Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2013;94:1223-9

ORIGINAL ARTICLE

Does Exercise Tolerance Testing at 60 Days Poststroke Predict Rehabilitation Performance?

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Abstract

Objective: To assess the relationship between exercise tolerance test (ETT) performance at 6 weeks poststroke and subsequent performance in a treadmill and overground locomotor training program (LTP).

Design: Prospective cohort study.

Setting: Exercise testing laboratory in either a primary care hospital or outpatient clinic.

Participants: Community-dwelling individuals (N=469), 54.9±19.0 days poststroke, enrolled in the Locomotor Experience Applied Post-Stroke randomized controlled trial.

Interventions: Not applicable.

Main Outcome Measures: For participants randomly assigned to LTP, the number of sessions needed to attain the training goal of 20 minutes of treadmill stepping was determined. Regression analyses determined the contribution of ETT performance (cycling duration), age, and 6-minute walk test (6MWT) distance to attainment of the stepping duration goal.

Results: Age, 6MWT, and ETT performance individually accounted for 10.74%, 10.82%, and 10.76%, respectively, of the variance in the number of sessions needed to attain 20 minutes of stepping. When age and 6MWT were included in the model, the additional contribution of ETT performance was rendered nonsignificant (P=.150).

Conclusions: To the extent that ETT performance can be viewed as a measure of cardiovascular fitness rather than neurologic impairment, cardiovascular fitness at the time of the ETT did not make a significant unique contribution to the number of sessions needed to achieve 20 minutes of stepping. The 6MWT, which involves less intensive exercise than the ETT and therefore is likely to be predominantly affected by neurologic impairment and muscular condition, appeared to account for as much variance as the ETT.

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Numerous factors contribute to functional recovery after stroke. Age,[1-3] cognition,[4] stroke type,[2,5] motor impairment,[1-3,6] and hemisensory loss[7,8] all impact recovery. Another less overt potential contributor to rehabilitation response is tolerance for exercise. Practice intensity and repetition are factors known to improve rehabilitation outcomes and require exercise capacity.[9] Comorbid cardiovascular conditions, present in 75% of poststroke patients, represent the leading cause of death in stroke survivors. However, formal exercise testing before the initiation of rehabilitation is not standard of care.[10] Exercise tolerance evaluation before rehabilitation may be valuable in creating effective exercise programs, but its role in informing rehabilitation performance has not been assessed.

Supported by the National Institute of Neurological Disorders and Stroke and the National Center for Medical Rehabilitation Research (grant no. RO1 NS050506).

No commercial party having a direct financial interest in the results of the research supporting this article has conferred or will confer a benefit on the authors or on any organization with which the authors are associated.

Clinical Trial Registration Number: NCT0024391.

0003-9993/13/$36 - see front matter © 2013 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2013.01.031

The randomized controlled trial, Locomotor Experience Applied Post-Stroke (LEAPS),[11,12] compared a locomotor training program (LTP) that included stepping on a treadmill with partial body weight support (BWS), followed by overground walking training, to an impairment-based home exercise program (HEP) of strength and balance, for improving the functional level of walking.[13,14] The goal of each LTP session was to walk at .89m/s for a total of 20 minutes of stepping. Given the prevalence of comorbid cardiovascular disease and the rigor of LTP for individuals just 2 months poststroke, an exercise tolerance test (ETT) was requisite to assess exercise capacity and confirm the ability to safely participate in progressive LTP. We evaluated the relationship between ETT performance and participants' subsequent LTP performance. We posited that higher ETT performance (longer cycling duration) would be associated with greater locomotor training readiness (number of sessions needed to attain ≥20min of stepping on the treadmill).

Methods

Participants

The LEAPS trial was approved by the institutional review board at each trial site, and written informed consent was obtained. Before trial randomization participants passed a chart review and physical and cognitive screen 5 to 45 days poststroke. Participants proceeded to an ETT as the final stage of screening.[11,12]

Inclusion criteria included stroke within the previous 45 days, residual paresis, ability to walk 3.0m with 1-person assist, ability to follow a 3-step command, and walking speed <0.8m/s. Given the presence of comorbid cardiovascular disease and the potential rigor of the intervention, there were extensive exclusion criteria specific to cardiovascular and pulmonary conditions: myocardial infarction or heart surgery within the previous 3 months; history of congestive heart failure; serious and/or unstable cardiac arrhythmias; hypertrophic cardiomyopathy; severe aortic stenosis; angina or dyspnea at rest or during activities of daily living; class 3 or 4 heart failure according to the New York Heart Association; coronary artery bypass grafts or valve replacement within the previous 3 months if participation was not approved by a cardiothoracic surgeon and either a cardiologist or primary care physician; history of serious chronic obstructive pulmonary disease or use of supplemental oxygen; history of pulmonary embolism within 6 months; and severe hypertension with systolic blood pressure (SBP) >200mmHg and diastolic blood pressure (DBP) >110mmHg, not reduced to ≤180/100mmHg with medical therapy.[11]

List of abbreviations:

APMHR	**age-predicted maximum heart rate**
BWS	**body weight support**
DBP	**diastolic blood pressure**
ECG	**electrocardiography**
e-LTP	**early locomotor training program**
ETT	**exercise tolerance test**
HEP	**home exercise program**
LEAPS	**Locomotor Experience Applied Post-Stroke**
LEFM-M	**Lower Extremity Fugl-Meyer−Motor Assessment**
l-LTP	**late locomotor training program**
LTP	**locomotor training program**
MET	**metabolic equivalent**
RPE	**rate of perceived exertion**
RPP	**rate-pressure product**
SBP	**systolic blood pressure**
6MWT	**6-minute walk test**
10MWT	**10-meter walk test**
$\dot{V}O_2$max	**maximum oxygen consumption**

Procedure

Exercise tolerance test

After completion of a screening questionnaire to assess cardiac medical history, cardiac disease risk factors, family cardiac history, and current medications, a physical examination by a cardiologist determined ETT eligibility. If contraindicated, participants were referred to their primary care physician and excluded from the trial.

The ETT, using a previously established bicycle[a] ergometry protocol,[15,16] was conducted in cardiologist-supervised assessment laboratories with trial staff providing standardized instructions. Electrocardiography (ECG) electrodes (n=10) in the standard configuration monitored cardiac status. ECG, blood pressure, and heart rate were recorded for 1 minute supine, followed by 1 minute sitting. Participants sat on the bicycle or behind it in a chair (if poor sitting balance) with their hemiparetic leg secured to the ergometer with a boot and their hemiparetic arm to the handle bar with a glove support. Vital signs were recorded for an additional 2 minutes. Requisite parameters to commence were as follows: DBP ≤100mmHg, SBP ≤180mmHg, and heart rate ≤100 beats/min. Participants pedaled 40 to 60rpm with 10W/min (from 0W) power increase. Heart rate from the ECG tracing was recorded every minute, and blood pressure readings, obtained manually, were recorded every 2 minutes. Participants reported their rate of perceived exertion (RPE), using the Borg Scale,[17] every minute.

Target ETT endpoint was 90% age-predicted maximum heart rate (APMHR; 220−age). For those receiving beta-blockers, the target endpoint was RPE >18. ETT was terminated before attaining these target endpoints if 40rpm could not be maintained or if the participant experienced the onset of preestablished limiting symptoms. At test termination, a final RPE score was recorded, resistance was removed, and pedaling continued at 40rpm for 1 minute. Blood pressure and heart rate were recorded 1, 3, and 5 minutes posttest or until vital signs returned to pretest values. The cardiologist provided written documentation for ETT termination and determined trial eligibility. If a preestablished ETT failure point occurred, the participant was managed medically, referred for follow-up care, and excluded from the trial.

ETT outcome measures

Percentage APMHR and absolute rate-pressure product (RPP) at peak exercise intensity (peak RPP) described maximal exercise performance. Percentage APMHR was chosen as a primary outcome measure because of its relation to maximum oxygen consumption ($\dot{V}O_2$max).[18] RPP, an index of myocardial oxygen consumption, was calculated at rest and at maximal exercise according to the following formula: RPP = (heart rate × SBP)/100.[19] The percentage increase in RPP from rest to maximal exercise (%RPP) was also calculated. ETT performance was defined as cycling duration from the initial