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The relationship between fatigue, aerobic fitness, and motor control, in people with chronic stroke. A pilot study

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Abstract

Background—Fatigue is a commonly neglected issue despite the high incidence rate reported in people post-stroke.

Objective—To explore the relationship between fatigue, aerobic fitness, and motor control in people with chronic stroke.

METHODS—Nine people post-stroke participated in this cross-sectional study (7 females, mean age=56.8(11.8) years, range 47–73, time post-stroke=47.6(51.2) months, range 11–140). Participants performed a six-minute-walk exercise in order to induce fatigue, followed immediately by a Fatigue Index (FI) scale to report fatigue at the moment. The distance walked (6MWD) was documented. On a separate visit, aerobic fitness was characterized by VO_{2Peak} using a cycle-ergometer. In addition, Fugl-Meyer (FM) test was administered to assess motor control of the hemiparetic side. Pearson Product Correlation Coefficient and multiple linear regression were used to analyze the relationships between FI, VO_{2Peak} and FM.

Results—VO_{2Peak} showed significant positive correlations with FM (r=.779, p=.013) and 6MWD (r=.726, p=.027). FI displayed significant negative correlations with VO_{2Peak} (r=−.739, p=.023) and FM (r=−.873, p=.002), but not with 6MWD (r=−.620, p=.075). Using stepwise multiple regression, we found that that FM was an independent predictor of FI (p=.002) and explained 76.2% of variance in FI (R^2=.762).

Conclusion—Our data suggests that motor control capability may be a good predictor of fatigue in people post-stroke. Fatigue is a complex phenomenon; a quantifiable measure that is sensitive to multiple components is needed in order to distinguish the nature of fatigue and its contributing factors.

Keywords

stroke; fatigue; aerobic fitness; motor control

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INTRODUCTION

Fatigue is a common problem among people after stroke[1, 2] that may hamper full participation in a rehabilitation program.[3] Nevertheless, surveys suggest that it is commonly neglected issue by clinicians as well as care-givers.[1, 4, 5] Fatigue has been documented in studies focused on cancer treatment,[6–10] management of individuals with post-polio symdrome,[11] and nursing care interventions.[12,13] Fatigue has been defined as a feeling of early exhaustion, weariness, lack of energy and aversion to effort.[14] A high incidence of fatigue has been reported in people post-stroke.[1, 2, 4, 5, 14] Glader et al suggest that survivors of stroke with fatigue have a higher fatality rate three years after stroke due to its association with sedentary lifestyle.[4] There appear to be multiple contributors of fatigue including depression, chronic pain, sleep disorder, immobility, and lack of exercise.[15] Fatigue also impacts on performance of daily activities, especially those requiring physical effort.[3] Researchers have recently begun to explore the negative impact of fatigue on stroke rehabilitation.[1, 5, 14, 16] Little is known, however, about the factors contributing to fatigue in people who have had a previous stroke.

In survivors of stroke, decreased aerobic capacity,[17–20] decreased endurance,[21] and increased energy expenditure associated with impaired motor movements[18, 22] may be related to fatigue and can further affect daily functions such as walking.[23] The peak oxygen uptake (VO_{2peak}) of survivors of stroke has been reported to be low (13 ml/kg/min ~ 16 ml/kg/min), only approximately 50% – 60% of the age-matched adults without stroke.[18, 19, 24] This reduced VO_{2peak} may be attributed to a reduction in the number of motor units capable of being recruited during exercise, the reduced oxidative capacity of paretic muscle,[25] and the sedentary lifestyle of survivors of stroke.[26] When studying fatigue in people post-stroke, it is important to acknowledge that the potential contribution of aerobic fitness level.

Survivors of stroke may experience increased energy expenditure during gait due to the inability to activate normal motor patterns,[18] such limitation may cause poor biomechanical efficiency and promote an earlier onset of fatigue. Physical impairment, therefore, is considered to be a contributing factor to fatigue in people post-stroke.[2, 5, 27, 28]

The primary purpose of this pilot study was to explore the relationships between fatigue, aerobic fitness, and motor control in people with chronic stroke. We hypothesized that, for individuals with chronic stroke, there would be 1) a negative relationship between fatigue and aerobic fitness level; 2) a negative relationship between fatigue and the level of motor control; and 3) a positive relationship between aerobic fitness level and the level of motor control.

METHODS

Design

Data in this correlational pilot study are a subset from a larger study. The parent study was designed to compare function and aerobic fitness in people with stroke and Type 2 diabetes mellitus compared to stroke alone. Approval of the parent study was obtained from the

Human Subject Committee of the University of Kansas Medical Center. This pilot study is a secondary analysis of data previously collected in the parent study. We included all participants who completed a peak effort graded exercise test (VO_{2peak}) using a cycle ergometer, the Fugl-Meyer test (FM), and a Fatigue Index (FI) after a fatigue-inducing six-minute-walk (6MW) exercise. Although the primary purpose of the 6MW was to induce fatigue before the FI was administered, the distance walked (6MWD) during this exercise was also documented.

Subjects

Subjects recruited for the parent study signed an institutionally approved informed consent. To meet the inclusion criteria, subjects must have had:

1. a single stroke at least 6 months prior confirmed by clinical assessment.
2. ability to transfer from a sitting to a standing position without assistance.
3. ability to walk 30-feet independently with or without assistive devices.
4. Mini-Mental-Status-Exam score of ≥ 24, which indicated the ability to understand instructions and communicate verbally.
5. primary physician's medical release to confirm that subject is medically stable and able to participate in a maximal exercise test.

Subjects were excluded if they reported any of the following conditions:

1. any musculoskeletal condition that could potentially affect the ability to perform the motor tasks of the study
2. significant cardiac arryhthmia, hypertrophic cardiomyopathy, severe aortic stenosis, or pulmonary embolus
3. recent symptoms of chest discomfort.

Nine individuals from the parent study were included in the current analysis (2 males, 7 females, mean age = 56.8(11.8) years, range 47–73, time post-stroke = 47.6(51.2) months, range 11–140); 5 had right hemisphere strokes and 4 had left hemisphere strokes.

Procedures

In the parent study, participants were evaluated in two separate sessions. Session 1 included examination using FM, completion of a fatigue-inducing 6MW, and subsequent completion of a FI on a self-reported verbal scale. Session 2 required the subjects to undergo a peak effort graded exercise test on a cycle ergometer to determine aerobic fitness level. The experimental procedures are illustrated in figure 1.

Motor Control—The Fugl-Meyer[29] test, a feasible clinical examination that has been used widely in people post-stroke, has three components: sensory, upper extremity, and lower extremity evaluations. The FM requires the subjects to perform movements of sequential stages of motor-return using the affected side. In this study, the full version of the Fugl-Meyer test (FM) was used to assess the motor control capability of each subject. The FM is

an ordinal scale, with total possible points of 124. This test was administered prior to the fatigue-inducing 6MW exercise.

Fatigue-Inducing Walk—The Six-Minute-Walk Test (6MW)[30, 31] was used to induce fatigue prior to assessing the level of fatigue. The 6MW was performed on a 100-feet walkway. Subjects were informed that the goal of the test was to cover as much distance as possible during 6 minutes. Standardized verbal encouragement was given to the subjects every minute. Subjects were permitted to use their usual assistive or orthotic device, and were guarded by a test administrator during the walk for safety. None of the subjects required assistance during testing. The 6MW yield continuous data, measured in meters.

Fatigue Index—Fatigue was measured using a 10-point verbal analogue scale with a standardized statement by the test administrator. To administer the scale, the administrator described to the subjects "On a scale of 1 to 10; with 1 being no fatigue at all, and 10 being severe fatigue, please indicate how tired you feel at this moment." This ordinal scale was administered immediately after the fatigue-inducing 6MW exercise.

Aerobic Fitness—Peak oxygen uptake (VO_{2peak}) was measured using a cycle ergometry stress test[32] and a calibrated metabolic cart (Parvo Medics TrueOne 2400). It provides continuous data and measures VO_{2peak} in ml/kg/min. Although cycle ergometer may underestimate VO_{2peak} as compared to the treadmill, we found it a safer modality to use due to balance issues many survivors of stroke may experience on a treadmill. Since our study did not screen for level of motor control, treadmill may not be feasible for our subjects to complete the exercise test due to inadequate gait pattern and motor functions. Prior to the test, subjects were asked to refrain from eating food for an hour and drinking caffeine for 2 hours prior to the test. They were also instructed in the testing procedure and oriented to a 15-point Borg's Rate of Perceived Exertion (RPE) scale[33]. Subjects pedaled at 50 rpm with an external power of 0 Watts (W) for the first three minutes;[32] the workload was increased by 10W every minute, with standardized verbal encouragement. Heart rate and rhythm were monitored continuously with a 12-lead ECG system; blood pressure and RPE were measured every 2 minutes during the test. The test continued until peak effort was achieved. In this study, peak effort and the successful completion of the VO_{2peak} test was determined by reaching 1) 90% of the predicted maximal heart rate [(220-age) × 0.9], and 2) greater than 1.1 for respiratory exchange ratio (RER).[34] The test was terminated early if the subjects showed signs of angina, dyspnea, inability to maintain cycling cadence > 40 rpm, hypertension (>250 mmHg systolic or >115 mmHg diastolic), hypotension, or ischemic ECG abnormalities. A cool-down period of four minutes with 0W of workload at 40 rpm followed the end of the test. VO_{2peak} value was collected and recorded in ml/kg/min.

Statistical analysis

Means and standard deviations (SD) for demographics and outcome measures were established. In order to check normality of data, we analyzed standardized residuals using histogram and the normal PP-plot. Pearson Product Correlation Coefficients were calculated to explore the relationships between concepts of fatigue (FI score), aerobic fitness (VO_{2peak}) and motor control (FM scores). Correlations between 6MWD and VO_{2peak} and 6MWD and

FI were also calculated. Multiple regression was used to determine potential predictors of fatigue in a secondary analysis, using FI as the response variable and VO_{2Peak} and FM as explanatory variables.

RESULTS

Descriptive data is illustrated in Table 1. Each subject's completion criterion of the peak effort graded exercise test is illustrated in Table 2. Out of 9 participants, 3 successfully completed the graded exercise and achieved maximal effort; 6 had difficulties due to joint pain, abnormal muscle tone, or limited range of motion and did not reach predicted HR or RER values. VO_{2Peak} value was recorded as peak effort prior to the termination of the exercise test.

Fatigue (FI score) displayed significant negative correlations with aerobic fitness (VO_{2Peak}) ($r=-.74$, $p=.023$) and motor control (FM score) ($r=-.87$, $p=.002$) (Figures 2 & 3, respectively). Aerobic fitness (VO_{2Peak}) showed significant positive correlations with motor control (FM score) ($r=.78$, $p=.013$) (Figure 4). 6MW distance (6MWD) showed a significant positive correlation with aerobic fitness (VO_{2Peak}) ($r=.73$, $p=.027$) (Figures 5), but not with fatigue (FI score) ($r=-.62$, $p=.075$) (Figure 6). Using stepwise multiple regression, we found that that motor control (FM score) was an independent predictor of fatigue (FI score) ($p=.002$) and explained 76% of variance in fatigue ($R^2=.76$) experienced immediately after a walking exercise. In our regression model, VO_{2Peak} was not a significant independent predictor of fatigue ($p=.647$).

DISCUSSION

The primary finding of this pilot study was a negative relationship between fatigue, as measured by FI score, and motor control, as measured by FM score, in people post-stroke. In addition to the strong correlation, we found that motor control capability may be a good predictor for fatigue in survivors of stroke. Poor motor control has been considered a contributing factor to post-stroke fatigue due to physical limitations and poor biomechanical efficiency after stroke. [3, 27, 28, 35] Specifically, people post-stroke often experience the increased energy expenditure of hemiparetic gait due to the inability to activate normal motor patterns,[18] which may lead to an earlier onset of fatigue.

The secondary finding of this pilot study was a significant negative correlation between fatigue, as measured by FI score, and aerobic fitness, as measured by VO_{2Peak}. This finding supports our hypothesis that there is a direct negative relationship between fatigue and aerobic fitness level in people post-stroke; and it would support future investigation of the contribution of aerobic fitness to fatigue in people post-stroke. Michael et al[27], however, did not find a direct association between aerobic fitness level and post-stroke fatigue. They assessed VO_{2Peak} using a maximal graded exercise test on a treadmill,[18] which required participants with a higher level of motor control. Our study included people post-stroke with lower level of motor control to perform the maximal graded exercise test on a cycle ergometer. Michael et al used the Fatigue Severity Scale[36] to assess fatigue, which may not be sensitive to detect fatigue immediately after exercise. In our study, the FI was

administered immediately after the fatigue-inducing distance walk in order to capture the level of fatigue after exercise. The difference in exercise and fatigue measurement protocols may explain the differing results of our work and that of Micheal et al.

If there is indeed a strong relationship between aerobic fitness and fatigue, increase in aerobic fitness after stroke through exercise may also affect level of fatigue.[17, 38] Due to the many potential contributors to fatigue, future investigations may require more sensitive instruments to detect different constructs of fatigue in people post-stroke. More specifically, when studying fatigue in people post-stroke, it is important to acknowledge that the potential role of aerobic fitness level may be more closely related with the physical aspect of fatigue rather than psychological aspects of fatigue.

Our third hypothesis predicted that there would be a positive relationship between aerobic fitness and motor control; which was confirmed by the significant positive correlation we observed between VO_{2Peak} and FM scores. The literature has shown that poor motor function such as walking impairment or any kind of mobility deficit is significantly related to fatigue.[2, 5, 27, 28] Our finding is consistent with previous studies that examined the relationship between walking ability, lower extremity motor control and aerobic fitness level in people post-stroke.[31, 39] This finding further reinforces the previous statement that future rehabilitation strategies should consider including both aerobic fitness and mobility interventions.[27]

Limitations

One of the limitations in this pilot study is the small sample size. Although statistical significance was achieved between variables as well as in regression model, a larger sample size is recommended in future studies in order to achieve higher statistical power. Due to the limited sample size, we were unable to analyze the difference of fatigue between individuals with different stroke subtypes and lesion locations. In people post-stroke, the relationship between the presence of fatigue and stroke subtype and lesion location has been controversial. Recent neurobehavioral studies suggested that fatigue may be linked to the interruption of neural networks.[14] Staub and colleagues found that fatigue was found mainly in people with a brainstem infarct at 54.5%, less often in people with subcortical infarct at 37.5%, and rarely in people with cortical infarct at 6.25%.[14] However, other researchers have suggested that stroke subtype and lesion side or location did not seem to be related to post-stroke fatigue.[1, 2, 4, 5] In addition, Schepers and colleagues[35] examined the relation between fatigue at 1 year post-stroke and personal characteristics, stroke characteristics, and post-stroke impairments. The results revealed findings consistent with previous studies[1, 4] to support that fatigue is not related to lesion side and stroke location. Because of the contradicting findings from previous investigations, the relationship between the presence of fatigue and stroke lesion side and location is unclear. With a larger sample size, future studies should consider investigating the difference in fatigue among individuals with lesions in with different hemispheres and locations.

Another limitation in this study was that a verbal fatigue index was used to measure fatigue. The fatigue index was described to the subjects as an ordinal scale from 1 to 10 with a self-perceived rating. Fatigue is a complex construct with physiologic and psychosocial

components; the instrument used in this pilot study was likely not sensitive enough to detect all those components. Although our scale is a simplified version of a 100-point fatigue scale used previously[44] and is similar to the scale used in pain management literature,[37] its sensitivity is yet to be determined. Future studies should attempt to use instruments that are well-defined and are sensitive to detect different constructs of fatigue.

Similar to previous research that involved fatigue-inducing exercise,[44] we also acknowledge the difficulty of inducing "standardized fatigue." Since the 6MW may not consistently induce the same level of fatigue in every participant, future studies should consider a standardized fatigue-inducing method with fixed workload and duration.

Conclusions

The results of this pilot study data suggest a relationship between fatigue, aerobic fitness, and motor control. We found that motor control capability appears to be a good predictor for fatigue in people post-stroke. This could mean that improving motor control capability may decrease the level of fatigue experienced throughout daily activities in people with chronic stroke. As stroke is more common in the elderly, fatigue is an important issue due to its association with deterioration of various aspects of everyday life. The combination of stroke, fatigue, and sedentary lifestyle can create a morbid downward-spiral in terms of quality of life and functions. Therefore, it is essential to better understand the nature of fatigue. If more contributing factors of fatigue could be identified, clinicians would be able to modify therapeutic treatment accordingly for post-stroke rehabilitation.

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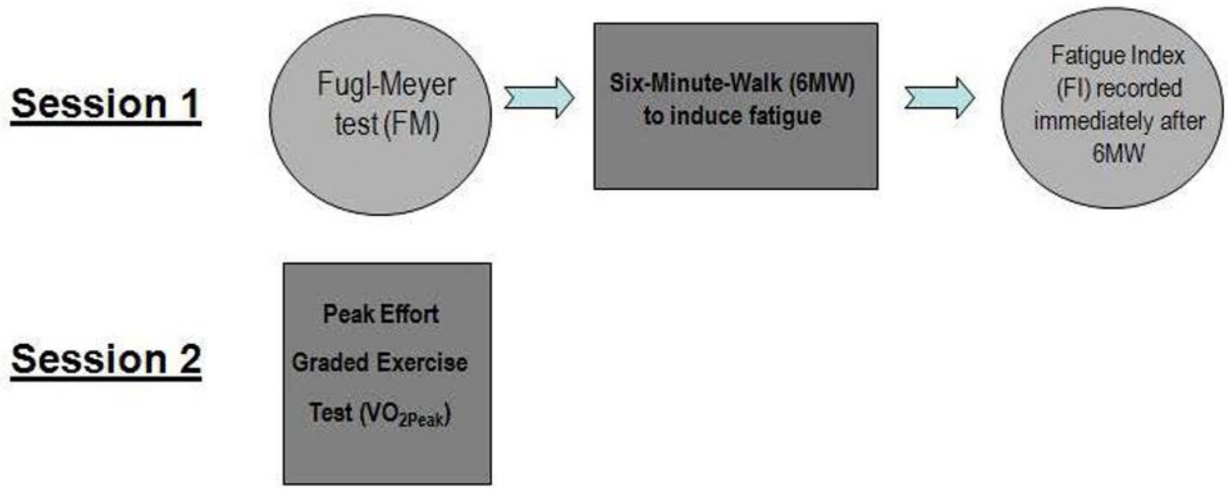

Figure 1.
Experimental procedures.

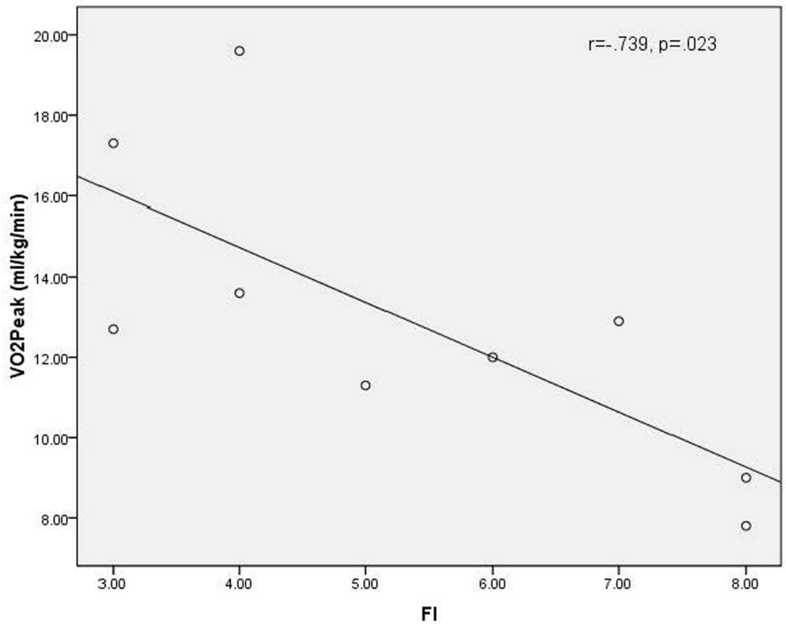

Figure 2.

Scatterplot illustrating the correlation between Fatigue (FI) and Aerobic Fitness (VO_{2Peak}).

FI = Fatigue Index

VO_{2Peak} – Peak oxygen uptake

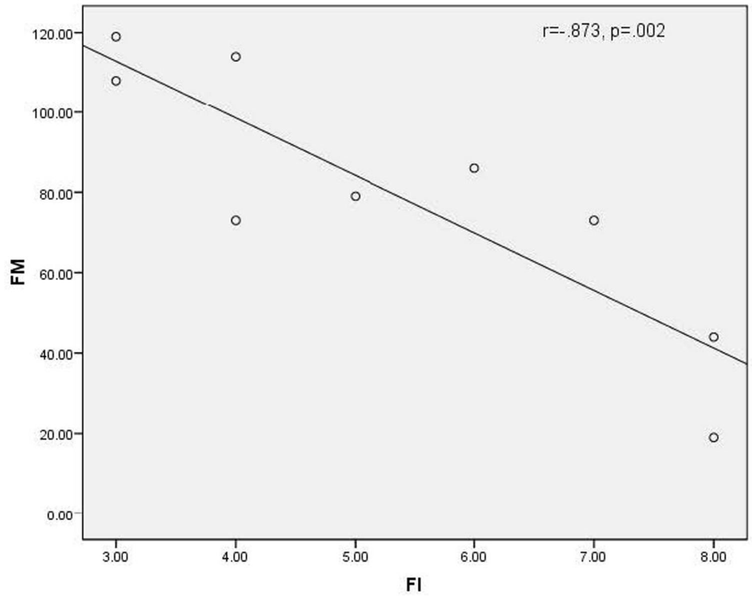

Figure 3.

Scatterplot illustrating the correlation between Fatigue (FI) and Motor Control (FM).

FI – Fatigue Index score

FM – Fugl-Meyer score

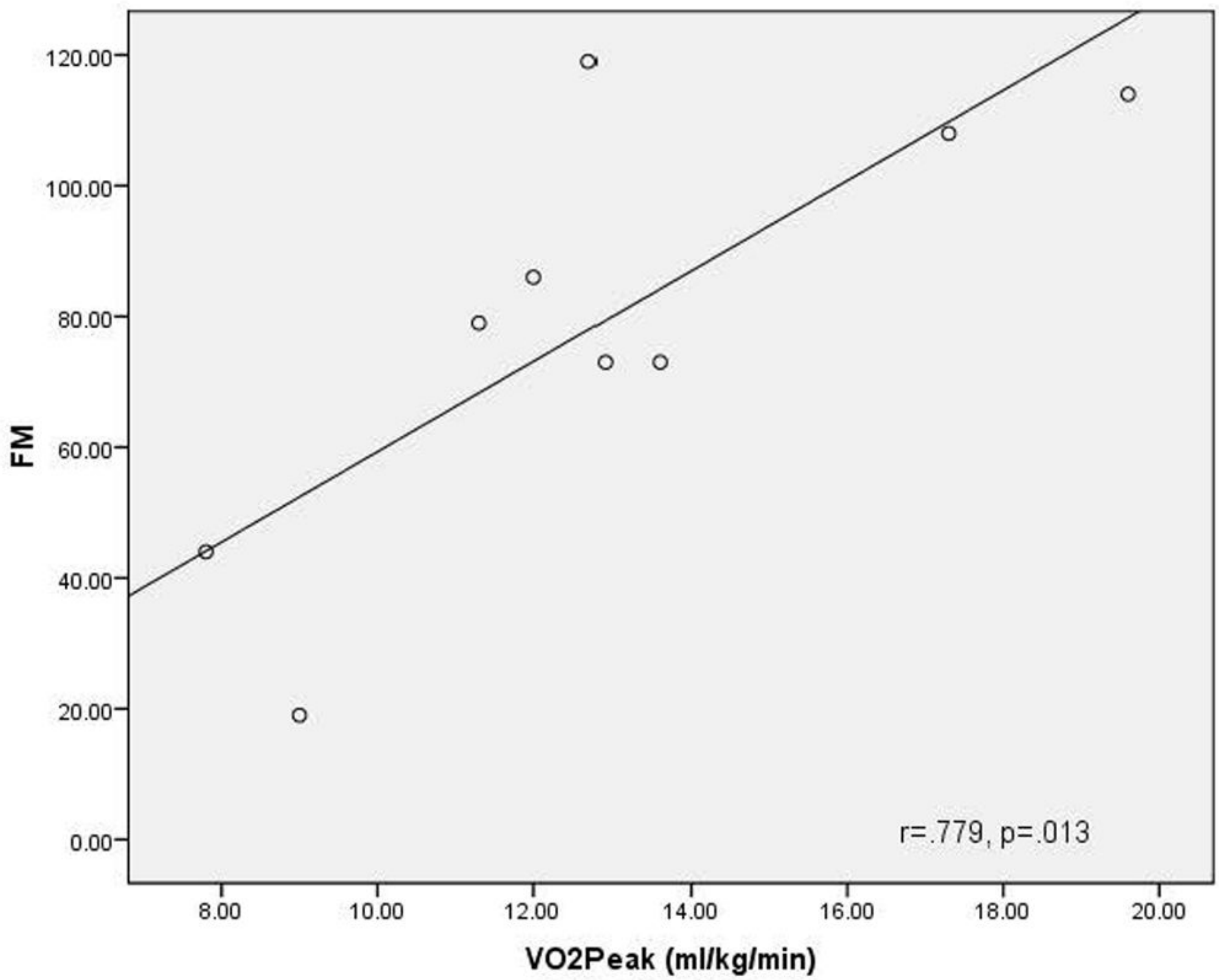

Figure 4.

Scatterplot illustrating the correlation between Aerobic Fitness (VO_{2Peak}) and Motor Control (FM).

VO_{2Peak} – Peak oxygen uptake

FM – Fugl-Meyer score

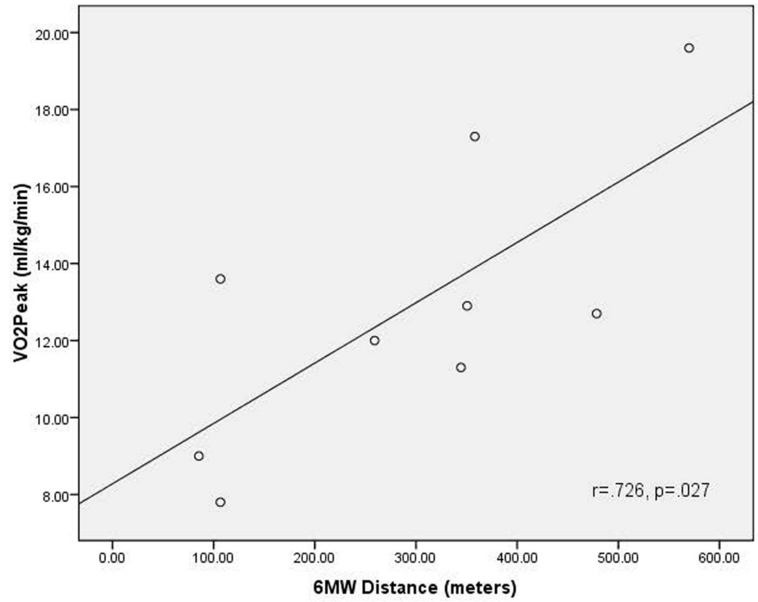

Figure 5.

Scatterplot illustrating the correlation between Six-Minute-Walk distance (6MWD) and Aerobic Fitness (VO_{2Peak}).

6MWD – Six-Minute-Walk distance

VO_{2Peak} – Peak oxygen uptake

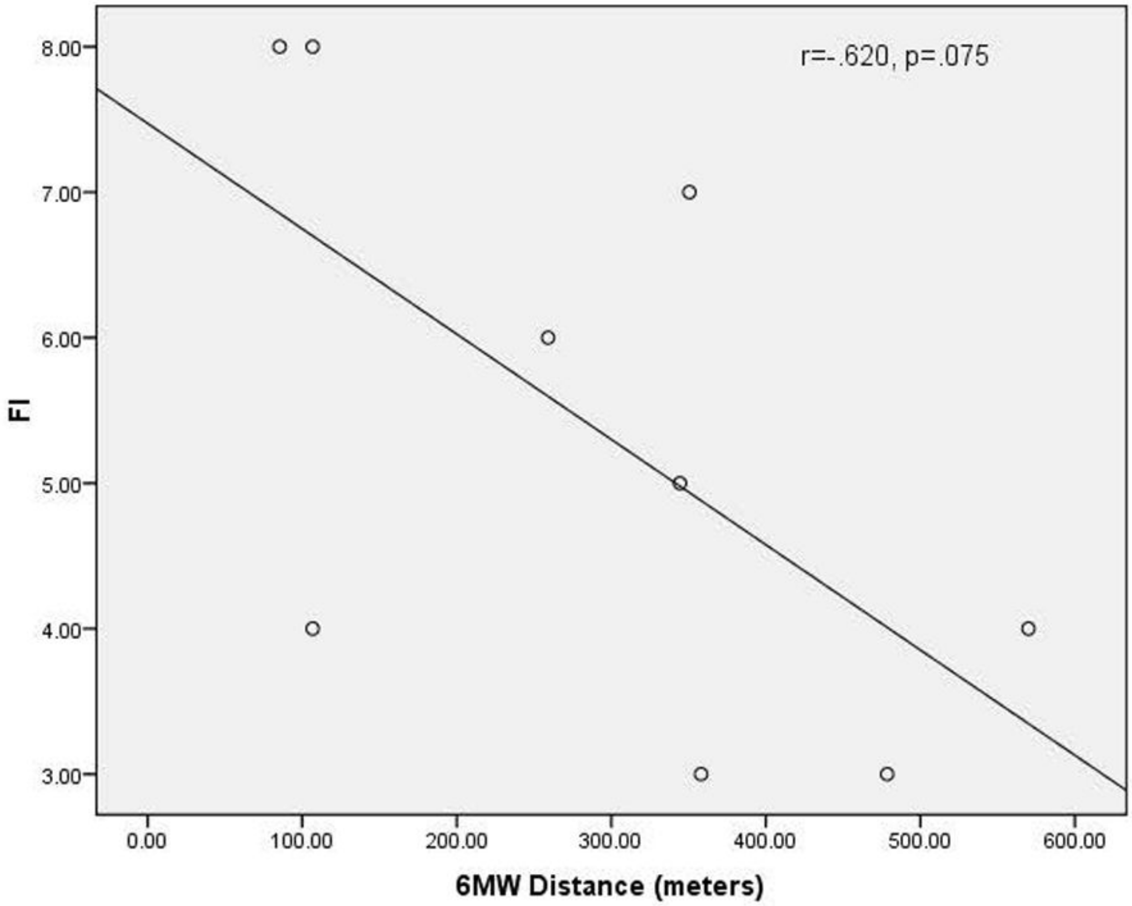

Figure 6.
Scatterplot illustrating the correlation between Six-Minute-Walk distance (6MWD) and Fatigue (FI).
6MWD – Six-Minute-Walk distance
FI – Fatigue Index score

Table 1

Descriptive statistics.

	Mean	S.D.	Range
Age (years)	56.8	11.8	47 – 73
Time Post-Stroke (months)	47.6	51.2	11 – 140
FI Score (1–10)	5.3	2.0	3 – 8
VO_{2Peak} (ml/kg/min)	12.91	3.70	7.8 – 19.6
FM Score (1–100)	79.4	32.8	19 – 119
6MW Distance (meters)	295.5	171.4	85 – 478

FI – Fatigue Index score

VO_{2Peak} - Peak oxygen uptake

FM – Fugl-Meyer score

6MW Distance – Six-Minute-Walk distance

Table 2

Individual Results of Peak Effort Graded Exercise Test using a Cycle Erogmeter

Subject	Predicted MHR or RER > 1.1	Reason to Terminate Test
1	Not Achieved	Joint Pain
2	Achieved	Test Completed
3	Achieved	Test Completed
4	Achieved	Test Completed
5	Not Achieved	Abnormal Muscle Tone
6	Not Achieved	Abnormal Muscle Tone
7	Not Achieved	Limited Range of Motion
8	Not Achieved	Limited Range of Motion
9	Not Achieved	Joint Pain