Reasons for terminating an exercise test provide independent prognostic information: 2014 apparently healthy men followed for 26 years

Johan Bodegard1*, Gunnar Erikssen2, Jørgen V. Bjørnholt1, Knut Gjesdal3, Knut Liestøl4, and Jan Erikssen1

1Department of Clinical Epidemiology, University of Oslo, Akershus University Hospital, PO Box 75, NO-1474 Nordbyhagen, Norway; 2Hjerteavdelingen, Rikshospitalet, Oslo, Norway; 3Department of Cardiology, Ulleval University Hospital, Oslo, Norway; and 4The Department of Informatics, University of Oslo, Norway

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Aims We wanted to study whether reasons for terminating an exercise test might influence long-term mortality of healthy men, a previously unreported subject.

Methods and results During 1972–75, 2014 men aged 40–59, free from somatic diseases and not using drugs, underwent an examination programme including case history, clinical examination, various blood tests, and a symptom limited exercise ECG-test. The following reasons for test termination were noted: impaired breathing, lower limb fatigue, exhaustion (=combined lower limb fatigue and impaired breathing), high heart rate, abnormal blood pressure response, heart arrhythmias, increasing chest pain during exercise, marked ST-depressions during the test, and refusal to continue. Follow-up was 26 years. When adjusting for age, men who stopped exercising exclusively because of impaired breathing (n = 178) had a 1.86-fold increased risk (95% CI 1.34–2.60; P = 0.0002) of dying from coronary heart disease (CHD), a 1.64-fold increased risk (95% CI 1.32–2.03; P < 0.0001) of dying from any cause, and a 3.47-fold increased risk (95% CI 2.24–5.12; P < 0.0001) of dying from pulmonary causes compared with men having defined exhaustion (n = 1376). After adjustment for age, smoking, total serum cholesterol, fasting blood glucose, systolic blood pressure, and physical fitness, impaired breathing remained significantly associated to an increased risk of dying from CHD, pulmonary disease, or any causes.

Conclusion Healthy men who stop bicycle exercising only because of impaired breathing have a high long-term CHD-, pulmonary-, and total-mortality, and such men may need further diagnostic scrutiny and follow-up.

KEYWORDS
Long term prognosis; Exercise testing; Coronary heart disease mortality; Termination reason; Pulmonary disease mortality; Total mortality

Introduction

Exercise testing is currently not advocated for diagnostic purposes in healthy subjects because of low sensitivity and specificity. However, a number of physiological responses to exercise testing, besides the exercise ECG, have marked, long-term prognostic impact also in healthy subjects, and hence, exercise testing has recently been suggested for use for prognostic purposes also in apparently healthy subjects. Symptom limited exercise testing in healthy subjects is a safe procedure, provided acknowledged contraindications are respected and the test is terminated according to current guidelines. In apparently healthy subjects, the majority of the tests are terminated either by the patient or by the physician, because of impaired breathing/dyspnoea, lower limb muscular fatigue, and exhaustion or, for safety reasons, solely because of very high heart rates. A few tests may reveal findings which suggest that an apparently healthy man undergoing exercise testing may not be entirely healthy. Thus, some tests have to be terminated for clinical reasons such as arrhythmias, suspected angina pectoris, or development of marked ST changes in the exercise ECG.

The aim of the present study is to analyse whether various reasons for terminating exercise have a different influence on long-term total and/or cardiac mortality. To our knowledge, this aspect of exercise testing has not been reported previously. The population studied consists of 2014 men aged 40–59, initially judged to be apparently healthy. All underwent a symptom limited exercise test between 1972 and 1975. Follow-up on mortality was on an average 26 years.

Methods

In 1972–75, a cardiovascular survey examination was conducted in a group of apparently healthy men aged 40–59, working in five governmental institutions in Oslo, Norway. Of 2341 eligible
men, 2014 agreed to participate (86%). Eligibility was decided after careful study of all company health files. Presence of the following diseases/conditions caused primary exclusion: known or suspected heart diseases including coronary heart disease (CHD), drug treated hypertension, diabetes mellitus, malignancy, and other chronic diseases (e.g., advanced liver, kidney, or pulmonary diseases). Subjects on any chronic drug regimen were also excluded, as were those who for various reasons were judged unable to properly conduct a symptom limited bicycle exercise ECG test (e.g., for orthopedic, neurologic, or muscular reasons). Those who had had a febrile illness just prior to scheduled testing had to postpone the test for at least 14 days. Men who on arrival reported that one of the earlier mentioned diseases had been diagnosed elsewhere, but were unreported in their company health files, were examined, but excluded. Details about the selection/exclusion criteria are presented elsewhere.7

All men underwent the same examination programme, always in the same order as reported earlier. 7 In brief, the men arrived at ~07.00 AM after 12 h fasting and at least 8 h of abstinence from smoking. The examination programme included height/weight measurements, spirometry, chest X-ray, a number of blood tests, a comprehensive case history, clinical examination, phonocardiography, resting 12-lead ECG, and a symptom limited bicycle exercise ECG test. As part of the case history, all answered a comprehensive health questionnaire in which the MRC respiratory questionnaire was included.8

Exercise ECG testing

Exercise testing was conducted on an electrically braked Elema bicycle. The starting load was 600 k.p.m. (=100 W), and the load was increased by 300 k.p.m. (=50 W) every 6 min. Blood pressure was measured at 1, 3, and 5 min on all loads, besides immediately prior to test termination, using a mercury sphygmomanometer. Readings were made to the nearest 5 mmHg.

The test leader (J.E.) was present during all tests, and encouraged all test subjects to exercise as long as they tolerated. The test was continued until a subject refused to continue, or as long as the attending physician felt it safe. Often more than one of the reasons for test termination were reached simultaneously (discussed subsequently).

Physical fitness was defined as working capacity divided by body weight, with working capacity defined as the cumulated work performed at test termination as reported earlier.4

The exercise ECGs were monitored continuously during the test and were registered at 2, 4, and 6 min on all loads, at test termination and at 0–30 s and at 1, 3, and 5 min post-exercise. ECGs were read as described earlier.4

Reasons for terminating an exercise test

Impaired breathing (Group I)

- The test subject claimed that he had become severely short of breath and therefore felt unable to continue exercising.
- Inability of the test subject to continue speaking with the test leader because of heavy and rapid breathing (For safety reasons, the test leader always chatted with the test subjects during the test in order to be able to observe when breathing became too difficult for speaking, a criterion very similar to and often overlapping with the following criterion).
- Development (often suddenly) of a very rapid respiratory rate, in disproportion to the increase in heart rate, mostly observed on a high exercise load (taken as a sign of having reached the subject’s peak exercise capacity).
- Development of prolonged audible and obviously asthmatic type of breathing (for safety reasons).

Lower limb fatigue (Group II)

Lower limb fatigue was said to be present if the test leader observed marked difficulties in further pedalling and/or if a test subject claimed that he was unable to pedal further because of lower limb tiredness (none had coordination difficulties in pedalling).

Exhaustion (Group III)

Exhaustion was said to be present if a subject had developed both impaired breathing and lower limb fatigue, when the test had to be stopped. For safety reasons, some subjects were stopped only because of high heart rate according to the following rule: provided heart rate at the end of one load had reached >90% of maximal predicted heart rate (MPHR) according to the formula: 

\[ \text{MPHR} = (220 - \text{age}) \text{ (b.p.m.)} \]

However, if this load was also completed without developing any other specified reason for terminating the test, no further load was added regardless of heart rate response. These subjects were included in the ‘exhaustion group’.

Other reasons (Group IV)

Angina pectoris. Retrosternal chest pain [with or without radiation to the arm(s), jaw, back, or upper abdomen] developing during the test, increasing gradually as the test continued and eventually forcing the test subject to stop exercising. A necessary prerequisite was also that the pain gradually vanished within a few minutes of test termination. (NB: None had a diagnosis of known or suspected angina pectoris prior to participating in the survey.)

Heart arrhythmias. A variety of arrhythmias or conduction disturbances was anticipated. However, the only arrhythmias observed necessitating test termination were supraventricular tachycardia, paroxysmal atrial fibrillation/flutter, or observation on the ECG monitor of three or more rapid, consecutive ventricular extrasystoles four or more times within 1 min on one load.

Marked ST-depression during exercise. If an ST-depression >3 mm 0.08 s from the J-point was observed on the monitor (and confirmed on the ECG) during exercise, the test was always stopped for safety reasons.

Miscellaneous reasons. Were any reason given by the test subjects. However, almost exclusively these men stopped suddenly on one of the lower loads after claiming ‘I do not want to continue’, without further justification.

High systolic blood pressure. The test was stopped for safety reasons if a blood pressure of 300 mmHg was reached, because the top of the mercury scale of the sphygmomanometer was 300 mmHg.

Systolic blood pressure drop. A drop to <75% of the highest blood pressure measured earlier during the test.

A special note was made on whether subjects in groups I–III had reached >90% of their MPHR, and/or had an ST-depression in the exercise ECG of >0.50 mm.10

Follow-up procedures

With permission from the Norwegian Data Inspectorate and the Norwegian Board of Health, a complete cause-specific survey of all deaths in the material was obtained from Statistics Norway. Mortality data are complete up to 31 December 1999, except for two men who had moved abroad and were lost to follow-up after 1995.

Earlier, in 1995, the study group performed a nationwide search for a number of hospital verified disease events for all subjects, in all Norwegian hospitals. Relevant morbidity data are complete up
to 31 December 1994. The only morbidity data included in the present report are:

- hospital verified acute myocardial infarctions (AMIs) and
- cases of coronary artery bypass grafting (CABG).

Statistical methods

Differences in baseline data between groups were tested by Students t-test, Fisher’s exact test, and Wilcoxon test according to data type. When comparing data between the groups, our P-values are two-tailed and are considered significant if P < 0.05.

The risk of mortality and morbidity events was estimated by Kaplan-Meier plots and tested with log-rank test (Mantel–Cox test). When calculating relative risk by including further covariates, Cox proportional-hazards modelling was used. The Cox model included variables earlier identified as important prognostic factors. Diagnostic plots of log S(t) vs. log(t) indicated that the proportional hazard assumption was acceptable. The linearity assumptions were tested by evaluating regression results with the variables split into categories. When testing for the prognostic information contained in the reasons for terminating the exercise test, the overall significance of the three-category variable was tested before comparing the ‘impaired breathing’ and the ‘lower limb fatigue’ categories to the ‘exhaustion’ group (the reference group).

All models were computed using the StatView™ computer package version 5.0 for Windows.

Results

Follow-up was 26 years (range 24.8–27.3) for mortality and 21.5 years (range 19.8–22.3) for cardiac morbidity.

Group I comprises the 178 men who stopped exercising because of impaired breathing; group II, the 369 men who stopped because of lower limb fatigue; group III, the 1376 men who stopped because of exhaustion; and group IV, the 91 men who stopped exercising for ‘other reasons’.

In groups I, II, and III, there were 64, 137, and 221, respectively, who did not reach ≥90% of their MPHR.

Table 1 presents various clinical, physiological, and laboratory data in groups I–III. Some differences seem worth noting: men from group I were older, were more often smokers, had higher resting systolic blood pressure, had lower maximal heart rate, poorer physical fitness, and had a higher frequency of ST-depressions ≥0.50 mm than men in group III. Men from group II were in most respects similar to men from group III, except for reaching a lower maximal heart rate and a lower rate of exercise ECG ST-depression ≥0.5 mm.

In group IV, 21 stopped because of angina pectoris, 21 because of arrhythmias, nine because of an ST-depression ≥3 mm, two because of ‘high blood pressure’, one because of ‘blood pressure drop’, and 37 because of ‘do not want to continue’. Men in all subgroups were older than men in groups II and III, all (but the arrhythmia sub-group) had a mean total cholesterol value ≥7.0 mmol/L and all subgroups presented a very low physical fitness (detailed data not shown). Group IV was not extensively analysed because of group heterogeneity, low numbers in the subgroups, and because the majority could not be considered healthy (developing angina pectoris, etc.).

26 years crude mortality data

Table 2 shows that mortality in groups II and III are strikingly similar: both groups had a 26 years total mortality of approximately one-third and a death rate from pulmonary causes (combined pulmonary carcinoma, asthma/emphysema, chronic obstructive lung disease, or pneumonias) of ~5%. In contrast, group I had a significantly higher both CHD-, pulmonary-, and all-cause-mortality.

Mortality in subgroups of group IV resembled that in group I, including in the ‘do not want to continue’ subgroup (detailed data not shown).

Figure 1 shows the 26 years survival curves (Kaplan–Meier) for groups I–III. Groups II and III have virtually identical total mortality over the total observation period, whereas group I has a markedly higher mortality (P < 0.0001). The sequential group IV-mortality follows mortality in group I closely (detailed data not shown).

CHD mortality (26 years follow-up)

Table 3 shows the relative risk (Cox-regression analysis) regarding long-term CHD mortality in groups I–III. After adjusting for age, the impaired breathing group shows a 1.86-fold increased risk (95% CI 1.34–2.60) of dying from CHD compared with the exhaustion group.

After adjusting for age, smoking, total cholesterol, resting systolic blood pressure, fasting blood glucose, and physical fitness, the impaired breathing group shows a 1.55-fold increased risk (95% CI 1.10–2.18) of dying from CHD compared with the exhaustion group.

In group II, 21 stopped because of angina pectoris, 21 because of lower limb fatigue; group III, the 1376 men who stopped because of exhaustion; and group IV, the 91 men who stopped exercising for ‘other reasons’.

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Mortality in subgroups of group IV resembled that in group I, including in the ‘do not want to continue’ subgroup (detailed data not shown).

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First severe CHD-event (21.5 years follow-up)

The men from group I had a 1.56-fold increased age adjusted risk (95% CI 1.25–1.96; P < 0.0001) of having one first, severe CHD-event over a follow-up period of 21.5 years. A severe event was defined as having had a first non-fatal, hospital verified myocardial infarction, a coronary bypass operation, or primary death from CHD during a follow-up period of 21.5 years; no case was counted twice (Table 4).

All-cause mortality (26 years follow-up)

Table 5 shows the relative risk regarding long-term all-cause mortality in the groups I–III. Men from group I demonstrates a 1.64-fold increased risk (95% CI 1.32–2.03) of dying from any cause compared with men from group III, over an observation time of 26 years. After adjusting for the same variables as earlier, men from group I had a 1.43-fold increased risk (95% CI 1.15–1.79) of dying from any cause.

Pulmonary disease mortality (26 years follow-up)

After adjusting for age, group I had a 3.47 fold increased risk (95% CI 2.45–3.56) of dying from pulmonary diseases (pulmonary carcinoma, asthma/emphysema, chronic obstructive lung disease, or pneumonia) during the observation time of 26 years (Table 6). After adjusting for all variables included in the earlier mentioned multivariable model, the risk was increased 2.98-fold (95% CI 1.98–4.68). The risk even remains strong and significant after additional adjustment for FEV1 (detailed data not shown).

Figure 2 presents a Venn diagram for the 178 men who stopped exercising because of impaired breathing and the 164 men who answered affirmative to the question from the MRC questionnaire8: ‘are you troubled by shortness of breath when hurrying on level ground or walking up a
slight hill? A surprisingly small overlap (n = 41) between these two groups of men was seen. The MRC questionnaire-positive men and men who stopped exercising because of impaired breathing had a virtually identical (high) CHD-, pulmonary-, and total-mortality. The 41 men in the 'overlap group' had a very high all-cause mortality, to a high degree associated with high death rates from pulmonary diseases.

Several baseline contrasts exist among groups I–III for a number of variables (Table 1). In all groups, however, those who died were slightly older, had higher resting and exercise blood pressure, reached a lower maximal heart rate, had lower physical fitness, smoked more, and had lower FEV1 values when compared with the survivors. Only minor and insignificant group differences were found for total cholesterol, triglycerides, and BMI (detailed data not shown).

Discussion

Extensive data from maximal and symptom limited exercise testing in healthy men demonstrate that considerable prognostic information can be obtained from analysing responses to exercise testing (exercise ECG, maximal heart rate, heart rate increase during exercise and decrease post-exercise, various blood pressure responses, and physical fitness). However, to our knowledge, none has previously systematically examined whether different reasons for terminating exercise tests may provide additional prognostic information in apparently healthy subjects.
Our data strongly indicate that it is prognostically important why an exercise test has to be stopped. Because exhaustion, defined as the combination of marked muscular fatigue preventing further pedalling and impaired breathing, may be regarded as 'the most normal' reason for stopping exercising, we compared the outcome of such subjects with those who stopped for other reasons.

Apart from reaching a lower maximal heart rate, those who stopped because of lower limb fatigue (group II) resembled the exhaustion group (group III) in almost all respects, both regarding all other baseline findings and all mortality figures. In contrast, men who stopped only because of perceived or observed breathing difficulties demonstrated significantly higher CHD-, pulmonary-, and total-mortality. Thus, impaired breathing as the main reason for having to stop an exercise test was an ominous finding when not part of an 'exhaustion syndrome'. Importantly, this holds true whether this was a subjective phenomenon (dyspnoea) or an objective observation made by the test leader causing him to terminate the test for safety reasons.

Conceivably, part of these mortality differences might be related to differences in baseline characteristics. Thus, men from group I were slightly older than men in group III, and were also more often smokers, had higher blood pressure, poorer physical fitness, lower FEV1, and lower maximal heart rate than men in group III.

However, after adjusting for a number of acknowledged confounders, including age, smoking, systolic blood pressure, fasting blood glucose, and also for physical

| Table 3 | Cox analysis showing the 26 years relative risk (RR) of CHD mortality among 1923 healthy middle-aged men who terminated a symptom limited exercise test because of impaired breathing (n = 178) and lower limb fatigue (n = 369) were compared with those who terminated because of exhaustion (n = 1376) |
|---|---|---|---|
| Reasons for termination (age adjusted) | RR | 95% CI | P-value |
| Group I (impaired breathing) | 1.86 | 1.34–2.60 | 0.0011
| Group II (lower limb fatigue) | 1.10 | 0.81–1.49 | 0.5511
| Group III (exhaustion) | 1.00 | — | — |
| Reasons for termination (multivariable) | | | 0.0408
| Group I (impaired breathing) | 1.55 | 1.10–2.18 | 0.0014
| Group II (lower limb fatigue) | 1.09 | 0.80–1.48 | 0.6077
| Group III (exhaustion) | 1.00 | — | — |
| Age (1 SD = 5.46 years) | 1.51 | 1.33–1.72 | <0.0001
| Smoking (no) | 0.57 | 0.45–0.72 | <0.0001
| Total cholesterol (1 SD = 1.19 mmol/L) | 1.15 | 1.03–1.28 | 0.0154
| Systolic blood pressure (1 SD = 17.6 mmHg) | 1.21 | 1.09–1.35 | 0.0007
| Fasting blood glucose (1 SD = 0.557 mmol/L) | 1.18 | 1.08–1.30 | 0.0005
| Physical fitness (1 SD = 0.785 J/kg) | 0.72 | 0.60–0.85 | 0.0001 |

For definitions, see Methods. Men in group IV (n = 91), i.e. those who were stopped because of high/low systolic blood pressure, angina pectoris, arrhythmias, ST-depression ≥3 mm, or other unspecified reasons were excluded from this table. SD, Standard deviation.

*aSignificance level for multiple group comparisons.

| Table 4 | Cox analysis showing the 22 years relative risk (RR) of combined end-point consisting of non-fatal myocardial infarction, CABG, and death of myocardial infarction among 1923 healthy middle-aged men who terminated a symptom limited exercise test because of impaired breathing (n = 178) and lower limb fatigue (n = 369) were compared with those who terminated because of exhaustion |
|---|---|---|---|
| Reasons for termination (age adjusted) | RR | 95% CI | P-value |
| Group I (impaired breathing) | 1.56 | 1.25–1.96 | <0.0001
| Group II (lower limb fatigue) | 1.01 | 0.82–1.23 | 0.9514
| Group III (exhaustion) | 1.00 | — | — |
| Reasons for termination (multivariable) | | | 0.0338
| Group I (impaired breathing) | 1.35 | 1.07–1.68 | 0.0115
| Group II (lower limb fatigue) | 0.98 | 0.80–1.20 | 0.8695
| Group III (exhaustion) | 1.00 | — | — |
| Age (1 SD = 5.46 years) | 1.33 | 1.22–1.44 | <0.0001
| Smoking (no) | 0.62 | 0.53–0.72 | <0.0001
| Total cholesterol (1 SD = 1.19 mmol/L) | 1.14 | 1.07–1.23 | 0.0002
| Systolic blood pressure (1 SD = 17.6 mmHg) | 1.15 | 1.07–1.23 | 0.0003
| Fasting blood glucose (1 SD = 0.557 mmol/L) | 1.04 | 0.97–1.12 | 0.2946
| Physical fitness (1 SD = 0.785 J/kg) | 0.81 | 0.73–0.90 | <0.0001 |

For definitions, see Methods. Men in group IV (n = 91), i.e. those who were stopped because of high/low systolic blood pressure, angina pectoris, arrhythmias, ST-depression ≥3 mm, or other unspecified reasons were excluded from this table. SD, Standard deviation.

*aSignificance level for multiple group comparisons.
fitness, the negative prognostic impact of impaired breathing persisted.

Although a high heart rate at exercise test termination is considered a beneficial prognostic finding, it was not a protective finding among those who stopped exercising because of impaired breathing, but appeared so in the exhaustion group (detailed data not shown).

Importantly, on inclusion none had a diagnosis of asthma, only a minority had an FEV1 below 2.5 L, few had electrocardiographical signs of left ventricular hypertrophy, left axis deviation or an enlarged heart (>500 mL/m² in relative heart volume), and none had pulmonary congestion on their chest X-ray (detailed data not shown).

It is somewhat surprising that dyspnoea, a poorly quantifiable symptom or sign, has such a negative prognostic importance even after adjustment for a number of relevant risk factors. It is also surprising that the exercise test and the MRC questionnaire seem to define different populations.

The possible explanations for our findings are purely conjectural but two explanations seem reasonable: first, the high mortality from pulmonary causes suggests that previously unknown/undiagnosed pulmonary diseases were unveiled by the exercise test. Next, the finding of a combined high 26 years CHD mortality and a significantly increased 21.5 years incidence of first, severe CHD events further suggest that a proportion of those who stopped because of impaired breathing in fact may have had to stop because of atypical angina (‘angina equivalent’). Thus, it is likely that the ‘impaired breathing group’ contained a fairly high number of men with previously

Table 5 Cox analysis showing the 26 years relative risk (RR) of total mortality among 1923 healthy middle-aged men who terminated a symptom limited exercise test because of: impaired breathing (n = 178) and lower limb fatigue (n = 369) were compared with those who terminated because of exhaustion (n = 1376: for definitions, see Methods)

<table>
<thead>
<tr>
<th>Reasons for termination (age adjusted)</th>
<th>RR</th>
<th>95% CI</th>
<th>P-values</th>
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<td>Group I (impaired breathing)</td>
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<td>Group II (lower limb fatigue)</td>
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<td>Group III (exhaustion)</td>
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<tr>
<td>Reasons for termination (multivariable)</td>
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<td>Group I (impaired breathing)</td>
<td>1.43</td>
<td>1.15-1.79</td>
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<td>Group II (lower limb fatigue)</td>
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<td>Group III (exhaustion)</td>
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<td>Fasting blood glucose (1 SD = 0.557 mmol/L)</td>
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<td>1.02-1.17</td>
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<td>Physical fitness (1 SD = 0.785 J/kg)</td>
<td>0.80</td>
<td>0.72-0.88</td>
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Men in group IV (n = 91), i.e. those who were stopped because of high/low systolic blood pressure, angina pectoris, arrhythmias, ST-depression ≥3 mm, or other unspecified reasons were excluded from this table. SD, Standard deviation.

*Significance level for multiple group comparisons.

Table 6 Cox analysis showing the 26 years relative risk (RR) of dying from pulmonary causes among 1923 healthy middle-aged men who terminated a symptom limited exercise test because of impaired breathing (n = 178) and lower limb fatigue (n = 369) were compared with those who terminated because of exhaustion

<table>
<thead>
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<th>RR</th>
<th>95% CI</th>
<th>P-values</th>
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<td>Group I (impaired breathing)</td>
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<td>Group III (exhaustion)</td>
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<td>Group III (exhaustion)</td>
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<td>Age (1 SD = 5.46 years)</td>
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<td>Smoking (no)</td>
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</tr>
<tr>
<td>Systolic blood pressure (1 SD = 17.6 mmHg)</td>
<td>1.00</td>
<td>0.84-1.19</td>
<td>0.9934</td>
</tr>
<tr>
<td>Fasting blood glucose (1 SD = 0.557 mmol/L)</td>
<td>0.98</td>
<td>0.81-1.20</td>
<td>0.8654</td>
</tr>
<tr>
<td>Physical fitness (1 SD = 0.785 J/kg)</td>
<td>0.71</td>
<td>0.54-0.93</td>
<td>0.0139</td>
</tr>
</tbody>
</table>

For definitions, see Methods. Men in group IV (n = 91), i.e. those who were stopped because of high/low systolic blood pressure, angina pectoris, arrhythmias, ST-depression ≥3 mm, or other unspecified reasons were excluded from this table. SD, Standard deviation.

*Significance level for multiple group comparisons.
unrecognized pulmonary and/or CHD, revealed by the exercise test, earlier unrecognized and unsuspected because of few or lacking symptoms and signs at rest. The high prevalence of ST-depression $>0.5$ mm in the exercise ECG in group I may also point in the same direction.\(^7\)

Unrecognized heart failure is an unlikely explanation because heart volume was normal in most subjects and they lacked pulmonary congestion on the chest X-rays. However, we have no data to further substantiate this notion.

We initially tried to introduce the Borg scale during the testing, but it proved of little value for our purpose and was, therefore, abandoned. However, to our knowledge, none has reported prognostic importance of the Borg scale scoring, and moreover, this scale provides a composite figure embracing all sorts of discomfort.

One might claim that studying respiratory symptoms during a bicycle exercise test is cumbersome, probably poorly reproducible and hardly more informative than, for instance, the MRC respiratory questionnaire.\(^8\) However, whereas an almost identical number of men stopped exercising because of impaired breathing and answered affirmative because of impaired breathing.

Although too cumbersome for general use during exercise testing, more advanced cardiopulmonary tests may be advocated among apparently healthy men who stop exercising solely because of dyspnoea.

**Strengths of the study**

Data have been collected prospectively, following a protocol of standardized examinations. All exercise tests were performed by the same test leader (J.E.). The number of subjects is large, the follow-up is long, and there is a high number of events. Apart from lacking a few fasting blood glucose values, data are complete, including follow-up mortality, and morbidity. Thus, we have no work-up bias. The findings show low $P$-values.

**Limitations of the study**

We have no baseline repeatability data on reasons for exercise termination, but a baseline test-retest of the exercise ECG response in $10\%$ of the material showed that $90\%$ had a repeat working capacity within $5\%$ of the first test results and within $10\%$ in the remaining ones.\(^7\)

The data are limited to apparently healthy men from a country with a high CHD prevalence. Moreover, the data cannot be extrapolated to age $<40$ years or $>60$ years in men, and not to women.

Whereas physiological variables like maximal heart rate, physical fitness, etc. can be measured accurately and repeatably, one might claim that both impaired breathing and lower limb fatigue are subjective when expressed as symptoms by the test subjects or signs by the test leader. Inter-observer and intra-observer variation may be large, and hence, the present data must be accepted with caution until repeated by others.\(^12\)

Baseline variables, on which the statistical analyses may be based, often show sequential changes. We have, for example, shown that physical fitness\(^13\) and smoking habits\(^14\) change markedly in a sizeable proportion of the present participants over a period of 8 years. The size and direction of such changes may have an important impact on the further course in the study population. The overall effect of such sequential changes may be difficult to assess.

Our test results refer to ‘symptom limited’ tests and not to defined maximal exercise tests. Because most men who reached our upper high heart rate limit appeared able to exercise further had they not been stopped by the test leader, the inclusion of these men in the exhaustion group may probably have led to a slight underestimation of group contrasts in fitness and maximal heart rate.

The blood pressure criteria for stopping exercising may also be criticized although all subjects where persummed to be healthy.

Finally, data from treadmill and bicycle tests should be compared with caution.

**Conclusion**

In healthy men, who have to stop exercise testing because of dyspnoea in the absence of an ‘exhaustion syndrome’, long-term CHD-, pulmonary-, and total-mortality are increased. Such subjects deserve further scrutiny.

**References**