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A Comparative Study of Treadmill Tests and Heel Raising Exercise for Peripheral Arterial Disease

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Objectives: *This two part study validated a 1 min treadmill exercise test and compared this with simple heel raising exercise.*
Methods: *In an initial study of 24 claudicants (aged 43–79, median 63 years), ankle pressures were measured immediately after repeated treadmill exercises: for 1 min, until onset of claudication, and until maximum tolerated walking distance. Absolute value, fall and percent change in pressures were calculated. The results of this part of the study were then used as a "gold standard" for comparison with 30 s of heel raising and treadmill exercise. This second stage was performed on 21 symptomatic limbs (14 claudicants aged 42–73, median 69 years).*
Results: *Variability was least for pressures expressed as percent change after 1 min of exercise. The paired t-test revealed a significant correlation between the two methods of exercise* ($p<0.05$)*.*
Conclusion: *Heel raising produced changes in ankle pressure which correlated well with those induced by treadmill exercise. We recommend the use of simple heel raising when a stress test is required to diagnose lower limb arterial insufficiency in the outpatient clinic.*

Key Words: Treadmill; Heel raising; Exercise test; Claudication; Ankle pressure.

Introduction

The resting ankle-brachial index (ABI) is reduced in most patients with claudication, supporting the diagnosis of peripheral arterial insufficiency. Exercise testing is a stress test used in cases of doubt when suspected claudicants have normal or near normal resting ankle Doppler pressures.[1–4] A treadmill has traditionally been used in exercise testing for peripheral arterial disease[1–6] but some patients find treadmill exercise stressful, particularly when required to continue for a prolonged period. In an attempt to simplify treadmill exercise testing, Laing and Greenhalgh[7] validated a 1 min exercise test which was sufficiently sensitive to detect mild arterial insufficiency, yet rapid to perform and without undue stress to the patient. They found that the fall in the ankle pressure measured immediately after 1 min of treadmill exercise was the same as that recorded after more prolonged exertion, suggesting that there was little to be gained by making the patient walk until the onset of claudication or limit of tolerance.

A treadmill is relatively inconvenient for use in the outpatient clinic, is expensive, and generally requires a dedicated operator. In practice, many vascular surgeons use methods such as heel raising, mounting steps, or simple walking as a stress test. The main aim of this study was to compare a brief period of heel raising exercise against a standard treadmill test. Scant attention has been paid to the ideal way of assessing pressure changes (for example: absolute pressure, changes in pressure, or changes in ABI) after exercise.[8] We therefore conducted a preliminary study to examine the variability associated with different treadmill exercise regimes and different methods of presenting the results. In the main part of the study, the correlation between heel raising exercise and the "gold standard" treadmill exercise test was investigated to assess the efficacy of heel raising as an alternative to the treadmill.

Patients and Methods

Comparison of different treadmill tests

Twenty-four patients with intermittent claudication (19 men and 5 women) aged 43–79 (median 63 years)

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were admitted to the hospital 2 days prior to their scheduled angiography date. Patients were studied on three consecutive days prior to angiography. Baseline ankle and brachial systolic Doppler pressures were measured using an 8 MHz probe after 15 min of rest. Each patient then walked on a treadmill at a speed of 4 km/h, up a 10 degree gradient for 1 min under ECG monitoring. Ankle and brachial pressures were measured 30 and 90 s after the end of exercise and then at 5 min intervals. After a 15 min rest, each patient walked again on the treadmill to determine claudication and maximum walking times (up to a maximum of 10 min). Ankle pressures were recorded at 30 and 90 s, and 4, 6, and 10 min after exercise. The pressures measured were expressed in three different ways:

(1) The post-treadmill absolute pressure.
(2) The change (fall) in pressure (pre − post treadmill) – the "pressure gradient".
(3) the percent change (fall) in pressure from resting value $[(\text{pre} - \text{post})/\text{pre}] \times 100$.

For example, for a patient whose resting ankle pressure of 100 mmHg dropped to 40 mmHg after treadmill exercise, the following results were recorded:

(1) the post-treadmill exercise absolute pressure = 40 mmHg.
(2) The pressure gradient = 60 mmHg.
(3) the percent change in pressure $= [(100-40)/100] \times 100 = 60\%$.

The variability of each parameter in individual patients over the 3 days was determined by calculating the coefficient of variability (standard deviation divided by the average of results over 3 days). The variability of each test in the whole group of patients was determined by calculating the mean coefficient of variability (root mean square).

Comparison of heel raising exercise with treadmill testing

A further group of 14 patients (10 men and 4 women, aged 42–73, median 69 years) was selected, from whom 21 symptomatic limbs were studied. All of these patients had been referred with a history suggestive of intermittent claudication with an ABI of over 0.8. Patients unwilling or dubious about participation, those with a history of angina or recent myocardial infarct and those with limited mobility (stroke, arthritis) were excluded. In seven patients with bilateral claudication, each of the affected limbs was studied separately. The order of the two tests was chosen at random. A 15 min period of rest was taken prior to each bout of exercise. After each test the patient laid supine as rapidly as possible and the ankle and brachial pressures were measured.

The subjects were exercised on a treadmill for 1 min on an upward gradient of 10 degrees at 4 km/h. Heel raising exercise was carried out to the maximum height comfortably achievable by the patient at the maximum speed tolerated (at least 1 heel raise per second) for 30 s. A duration of 30 s heel raising was chosen for two reasons: first this was the approximate duration of heel raising routinely used in our clinic (many patients found more prolonged heel raising difficult), second, pilot studies comparing 1 min of heel raising against 30 s showed a similar fall for each duration.

Baseline Doppler ankle and brachial systolic pressures were taken at rest and 30 s after each exercise test. As in the initial part of the study, Doppler pressure was taken throughout from the ankle artery with the best signal. For each test, ankle pressure gradient before and after, ABI, and percent change in pressure from resting values were calculated.

We analysed the results in two ways:

(1) Graphically, to demonstrate the pressure fall seen following both exercise regimes, this gives a qualitative assessment of pressure changes induced by each method
(2) Having demonstrated (in the first part of the study) that pressures expressed as a pecentage change are least variable, we applied the paired t-test to these results to test the hypothesis that there is no significant difference between the two exercise tests.

Results

Comparison of different treadmill tests

The coefficients of variability for resting ankle pressures and ABIs were $16.6 \pm 3.4\%$ (Average ± s.d) and $18.05 \pm 4.8\%$, respectively. Table 1 shows the coefficients of variability of ankle pressures for treadmill exercises. There was a trend towards increased variability of ankle pressure changes with longer time intervals after cessation of exercise. Measurements at 30 s after exercise showed the lowest variability of results as shown in Table 1. Variability figures were generally lower after 1 min tests than after more prolonged exercise. In addition, variability was found to be least when pressures were expressed as a percentage change in pressure.

Table 1. Coefficients of variability (S.D./mean +/− S.D.) of ankle pressures from 24 patients recorded on three successive days: These are expressed as absolute pressure, change in pressure and percent change in pressure. The pressures were measured after 1 min of exercise (upper two rows) and maximum tolerated exercise on the treadmill (lower five rows). Pressure readings were taken following exercise at the times specified in the second column.

Treadmill exercise test	Rest period	Post-treadmill exercise pressure (mmHg)	Gradient pressure (mmHg)	% Change in pressure
1 min	30 s	28.1 +/− 45.6	20.7 +/− 14.9	9.4 +/− 11.8
1 min	90 s	73.7 +/− 104.0	43.1 +/− 27.9	33.8 +/− 30.6
Max	30 s	94.6 +/− 114.7	23.2 +/− 17.5	14.9 +/− 14.4
Max	90 s	84.1 +/− 108.0	37.8 +/− 28.4	29.9 +/− 29.9
Max	4 min	73.6 +/− 84.0	49.6 +/− 41.1	47.5 +/− 46.9
Max	6 min	64.1 +/− 90.7	75.4 +/− 60.7	84.0 +/− 85.2
Max	10 min	57.7 +/− 90.4	93.9 +/− 56.1	89.1 +/− 56.9

Gradient = pre − post exercise.

Table 2. Absolute and gradient (mmHg), and percent change in ankle pressures for treadmill and heel raising exercise.

Limb no.	Td (pre)	Td (post)	Td (Gradient)	% Change Td	Heel (pre)	Heel (post)	Heel (Gradient)	% Change Heel
1	120	120	0	0.0	130	125	5	3.8
2	105	100	5	4.8	110	100	10	9.1
3	120	120	0	0.0	115	80	35	30.4
4	140	120	20	14.3	130	90	40	30.8
5	115	60	55	47.8	115	95	20	17.4
6	135	65	70	51.9	135	90	45	33.3
7	160	120	40	25.0	170	160	10	5.9
8	140	100	40	28.6	140	140	0	0.0
9	150	140	10	6.7	145	145	0	0.0
10	150	130	20	13.3	145	140	5	3.4
11	110	110	0	0.0	110	85	25	22.7
12	110	65	45	40.9	110	75	35	31.8
13	120	60	60	50.0	120	45	75	62.5
14	90	35	55	61.1	90	40	50	55.6
15	135	125	10	7.4	130	125	5	3.8
16	110	80	30	27.3	110	90	20	18.2
17	120	85	35	29.2	120	95	25	20.8
18	75	75	0	0.0	75	60	15	20.0
19	120	120	0	0.0	120	120	0	0.0
20	130	80	50	38.5	130	100	30	23.1
21	125	125	0	0.0	140	130	10	7.1
Average	123	97	26	21.3	123	101	22	19.0
S.D.	20	29	24	20.5	20	33	20	17.5

Td = treadmill exercise; Heel = heel raise exercise; Pre = before exercise; Post = After exercise; Gradient = pre − post exercise.

Comparison of heel raising exercise with treadmill testing

Table 2 shows absolute pressure, change in pressure (gradient) and percent change in ankle pressures for treadmill and heel raising exercise. Fig. 1 presents mean absolute pressure before and after the two different exercise regimes with 95% confidence limits. Paired t-testing revealed no significant difference ($p<0.05$) between percent change in pressure induced by each exercise regime.

Discussion

While the ankle systolic Doppler pressure remains unchanged or elevated after exercise in normal individuals, it will fall in claudicants as an objective indicator of the presence and severity of the peripheral arterial disease.[3,4,9] In claudicants, peak limb blood flow is reached at low work levels[10] and once the maximum fall in pressure has been produced, more intense or prolonged exercise will not cause the level to fall further. This helps to explain why a limited

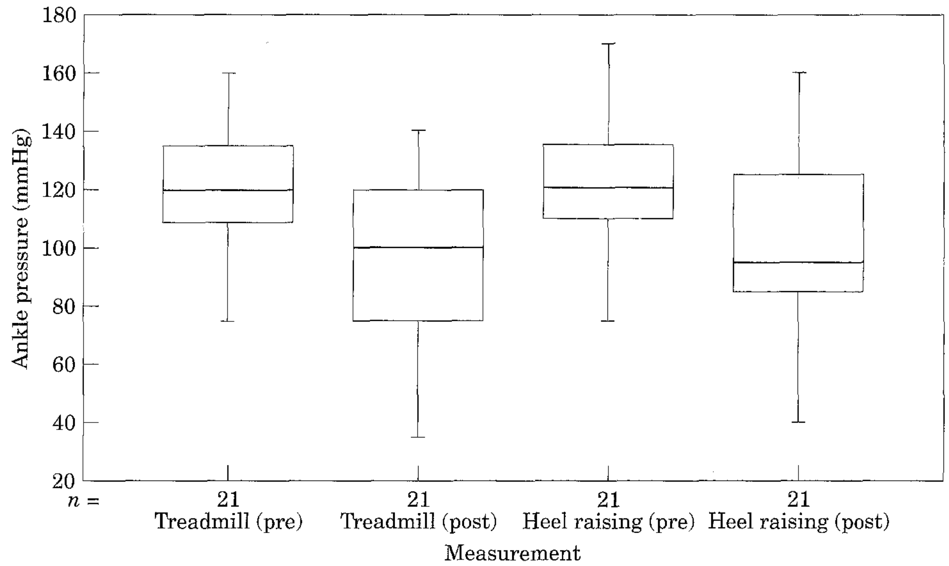

Fig. 1. Median, upper and lower quartile, and range of ankle pressures before and after the two exercise regimes.

period of exercise causes a reproducible fall in pressure. This study has provided further support for the reproducibility of the 1 min treadmill exercise test[7] in detection of peripheral arterial disease. One minute of treadmill exercise compared favourably with more prolonged exercise tests, and was used as the "gold standard" in the second part of the study.

The fall in ankle pressure after exercise is maximal at the time exercise is stopped, and recovers progressively thereafter. It is therefore not surprising that pressures measured at the shortest time after cessation of exercise show the least variability. In practice, getting a patient onto a couch, attaching a cuff, and making a pressure measurement can be done with speed and skill in about 30 s. While the brachial systolic Doppler pressure value is required for calculation of ABI, brachial pressure measurements are often delayed longer after exercise than the ankle pressures and, in practice, trying to make more than one measurement within the first minute or so after cessation of exercise is difficult. Our findings show no disadvantage to using ankle pressures alone rather than ABI; this concurs with the experience of Laing.[8]

The percent change in ankle pressure seemed less variable than the absolute change in pressure or pressure gradient induced by treadmill exercise, although formal statistical testing testing of these differences was not really possible. A theoretical advantage of the percent change in pressure is that it takes into account the initial resting pre-exercise ankle pressure. For example, a fall of 30 mmHg is more significant if the initial ankle pressure is 80 mmHg rather than 150 mmHg.

Treadmill testing has become synonymous with exercise testing for the assessment of peripheral arterial disease. This has happened because those who write most about non-invasive testing have vascular laboratories equipped with treadmills and personnel to supervise their use. Treadmill tests have been validated in clinical studies; the treadmill has an aura of technological merit; and treadmill testing attracts financial return for those in commercial health care. Furthermore many clinicians rely on treadmill tests to obtain more extensive information about their patients, for example total walking distance and presence of concurrent disease. Simple clinic tests, such as walking up steps or heel raising are perceived to lack these attributes, even though they are in common use. Heel raising is a quick and simple diagnostic test which requires no complex equipment, no specially trained staff and can be performed in the outpatient clinic. We have demonstrated that heel raising is as likely as treadmill exercise to produce a pressure indicative of peripheral arterial disease. In addition some patients in our study commented that they found heel raising preferable to treadmill exercise.

We recommend the use of 30 s of simple heel raising exercise when a stress test is required to diagnose lower limb arterial insufficiency. It has reproducible results and avoids precipitating cardiopulmonary insufficiency symptoms in susceptible patients. Surgeons who use treadmill exercise for serial testing[8,11] and those who routinely send their patients to a vascular laboratory should have no reason to change this well proven method of assessment. However, surgeons who would prefer a quicker stress test in their busy outpatient clinics can use simple heel raising as a practical technique in suspected claudicants in the knowledge that the results are equally valid.

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