for the women. The 67% mean ratio for the women may have been influenced by the severity of MS, since the most severely affected patient was a woman.

The influence of cadence on speed of walking was reported by Lamoreux, who indicated that cadence values from 100 to 110 steps/min. reflected normal walking speeds of 72 to 87/min. The 107 to 104 steps/min. cadence values in the present study occurred at a mean walking speed of 64.5m/min. Murray⁷ reported normal free walking speed values, for men aged 20 to 60 years, to be 151cm/s with a cadence of 113 steps/min. For women aged 20 to 70 years, Murray and co-workers⁸ reported a free walking speed of 130cm/s, associated with a cadence of 117 steps/min. Patients with Parkinson’s disease were reported by Murray and associates⁹ to have free walking speeds of 95 to 67cm/s with cadence values of 108 to 89 steps/min. A cadence/speed of walking ratio may be one way to compare the different values found in the literature.

To examine the gait parameters associated with the degenerative nature of MS, the pretest gait parameters were correlated with the Kurtzke Scale. The Kurtzke Scale values in the present study were limited to a range of three points (ratings of 3 to 6). This range of rating values may have masked true relationships; however, subjects with ratings of 7 and higher are restricted to wheelchairs and scale values of 1 have no visible movement limitation. The results of this study (significant correlations between the Kurtzke Scale and step length, hip excursion at the initial phase of support, and ankle excursion at mid-support) suggests that MS tends to affect the range of motion more than the rate of joint motion. Asymmetry values would tend to indicate that the degenerative changes take place equally on both sides of the body.

Considering the nature of MS, the authors of this report felt that it would be inappropriate and potentially dangerous for a person with MS to participate in a jogging or cycling exercise program. However, the buoyancy produced by water and effective control of water temperature were characteristics considered ideal for the promotion of therapeutic responses. The intervention of the aquatic fitness program in the present study seemed to have no effect on the studied gait parameters. This is further supported by the correlation values. The same gait parameters that correlated significantly on the pretest also were significant on the midtests and posttests. The nonspecific nature of the exercise program may have been responsible for the lack of gait development instead of general strength; measurement of flexibility and endurance may have produced different results. The results of this study tend to disagree with Russell’s¹⁰ implications that a rest-exercise program for patients with MS arrests the pathogenic process. Other benefits, such as feeling less fatigue and the ability to work harder that were reported by the subjects in this study, may be realized through aquatic fitness programs.

In summary, the walking gait of patients with MS, as studied here, was characterized by short, quick steps. The lack of full range of motion in the lower legs may be the most striking MS gait characteristic.

References

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