Profile of Patients at Admission into an Inpatient Stroke Rehabilitation Programme: Cardiorespiratory Fitness and Functional Characteristics

Dina Brooks, Ada Tang, Kathryn M. Sibley, and William E. McIlroy

ABSTRACT

Purpose: The purposes of this study were to characterize the cardiorespiratory capacity of individuals on admission to inpatient rehabilitation following stroke and to examine the relationship between measures of cardiorespiratory capacity and standard indices of neurological deficit and functional status.

Methods: We recruited 45 patients within the first 10 days of admission to rehabilitation. We performed measures of aerobic fitness ($\text{VO}_{2\text{peak}}$), functional status (Functional Independence Measure [FIM] and Clinical Outcomes Variable Score [COVS]), and neurological deficit (National Institutes of Health Stroke Scale [NIHSS] and Chedoke-McMaster Stroke Assessment scale [CMSA]).

Results: Nineteen women and 26 men with a mean (SD) age of 65.2 (14.5) years were admitted to rehabilitation 16.2 (11.9) (minimum 3, maximum 62) days post-stroke. Average $\text{VO}_{2\text{peak}}$ was less than half the value expected in age-matched healthy individuals at 11.1 (3.1) ml/kg/min. The associations between $\text{VO}_{2\text{peak}}$ and FIM, NIHSS, and COVS were weak ($r=0.25$, -0.12 , and 0.26 respectively, $p=0.12$, 0.46 , and 0.10 respectively). There were no differences in $\text{VO}_{2\text{peak}}$ in higher-functioning individuals with CMSA leg scores of 5 and 6 compared to lower-functioning individuals with scores of 3 and 4 ($p=0.30$).

Conclusion: Cardiorespiratory capacity is extremely low in individuals during the first 3 months after stroke. Alternative measures of functional or clinical status do not adequately reflect this cardiorespiratory state; thus, routine measurement of cardiorespiratory capacity should be considered, along with a risk-factor profile.

Key Words: exercise, fitness, rehabilitation, stroke

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RÉSUMÉ

Objectif : Cette étude a pour objectif de caractériser la capacité cardiorespiratoire des individus lors de l'admission de patients hospitalisés qui ont subi un accident vasculaire cérébral et d'examiner le lien entre les mesures de la capacité respiratoire et les indices standards de déficit neurologique et des capacités fonctionnelles.

Méthodes : Nous avons recruté 45 patients lors des dix premiers jours de l'admission à la réadaptation. Nous avons effectué des mesures de la capacité aérobique ($\text{VO}_{2\text{peak}}$), des capacités fonctionnelles (système de mesure d'autonomie fonctionnelle [SMAF], du score variable des résultats cliniques (Clinical Outcomes Variable Score [COVS]) et du déficit neurologique (National Institutes of Health Stroke Scale [NIHSS] et l'évaluation Chedoke-McMaster de l'AVC [ECMA]).

Résultats : Dix-neuf femmes et 26 hommes ayant une moyenne d'âge de 65,2 (14,5) ans ont été admis en réadaptation 16,2 (11,9) (minimum 3, maximum 62) jours après un accident vasculaire cérébral. Le $\text{VO}_{2\text{peak}}$ moyen était moins que la moitié des valeurs attendues chez des individus en santé du même âge à 11,0 (3,1) ml/kg min. Les associations entre le $\text{VO}_{2\text{peak}}$ et SMAF, NIHSS et COVS étaient faibles ($r=0,25$; $-0,12$ et $0,26$, respectivement, $p=0,12$, $0,46$ et $0,10$ respectivement). Le $\text{VO}_{2\text{peak}}$ ne présentait aucune différence entre chez les individus aux capacités supérieures

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dont les scores CMSA pour les jambes étaient de 5 et 6 en comparaison des individus aux capacités réduites ayant des scores de 3 et 4 ($p=0,30$). *Conclusion*: La capacité cardiorespiratoire est extrêmement faible chez les individus durant les trois premiers mois suivant un accident cérébral vasculaire. D'autres mesures de capacités fonctionnelles ou cliniques ne reflètent pas adéquatement ces capacités cardiorespiratoires. Par conséquent, les mesures régulières de capacités cardiorespiratoires devraient être prises en compte avec un profil de facteur de risque.

Mots clés: accident vasculaire cérébral, exercice, mise en forme, réadaptation

INTRODUCTION

The incidence of first stroke ranges from 81 to 150 per 100,000 persons.¹ When age is factored in, the incidence doubles for each decade after age 55, with more than 70% of all strokes occurring among individuals over age 65.² While mortality rates have been declining since the 1950s,³ thanks in part to advances in acute stroke treatment and early symptom recognition, the prevalence of stroke has remained the same^{4,5} or even increased.^{4,5} With more individuals surviving stroke, there is increasing prevalence of associated deficits that currently make stroke the leading cause of neurological disability in adults.^{6,7}

While stroke is commonly considered a neurological disorder, as evidenced by the primary focus on neurobehavioural symptoms, it is principally a result of cardiovascular disease. Though attention is paid to minimizing neurological disability after stroke, a major effort should be directed to improving cardiovascular health and reducing the risk of secondary vascular events. As many as 35% of persons who have survived stroke are likely to sustain a second stroke within 5 years of the initial event, of which one-quarter are likely to be fatal.⁸ Even individuals with mild stroke with no persisting neurological deficits, or those with a history of transient ischemic attack (TIA), have a higher risk of future stroke.⁸

Aerobic capacity is an important post-stroke measurement because it serves as an index of an individual's cardiorespiratory capacity, which is linked to risk of subsequent cardiovascular events and the capacity to engage in activities of daily life. A summary document from the Stroke Council of the American Heart Foundation outlines a list of risk factors for stroke⁹ and recognizes physical inactivity as a significant factor. If smoking, inactivity, and obesity were avoided, an estimated 79% of all strokes could be prevented.¹⁰ The role of physical activity in determining stroke risk is believed to be mediated through several well-recognized modifiable risk factors, including hypertension, glucose tolerance, serum lipids, and body weight. In addition, low levels of aerobic capacity have a negative impact on the activity patterns of individuals after stroke, limiting their therapeutic exercise tolerance and reducing the total amount and intensity of activity. In fact, 60% of persons who have survived stroke report challenges with walking and, as a result, often report a limit in their whole-body

activities.^{11,12} This limitation leads to a further reduction in cardiorespiratory fitness and an increased risk of vascular events.

Six months post-stroke, exercise capacity has been estimated to be between 55% and 75% of values expected for healthy people of similar age, sex, and physical activity status.^{13–15} Although considerable information is available about individuals long after stroke,^{13–15} there is relatively little information characterizing individuals in the early post-stroke period.^{14,16,17} This subacute period, up to 3 months post-stroke, is important because specific information about cardiorespiratory status can affect the post-stroke treatment strategy. Thus, our goal in the present study was to characterize cardiorespiratory capacity among individuals admitted to inpatient rehabilitation soon after stroke. To determine the extent to which cardiorespiratory capacity could be inferred from conventional indices of neurological or functional status, we examined the relationships between measures of cardiorespiratory capacity and standard clinical indices.

METHODS

The research ethics boards at the University of Toronto and the Toronto Rehabilitation Institute approved the study. All study participants provided written informed consent. This study was part of a larger trial examining the effect of aerobic exercise in the subacute stroke population.

Participants

We recruited 45 individuals with stroke from the Toronto Rehabilitation Institute. Inclusion criteria were that participants (1) be able to provide informed consent, (2) be able to understand the evaluation procedures, (3) have a Chedoke-McMaster Stroke Assessment (CMSA)¹⁸ leg impairment score greater than 2 (where active voluntary movement is present without facilitation), and (4) be less than 3 months post-stroke upon entry into the study. Exclusion criteria were the presence of contraindications to maximal exercise testing, as outlined by the American College of Sports Medicine (ACSM),¹⁹ or of musculoskeletal impairments or pain that would limit the individual's ability to perform the tests.

Measures

We recorded participant characteristics, demographic information, lesion type and location, time post-stroke, medications, comorbidities, and risk factors. We performed measures of aerobic fitness, functional status, and neurological deficit during the first 10 days of admission to inpatient rehabilitation. Inpatient rehabilitation consisted of physical, occupational, and speech and language therapy 2 to 5 days per week and lasted an average of 4 to 5 weeks.

Measures of Neurological Deficit

Chedoke-McMaster Stroke Assessment (CMSA)

In the CMSA impairment inventory, a score of 1 indicates flaccid paralysis, 3 describes a limb whose spasticity and weakness are marked, and 7, the maximum score, indicates normal limb function, including complex movement patterns with appropriate muscle timing and coordination.¹⁸ Although the CMSA includes six impairment dimensions—shoulder pain, postural control, arm, hand, leg, and foot motor recovery—only the leg scores were used when comparing $\text{VO}_{2\text{peak}}$ in the present study.

National Institute of Health Stroke Scale (NIHSS)

The NIHSS is a measure of neurological deficit that primarily measures motor and sensory impairment, aphasia, apraxia, and neglect.^{20–22} The 15-item assessment includes aspects such as level of consciousness, sensation, speech, visual fields, motor strength, facial symmetry, neglect, and communication. Scoring of each item ranges from 0 to 2, 3, or 4, depending upon the item in question. A score of 0 indicates no neurological deficit for that item.

Measures of Functional Status

Functional Independence Measure (FIM)

This measure has a maximum score of 126 and consists of 23 items in 7 areas of function: self-care, sphincter control, mobility, locomotion, communication, social adjustment/cooperation, and cognition/problem solving.²³ A higher score reflects a higher level of independence. Different components of the FIM were completed by various members of the health care team based on observed performance within 48 hours of admission.

Clinical Outcomes Variable Score (COVS)

The COVS evaluates patient mobility and consists of 13 items assessing activities including rolling, transfers, ambulation velocity, and endurance. Each item is scored on a 7-point scale; accordingly, the total score can vary from 13 to 91, with higher scores representing greater functional levels. Although this measure is completed

routinely as part of the stroke rehabilitation programme, there is limited literature on the measurement properties of this scale.²⁴

Measure of Cardiorespiratory Capacity

A semi-recumbent cycle ergometer (Biodex Medical Systems, Shirley, NY) was used to assess aerobic fitness during a maximal exercise test. We secured the foot on the participant's hemiparetic side to the pedal if needed. The ramp protocol included a 2-minute warm up at 10 watts with a target cadence of 50 revolutions per minute, followed by progressive 5-watt increases in power output every minute. This protocol was designed specifically for this study, considering issues with strength and fatigability post-stroke and anticipating a total test time of 8 to 10 minutes.²⁶ Participants were familiarized with the testing protocol with at least one practice trial prior to the actual test. Respiratory gas exchange was measured with a metabolic cart (AEI Technologies, Pittsburgh, PA), and averages were calculated at 30-second intervals. Blood pressure (BP; SunTech Medical, Morrisville, NC), heart rate (Polar Electro Inc., Woodbury, NY), and rating of perceived exertion (RPE, 0–10 Borg scale) were monitored throughout. In addition, we monitored a five-lead electrocardiogram (Remco Italia, Milan, Italy). The test was terminated according to ACSM guidelines¹⁹ or if the participant was unable to maintain the required pedalling rate despite encouragement. Peak oxygen uptake ($\text{VO}_{2\text{peak}}$), peak heart rate, and peak work rate were determined as the highest values reached during the exercise test. In addition, the respiratory exchange ratio at test termination and end systolic and diastolic pressures were recorded.

We have previously demonstrated the feasibility of this symptom-limited, maximal exercise testing protocol with individuals post-stroke.²⁶ We have also shown that individuals in early stages post-stroke cannot consistently achieve criteria for maximal VO_2 . Three-quarters of the sample ($n=35$) met at least one criterion for maximal VO_2 , mainly a plateau in VO_2 at the end of the test, respiratory exchange ratio greater than 1, or heart rate within 10 beats of age-predicted maximal heart rate. However, only one participant was able to achieve all three criteria. Given these limitations in the traditionally used criteria, $\text{VO}_{2\text{peak}}$ may be used as the best estimate of aerobic capacity.

Data Analysis

Descriptive statistics were calculated for all measures. Correlation analyses were performed to determine the relationships between $\text{VO}_{2\text{peak}}$ and NIHSS, $\text{VO}_{2\text{peak}}$ and FIM, and $\text{VO}_{2\text{peak}}$ and COVS. A one-way analysis of variance (ANOVA) was performed to determine the

difference between VO_2peak and levels of leg impairment. Statistical significance was set at $p < 0.05$.

RESULTS

Patient Characteristics

Participant characteristics are presented in Table 1. Mean (SD) age was 65.2 (4.5) years (minimum 19, maximum 90), with a total of 19 women and 26 men and a mean body mass index of 26.7 (6.1) kg/m^2 (minimum 19, maximum 37.4). Participants were admitted to rehabilitation 16.2 (11.9) (minimum 3, maximum 62) days post-stroke. Fourteen participants did not require any gait aids for walking, 7 used a single-point cane, and 13 used a 2-wheeled walker or rollator. Ten patients were

non-ambulatory at the time of admission and testing. Most had at least one risk factor for stroke, including hypertension ($n=28$), high cholesterol ($n=14$), coronary artery disease ($n=11$), and atrial fibrillation ($n=5$); 15 individuals had a positive smoking history. Five patients in the sample had a history of a previous stroke, and 5 had a history of a previous transient ischemic attack.

Aerobic Fitness, Neurological Deficit, and Functional Status

Individual values for measures of aerobic fitness, neurological deficit, and functional status in this sample are presented in Table 2. Note that the mean (SD) VO_2peak was 11.1 $\text{ml}/\text{kg}/\text{min}$ (3.1) (minimum 5.2, maximum 17.5). Figure 1 presents the distribution of VO_2peak , with the greatest frequency at 9.1–10 $\text{ml}/\text{kg}/\text{min}$ and

Table 1 Characteristics of Participants

Participant	Age	Gender	Location	Side	Type	Medications
1	87	F	MCA	L	I	
2	50	F	MCA	L	I	b-block, ACE
3	81	M	Pons	L	H	n/a
4	68	M	Corona radiata—internal capsule	R	H	ACE
5	76	F	Lacuna	R	I	ACE
6	49	M	Internal capsule	L	H	ACE
7	62	M	External capsule—basal ganglia	R	I	
8	57	F	Pons	R	I	
9	58	M	MCA	L	I	
10	78	M	Cerebellum	L	I	
11	66	F	Posterior temporal, multiple infarcts	L	I	b-block, ACE
12	74	M	Posterior putamen	R	I	ACE
13	70	F	Frontal lobe	R	I	b-block, ACE
14	55	M	MCA	R	I	ACE
15	69	M	Lacuna—caudate nucleus	R	I	ACE
16	49	M	MCA	R	I	
17	73	M	Lacuna	L	I	ACE
18	71	F	MCA	L	I	
19	72	M	Lacuna—internal capsule	R	I	b-block
20	53	M	Internal capsule	R	H	ACE
21	63	F	Posterior medial lentiform	L	H	
22	87	M	Thalamic hypodensity	R	I	
23	50	F	Internal capsule	L	I	
24	74	F	Internal capsule	L	I	ACE
25	67	M	Midbrain, pons	R	I	b-block
26	19	F	Internal capsule	L	I	
27	57	M	MCA	R	I	ACE
28	53	F	ACA	L	I	
29	47	M	Cerebellum	L	I	b-block, ACE
30	90	F	Unknown	R	Unclear	
31	64	F	Insular cortex	L	I	ACE
32	81	M	SAH with intraventricular extension	R	H	ACE
33	49	M	Lacuna—pons	R	I	
34	80	M	Lacuna	L	I	ACE
35	66	M	Thalamic	R	H	b-block, ACE
36	77	M	Thalamic	R	H	ACE
37	42	F	MCA	L	I	
38	77	M	Posterior putamen-basal ganglia	L	I	
39	60	F	Cavernoma-brainstem	N/A	H	
40	87	F	PCA—basal ganglia and pons	L	I	ACE
41	79	F	Periventricular, especially frontal horn	R	I	ACE
42	52	M	Thalamic	R	H	b-block, ACE
43	72	F	Frontoparietal	R	I	b-block
44	58	M	Lacuna-central pons	R	I	ACE
45	64	M	MCA	R	I	ACE

b-block = beta-blockers; ACE = ACE inhibitors; L = left; R = right; I = ischemic; H = hemorrhagic; MCA = middle cerebral artery; ACA = anterior cerebral artery; PCA = posterior cerebral artery; SAH = subarachnoid haemorrhage

Table 2 Measures of Neurological Deficits, Functional Status, and Aerobic Fitness

Participant	Measures of Aerobic Fitness					Functional/Neurological Status					
	MaxWR (watts)	HR max (beats/min)	VO ₂ peak (ml/kg ¹ min ⁻¹)	Max RPE	End RER	ESP (mmHg)	EDP (mmHg)	FIM	COVS	NIHSS	CMSA leg/foot
1	n/a	57	5.2	10	0.89	130	53	82	66	6	5 / 4
2	35	155	10.6	8	0.95	135	88	92	56	2	5 / 4
3	40	91	12.3	7	1	161	74	110	70	3	6 / 5
4	25	101	9.5	5	0.99	187	91	94	63	4	4 / 5
5	30	98	9.2	7	1.09	205	102	96	63	3	5 / 4
6	45	113	13.8	7	1.02	159	93	100	80	3	6 / 4
7	85	145	15	4	1.02	178	74	95	70	1	6 / 5
8	60	140	12.3	6.5	1.22	170	69	113	84	1	5 / 5
9	45	118	12.3	10	1.08	216	92	77	59	7	5 / 4
10	40	76	11.8	5	0.92	151	80	79	63	1	6 / 5
11	20	66	6.7	3	0.87	150	72	83	79	3	6 / 5
12	25	98	11.9	9	1.15	195	128	58	31	9	3 / 2
13	40	78	9.2	7	0.99	180	75	89	60	4	4 / 4
14	60	126	10.9	10	1.08	200	67	104	87	6	6 / 6
15	60	129	12	8.5	1	238	115	72	54	11	4 / 4
16	35	120	8.6	10	0.95	150	110	44	28	8	3 / 2
17	55	126	12.1	5	1.03	190	116	74	53	7	3 / 3
18	30	112	11.6	2	1.12	163	101	79	36	8	3 / 2
19	35	78	9.5	1	0.86	172	97	60	48	5	3 / 3
20	65	107	12.6	7	0.95	203	90	77	58	3	4 / 4
21	35	105	10.1	7	0.74	127	96	n/a	60	5	6 / 5
22	55	86	14.1	10	1.08	183	82	80	63	5	5 / 5
23	65	133	17.5	10	0.76	177	103	100	78	3	5 / 4
24	25	119	9.4	4	1.08	193	85	89	53	3	3 / 2
25	50	85	10.1	9	0.84	140	90	96	69	5	4 / 3
26	40	117	8.2	5	0.95	140	93	97	68	3	6 / 5
27	70	123	14	7	1.09	154	86	57	35	7	3 / 1
28	50	145	13	9	1.12	172	95	114	84	2	4 / 5
29	65	119	13.7	10	1.03	155	83	111	76	4	6 / 5
30	15	98	8.8	3	0.99	165	83	68	53	3	4 / 3
31	55	105	15	5	1.04	186	106	82	72	5	6 / 5
32	60	90	11.5	10	1.03	136	80	96	66	4	4 / 4
33	50	107	9.8	5	0.99	209	130	61	38	5	4 / 3
34	25	101	8.5	7	1.13	n/a	n/a	66	36	5	3 / 3
35	35	67	9.6	3	0.98	179	90	67	40	5	3 / 2
36	35	114	9.3	7	0.91	159	75	73	51	8	4 / 3
37	35	126	12.7	3	0.96	131	77	101	80	2	6 / 6
38	20	83	8.6	7	0.87	168	76	81	81	3	4 / 4
39	40	133	12.8	10	1.05	159	82	78	57	7	3 / 2
40	20	100	6.6	5	1.01	123	81	72	32	n/a	3 / 1
41	55	110	11.3	7	1.04	158	74	90	73	n/a	6 / 6
42	65	97	16.6	n/a	1.13	130	100	75	64	3	6 / 5
43	35	92	9.4	1.5	0.94	165	74	90	83	5	5 / 4
44	75	126	n/a	10	n/a	169	86	108	88	7	5 / 5
45	65	120	13.2	5	0.93	190	115	110	81	9	6 / 4
Mean±SD	44±18	107±23	11.1±3.1	6.7±2.8	1.00±0.18	168±36	89±21	84±21	62±17	5±2	

Max WR = maximum work rate; HR max = maximum heart rate; VO₂peak = peak oxygen consumption; Max RPE = maximum rating of perceived exertion; End RER = end respiratory exchange ratio; ESP = end systolic blood pressure; EDP = end diastolic blood pressure; FIM = functional independence measure; COVS = Clinical Outcomes Variable Score; NIHSS = National Institutes of Health Stroke Scale; CMSA = Chedoke-McMaster Stroke Assessment Scale

Subject 1 has no max WR value because they could not maintain 50 rpm required to do the max test. Even the warm-up was completed at around 20 rpm.

Subject 21 does not have a FIM value recorded because this score is normally obtained from the patient chart but for some reason was not completed for this patient.

Subjects 40 and 41 did not complete the NIHSS test because no clinician certified to administer the test was available at the time of testing.

Subject 42 does not have an RPE recorded for the end of the test because the test was ended abruptly due to leg pain and the last rating was not taken.

Subject 44 does not have an RER or VO₂ value because of technical problems with the calibration of the gas analyzer machine.

12.1–13 ml/kg/min. The primary reasons for termination of exercise were lower-extremity fatigue ($n=14$), inability to maintain target pedalling cadence at 50 RPM ($n=8$), difficulty breathing ($n=6$), and general fatigue ($n=4$).

The mean (SD) index of neurological status (NIHSS) was 5.2 (2.0) (minimum 1, maximum 11). The mean for indices of functional independence (FIM) was 84 (21) (minimum 44, maximum 114), and mobility (COVS)

was 62 (17) (minimum 28, maximum 88). The measure of leg impairment (CMSA) varied from 3 to 6 for the leg and from 1 to 6 for the foot.

Relationships between Measures

The associations between VO₂peak and FIM, NIHSS, and COVS were weak ($r=0.25$, -0.12 , and 0.26

Figure 1 Histogram of VO₂ peak scores.

Figure 2 Scatter plot and line of best fit for VO₂ peak and FIM scores ($r=0.25$, $p=0.12$).

respectively, $p=0.12$, 0.46 , and 0.10 respectively) (Figures 2–4). There was a trend toward higher VO₂peak in individuals with CMSA leg scores of 5 and 6 than in those with scores of 3 and 4 (Figure 5); however, there were no differences when all four groups (scores 3, 4, 5, and 6) were compared ($F_{3,41}=1.33$, $p=0.30$), and this difference did not exceed the reported variability in VO₂peak of 2–4%.²⁵

DISCUSSION

The results of this study demonstrate that the cardiorespiratory capacity of individuals in the subacute phase post-stroke admitted to inpatient rehabilitation was less than half the average age-adjusted norm (11.1 versus 21.7 ml/kg/min). In fact, no individual patient had

Figure 3 Scatter plot and line of best fit for VO₂ peak and NIHSS scores ($r=-0.12$, $p=0.46$).

Figure 4 Scatter plot and line of best fit for VO₂ peak and COVS scores ($r=0.26$, $p=0.10$).

Figure 5 Mean and standard errors of VO₂ peak values by CMSA leg scores ($F_{3,41}=1.27$, $p=0.30$).

a VO_2 peak that reached the mean of age-matched levels. Such low levels of aerobic capacity will have a significant impact on an individual's functional capacity, including his or her ability to engage in meaningful levels and intensities of physical rehabilitation. Low fitness levels are also likely to be associated with elevated risk of second stroke through risk factors such as blood pressure and blood lipid profile, which can be importantly influenced by activity profiles.

It is noteworthy that the very low levels of aerobic capacity were in contrast to moderate to high average scores on clinical and functional outcomes. In addition, there was no significant association between the clinical or functional status and cardiorespiratory fitness. The unique importance of a measure of cardiorespiratory capacity and the inability to predict cardiorespiratory status from conventional indices of stroke recovery lead us to conclude that cardiorespiratory function should be an essential outcome to assess after stroke. More generally, the potential long-term influence of cardiorespiratory fitness on functional capacity and on the risk of a future stroke or cardiovascular event leads to the recommendation that cardiorespiratory fitness should be an essential outcome measured in the early phase post-stroke, as it is following cardiac events. This study highlights the poor cardiovascular health status of stroke patients and the need to address the cardiovascular determinants of health for stroke, as is standard clinical practice for individuals with cardiac disease.

The levels of cardiorespiratory capacity measured in the present study are consistent with findings from previous studies. MacKay-Lyons and Makrides¹⁴ reported that VO_2 peak increased from a mean (SD) of 14.8 (5.4) ml/kg/min at 1 month to 17.3 (7.0) ml/kg/min at 6 months after stroke. Kelly et al.¹⁷ reported that VO_2 peak was only 50% of values reported in the literature for a healthy age- and gender-matched group in a sample at a median of 30 days after stroke. The participants in our study were more acute than those reported on in previous investigations. Similarly, patients in the chronic post-stroke period (more than 3 months after stroke) have been reported to have aerobic capacity between 55% and 75% of values expected in healthy age- and gender-matched individuals.^{13,15}

Several factors may help explain the low aerobic capacity found in the early post-stroke phase. Pre-morbid cardiorespiratory status may have been compromised, and low physical activity levels may have contributed to the risk of stroke. In addition, sensorimotor deficits occurring as a result of stroke may compromise the individual's ability to engage in physical activities such as walking, resulting in a further decline in aerobic capacity along with reduced motor-unit recruitment and oxidative capacity of the paretic muscles during exercise.¹³ Finally, neuromuscular weakness and fatigue of the paretic limb may affect the ability to perform such

activities and thus result in low measure of cardiorespiratory capacity.

While this study highlights the importance of measuring cardiorespiratory capacity post-stroke, a fundamental challenge is the development of an exercise test that is able to meet the specific needs of persons who have experienced stroke. As noted previously, measures of neurological deficit and functional status do not reflect aerobic capacity. The considerable variability in motor control among persons who have sustained stroke influences the optimal modality for testing aerobic capacity and also influences the appropriate training modalities when attempting to positively influence cardiovascular health. We believe that treadmill walking is a natural choice because of its task specificity to an activity of daily living, mainly community walking. However, lower-extremity motor recovery and postural control issues may preclude individuals from sustaining activity levels on a treadmill that result in peak aerobic capacity. For this reason, treadmill testing may be used with partial body-weight support systems in individuals with stroke. However, body-weight support results in lower oxygen consumption in individuals with hemiparesis;²⁷ in addition, it may not be readily available in all clinical settings. Cycle ergometry may be a testing modality that a broader range of persons post-stroke are likely able to perform, in part because of the limited need for dynamic stability, particularly in the semi-recumbent position, and because there is no requirement for limb placement, since the feet are fixed to the pedals. Ongoing development of new modalities is likely to better address the unique challenges of assessing fitness level in individuals who have had a stroke.

Traditional guidelines suggest 20 to 30 minutes of regular exercise that is of moderate to vigorous intensity, 3 to 5 times per week, for those without medical contraindications. The intensity of the activity should represent approximately 50% to 70% of maximum capacity in order to achieve cardiorespiratory gains, and this has been shown to be feasible in the early period after stroke.²⁸ The challenge of choosing the activity is largely associated with the suitability and safety of the exercise selected. A walking programme is appropriate only for the subset of individuals post-stroke who are able to walk rapidly enough to achieve target heart rates. Otherwise, a semi-recumbent cycle ergometer is a safe and acceptable form of training, which has been successfully used in the subacute and chronic stages after stroke.^{28,29} Concerns about adherence to any exercise programme can be overcome by encouraging patients to enrol in a group exercise programme, through monitoring of activity logs, or even through the use of inexpensive pedometers. At present, models for delivering programmes for persons post-stroke at subacute and eventually chronic stages are being developed, but these must be coupled with an awareness of the importance of

addressing the determinants of cardiovascular health beyond pharmacological agents.

CONCLUSION

Clinicians should consider the routine measurement of aerobic capacity in patients post-stroke. Cardiorespiratory capacities of individuals in the subacute phase following stroke who were admitted to inpatient rehabilitation were considerably lower than average age-adjusted norms. Measures of neurological deficit and functional status do not reflect aerobic capacity. Low cardiorespiratory capacity has a negative impact on function and recovery post-stroke, as well as increasing the future risk of stroke and other cardiovascular events.

KEY MESSAGES

What Is Already Known on This Subject

Stroke is not only a neurological disorder, as evidenced by neurobehavioural symptoms, but also a result of cardiovascular disease. Exercise capacity is compromised in individuals long after stroke. However, there is relatively little information on individuals in the early post-stroke period. This subacute period, up to 3 months post-stroke, is important because specific information about cardiorespiratory status could affect the post-stroke treatment strategy.

What This Study Adds

Cardiorespiratory capacity of individuals up to 3 months post-stroke is severely compromised. Measurement of cardiorespiratory capacity should be routinely considered in these patients as part of their risk profile.

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