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REVIEW ARTICLE (META-ANALYSIS)

Exercise Stress Testing After Stroke or Transient Ischemic Attack: A Scoping Review

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Abstract

Objective: To provide insight into exercise stress testing after stroke or transient ischemic attack (TIA) in terms of feasibility, safety, and protocols used.

Data Sources: PubMed, Embase, CINAHL, and Web of Science were searched for relevant studies published from inception to March 2014, and reference lists were hand searched.

Study Selection: To be included in the review, the articles needed to include participants diagnosed with stroke or TIA and have any form of test to assess exercise capacity.

Data Extraction: The scoping review methodology does not include critical appraisal of the literature but was chosen to reflect all aspects of exercise stress testing after stroke or TIA. Two reviewers performed screening for eligible studies independently, and 1 reviewer extracted the data.

Data Synthesis: We found a total of 112 studies involving 5008 participants describing symptom-limited (n = 103), submaximal (n = 9), and field (n = 6) exercise stress test protocols. Some of the studies reported on data from >1 protocol. Metabolic analysis was included in 87% of the studies involving symptom-limited tests, 40% of submaximal studies, and 29% of field tests. Monitoring of blood pressure, perceived exertion, and electrocardiographic responses was done in 54%, 42%, and 95% of all studies, respectively. A mere 10% of all studies reported on electrocardiographic abnormalities detected during testing. No serious adverse events were reported.

Conclusions: Symptom-limited exercise stress testing appears to be safe in patients with stroke or TIA and provides a more valid measure of exercise capacity than submaximal and field tests. The level of disability may compromise feasibility, and test modality should be chosen carefully to optimize test results.

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Aerobic fitness is one of the most important determinants of cardiovascular disease. Lack of fitness with its associated vascular risk factors[1] and physical inactivity accounts for as much as 28.5% of stroke population–attributable risk, second only to hypertension.[2] Evidence of low aerobic fitness in the stroke and transient ischemic attack (TIA) populations[3,4] underlines the need for the inclusion of aerobic exercise in rehabilitation for optimal stroke recovery and secondary prevention.[5]

It is generally recommended that an exercise stress test be conducted prior to engaging patients poststroke in vigorous dynamic exercise.[5] However, it is not self-evident that people poststroke can safely and effectively perform stress tests, given the lack of postural and motor control and high prevalence of cardiovascular disease characteristics of the stroke population.[6] On the other hand, given the high prevalence rates for silent cardiac ischemia[7] with a 5-year risk of >20% for myocardial infarction or sudden death,[8] it is prudent to screen for cardiovascular abnormalities prior to prescribing aerobic exercise. Further, because aerobic exercise is dose dependent, exercise testing provides an indication of the training intensity to optimize outcomes while limiting risk of adverse events.

The symptom-limited graded stress test with electrocardiographic monitoring involves having the patient perform aerobic exercise to exhaustion. During the test it is common to monitor

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oxygen and carbon dioxide in the exhaled breath (metabolic analysis). This metabolic analysis gives information on oxygen consumption and the relation between oxygen consumption and exhaled carbon dioxide (respiratory exchange ratio [RER]). The term symptom-limited refers to the test being terminated when symptoms such as volitional exhaustion or signs or cardiac ischemia occur. The test indicates the patient's physiological capacity in response to exercise in terms of peak heart rate, peak oxygen consumption (Vo_2peak), or peak metabolic equivalent tasks (1 metabolic equivalent task is the resting metabolic rate of 3.5mL/kg of oxygen per minute). However, the feasibility and risks of maximal stress testing in the stroke and TIA populations are not fully known.[5] Furthermore, concerns about lack of access to testing facilities and costs have led to questions regarding the need for symptom-limited screening tests. An alternative is the submaximal test where the patient performs an aerobic exercise to a target submaximal heart rate, and exercise time and peak workload are recorded.[9] Maximal oxygen consumption can then be predicted using different regression models or nomograms. Surrogates for bona fide stress tests include field tests (eg, 6-minute walk test [6MWT]) or use of various nonexercise-based equations of maximal heart rate.[1,10] Even more remote from formal testing is the use of indirect measures (eg, Borg rating of perceived exertion [RPE]), which use ordinal scales ranging from 6 to 20 or 0 to 10.[11]

Current uncertainties surrounding the feasibility and safety of exercise testing and the extent to which testing protocols follow accepted procedures prompted us to explore the available literature. To do so, we chose the scoping review methodology described by Arksey,[12] Levac,[13] and colleagues, which allows for a comprehensive overview of a broad topic without the restrictions of rigorous inclusion criteria regarding study design, number of included studies, or study quality. This approach does not set out to synthesize evidence but rather is helpful in the exploration of general concepts or, as in our case, a family of assessment tools. The aim of this scoping review was therefore to provide insight into exercise stress testing after stroke or TIA in terms of feasibility, safety, and protocols used. This information will help inform future clinical trials and professional education opportunities designed to enhance stroke rehabilitation outcomes.

Methods

Study selection

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses[14] guidelines were used as a reporting structure for this scoping review. We conducted electronic searches of the following 4 citation databases from inception to March 2014: PubMed, Embase, CINAHL, and Web of Science. A comprehensive search strategy for primary studies, developed by a librarian with expertise in comprehensive reviews (R.P.), used index and text word terms for the following concepts: (stroke OR TIA) AND exercise test. No language or year of publication limits were applied to the searches, but only studies in English was eligible. Animal studies were excluded. The full search strategies for each of the databases are available in the Supplemental Tables S1 through S5 (available online only at http://www.archives-pmr.org/). Reviews, editorials, opinion articles, or grey literature were not included in this review. The reference lists of the most recent included studies and existing reviews were also checked for additional studies.

List of abbreviations:

NIHSS	**National Institutes of Health Stroke Scale**
RER	**respiratory exchange ratio**
RPE	**rating of perceived exertion**
6MWT	**6-minute walk test**
TIA	**transient ischemic attack**
Vo_2peak	**peak oxygen consumption**

Eligibility criteria/study selection

Two independent reviewers screened the retrieved citations for eligibility. Studies were included if they met the following inclusion criteria: (1) participants were diagnosed with stroke or TIA and (2) any form of test was used to assess exercise capacity. Studies were excluded if they reported on $\geq$1 diagnosis without subgroup analysis. Two persons independently reviewed titles and abstracts (J.G. and a research assistant). The final screening for eligibility by reading the full articles was performed by one of the authors (J.G.). Any discrepancy was resolved through discussion among the authors, and in the event of an impasse, the final decision was made by one of the authors (M.M.-L.). A quality assessment of the included studies is not a part of the methodology of scoping reviews and was therefore not performed.

Data extraction and data analysis

Data from the individual studies were extracted (by J.G.). Stroke severity was defined as mild (National Institutes of Health Stroke Scale [NIHSS] score $\leq$5), moderate (NIHSS score 6−14), and severe (NIHSS score 15−31).[15] If the NIHSS score was not available, severity was estimated from other reported impairment measures (Modified Rankin Scale and the Scandinavian Stroke Scale,[15] Fugl-Meyer Motor Assessment,[16] Functional Ambulatory Category,[17] Orpington Prognostic Scale,[18] Chedoke-McMaster Stroke Assessment[19]) or by a statement from the authors. For purposes of this review, the time since stroke onset was defined as acute (<1mo), subacute (1−6mo), and chronic (>6mo).[20] For exercise trials, only the findings from baseline exercise tests were recorded. If the percentage of the predicted maximal heart rate was not provided in an article, we calculated it by using the group's mean documented maximal heart rate and the predicted maximal heart rate (220−*age*),[21] where *age* was the group's mean age. For this review we defined a maximal test as attainment of $\geq$95% of predicted maximal heart rate. Data from a random selection of 10% of the included studies were extracted by a second person (M.M.-L.) to validate this process.

Results

The review identified 112 studies meeting the inclusion criteria (fig 1), involving a total of 5008 participants. The study characteristics and participant demographics are shown in table 1. Most of the included studies involved people in the chronic poststroke period, and of the studies that reported the sex of participants, approximately two thirds were men. A broad spectrum of stroke severity was noted within most studies, but only 2 studies involving symptom-limited tests and no studies involving submaximal tests included mainly severely impaired stroke survivors, and they were therefore merged with the moderately severe group.