PHYSICAL FITNESS OF PROFESSIONAL FIREMEN

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Abstract:

The purpose of this study is twofold: (1) screening the physical fitness of a professional fire-brigade and (2) testing the influence of a training program on the physical fitness of professional firemen.

The sample consisted of 95 professional firemen (42.0 ± 9.1 years) of a professional fire-brigade in Belgium. Stature and body mass were measured. Body composition was estimated by bioelectrical impedance analysis (BIA). Physical condition was determined using the EUROFIT test battery. During 4 months the subjects performed an exercise program twice a week.

High values for body mass index (BMI) (27.1±3.3kg/m^2) and percentage of body fat (26.0±4.9%), and a low score for endurance capacity were observed. Correlation analyses demonstrate that motor capacity decreases with ageing. Analysing the differences (Test session 2 - Test session 1) indicates that there were no significant changes in physical fitness over the 4-month training period. Comparing the two groups with the different number of training sessions attended did not reveal any significant differences between the two groups.

It can be concluded that (1) the firemen of the fire-brigade under study were rather old, had a high BMI and a high percentage of body fat; (2) the performance at the endurance shuttle run did not reach the anticipated standard; (3) the training program did not gain the desired results.

Key words: *body composition, motor performance, exercise program*

KÖRPERLICHE LEISTUNGSFÄHIGKEIT VON PROFESSIONELLEN FEUERWEHRMÄNNERN

Zusammenfassung:

Das Ziel dieser Studie war zweifach: die körperliche Leistungsfähigkeit von professionellen Feuerwehrmännern zu überprüfen, und 2) den Einfluss eines Trainingsprogramms auf die körperliche Leistungsfähigkeit von professionellen Feuerwehrmännern zu testen. 95 professionelle Feuwerwehrmänner (die 42,0±9,1 Jahre alt waren) aus einer professionellen Feuerwehr aus Belgien nahmen an dieser Forschung teil. Es wurden sowohl die Statur und als auch die Körpermasse gemessen. Die Körperzusammensetzung wurde mittels der bioelektrischen Impedanzanalyse (BIA) geschätzt. Die körperliche Leistungsfähigkeit wurde mittels der EUROFIT-Testbatterie festgestellt. Während des viermonatigen Zeitraumes nahmen die Probanden zweimal pro Woche an einem Übungsprogram teil. Es wurden hohe Werte des Körpermassenindexes (27,1±3,3kg/m^2) und des Anteils vom Körperfett (26,0±4,9%) erhalten, aber die Werte der Ausdauerkapazität waren niedrig. Die Korrelationsanalysen zeigten, dass sich die motorische Fähigkeit mit dem Alter verringert. Die Analyse von Unterschieden (Testmessung 2 – Testmessung 1) zeigte, dass bei den Feuerwehrmännern keine bedeutende Unterschiede in der körperliche Leistungsfähigkeit nach dem viermonatigen Trainingszeitraum entstanden. Der Vergleich von zwei Gruppen, die unterschiedlich oft an den Trainingsstunden teilgenommen haben, zeigte keine bedeutenden Unterschiede zwischen den Gruppen.

Aufgrund der durchgeführten Studie sind die folgenden Schlussfolgerungen möglich: 1) Die Feuerwehrmänner, die an der Forschung teilgenommen haben, waren ziemlich alt, sie hatten sowohl einen hohen Körpermassenindex als auch den hohen Anteil vom Körperfett. 2) Die Ergebnisse des Ausdauer-Pendellaufes haben die antizipierte Norm nicht erreicht. 3) Das Trainingsprogram hat die gewünschten Ergebnisse nicht erreicht.

Schlüsselwörter: *Körperzusammensetzung, motorische Leistung, Übungsprogramm*

Introduction

Literature shows that fire fighting is one of the most physically demanding jobs (Lemon & Hermiston, 1977; Duncan, Gardner, & Bernard, 1979; Kilbom, 1980; Davis, Dotson, & Santa Maria, 1982; O'Connel et al., 1986; Romet & Frim, 1987; Schonfeld, Doerr, & Convertino, 1990; Stevenson et al., 1992; Jamnik & Gledhill, 1992; Gledhill & Jamnik, 1992a; Gledhill & Jamnik, 1992b; Donovan & McConnell, 1999; Malley et al., 1999; Williford et al., 1999). It has been demonstrated that, for example, wearing fire-fighting gear increases energy expenditure during fire-fighting tasks by 33% (Davis et al., 1982). Wearing a self-contained breathing apparatus results in an increase in oxygen uptake of 0.54 l/min and in a decrease of 20% in the maximal capacity. Authors investigating the influence of heat on heart rate concluded that extremely high temperatures result in an increase in heart rate by +/- 20 beats per minute (Kilbom, 1980). It has also been shown that during simulated fire-fighting tasks the heart rate can rise up to 90% of the maximal heart rate (Duncan et al., 1979; O'Connel et al., 1986; Schonfeld et al., 1990). Nevertheless, differentiation is necessary because the physical demands differ according to the job-specific task that a fireman has to execute (Romet & Frim, 1987). The extremely high physical demands of the job result in a large number of job-related injuries with an even high incidence of premature deaths (Gledhill & Jamnik, 1992a; Gledhill & Jamnik, 1992b; Williford et al., 1999). It is obvious, regarding the safety of the firemen and the population, that firemen need to be in an excellent physical condition to be able to do this demanding job (Kilbom, 1980; Brickman, Jr., 1999). A balance has to be found between the workload and the capabilities of the individual firemen, that are determined by factors such as age, anthropometric parameters (percentage of body fat, fat-free mass, body mass index) and motor capacity (strength and endurance) (Davis et al., 1982; Gledhill & Jamnik, 1992a; Williford et al., 1999; Kales et al., 1999). It has been shown that fire-fighting tasks such as climbing fire-escapes, hoisting tasks, forcing an entry and saving victims are significantly related to factors such as stature, body mass, fat-free mass, percentage of body fat, total hand-grip strength, push-up scores, sit-up scores and endurance (Williford et al., 1999). A high level of muscle strength and muscle endurance, particularly of the trunk and lower limbs, is necessary to execute the fire-fighting tasks easily and smoothly and also to prevent injuries of the lower back (Lemon & Hermiston, 1977). Body composition factors such as percentage of body fat and, moreover, the percentage of fat-free mass are important determinants. In previous research it has been shown that the performance is more influenced by the increasing percentage of body fat than by the increasing age (Davis et al., 1982). Overweight, and especially obesity, is a limiting factor not only for fire-fighting but also for the health of the firemen (Davis et al., 1982; Gledhill & Jamnik, 1992a; Kales et al., 1999).

In different countries (e.g. France, Canada, USA) the physical preparedness of firemen has been studied extensively (Schonfeld et al., 1990; Williford et al., 1999). Additionally, in the domain of 'Occupational Fitness Screening' a great deal of know-how is available at present (Adams et al., 1986; Stevenson et al., 1992; Jamnik & Gledhill, 1992; Brickman, Jr., 1999). Firemen should perform activities at least twice a week which train muscle strength, muscle endurance and cardiovascular fitness and which decrease the percentage of body fat and increase the percentage of fat-free mass (Kilbom, 1980). These activities are necessary to maintain the physical preparedness of the firemen. In Belgium hardly any investigation has been done on firemen. The purpose of this study is twofold: (1) screening the physical fitness of a professional fire-brigade and (2) testing the influence of a training program on the physical fitness of this group.

Methods

Subjects

The sample consisted of 95 professional firemen of a fire-brigade in Belgium. Four groups were formed (A, B, C, D). These groups were based on the existing crews of the fire-brigade. The groups A (n=28), B (n=29) and C (n=27) represented the different teams working in shifts. The fourth group D (n=11) was formed of the officers. The mean age of the total group was 42.0 ± 9.1 years, varying from 25.5 to 59.1. The subjects were informed of the purpose of this study and the test procedures during special information sessions.

Acknowledgement

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Anthropometry

The stature and body mass were measured prior to the physical tests. Stature was measured using the Martin's anthropometer with a precision of 0.1 cm. Body mass was measured using a Seca spring balance with a precision of 1 kg. The subjects were barefoot and wore light sportswear. The body mass index (BMI= body mass (kg) / height^2 (m)) was calculated as an index for being overweight.

Body composition

The components of the body composition were estimated based on the reactance and resistance measured by bioelectrical impedance. The BIODYNAMICS Model 310 was used which is a device using a current of 800 mA with a single frequency of 50 kHz. The measurements were made following the procedure described by Heyward & Stolarczyck (1996). The fat-free mass was estimated using the formula of Segal et al. (1988):

$$FFM = 22.66827 + 0.00132\ (HGT) - 0.04394\ (RES) + 0.3052\ (WGT) - 0.1676\ (AGE),$$

with FFM = fat-free mass (kg), HGT = height (cm), WGT = weight (kg), RES = resistance (Ω) and AGE = age (year).

Fat mass and percentage of body fat were derived from the fat-free mass.

Physical fitness tests

Physical fitness was measured using the EUROFIT test battery. This battery consists of several tests (Table 1) which measure the basic motor capacity of the subjects. All tests were performed in the fire station under standardised conditions. The subjects wore light sport shoes to perform the standing broad jump, the shuttle run and the endurance shuttle run (Council of Europe, 1993).

Training programme

During a period of 4 months the subjects (n=81) performed an exercise programme in which the different fitness components were trained. The firemen exercised 2 times a week during 45 minutes each session under the supervision of 2 trainers. It was made sure that in each session different fitness components were trained, but there was no specific training to prepare the subjects for the different tests of the EUROFIT battery. These training sessions were organised for the different groups during working-hours in the fire station. In total ± 192 sessions were provided. Attending the training sessions was not obligatory, and so the number of sessions the subjects participated in varied between 0 and 23 with a mean of 13.3 sessions. Attendance was noted so that it was possible to take the number of the sessions attended into account in the analyses.

Statistical analysis

Baseline analyses

After the first test session descriptive statistics (Mean, SD, Min, Max) were calculated for the total group and the four different teams (A, B, C, D). Possible differences between the groups were detected by analyses of variance. To determine the influence of age on the performance in various tests, correlation coefficients were calculated between the chronological age and the measured anthropometric characteristics and physical fitness components. The percentiles P1, P5, P10, P25, P50, P75, P90, P95 and P99 were calculated to construct a profile chart of the fire brigade.

Analyses of the training programme

Descriptive statistics were calculated for the measurements of the first and the second test session (n=81). Changes between test session 1 (T1) and test session 2 (T2) were calculated and analysed using *t*-tests for dependent samples. The relation between the results of T1 and T2 was explored by correlation analyses.

Based on the exercise sessions attended the subjects were divided into two groups. Group 1 (n=26) attended 13 exercise sessions or less and group 2 (n=28) exercised during at least 16 sessions. The differences between the two groups at T1 were explored using *t*-tests for independent samples. The effect of the training programme was studied using *t*-tests for the independent samples by comparing the results of the two groups at T2.

The significance level was set on p = 0.05. Statistical analysis was executed using the SAS package (version 6.12, SAS Institute Inc., Cary, North Carolina, USA).

Results

Baseline analysis (T1)

The descriptive statistics (Mean, SD, Min and Max) of the 95 subjects are presented in Table 1. In Table 2 the profile chart is given based on the percentiles of the firemen.

In Table 3 the descriptive statistics are shown arranged by group (A, B, C, D). The analyses of variance demonstrated that there were no significant differences between the four groups. The correlations between the chronological age and several anthropometric and motor characteristics are presented in Table 4. The correlation coefficients range between r = -0.55 and r = +0.39. The results indicate that significant ($p \leq 0.01$) negative correlation coefficients are found between the chronological age and several motor characteristics. This is an indication that there is a decrease in physical fitness with ageing.

Table 1. Descriptive statistics (n=95)

	Mean	SD	Min	Max
Age (years)	42.0	9.1	25.5	59.1
Height (cm)	176.0	6.1	161.4	190.4
Body mass (kg)	83.9	11.2	55.0	118.0
BMI (kg/m²)	27.1	3.3	18.5	38.6
Body fat percentage (%)	26.0	4.9	14.0	39.4
Fat-free mass (kg)	61.7	6.2	47.2	78.3
Fat mass (kg)	22.2	6.6	7.8	46.6
Flamingo balance (n)	13.1	4.7	3	30
Plate tapping (sec)	10.6	1.2	8.2	13.8
Sit-and-reach (cm)	24.4	7.9	5	42
Standing broad jump (cm)	211.4	23.8	150	284
Handgrip L (kg)	55.3	6.5	40	70
Handgrip R (kg)	57.1	7.2	42	76
Sit-ups (n)	22.5	5.6	4	34
Bent-arm hang (sec)	24.1	15.6	0	81.7
Shuttle run 50 (sec)	22.0	1.8	17.1	28.7
Endurance shuttle run (min)	5.0	2.4	0.5	10.5

Table 2. Anthropometric and motor profile chart for firemen (n = 95)

	Percentiles								
Dimension	1	5	10	25	50	75	90	95	99
Age (years)	25.5	27.2	28.1	34.1	43.2	50.2	53.1	55.9	59.1
Height (cm)	161.4	165.2	167.5	172.0	176.1	180.5	184.7	186.7	190.4
Body mass (kg)	55.0	69.0	71.0	75.5	82.5	93.5	100.0	102.5	118.0
BMI (kg/m^2)	18.5	22.4	23.0	24.7	26.7	29.4	31.0	32.2	38.7
Body fat percentage (%)	14.0	17.1	19.8	23.4	26.1	29.2	32.0	33.7	39.4
Flamingo balance (n)	30	21	19	16	13	10	8	6	3
Plate tapping (sec)	13.8	12.6	12.4	11.4	10.3	9.9	8.9	8.7	8.2
Sit-and-reach (cm)	5	10	14	18	26	30	33	37	42
Standing broad jump (cm)	150	170	183	198	211	224	241	255	284
Handgrip L (kg)	40	46	48	50	54	60	65	67	70
Handgrip R (kg)	42	45	48	52	58	62	66	70	76
Sit-ups (n)	4	14	16	20	23	26	30	31	34
Bent-arm hang (sec)	0.0	2.3	6.8	12.6	22.6	32.4	42.7	58.0	81.7
Shuttle run (sec)	28.7	24.9	24.1	22.9	21.8	21.0	20.3	19.5	17.1
Endurance shuttle run (min)	0.5	1.5	2.0	3.0	5.0	7.0	8.5	9.5	10.5

Table 3. Descriptive statistics arranged by group

	Group A (n=28)	Group B (n=29)	Group C (n=27)	Group D (n=11)
Age (years)	40.2±9.7	41.0±9.5	43.2±8.8	46.3±6.1
Height (cm)	177.6±4.8	175.4±7.4	175.4±5.9	174.6±5.3
Body mass (kg)	82.1±8.4	84.3±13.1	87.2±11.9	79.7±9.0
BMI (kg/m²)	26.0±2.7	27.4±3.6	28.3±3.6	26.1±1.9
Body fat percentage (%)	24.3±4.5	25.9±5.1	27.5±5.2	27.2±3.2
Flamingo balance (n)	12.5±3.9	13.3±5.6	13.0±4.4	14.1±5.3
Plate tapping (sec)	10.7±1.2	10.4±1.3	10.8±1.3	10.2±0.7
Sit-and-reach (cm)	25.6±8.7	22.7±7.5	24.1±8.0	26.5±6.5
Standing broad jump (cm)	218.2±20.4	209.6±28.3	207.9±23.8	207.3±17.9
Handgrip L (kg)	55.7±5.9	56.3±7.0	54.7±7.2	53.7±5.2
Handgrip R (kg)	57.7±6.2	57.6±7.5	57.9±8.4	52.7±4.5
Sit-ups (n)	24.7±3.9	22.0±5.1	19.9±7.3	24.1±3.7
Bent-arm hang (sec)	29.6±14.5	23.5±17.2	20.5±15.6	20.2±11.5
Shuttle run 50 (sec)	21.8±1.4	22.3±1.8	22.0±2.0	21.8±2.1
Endurance shuttle run (min)	5.7±2.2	4.7±2.5	4.6±2.4	5.4±2.3

Table 4. Correlation coefficients between age on the one hand and height, body mass and the Eurofit tests on the other (n=95)

	r
Height	-0.23*
Body mass	0.17
Flamingo balance	0.36**
Plate tapping	0.24*
Sit-and-reach	-0.22*
Standing broad jump	-0.55**
Handgrip L	-0.07
Handgrip R	-0.04
Sit-ups	-0.49**
Bent-arm hang	-0.40**
Shuttle run 50	0.39**
Endurance shuttle run	-0.47**

* $p < 0.05$
** $p \leq 0.01$

Training results

In Table 5 the descriptive statistics of test session 1 (T1) and test session 2 (T2), the *t*-test analyses (T2-T1) and the correlation coefficients (T1 vs. T2) are presented for the 81 subjects with measurements at both test sessions. The *t*-test analyses indicate that there are no significant ($p \leq 0.01$) changes from T1 to T2. In Table 6 the descriptive statistics of the two training groups are shown. No significant differences existed at T1 between the two groups (results not shown). The results of the *t*-tests at T2 demonstrate that there are no significant differences between the subjects who exercised during 13 sessions or less and the subjects who exercised during more than 16 sessions (Table 6).

Table 5. Descriptive statistics (mean±SD) of the anthropometric and motor characteristics at T1 and T2; t-values (T2-T1) and correlation coefficients between T1 and T2 (n=81)

	T1	T2	t	r
Height (cm)	175.8±6.1	175.7±6.1	-0.08	0.99**
Body mass (kg)	83.0±10.3	83.6±10.6	0.9	0.97**
BMI (kg/m²)	27.0±3.1	27.1±3.2	0.3	0.96**
Body fat percentage (%)	25.5±4.4	26.2±4.4	0.7	0.95**
Fat-free mass (kg)	61.3±5.9	61.4±6.1	0.1	0.97**
Fat mass (kg)	21.4±5.8	22.2±5.9	0.1	0.96**
Flamingo balance (n)	12.8±4.8	12.2±4.8	-0.6	0.55**
Plate tapping (sec)	10.6±1.2	10.5±1.6	-0.1	0.48**
Sit-and-reach (cm)	25.4±7.7	25.9±8.0	0.7	0.92**
Standing broad jump (cm)	211.7±23.6	209±26.6	-2.6	0.89**
Handgrip L (kg)	55.5±6.5	57.4±7.3	1.9	0.82**
Handgrip R (kg)	57.1±7.1	60.4±7.7	3.25	0.81**
Sit-ups (n)	22.6±5.2	24.7±5.9	2.1	0.80**
Bent-arm hang (sec)	25.3±15.7	24.3±15.3	-1.0	0.84**
Shuttle run 50 (sec)	21.9±1.7	21.1±1.6	-0.8	0.71**
Endurance shuttle run (min)	5.2±2.4	5.7±2.4	0.5	0.80**

** $p < 0.01$

Table 6. Descriptive statistics (mean±SD) and t-test analyses on T2 between the two training groups

	Group 1 (n=26)	Group 2 (n=28)	t
Age (years)	41.0±8.7	42.4±8.4	0.6
Height (cm)	176.1±6.1	176.1±6.5	0.03
Body mass (kg)	84.1±9.1	83.8±10.5	0.08
BMI (kg/m²)	27.1±2.9	27.1±3.1	0.1
Body fat percentage (%)	26.7±4.0	26.4±3.9	0.3
Fat-free mass (kg)	61.5±6.3	61.5±6.1	0.01
Fat mass (kg)	22.6±4.8	22.4±5.4	0.1
Plate tapping (sec)	10.5±1.3	10.7±2.2	0.3
Sit-and-reach (cm)	25.2±7.5	27.2±7.7	1.0
Standing broad jump (cm)	209.6±22.6	205.1±29.7	0.6
Handgrip L (kg)	58.7±7.0	56.9±7.2	0.9
Handgrip R (kg)	60.2±7.1	60.3±8.7	0.02
Sit-ups (n)	25.0±5.5	24.2±5.5	0.5
Bent-arm hang (sec)	20.0±14.2	24.7±15.7	1.2
Shuttle run 50 (sec)	21.3±1.4	21.3±2.1	0.04
Endurance shuttle run (min)	5.2±2.1	5.7±2.4	0.8

Discussion and conclusions

Baseline analysis

The descriptive statistics of anthropometric variables from previous studies investigating firemen and the descriptive statistics of test session 1 of the present study are shown in Table 7. In the present study a sample of 95 subjects was used which is rather large compared with previous studies. The mean age was 42.0 ± 9.1 years. Most of the subjects (n=78) were older than 33 years of age, which indicates that the fire-brigade under study is a relatively old brigade. Comparable values are reported in the present study for stature and body mass.

Table 7. Overview of literature concerning anthropometric characteristics of firemen (Mean ± SD)

	Sample (n)	Country	Age (years)	Height (cm)	Body mass (kg)	BMI (kg/m²)	Body fat percentage (%)
Davis et al (1982)	100	US	33.1±7.6	176.7±5.4	83.4±10.9	26.9	21.1±6.7
O'Connel et al (1986)	17	US	32.3±6.7	182.1±5.1	82.0±8.2	24.8	15.3±3.0[a]
Ben-Ezra and Verstaete (1988)	38	US	35.1±1.6	176.9±1.0	81.9±1.6	26.2	
Schonfeld et al (1990)	20	US	38.6±2.5	175.7±1.1	75.4±1.9	24.3	22.4±0.9
Gledhill & Jamnik (1992b)	53	Canada	30.4±3.5	179.3±6.3	81.6±12.3	25.4±2.29	
Stevenson et al (1992)	65	Canada	24.1	176.8±6.3	77.0±11.2	24.63	
Smith & Petruzzello (1998)	10	US	34.4±5.0	178.6±6.5	83.3±8.0	26.0	25.1±5.4[b] 17.7±5.5[a]
Williford et al (1999)	91	US	31.7±7.4	177.3±6.4	84.0±10.9	26.8	13.8±4.3[a]
Kales et al (1999)	329	US	39±6.9			29.0±4.0	
Williams et al (1999)	47	UK	19.3±3.21	175.3±6.0	71±9.63	23.1	10.9±3.6
Malley et al (1999)	40	US	43±8		80±10		24±5
Peterson et al (2000)	17	Canada	27.7±8.1	179.1±7.0	78.7±10.8	24.5	
This study	95	Belgium	42.0±9.1	176.0±6.1	83.9±11.2	27.1±3.3	26.0±4.9

a: skinfold measurements, b: bioelectrical impedance spectroscopy

However, the BMI in the present study (27.1 ± 3.3) was the second highest of all the reported values, with only Kales et al. (1999) reporting a higher value (29.0 ± 4.0). The used cut-scores indicate that the firemen of that fire-brigade were overweight (Kales et al., 1999). High values for the percentage of body fat were noticed. It should be mentioned, however, that the values reported in literature were derived from skinfold measurements and not from bioelectrical impedance as in the present study. It was decided to use bioelectrical impedance analysis (BIA) because it was demonstrated by Biaggi et al. (1999), who compared air-displacement plethysmography, hydrostatic weighing and BIA to determine body composition, that the BIA-method is the most valid field method. These results indicate that the high values of BMI are the consequence of a high percentage of body fat. Not only this has a negative influence on motor performance, but it also increases the risk of cardiovascular diseases, diabetes mellitus and hypertension (Henry, 1994). A linear relation between BMI and mortality has been demonstrated (Henry, 1994; Kales et al., 1999). The high prevalence of overweight and obesity and the corresponding health effects demand the development of fitness promoting programs for firemen (Kales et al., 1999). The percentage of body fat, fat distribution and the percentage of fat-free mass are important factors. Davis et al. (1982) demonstrated that an increasing percentage of fat mass has a more detrimental effect on the performance than increasing age.

The motor components, which were incorporated in this study, have not been very extensively investigated in previous studies. In literature values could only be found for the standing broad jump, bent-arm hang, sit-and-reach, handgrip and sit-ups (Table 8). Any comparison of these values is extremely difficult since different methods were used to assess the measurements. A rather low score was obtained for sit-and-reach. Only Davis et al. (1982) reported a comparable score (23.7 ± 9.1). The results of the anthropometric variables (Table 7) and of the motor components (Table 8) are most closely linked to the results of Davis et al. (1982). In literature most often items such as simulated fire-fighting tasks, heart rate measurements and VO_2 max measurements have been investigated. These studies demonstrated that even with the absence of stress and heat, fire-fighting tasks are very physically demanding. It has been shown that during simulated fire-fighting tasks the subjects perform at 60% to 80% of the maximal oxygen uptake (VO_2 max) and at 97% of the maximal heart rate (Davis et al., 1982; O'Connel et al., 1986; Romet & Frim, 1987; Schonfeld et al., 1990; Sothman, Saupe, & Jasenof, 1990; Gledhill & Jamnik, 1992a; Gledhill & Jamnik, 1992b; Malley et al., 1999). Heat and special intervention equipment also contribute to the physical demands of the job. The extreme temperatures cause a mean increase in heart rate of 20 beats per minute (Donovan & McConnell, 1999). Wearing the protective gear and the equipment increases energy expenditure by 1/3; the effects of stress and heat not being included (Davis et al., 1982; Schonfeld et al., 1990). Williford et al. (1999) demonstrated that significant correlations exist between motor tests and specific fire-fighting tasks. Nevertheless, Jackson (1994) prefers to use job-specific tasks as selection tests complemented with motor tests.

Table 8. Overview of literature concerning motor capacity of firemen

	Davis et al (1982)	Misner et al (1989)	Schonfeld et al (1990)	Gledhill & Jamnik (1992a)	Stevenson et al (1992)	Williford et al (1999)	**This study**
Sample (n)	100		20	53	65	91	95
Flamingo balance (n)							13.1±4.7
Plate tapping (sec)							10.6±1.2
Sit-and-reach (cm)	23.7±9.1[d]		27.0±2.0[e]	39±7.4[c]		32.0±8.6	24.4±7.9
Standing broad jump (cm)	192.9±25.58	205.4					211.4±23.8
Handgrip L (kg)		51.8					55.3±6.3
Handgrip R (kg)		55.7	51.5±1.2				57.1±7.2
Total handgrip (kg)					100.4±16	116.8±17.7	112.4
Sit-ups (n)	36.9±11.7[b]		55.8±5.4[b]	41.8±9.2[a]	36.5±9.3[a]	39.9±7.8[a]	22.5±5.6
Bent-arm hang (sec)		49.5					24.1±15.6
Shuttle run 50 (sec)							22.0±1.8
Endurance shuttle run (min)							5.0±2.4

a: number in 1 min, b: number in 2 min, c: overhang 26cm, d: Wells & Dillon, e: overhang 25.4cm

In Table 4 it is clearly demonstrated that significant correlations were found between most of the motor components and the chronological age. Only for body mass and left and right hand grip no significant correlations were observed. These correlation coefficients were mainly negative which indicate that performance decreases with ageing. The observed positive correlations for flamingo balance, plate tapping and shuttle run 50 indicate the same finding since higher scores on these tests represent a poorer result. Also Lusa, Louhevaara, & Kinnunen (1983) noticed weaker performances with increasing age. These findings demonstrate that age is an important factor, which should be taken into account. Kilbom (1980) reported a decrease in maximal aerobic capacity with ageing. It is concluded from that study that an effective physical training programme should be performed at least twice a week.

In Table 9 the results of previous research concerning VO_2 max are presented. Since it was impossible to assess a VO_2 max test in the present study only the endurance shuttle run test was used. Based on the results reported by Ramsbottom, Brewer and Williams (1988) it was possible to transform the results of the endurance shuttle run to a VO_2 max score. These authors have shown that in a group of young adults (19-36 years of age) a score of 5 minutes for the endurance shuttle run (which is the mean score in the present study) represents a VO_2 max score of 31.0 ml/kg/min. Although this is a rough estimate it demonstrates that the subjects in this study have a poor cardiovascular capacity. A value of 45 ml/kg/min is suggested as the minimum value, which is required to be able to perform fire-fighting tasks optimally (Gledhill & Jamnik, 1992b). Since VO_2 max decreases with ageing, it is necessary to be cautious using this prescription (Kilbom, 1980). Kilbom (1980) suggested a bicycle test at 250 Watt during 6 minutes as a selection test. This corresponds with a VO_2 max score of 3.5 l/min. In this study a score of 45 ml/kg/min represents a 9-minute score at the endurance shuttle run. This corresponds with P90 in Table 2. It can be concluded that only 10 percent of the fire-brigade crews reached the minimum standard.

high correspondence between the two test sessions.

In Table 6 it is shown that there are no significant differences between the two extreme training groups. From these findings it can be concluded that the training programme did not gain the desired outcome. Several facts can explain these results. The too low intensity of the training program was the main reason, which is also confirmed in literature (Williams et al., 1999).

Table 9. Overview of literature concerning VO_2 max values in firemen

Author	Sample		VO_2 max (l/min)	VO_2 max (ml/kg/min)	test
	N	Country			
Davis et al (1982)	100	US	3.28	39.6	Åstrand en Rodahl
Puterbaugh & Lawyer (1983)	27	US	3.61±1.10		Bruce and Hornsten
O'Connel et al (1986)	17	US	3.97±0.58		
Adams et al (1986)	350	US		42.3±4.6	Bruce protocol
Ben-Ezra & Verstraete (1988)	38	US	3.5±0.1 3.3±0.1	43.1±1.4 40.1±1.4	Progressive test treadmill Progressive test step
Schonfeld et al (1990)	20	US		48.5±2.1	Bruce protocol
Gledhill & Jamnik (1992a)	51	Canada	3.97±0.46	48.7±7.0	Open circuit with Douglas sac
Donovan & McConnell (1999)	8	UK	4.52±0.13		
Williams et al (1999)	51	UK	3.39±0.61	48.4±6.28	Estimated based on 20m shuttle run[a]
Peterson et al (2000)	17	Canada		51.8±6.1	Bicycle ergometer test
Sothman et al (1990)	136	US		34.72±5.48	Submaximal test op treadmill
This study	95	Belgium		± 31.0	Estimated based on 20m shuttle run[a]

a: value estimated based on Ramsbottom R et al. (1988)

Training results

To be able to execute this study several agreements had to be made with the Union. Absolute guarantee had to be given that the results would not have any consequences on their professional career. Moreover, the subjects were completely free to attend the exercise sessions or not. Although the training sessions were organised during the working hours, only the motivated firemen attended the sessions regularly. As a consequence the training results are not a generality to other fire-brigades of other countries where attendance at the training sessions can be made obligatory.

The *t*-values shown in Table 5 indicate that there are no significant ($p \leq 0.01$) differences between the results of test session 1 (T1) and test session 2 (T2). The mostly high positive correlation coefficients between T1 and T2 also indicate a

Because of the large age range of the subjects (25.5 – 59.1 years) it was not possible to give a training program which was optimal for each individual. A second reason was the fact that the firemen were not sports-minded. This can explain the low compliance to the training programme offered, which should have been executed twice a week for 45 minutes. It was postulated in previous research that training and schooling, and also selection tests, are necessary for physically demanding jobs (Jackson, 1994; IImarinen, 2000). Specifically for firemen, this means that strength, flexibility and endurance should be trained. Since several stations needed to be permanently manned and interventions had absolute priority, the organisation of the training program was difficult. Therefore, it can be concluded that if training attendance is not obligatory and, as a consequence, the attendance rate is low, no gain in motor capacity will be achieved.

It can be concluded that (1) the firemen of the fire-brigade under study were rather old, had a high BMI and a high percentage of body fat; (2) the performance at the endurance shuttle run did not reach the anticipated standard; (3) the training program did not gain the desired results.

References

Adams, T. D., Yanowitz, F. G., Chandler, S., Specht, P., Lockwood, R., & Yeh, M. P. (1986). A study to evaluate and promote total fitness among fire fighters. *Journal of Sports Medicine and Physical Fitness*, ***26*** (4), 337-345.

Ben Ezra, V., & Verstraete, R. (1988). Stair climbing: an alternative exercise modality for firefighters. *Journal of Occupational Medicine*, ***30*** (2), 103-105.

Biaggi, R. R., Vollman, M. W., Nies, M. A., Brener, C. E., Flakoll, P. J., Levenhagen, D. K., Sun, M., Karabulut, Z., & Chen, K. Y. (1999). Comparison of air-displacement plethysmography with hydrostatic weighing and bioelectrical impedance analysis for the assessment of body composition in healthy adults. *American Journal of Clinical Nutrition*, ***69*** (5), 898-903.

Brickman, C. P., Jr. (1999). Fit-testing for firefighters. *Occupational Health Safety*, ***68*** (1), 56-58.

Council of Europe (1993). *Eurofit: Handbook for the Eurofit tests of physical fitness.* 2nd ed. Strasbourg: Council of Europe.

Davis, P. O., Dotson, C. O., & Santa Maria, D. L. (1982). Relationship between simulated fire fighting tasks and physical performance measures. *Medicin & Science in Sports & Exercises*, ***14*** (1), 65-71.

Donovan, K. J., & McConnell, A. K. (1999). Do fire-fighters develop specific ventilatory responses in order to cope with exercise whilst wearing self-contained breathing apparatus? *European Journal of Applied Physiology and Occupational Physiology*, ***80*** (2), 107-112.

Duncan, H. W., Gardner, G. W., & Barnard, R. J. (1979). Physiological responses of men working in fire fighting equipment in the heat. *Ergonomics*, ***22*** (5), 521-527.

Gledhill, N., & Jamnik, V. K. (1992b). Characterization of the physical demands of firefighting. *Canadian Journal of Sport Science*, ***17*** (3), 207-213.

Gledhill, N., & Jamnik, V. K. (1992a). Development and validation of a fitness screening protocol for firefighter applicants. *Canadian Journal of Sport Science*, ***17*** (3), 199-206.

Henry, C. J. K. (1994). Variability in adult body size: uses in defining the limits of human survival. In S.J.Ulijaszek & C. G. N. Mascie-Taylor (Eds.), *Anthropometry: the individual and the population* (pp. 117-129). Cambridge: Cambridge University Press.

Heyward, V. H., & Stolarczyk, L. M. (1996). *Applied body composition assessment.* Champaign, IL.: Human Kinetics.

IImarinen, M. (2000). A physical activity programme to support the work ability of ageing workers: Characteristics of a succesful physical activity programme. *Perspectives*, ***2,*** 105-125.

Jackson, A. S. (1994). Pre-employment physical evaluation. *Exercise and Sport Science Review*, ***22***, 53-90.

Jamnik, V. K., & Gledhill, N. (1992). Development of fitness screening protocols for physically demanding occupations. *Canadian Journal of Sport Science*, ***17*** (3), 222-227.

Kales, S. N., Polyhronopoulos, G. N., Aldrich, J. M., Leitao, E. O., & Christiani, D. C. (1999). Correlates of body mass index in hazardous materials firefighters. *Journal of Occupational and Environmental Medicine*, ***41*** (7), 589-595.

Kilbom, A. (1980). Physical work capacity of firemen: With special reference to demands during fire fighting. *Scandinavian Journal of Work and Environmental Health*, ***6*** (1), 48-57.

Lemon, P. W. R., & Hermiston, R. T. (1977). The human energy cost of fire fighting. *Journal of Occupational Medicine*, ***19***, 558-562.

Lusa, S., Louhevaara, V., & Kinnunen, K. (1983). Are the job demands on physical work capacity equal for young and aging firefighters. *Journal of Occupational Medicine*, ***25*** (8), 581-586.

Malley, K. S., Goldstein, A. M., Aldrich, T. K., Kelly, K. J., Weiden, M., Coplan, N., Karwa, M. L., & Prezant, D. J. (1999). Effects of fire fighting uniform (modern, modified modern, and traditional) design changes on exercise duration in New York City Firefighters. *Journal of Occupational and Environmental Medicine*, ***41*** (12), 1104-1115.

Misner, J. E., Boileau, R. A., & Plowman, S. A. (1989). Development of placement tests for firefighting. *Applied Ergonomics*, ***20***, 218-224.

O'Connel, E. R., Thomas, P. C., Cady, L. D., & Karwasky, R. J. (1986). Energy cost of simulated stair climbing as a job-related task in firefighting. *Journal of Occupational Medicine*, ***28***, 282-284.

Peterson, S. R., Dreger, R. W., Williams, B. E., & Mc Garvey, W. J. (2000). The effects of hyperoxia on performance during simulated firefighting work. *Ergonomics*, ***43*** (2), 210-222.

Puterbaugh, J. S., & Lawyer, C. H. (1983). Cardiovascular effects of an exercise program: a controlled study among firemen. *Journal of Occupational Medicine*, ***25*** (8), 581-586.

Ramsbottom, R., Brewer, J., & Williams, C. (1988). A progressive shuttle run test to estimate maximal oxygen uptake. *British Journal of Sports Medicine*, ***22*** (4), 141-144.

Romet, T. T., & Frim, J. (1987). Physiological responses to fire fighting activities. *European Journal of Applied Physiology and Occupational Physiology*, ***56*** (6), 633-638.

Schonfeld, B. R., Doerr, D. F., & Convertino, V. A. (1990). An occupational performance test validation program for fire fighters at the Kennedy Space Center. *Journal of Occupational Medicine*, ***32*** (7), 638-643.

Segal, K. R., Van Loan, M., Fitzgerald, P. I., Hodgdon, J. A., & Van Itallie, T. B. (1988). Lean body mass estimation by bioelectrical impedance analysis: a four- site cross-validation study. *American Journal of Clinical Nutrition*, ***47*** (1), 7-14.

Smith, D. L., & Petruzzello, S. J. (1998). Selected physiological and psychological responses to live-fire drills in different configurations of firefighting gear. *Ergonomics*, ***41*** (8), 1141-1154.

Sothman, M. S., Saupe, K. W., & Jasenof, D. (1990). Advancing age and the cardiorespiratory stress of fire suppression: determining a minimum standard for aerobic fitness. *Human Performance*, ***3*** (4), 217-236.

Stevenson, J. M., Bryant, J. T., Andrew, G. M., Smith, J. T., French, S. L., Thomson, J. M., & Deakin, J. M. (1992). Development of physical fitness standards for Canadian Armed Forces younger personnel. *Canadian Journal of Sport Science*, ***17*** (3), 214-221.

Williams, A. G., Rayson, M. P., & Jones, D. A. (1999). Effects of basic training on material handling ability and physical fitness of British Army recruits. *Ergonomics*, ***42*** (8), 1114-1124.

Williford, H. N., Duey, W. J., Olson, M. S., Howard, R., & Wang, N. (1999). Relationship between fire fighting suppression tasks and physical fitness. *Ergonomics*, ***42*** (9), 1179-1186.

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FIZIČKA PRIPREMLJENOST PROFESIONALNIH VATROGASACA

Sažetak

Uvod

Posao vatrogasca jedan je od tjelesno najzahtjevnijih. Ekstremno visoki profesionalni fizički zahtjevi rezultiraju velikim brojem ozljeda na radu, pa čak i visokom incidencijom prijevremene smrti. Očigledno je, promatra li se sigurnost vatrogasca u odnosu na ostatak populacije, da vatrogasci trebaju biti u odličnoj tjelesnoj kondiciji da bi bili sposobni obavljati tako zahtjevan posao. Potrebno je uravnotežiti profesionalna opterećenja s mogućnostima pojedinog vatrogasca, što je određeno različitim faktorima, kao što su dob, antropometrijske karakteristike (postotak masnog tkiva, bezmasna tjelesna masa, indeks tjelesne mase) i motoričke sposobnosti (snaga i izdržljivost). Pokazalo se da su vatrogasni zadaci, kao što su penjanje do požarnih izlaza, poslovi na dizalici, razvaljivanje ulaza i spašavanje žrtava, značajno povezani s nekim čimbenicima kao što su visina, tjelesna masa, bezmasna tjelesna masa, postotak masnog tkiva, snaga stiska šake, broj izvedenih sklekova, broj izvedenih "trbušnjaka" i izdržljivost.

Istraživači u raznim zemljama (npr. Francuskoj, Kanadi, SAD-u) dosta su proučavali fizičku pripremu vatrogasaca. Svaki vatrogasac trenira barem dva puta tjedno kako bi unaprijedio svoju mišićnu snagu, izdržljivost i kardiovaskularni status te kako bi smanjio postotak masnog tkiva i povećao mišićnu masu Te su aktivnosti nužne za održanje fizičke pripremljenosti vatorgasaca. U Belgiji gotovo da i nema istraživanja koja su se bavila vatrogascima. Svrha ovog istraživanja je dvostruka: (1) ispitati fizičku pripremljenost profesionalne vatrogasne jedinice i (2) provjeriti utjecaj trenažnog programa na razinu fizičke pripremljenosti te grupe.

Metoda

Uzorak ispitanika činilo je 95 profesionalnih vatrogasaca (42.0 ± 9.1 god.). Izmjerena im je tjelesna visina i tjelesna masa. Sastav tijela procijenjen je pomoću BIA. Tjelesna sposobnost određena im je uz pomoć baterije testova EUROFIT. Kroz period od četiri mjeseca ispitanici (N=81) su sudjelovali u programu vježbanja u okviru kojega su radili na unapređenju različitih komponenata fizičke pripreme. Vatrogasci su vježbali dva puta tjedno po 45 minuta pod vodstvom dva trenera. Svaki je trening bio isplaniran tako da je naglasak bio na razvoju različite komponente fizičke pripremljenosti, ali nije bilo ciljanog treninga glede različitih testova baterije EUROFIT. Pojedini treninzi bili su organizirani u okviru dva radna sata u vatrogasnoj stanici. Kako pohađanje treninga nije bilo obvezno, broj ispitanika po pojedinom treningu varirao je od 0 do 23, u prosjeku 13 po treningu. Prisustvovanje treninzima se bilježilo tako da se taj faktor mogao uzeti u obzir u okviru analize rezultata.

Rezultati

Izmjerene su visoke vrijednosti BMI (27.1 ± 3.3 kg/m^2) i postotka masnog tkiva (26.0 ±4.9%), kao i niska razina tjelesne izdržljivosti. Korelacijska analiza pokazala je da se motorički kapacitet smanjuje sa životnom dobi. Analiza razlika pokazuje da nema statistički značajnih razlika u tjelesnoj sposobnosti nakon provedenog četveromjesečnog trenažnog programa u odnosu na inicijalno stanje. Usporedba dviju grupa s obzirom na različit broj ispitanika koji su prisustvovali pojedinim treninzima nije pokazala statistički značajne razlike u tjelesnoj pripremljenosti.

Zaključak

Može se zaključiti da su (1) vatrogasci ispitivane vatrogasne jedinice prilično stari, visokih vrijednosti indeksa tjelesne mase te imaju visok postotak masnog tkiva; (2) ispitanici nisu postigli zadane norme u primjenjivanom zadatku izdržljivosti, (3) trenažni program nije polučio željene rezultate.