

COMPARISON OF THE TRONDHEIM FIREFIGHTER-TEST VERSUS A STANDARD 8 MIN TREADMILL TEST

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Since fire-fighting may be physically demanding, the Norwegian Labour Inspection Authority (NLIA) has set minimum requirements to a firefighter's physical ability and further approved a physical fitness test. Trondheim fire brigade has developed a different test that involves a number of firefighter-like activities. That test is examined here by letting 22 firefighters carry out both tests while a number of parameters were recorded. Two scores of the NLIA-test, the blood lactate concentration and the time to exhaustion when extending the test, both showed close linear relationships with the performance of the Trondheim test and could predict the latter performance with an error of ≈ 1.5 min. Therefore, a firefighter completing the Trondheim-test in less than ≈ 20.5 min fits the requirements of the NLIA.

Keywords: Fire-fighting; Lactic acid - blood; Performance predictors.

1. Introduction

Fire-fighting and rescue-work may be very physically demanding (Heimburg et al. 2006, Holmér and Gavhed 2007). First, the firefighter must move around, activities that often include vertical ascents. They must handle heavy equipment, for example pulling firehoses, and they must also be able to assist or even to carry victims unable to rescue themselves. Second, since the scene of the fire may be hot and possibly dangerous, a firefighter wears protecting clothing that weighs ≈ 10 kg. Moreover, in the Nordic countries firefighters are often dressed up as smoke divers to protect themselves from hazardous gases on the scene of the fire. That extra equipment adds a mass of 11–19 kg, depending on the design and the size of the bottles with pressurised air. Thus, the total protective equipment carried may weigh 20–30 kg. The mass of fire-fighting tools carried comes in addition.

These considerations suggest that there should be minimum requirements to firefighters' physical ability, as has been suggested by a number of former studies (Fogleman & Bhojani 2005, Holmér & Gavhed 2007, Rhea et al. 2004, Williford et al. 1999). In line with that the Norwegian Labour Inspection Authority (NLIA, no. "Arbeidstilsynet") established a minimum physical standard for Norwegian smoke divers a few years ago. A central part in those standards is a simple pass-or-fail-test that is based on 8 min walking on the treadmill on preset conditions. Those who complete the 8 min standardised treadmill walk, pass, while those who abort the test before 8 min of walking, fail. The directions of the Norwegian Labour Inspection Authority also state that other tests with similar physical requirements may be used as substitutes for the approved test.

One might think that standard laboratory tests like measuring the maximal O_2 uptake and the lactate threshold could be used. However, there is a considerable residual variation between the scores on such tests and the time needed to complete specific fire-fighting and rescue operations (Heimburg et al. 2006). Thus, more specific tests mimicking real fire-fighting work should be sought. A test worked out by the Trondheim fire brigade is examined here. That test includes a number of physically demanding firefighter-like activities. Physically fit subjects would expectedly have a low blood lactate concentration and a low heart rate after 8 min of exercise at the NLIA-approved test and further probably rate the test as not strenuous, and they would presumably be able to continue the exercise at increasing intensities for quite a long time. They would also presumably complete the Trondheim-test fast. The different measures would therefore presumably be related.

2. Aim

The main purpose of this study was to see how closely the performance of the Trondheim firefighter-test is related to scores on the test approved by the Norwegian Labour Inspection Authority.

3. Methods

3.1. Subjects

22 professional firefighters (21 men, one woman) in Trondheim fire brigade being 41 ± 9 yr old (mean \pm SD), weighing 84 ± 10 kg, being 1.81 ± 0.06 m tall and with a maximal O_2 -uptake of 51 ± 5 ml kg^{-1} min^{-1} have served as subjects in the present study. The subjects had completed the Trondheim-test examined here 8 ± 3 times (range: 1–11).

3.2. Experiments

The test approved by the Norwegian Labour Inspection Authority is as follows. The firefighter is dressed up for smoke diving, that is by wearing the standard protective equipment including a fireproof jacket and pants, and isolating underwear. During the test the standard protective boots are replaced by jogging shoes to avoid possible overload on the Achilles tendon during inclined treadmill walking, and the firefighter is not wearing a helmet. In addition the firefighter wears a backpack harness with a breathing apparatus with bottles with high-pressurised air, but he inspires from indoor air instead of from the apparatus' mask. The whole garment must weigh 24 kg; thus, if lightweight bottles are used, additional weigh is added by using sand bags. The treadmill speed is fixed at 1.56 m s^{-1} (5.6 km h^{-1}). During the first and second minutes, intended to be a quick warm-up, the treadmill inclination is 4% and 7%, respectively. At 2 min of exercise the inclination is raised to 12% and kept so for the next 6 min.

After 8 min of exercise we recorded the heart rate, took a blood sample from a fingertip and measured the blood lactate concentration while the subject continued walking on the treadmill, and the subject rated the perceived exertion. We have in this study extended the test by letting the subjects continue to volitional exhaustion as follows: At 8 min of exercise the inclination was increased to 14% and kept so for the rest of the test. If the subject was able to continue beyond 9 min of exercise, the speed

was increased by 0.056 m s^{-1} (0.2 km h^{-1}) every minute. The total exercise time was recorded and used as the performance score on this test.

In the Trondheim test the firefighter is dressed up for smoke diving in a hot environment, that is by wearing protective clothing and a breathing apparatus with a face mask and bottles containing high-pressured air. The whole protective equipment including the breathing apparatus weighs around 28 kg. The additional weight beyond that of the NLIA-approved test described above is made up of the boots and the helmet.

The Trondheim firefighter test consists of a number of different tasks including carrying four cans that each weighs 23 kg a distance of 11 m, agility (crawling thru a 2 m long tunnel with a diameter of 60 cm, balancing on a 4 m long and 10 cm wide beam), connecting or disconnecting altogether ten pairs of fire-fighting hoses, twice pulling a 5 m long fire-hose filled with sand to a total mass of 32 kg a distance of 58 m including stair climbing (one floor down and one floor up again). The most strenuous part appears to be physical work in a hot chamber ($>120 \text{ }^\circ\text{C}$). Here ten concrete blocks weighing 18 kg each are carried up a stair of seven steps each being 18 cm high, giving a vertical ascent of 1.26 m, and ten other blocks are brought down the same stair. Half of the blocks hang on hooks $\approx 0.8 \text{ m}$ above the floor, while the remaining half hangs on hooks $\approx 1.85 \text{ m}$ above the floor. After completing this part, the test procedure with pulling a 32 kg fire-hose, connecting and disconnecting fire-hoses, agility, and can-carrying is repeated. The test starts and ends with solving a small puzzle (suitable for $\approx 5 \text{ yr}$ old children). The whole test should be completed as fast as possible.

3.3. Measurements

The heart rate was measured using the heart rate monitor Polar Accurex Plus (PE 3000, Polar Electro, OY Kempele, Finland), set to register at 15 s intervals. The heart rate reserve after 8 min of exercise at the NLIA-test was taken as the heart rate measured at the end of the treadmill test less the heart rate after 8 min of treadmill walking.

The blood lactate concentration was measured with the portable 1710 Lactate ProTM analyser (Arkray Factory Inc, KDK Corporation, Shiga, Japan). This analyser needs a sample of only $5 \mu\text{l}$ of blood. The instrument has been validated separately, found accurate, reliable and useful for field experiments (Medbø et al. 2000). The ratings of perceived exertion was used on the ten-point Borg-Noble scale (Noble et al. 1983).

3.4. Statistics

The performance of the Trondheim-test versus scores of the NLIA-test were related by standard univariate least-square regression. The error of regression was used as the main parameter of the goodness of fit. The data are summarised as mean \pm SD.

4. Results

19 of the 22 subjects completed the 8 min treadmill test approved by the Norwegian Labour Inspection Authority as described in the method section. The remaining three subjects aborted the test after 4 min ($n = 1$) and 5–5.5 min ($n = 2$) because of volitional exhaustion. The heart rate, blood lactate concentration and the ratings of perceived exertion were recorded at exhaustion ($n = 3$) or after 8 min of exercise, and those

subjects who were not exhausted ($n = 18$), continued the exercise for another 1–11.5 min to exhaustion. The subjects exercised for 13.2 ± 4.8 min, and three subjects exercised for 19 min or some seconds more. That means that 16 subjects exercised beyond the point where the treadmill reached its maximum inclination and thus continued to exercise at a speed higher than 1.56 m s^{-1} . The highest exercise intensity used was 2.17 m s^{-1} (7.8 km h^{-1}) at an inclination of 14% ($n = 1$). At exhaustion the heart rate was $181 \pm 12 \text{ min}^{-1}$, the blood lactate concentration was $11.0 \pm 1.2 \text{ mmol L}^{-1}$, and the rating of perceived exertion was 9.0 ± 1.4 .

All 22 subjects carried out the Trondheim firefighter-test, and the time used was 16.4 ± 3.6 min (range 11.2 to 22.5 min). The three subjects that failed on the NLIA-test used ≈ 22 min on the Trondheim-test, while 17 of the 19 who completed the NLIA-test used less than 20 min. The average heart rate during the test was $165 \pm 10 \text{ min}^{-1}$, which is 90% of the peak heart rate measured in the heat chamber during that test. At the end of the test the blood lactate concentration was $9.3 \pm 2.2 \text{ mmol L}^{-1}$, and the rating of perceived exertion, after solving a final puzzle, was 5.8 ± 1.6 .

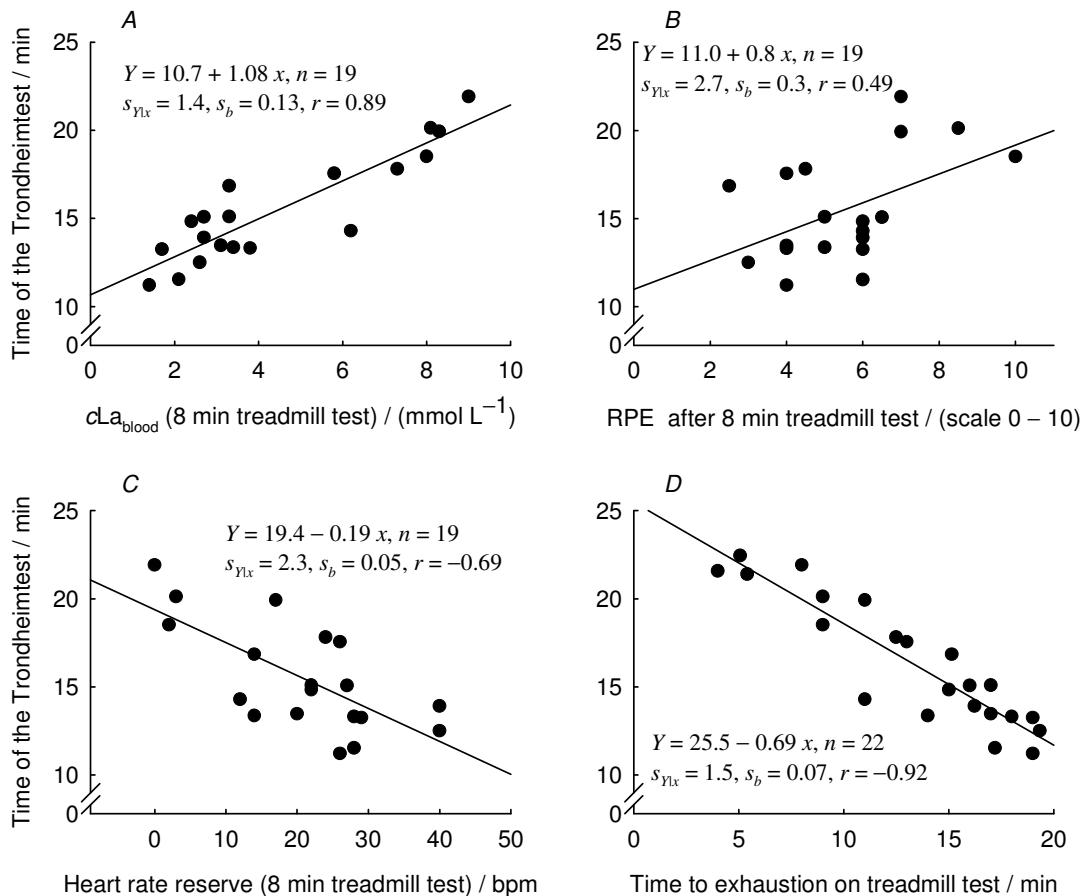


Figure 1. Relationships between the performance-time on the Trondheim-test (Y) versus scores on the extended treadmill test approved by the Norwegian Labour Inspection Authority (X). *A*, time on the Trondheim-test versus the blood lactate concentration after 8 min of treadmill walking. *B*, time on the Trondheim-test versus the rating of perceived exertion (RPE) after 8 min of treadmill walking. *C*, time on the Trondheim-test versus the heart rate reserve after 8 min of treadmill walking. *D*, time on the Trondheim-test versus versus the time to exhaustion at the

extended NLIA-approved treadmill test. n is the number of subjects, $s_{y|x}$ the error of regression, s_b the error of the slope, and r the correlation coefficient.

4.1. Regressions

The time needed to complete the Trondheim-test was related to the performance-scores on the approved NLIA-test (Figure 1 A, B, and C). There was a close linear relationship between the blood lactate concentration after 8 min of treadmill walking at the NLIA-approved test and the performance of the Trondheim-test, and the latter performance could be estimated from the blood lactate concentration with an error of 1.4 min (Figure 1A). There were likewise fair relationships between the performance of the Trondheim-test versus the ratings of perceived exertion or the heart rate reserve after 8 min of treadmill walking. However, the errors of estimate for the latter relationships were 2–3 min (Figure 1B and C). There was a close relationship between the time to exhaustion on the extended NLIA-approved test and the Trondheim-test, and the performance of the latter could be estimated with an error of 1.5 min when the time to exhaustion was known (Figure 1D).

The different performance-scores were closely correlated (f. ex. $r = -0.93$ between the blood lactate concentration after 8 min treadmill walking and the time to exhaustion on the treadmill test). Thus, multiple regressions using more than one possible predictor did not significantly improve the estimate of the time to complete the Trondheim-test.

5. Discussion

The main result in this study is that there were close, linear relationships between scores on the physical performance-test approved by the Norwegian Labour Inspection Authority and the Trondheim-test. Thus, the latter test may be used as an alternative to the NLIA-approved test. Our data suggest that subjects completing the Trondheim-test in 20–21 min or less, meet the standards set by the Norwegian Labour Inspection Authority. However, since most of our 22 subjects performed considerably better than that, further experiments with less fit subjects may be recommended to set a specific limit.

The test approved by the Norwegian Labour Inspection Authority is a simple pass-or-fail-test, that is, with a dichotomous outcome. To enable better comparisons with the Trondheim-test, we included several different measures taken from the NLIA-approved test. Our data suggests that the blood lactate concentration after 8 min of treadmill walking at standardised conditions is a simple and reliable measure of the firefighter's physical ability. That finding is in line with common understanding of physical fitness and testing (see f. ex. Weltman 1995). In addition the time to exhaustion at the extended NLIA-test appeared closely related to the performance on the Trondheim-test. That is likely to be a consequence of the fact that both tests are physically demanding, and both tests reflect the aerobic fitness of the firefighters. It should in this respect be noted that all our subjects were experienced smoke divers, and all had some experience with the tests used. It is conceivable that recruits unfamiliar with fire-fighting-work may perform worse on the Trondheim-test than their physical state suggests. That possible problem may need further research.

The Trondheim firefighter test includes a number of firefighter-like activities. The firefighters reported that this test therefore is experienced as being more relevant, and

that again is motivating. Trondheim fire brigade is not the first to develop such a test. Louhevaara et al. (1994) worked out a similar test. One disadvantage of these tests is that since each test is adapted to one specific test site, it may be difficult to compare the outcome of similar tests set up at different places. Consequently, when using tests like the Trondheim fire-fighter test or the one worked out by Louhevaara et al. (1994), there may be problems with setting a minimum requirement. By comparing the outcome with a standard, approved test as we have done here, that problem may be overcome.

We conclude that the Trondheim-test distinguishes well between physically fit and less fit firefighters. It may be used as an alternative to the established test.

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