The Effects of Aerobic Exercise on Cognitive Function in Patients Post Stroke

Jessica Nehring

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The Effects of Aerobic Exercise on Cognitive Function in Patients Post Stroke

Abstract

**Background**: Approximately 795,000 people have a stroke each year, of those 470,000 survive with mild to severe cognitive dysfunction. Stroke is the second leading cause of cognitive impairment and dementia in the country and the leading cause of disability. Only 1% of the brain has to be effected by stroke to lead to cognitive impairment. Because of the large impact stroke has on cognitive function it is critical to find cost effective ways to improve cognitive function in surviving stroke patients. Aerobic exercise has been shown to cause vascular changes with enhancement of cerebral blood flow, increase in neurotrophin factors and change the regulation of neurotransmitter synthesis in healthy adults. The purpose of this systematic review is to determine if stroke patients have the same improvement in cognitive function with aerobic exercise as healthy adults.

**Method**: An exhaustive literature search was conducted in Medline-OVID, CINAHL and Web of Science using the search terms stroke, cognition and aerobic exercise. Scientific terms that were synonymous to these three terms, including, cognitive function, exercise and cerebral vascular accident were searched to prevent any relevant research articles to be overlooked. Articles were limited to English only and conducted on humans. Excluded were articles that included children, subjects with prior cognitive delay, dementia, psychiatric disorders and systematic reviews. There were no exclusions using GRADE criteria.

**Results**: Four articles met the inclusion and exclusion criteria for the systematic review. One study was a randomized control trial, one was a randomized crossover trial and two were quasi-experimental design. Three of the four articles found a positive correlation between aerobic exercise and cognitive function, while one study was unable to reveal an association between the two variables. All studies found a positive correlation with motor function and aerobic exercise.

**Conclusion**: This systematic review determined that there is a correlation between improved cognitive function and aerobic exercise. There were many limitations to each study and future research is warranted due to the impact that improved cognitive function will have on stroke patients.

**Keywords**: Stroke, Cognition, Aerobic Exercise
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Subject Categories
Medicine and Health Sciences

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The Effects of Aerobic Exercise on Cognitive Function
in Patients Post Stroke

Jesse Nehring

A Clinical Graduate Project Submitted to the Faculty of the
School of Physician Assistant Studies
Pacific University
Hillsboro, OR
For the Masters of Science Degree, August 11, 2012

Faculty Advisor: Mary Von, DHEd, MS, PA-C.
Clinical Graduate Project Coordinator: Annjanette Sommers MS, PA-C.
Biography

[Information redacted for privacy]
Background: Approximately 795,000 people have a stroke each year, of those 470,000 survive with mild to severe cognitive dysfunction. Stroke is the second leading cause of cognitive impairment and dementia in the country and the leading cause of disability. Only 1% of the brain has to be effected by stroke to lead to cognitive impairment. Because of the large impact stroke has on cognitive function it is critical to find cost effective ways to improve cognitive function in surviving stroke patients. Aerobic exercise has been shown to cause vascular changes with enhancement of cerebral blood flow, increase in neurotrophin factors and change the regulation of neurotransmitter synthesis in healthy adults. The purpose of this systematic review is to determine if stroke patients have the same improvement in cognitive function with aerobic exercise as healthy adults.

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Results: Four articles met the inclusion and exclusion criteria for the systematic review. One study was a randomized control trial, one was a randomized crossover trial and two were quasi-experimental design. Three of the four articles found a positive correlation between aerobic exercise and cognitive function, while one study was unable to reveal an association between the two variables. All studies found a positive correlation with motor function and aerobic exercise.

Conclusion: This systematic review determined that there is a correlation between improved cognitive function and aerobic exercise. There were many limitations to each study and future research is warranted due to the impact that improved cognitive function will have on stroke patients.

Keywords: Stroke, Cognition, Aerobic Exercise
Acknowledgements

[Information redacted for privacy]
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List of Abbreviations

BDNF…………………………………………………Brain-Derived Neurotrophic Factor
MMSE...........................................................................................Mini Mental Status Exam
ARAT......................................................................................Action Research Arm Test
SRTT.............................................................Serial Reaction Timed Task
WCST.........................................................Wisconsin Card Sorting Task
PGFM........................................................Predictive Grip Force Modulation
GUG.................................................Get Up and Go Test
BB..............................................................Berg Balance Scale
WWT..............................................................Walking While Talking Test
RAVLT..............................................................Rey Auditory Verbal Learning Test
6MWT..............................................................Six Minutes Walk Test
SIS..............................................................Stroke Impact Scale
The Effects of Aerobic Exercise on Cognitive Function in Patients Post Stroke

BACKGROUND

According to The National Stroke Association approximately 795,000 people have a stroke each year, of those 470,000 survive with mild to severe cognitive dysfunction.\(^1\)-\(^3\) Fatality rates from stroke have decreased dramatically as treatment has improved.\(^4\) It is predicted that about 14% of all stroke survivors\(^2\) achieve full recovery of physical function, but that 43%-78% have some impairment to cognitive functioning.\(^2\),\(^5\) Stroke is the second leading cause of cognitive impairment and dementia in the U.S and the leading cause of disability.\(^2\),\(^3\) Only 1% of the brain has to be effected by stroke to lead to cognitive impairment.\(^3\)

Cognitive function, as defined by the National Institute on Aging, includes all aspects of mental activity, learning, perceiving, decision making and memory.\(^6\) Common cognitive impairment seen in stroke patients includes difficulty paying attention, trouble executing complex tasks, trouble recalling or analyzing information and difficulty planning and organizing.\(^4\) These impairments can decrease a stroke patient’s ability to live independently.\(^7\) Given an overloaded and expensive medical system it is important to find cost effective ways to serve the population.

Aerobic exercise is an affordable form of rehabilitation. Research addressing aerobic exercise and its ability to improve cognitive function in healthy adults has shown promising results. There are various hypothesis regarding aerobic exercise and cognition. Vascular changes with enhancement of cerebral blood flow, increase in neurotrophin
factors and a change in the regulation of neurotransmitter synthesis are some of the areas of research.\textsuperscript{8,9,11}

Cerebral blood flow is improved by up to 30% with aerobic exercise.\textsuperscript{8} This increase leads to greater oxygen and glucose transport to the brain, removing biological waste products that can damage the brain and promotes angiogenesis, the formation of new blood vessels.\textsuperscript{8-10} During development the human brain forms new blood vessels with little resistance.\textsuperscript{8} As humans age this production of blood vessels decreases, leading to decreased blood flow to the brain. Angiogenesis is crucial in improving blood flow to brain tissue, especially in stroke patients with already compromised brain vessels.

Many studies that have been conducted on animals illustrate how aerobic exercise improves neurotrophin factors in the brain.\textsuperscript{8,12,13} Neurotrophin factors aide in protecting and altering the structure of neurons in the hippocampus, cortex and cerebellum during development and it is thought that they help protect the aging brain from damage and degeneration.\textsuperscript{8,12,14} Two specific neurotrophin factors that have been researched are brain-derived neurotrophic factor (BDNF), which is important in stabilizing and increasing the neurons related to cognitive function and, insulin-like growth factor I, that is involved in modulation of BDNF.\textsuperscript{8,10,15}

With more patients surviving strokes and attempting to live on their own it is important to find ways of improving their quality of life. The benefit of aerobic exercise on brain function in healthy adults has long been accepted and so, the issue becomes whether stroke patients would similarly benefit.

There has been a great deal of research involving aerobic exercise and its affect on cognitive function in healthy adults, including those with dementia and psychological
disorders. Not much emphasis has been placed on the role of aerobic exercise and its
effects on cognitive function in patients post stroke. The purpose of this study is to
conduct a systematic review of research articles regarding aerobic exercise and cognitive
function in stroke patients and to determine if there is a positive correlation.

METHODS

An exhaustive literature search was conducted in Medline-OVID, CINAHL and
Web of Science using the search terms stroke, cognition and aerobic exercise. Scientific
terms that were synonymous to these three terms, including, cognitive function, exercise
and cerebral vascular accident were searched to prevent any relevant research articles to
be overlooked.

Articles were limited to English only and to studies conducted on humans. Studies
included stroke patients, with no prior history of dementia or cognitive delay, aerobic
exercise as the therapy and measurements of cognitive function. Studies were not limited
by publication date.

Excluded were articles that used children, subjects with prior cognitive delay,
dementia or psychiatric disorders and other systematic reviews. There were no exclusions
using GRADE criteria.

The articles reviewed were critically appraised using the GRADE approach to
evaluate their validity. Each article was placed into a category, high, medium, low and
very low, based on the quality of evidence. Table I illustrates the GRADE system used.

RESULTS

Four studies\textsuperscript{5,7,10,12} met the inclusion/exclusion criteria discussed in the methods
section. One study\textsuperscript{7} was a randomized control trial, one was a randomized crossover trial
and two were quasi-experimental design. There were two studies\textsuperscript{5,12} that conveyed a positive connection between aerobic exercise and improved cognitive function. There was one study\textsuperscript{7} that was able to illustrate an increase in a select cognitive function, related to sensorimotor control, but could not show a positive association between aerobic exercise and executive functioning, a subset of cognition. And there was one study\textsuperscript{10} that showed no association between the two variables.

\textbf{Ploughman et al}

Ploughman et al\textsuperscript{10} was a randomized crossover trial that was one of the earliest studies exploring aerobic exercise and its impact on cognition and hemiplegic hand function in stroke patients.

Twenty-one participants met all inclusion criteria including the ability to walk, MMSE score above 24, only one documented stroke and some hand movement. The 21 subjects were randomized into two groups, an A-B or B-A testing sequence. Session A and B were tested seven to ten days apart. Session A and B were divided in two parts, with part 1 and part 2 separated by a 60 minute break. Session A, part 1 was conducted in the following order: grip strength, cognitive test, treatment intervention and a repeated cognitive test. Part 2-assessment order was grip strength, arm motor test, control intervention, grip strength and a repeated arm motor test. Interventions consisted of 20 minute sessions of either the treatment, walking on a body weight supported treadmill at 70% of heart rate reserve, or the control, reviewing home exercise programs with a physical therapist. The cognition assessments included Trial-Making Tests parts A and B, Symbol Digit Substitution Test and Paced Auditory Serial Addition Test. The Action
Research Arm Test (ARAT) measured the motor skill of the subject’s hemiplegic hand.\textsuperscript{10} (See Table III for assessment explanation)

Analysis of data showed no correlation between aerobic exercise and improvement on cognitive assessments. Cognitive assessments improved with no significant difference between the control group and treatment group after intervention (paired $t$ test ranged from $p=0.36-0.75$). On the Trial-Making Test parts A and B both the treatment and control groups had significant improvement ($p<0.01$). The arm motor test did illustrate an improvement in upper extremity performance after the treatment ($p<0.005$).\textsuperscript{10}

**Quaney et al**

Quaney et al\textsuperscript{7} was a randomized control pilot study that randomized patients into two different intervention groups, a stretching group and aerobic exercise group. There were 38 individuals, 21 women and 17 men that met the inclusion criteria and agreed to be part of a study. Inclusion criteria required patients to have MMSE greater than 23, stroke 6 months prior to enrollment and adequate cardiac function.\textsuperscript{7}

The treatment group consisted of resistive stationary bicycle training at 70% maximal heart rate for 45 minutes, 3 days per week for 2 months. The control group performed stretching exercises for 45 minutes, 3 days per week for 2 months. Prior to starting the interventions each participant had baseline assessments for cognition, motor function and $V_{O_{2}}$max (mL/kg/min). These assessments were repeated after 2 months to provide post results and were again repeated 2 months after the interventions had stopped, so retention results could be evaluated. Researchers performing the assessments were blinded to the participant’s group assignments.\textsuperscript{7}
The cognitive assessments were composed of the Wisconsin Card Sorting Task (WCST), Stroop Task and Trial-Making Task parts A and B. The motor assessments included Serial Reaction Timed Task (SRTT), Predictive Grip Force Modulation (PGFM), Fugl-Meyer Sensorimotor Test, Get up and Go Test (GUG) and Berg Balance Scale (BB). At baseline the control group and treatment group were similar except for the SRTT Repeated test ($p<0.04$). In the SRTT Repeat test the treatment group had slower response times compared to the control group ($p=0.40$). After intervention the aerobic group had improvement of $V_o_2$max at post ($p=0.04$) when compared to the stretching group. At retention, however the aerobic group did not maintain $V_o_2$max ($p<0.4$). No significant difference was noticed, post or retention, between groups during the WCST ($p<0.14$, $p<0.62$), Stroop Test ($p<0.128$, $p<0.661$) or Trial-Making Test ($p<0.280$, $p<0.207$). This study did show significant improvement on the post assessment, motor learning tests, in the aerobic group, specifically the PGFM Color Cues Assessment ($p<0.038$), GUG ($p=0.038$) and BB ($p=0.053$). Berg Balance Scale was the only assessment to maintain significance through the retention.7

**Rand et al**

Rand et al5 was a quasi-experimental design consisting of eleven individuals who had sustained a stroke at least 12 months prior to the study, had lower extremity hemiparesis, could walk three meters with or without a cane and a MMSE score greater than 24.

Each individual participated in an intervention that was composed of aerobic exercise for one hour twice a week and a recreational and leisure session for one hour per
week for six months. Cognitive and motor assessments were conducted at baseline, three months and six months on all individuals.\textsuperscript{5}

Digital Span Backwards Test, Digit symbol Test, Trial-Making Test part B, Walking While Talking Test (WWT), the Stroop Test and the Rey Auditory Verbal Learning Test (RAVLT) made up the cognitive assessments. The motor assessments were evaluated through isometric muscle knee strength with a dynamometer, self-selected gait speed over five meters, and walking endurance using the Six Minutes Walk Test (6MWT).\textsuperscript{5}

The results illustrated an improvement after six months on the Stroop Test ($p=0.02$), the RAVLT-Long Delay ($p=0.04$) and the Digit Span Backwards Test. After three months there was improvement in the WWT Test ($p=0.04$), but no significant improvement from three months to six months. Changes in the motor assessments showed a positive relationship between the treatment and motor function, with the improvements observed between baseline and three months in the knee strength assessment ($p=0.04$) and the gait speed ($p=0.02$). Only small improvements were made during the last three months. The 6MWT showed significant improvements during both the baseline to three-month interval ($p=0.005$) and three months to six months interval ($p=0.003$).\textsuperscript{5}

\textbf{Kluding et al}

Kluding et al\textsuperscript{12} was a quasi-experimental pilot study that recruited individuals who had a history of a single stroke six months prior to the study. Nine people were selected from a total of 24 that were originally screened. All nine individuals were able to
walk 30 feet or more without assistance, had a score greater than 23 on MMSE and they had no other cardiovascular or neurological deficits.¹²

These nine individuals participated in a pretest-posttest study design with an intervention between the testing sessions. The intervention was aerobic exercise and lower extremity strength for 1 hour, 3 days a week for a total of 12 weeks. The assessments entailed a primary assessment of cognitive function and a secondary assessment of aerobic fitness. The primary measurements included the Digital Span Backwards Task, the Flanker Test and the Memory Component of Stroke Impact Scale (SIS). The secondary measurements were composed of peak aerobic capacity, walking endurance, the Fugl-Meyer Test, self-selected gait speed and SIS total score and mobility subscale score.¹²

The results showed a significant relationship between aerobic fitness and cognitive improvement on the Flanker Incongruent Test was significant (p=0.02). There was moderately strong improvement on the other cognitive assessments in relationship to aerobic fitness, but no others reached statistical significance.¹²

**DISCUSSION**

Research studying the effects of aerobic exercise on cognitive function post stroke is in its infancy. To date there are very few studies that have focused on this question and within these studies there are many limitations. However, each study results in a discussion about how aerobic exercise can positively affect stroke patients throughout their recovery and improved cognitive function appears to be part of those results.

Ploughman et al¹⁰ found a significant change in cognitive function assessments between pretesting and posttesting in both treatment and control groups. Because of the
improvement in both groups, Ploughman et al\textsuperscript{10} was unable to determine that aerobic exercise was a definitive factor. Refinement of the aerobic exercise parameters and cognitive assessments is warranted to determine the impact of exercise on cognition in stroke patients. This study\textsuperscript{10} was able to determine that motor function improves significantly with aerobic exercise. This was illustrated with improvement on the ARAT assessment between the treatment and control groups.

Quaney et al\textsuperscript{7} expanded on the Ploughman et al\textsuperscript{10} study by developing a randomized control trial that focused on exercise and cognitive function specifically, and by studying the effects of aerobic exercise over a longer period of time. This study\textsuperscript{7} showed a slight improvement in cognitive function in the aerobic groups; however, the results were not statistically significant. Like Ploughman et al\textsuperscript{10}, Quaney et al\textsuperscript{7} illustrated a significant improvement in motor learning, but not specifically in executive function. The Quaney et al\textsuperscript{7} study also looked at the retention of functioning after the interventions had ceased. Motor skills requiring memory, sensory and predictive behavior, were retained after two months at a significantly higher rate in the aerobic treatment group compared to the control stretching group.\textsuperscript{7} All other assessments in cognitive and motor function resulted in a loss of attained function after a two month break.\textsuperscript{7} This lack of retention is an interesting dilemma in the treatment prognosis and may suggest that longer studies need to be executed to determine if acquired changes can be maintained.

Rand et al\textsuperscript{5} and Kluding et al\textsuperscript{12} attempted to expand on the first two studies by increasing the length of interventions. Both studies\textsuperscript{5,12} showed significant improvement in cognitive and motor function after three months of aerobic exercise compared to baseline. Rand et al\textsuperscript{5} also evaluated subjects after three months and six months of continuous
treatment. Interestingly, motor function continued to increase from baseline and the three month values, however cognitive function improvement appeared to plateau between the three and six month study period. The Rand et al\textsuperscript{5} study results from the three month and six month time period are similar to the results found within the Quaney et al\textsuperscript{7} retention group. Both studies appear to show an initial increase in cognitive and motor function after continuous exercise over a period of time, ranging between two and three months. However, after two months of no aerobic exercise or three months of exercise, cognitive function plateaued or declined while motor function continued to increase.\textsuperscript{5,7} These results beg the question as to whether or not aerobic activity can cause a long term improvement in cognitive function.

**Limitations**

Of the four articles reviewed, three were pilot studies. The limitation to a pilot study is that they tend to be small sample size, quasi-experiments that are used to evaluate the cost, time, adverse effects and effect prior to carrying out a large scale randomized control trial. Two quasi-experimental studies were pilot studies with no control group, making it difficult to determine if aerobic exercise was an effective treatment in improving cognitive function.

The Ploughman et al\textsuperscript{10} study was limited with the short time between assessments and intervention. Cardio-respiratory function was not measured so it cannot be known if the treatment group had improvement compared to the control group in aerobic fitness.

A large limiting factor of research was determining a definitive definition of cognitive function. Cognitive function incorporates many different motor, memory and sensory functions. There are a variety of tools used to assess cognitive function and none
that is used as a gold standard. The challenge in this review was comparing results based off of the different cognitive assessment tools used. Ultimately the results were summarized based on improvement of cognitive function and not individual cognitive assessments.

**Quality**

To assess the quality of each study the GRADE assessment tool\textsuperscript{16} was used. All the studies were downgraded due to the small sample size, which can lead to a compromise in validity. Quaney et al\textsuperscript{7} was initially graded at a high level, because it was a randomized control trial, although, as stated above it was downgraded due to sample size. This study maintained a moderate grade since it blinded researchers from the subject groups.\textsuperscript{7} Ploughman et al\textsuperscript{10} started as a moderate study, stronger than Kluding et al\textsuperscript{12} and Rand et al,\textsuperscript{5} because of its crossover design. It was downgraded due to small sample size and lack of concealment to the researchers.\textsuperscript{10} Kluding et al\textsuperscript{12} and Rand et al\textsuperscript{5} both started as very low quality studies because they were neither randomized control studies nor observational studies. They could not be upgraded due to small sample size, lack of concealment and lack of control groups.\textsuperscript{5,12}

According to the GRADE criteria future research is important because it may change the estimate of effect, however the estimate of effect is very uncertain. Further studies would have to be randomized control studies with large sample size and stroke patients with a variety of deficits and lesions in different areas of the brain.

**Recommendations for Future Studies**

In order to answer the clinical question whether aerobic exercise improves cognition in patients post stroke, more research is warranted. Large randomized control
trials should be conducted to better validate results. Studies should include large sample sizes, long duration of treatment, long follow up and standardized cognitive assessments. Researchers should possibly determine the most effective and accurate manner of quantifying cognitive function.

CONCLUSION

There is substantial research about how healthy adults have cognitive benefit from aerobic exercise. Studies also show the cognitive improvement that dementia patients have with aerobic exercise. Research comparing exercise and cognition in stroke patients is not sufficient, there are too few studies of high validity. It is possible that aerobic exercise does not play any role in helping improve cognitive function in stroke patients, but rather only improves complex motor function. This cannot be determined until large scale randomized control studies are performed. It is apparent that stroke patients can benefit from aerobic exercise and to what extent cognitive function improves still needs to be researched.
REFERENCES


<table>
<thead>
<tr>
<th>Design</th>
<th>Limitations to quality</th>
<th>Inconsistency</th>
<th>Indirectness</th>
<th>Imprecision</th>
<th>Other Considerations</th>
<th>No of Patients</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-Over Design</td>
<td>No serious limitations</td>
<td>No inconsistency</td>
<td>No areas of indirectness</td>
<td>Serious**</td>
<td>None</td>
<td>21 (crossover)</td>
<td>☘⊕ΟΟ Low</td>
</tr>
<tr>
<td>Randomized Control Trail</td>
<td>No limitations</td>
<td>No inconsistency</td>
<td>No areas of indirectness</td>
<td>Serious**</td>
<td>None</td>
<td>19</td>
<td>☘⊕⊕Ο Moderate</td>
</tr>
<tr>
<td>Quasi-Experimental Design</td>
<td>Serious*</td>
<td>No serious inconsistency</td>
<td>No areas of indirectness</td>
<td>Serious**</td>
<td>None</td>
<td>11</td>
<td>☘ΟΟΟ Very Low</td>
</tr>
<tr>
<td>Quasi-Experimental Design</td>
<td>Serious*</td>
<td>No serious inconsistency</td>
<td>No areas of indirectness</td>
<td>Serious**</td>
<td>None</td>
<td>9</td>
<td>☘ΟΟΟ Very Low</td>
</tr>
</tbody>
</table>

* Trial lacks randomization, concealment and control group
** Small sample size used in this trial
## TABLE II: Summary of Findings

The effects of aerobic exercise on cognitive function in patients post stroke

**Patient:** patients who have sustained a stroke  
**Intervention:** aerobic exercise  
**Outcome:** improve cognitive function

<table>
<thead>
<tr>
<th>Author/year</th>
<th>Participants/ Design</th>
<th>Time of Assessments</th>
<th>Cognitive Function</th>
<th>Motor Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughman et al(^10) (2008)</td>
<td>21 Cross-over trial</td>
<td>7-10 days</td>
<td>No significant improvement(^*)</td>
<td>Improvement after intervention</td>
</tr>
<tr>
<td>Quaney et al(^5) (2009)</td>
<td>19 Randomized Control Trial</td>
<td>2 months / 4 months</td>
<td>2 months: No significant improvement after intervention / 4 months: No retention</td>
<td>2 months: Improvement after intervention / 4 months: Retention maintained in intervention group</td>
</tr>
<tr>
<td>Rand et al(^5) (2010)</td>
<td>11 Quasi-experiment (Single group)</td>
<td>3 months / 6 months</td>
<td>3 months: Improvement / 6 months: No improvement(^**)</td>
<td>3 months: Improvement / 6 months: Improvement</td>
</tr>
<tr>
<td>Kluding et al(^12) (2011)</td>
<td>9 Quasi-experiment (pretest-posttest)</td>
<td>3 months</td>
<td>Improvement</td>
<td>Improvement</td>
</tr>
</tbody>
</table>

\(^*\) Ploughman et al\(^10\) saw improvement in cognitive assessments after both treatment and control interventions.  
\(^**\) There was no improvement in cognitive function seen between the three-month assessment and six month assessment.  

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# TABLE III: Summary of Assessment Tools

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini Mental Status Exam (MMSE)</td>
<td>Tool commonly used assess cognitive function. Five areas are measured: orientation to time and place, registration, attention and calculation, recall and language. Each area is scored for a maximum score of 30, with a score of 23 or less indicating impairment of cognition.</td>
</tr>
<tr>
<td>Action Research Arm Test (ARAT)</td>
<td>A tool used to measure the ability to grasp and release blocks and cylinders of various sizes. A score of 4 points is assigned to 19 different activities: grip, grasp, pinch and gross motor. A total of 57 points for ability to complete all tasks within time limit.</td>
</tr>
<tr>
<td>Serial Reaction Timed Task (SRTT)</td>
<td>Used to measure implicit learned skill or learned skill without conscious awareness. Participants view a 12 element sequence (random or repeated) of colored circles as they appear on a computer screen. They press a key in response to the sequence. Faster times occur if the participant learn or anticipates the sequence.</td>
</tr>
<tr>
<td>Wisconsin Card Sorting Task (WCST)</td>
<td>A tool that measures learning rules and resistance to preservation. There are “64 cards based on color, shape or number of items”. Participants sort the cards based on any of the above categories, without knowledge of the “rules”. Once they make several correct responses the rule changes. This requires participants to use working memory and be able to switch memories.</td>
</tr>
<tr>
<td>Predictive Grip Force Modulation (PGFM)</td>
<td>Assessment of conditional learning. Participants use memory to build a relationship between the color of weight and the predict grip force needed to lift the object.</td>
</tr>
<tr>
<td>Stoop</td>
<td>Tool used to assess “selective attention and resistance to interference”. Participants are shown a colored “X” and must state the color. Then they are shown the word of a color with the ink being a different color (word “red” written in blue ink).</td>
</tr>
<tr>
<td>Trial-Making Test Part A and B</td>
<td>Assessment of visuomotor scanning, working memory, cognitive flexibility and changing attention. Part A participants draw lines in ascending order of numbers. Part B participants draw lines in ascending order of numbers but must alternate with letters.</td>
</tr>
<tr>
<td>Digital Span Backwards Test</td>
<td>Measures working memory and complex attention. Participants are to repeat in reverse order a list of 7 pairs of random numbers after the number have been read aloud.</td>
</tr>
<tr>
<td>Rey Auditory Verbal Learning Test (RAVLT)</td>
<td>This test measures learning, delayed recall and long-term memory. There is a 15 word list learning task with 5 learning trials.</td>
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<tr>
<td>Walking While Talking Test (WWT)</td>
<td>Assess the ability to “divide and switch attention between 2 tasks during a 20-ft walk, turn and return”. Participants were timed as they listed consecutive and alternating letters of the alphabet while walking.</td>
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