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Physical Fitness Profile of Professional Italian Firefighters: differences between age-group.

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UNIVERSITÀ DEGLI STUDI DI TORINO

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Abstract

Firefighters perform many tasks which require a high level of fitness and their personal safety may be compromised by the physiological aging process. The aim of the study was to evaluate strength (bench-press), power (countermovement jump), sprint (20 m) and endurance (with and without Self Contained Breathing Apparatus – S.C.B.A.) of 161 Italian firefighters recruits in relation to age groups (<25 yr; 26–30 yr; 31–35 yr; 36–40 yr; 41–42 yr). Descriptive statistics and an ANOVA were calculated to provide the physical fitness profile for each parameter and to assess differences ($p < 0.05$) among age groups. Anthropometric values showed an age-effect for height and BMI, while performances values showed statistical differences for strength, power, sprint tests and endurance test with S.C.B.A. Wearing the S.C.B.A., 14% of all recruits failed to complete the endurance test. We propose that the firefighters should participate in an assessment of work capacity and specific fitness programs aimed to maintain an optimal fitness level for all ages.

1. Introduction

Considerable information substantiates firefighting as one of the most hazardous civilian occupations, implying variable working conditions, unpredictable and heavy physical demands (Bos et al., 2004). Firefighters perform strenuous muscular work (i.e. climb stairs and ladders, carry and use heavy tools) in dangerous environments (extreme temperatures, toxic smoke) and chaotic conditions (loud noise and low visibility), under time urgency and psychological stress of knowing that civilians are in imminent danger.

To reduce the risk of injuries, firefighters wear personal protective devices, composed by layered thermal protective clothing, heavy footwear to protect against penetration and crush injuries, a helmet to protect the head and a Self-Contained Breathing Apparatus (S.C.B.A.) to protect against smoke and noxious gases. However, the use of S.C.B.A. (weighing 11–23 kg) can have negative effects on gait, metabolic and thermal efficiency, and fatigue (Perroni et al., 2008, Perroni et al., 2009, Perroni et al., 2010, Knapik et al., 2004, Blacker et al., 2010 and Qu and Yeo, 2011).

Musculoskeletal injuries, traumas, respiratory and cardiovascular diseases are the major risks resulting from exposure to multiple physical and chemical agents, and from particularly high level of stress experienced during emergency operations (Burnett et al., 1994). Recent statistics in the United States (C2 Technologies Report, 2007) reported that 46% or 55% of deaths were classified as the result of stress or overexertion that led to heart attack or stroke. Although the majority of these deaths were in firefighters over 45 years old, there were still 19 deaths due to heart attack for those under 45 years old. A study by Szubert and Sobala (2002) showed an analysis of the injury ratio (annual number of injuries per 1000 workers) by injury circumstances (Emergency operation, Physical training, Equipment maintenance and repair, Routine service, Commuting to/from work) and victim's age among firefighters. The ratio was the lowest (67.9) among firefighters aged 30–39 and the highest (76.1) among those aged more than 50 years. During compulsory physical training, accidents were less frequent (24.6) in the 40–49 firefighters age group than in 20–29 (30.8) and 50–59 (30.4) age groups.

High levels of fitness have been correlated with improved job performance during real firefighting activities (Elsner and Kolkhorst, 2008, Michaelides et al., 2008 and Rhea et al., 2004) and a decreased risk of injury (Knapik et al., 2001 and Mattila et al., 2007). Unlike some sports or occupations that focus on a single training goal (e.g., power, strength, or endurance), firefighters are required to optimize multiple training goals simultaneously. For instance, they must possess power to perform forcible entry maneuvers, strength to advance hose lines and perform salvage and overhaul tasks, and aerobic and muscular endurance to carry equipment up flights of stairs.

Given the limited availability of firefighters to take part in experimental settings during real emergencies, the physical demands and psychological distress of firefighters have been investigated mainly in laboratory (Bruce-Low et al., 2007 and Dreger et al., 2006) and in simulated firefighting activities (Eglin and Tipton, 2005, Harvey et al., 2008, Holmer and Gavhed, 2007, Perroni et al., 2010 and Perroni et al., 2009). Despite some authors (Bos et al., 2002; Kales et al., 2007 and Rhea et al., 2004) indicated a minimum level of 45 mL kg⁻¹ min⁻¹ VO₂max to successfully complete intense firefighting tasks, few indications are available regarding the minimum standards of muscle strength (Gledhill and Jamnik, 1992, Garver et al., 2005, Henderson et al., 2007 and Perroni et al., 2008).

Given the nature of their employment, a physiological age-related decline could be expected during the occupational period of firefighters. Although in the literature there are numerous studies about the relationship between physical activity and aging, there are only few surveys about firefighters (Rhea et al., 2004, Sluiter and Frings-Dresen, 2007, Davis et al., 2002 and Saupe et al., 1991).

The purpose of this study was to compare the fitness status (i.e., muscle strength, power, sprint and endurance) of Italian firefighters recruits in relation to the age. It was hypothesized that the younger age of firefighters might result in a higher fitness performances and that wearing protective clothing and S.C.B.A. might reduce the performances.

2. Methods

2.1. Participants

All the male Italian firefighters recruits (N = 161), who finished the residential Italian Fire Fighter Corp training course, had at least 3 years of previous firefighting experience and were not engaged in structured physical training programs. The subject had the following general baseline characteristics, as mean ± SD: chronological age 33 ± 7 yr, height 1.76 ± 0.06 cm, weight 75.8 ± 8.4 kg, BMI 24.4 ± 2.3 kg m⁻². All subjects were divided into five different age groups, under 25-year-old (<25 yr), 26- to 30-year-old (26–30 yr), 31- to 35-year-old (31–35 yr), 36- to 40-year-old (36–40 yr) and 41- to 42-year-old (41–42 yr).

2.2. Procedures

The local Institutional Review Board approved the study designed to investigate the differences of fitness level (i.e. aerobic, strength, and anaerobic evaluations) in firefighters. Fitness evaluations were administered during two experimental sessions with a gap of a week. The first session included anthropometric (i.e., weight, height and body mass), strength, anaerobic test and the aerobic power test which was performed without protective garments and S.C.B.A. The second session aimed to evaluate the aerobic power with protective garments and S.C.B.A.

Prior to the evaluation, each individual signed a consent form and answered to the AAHPERD exercise/medical history questionnaire to ascertain his activity level, educational background, dietary habits, tobacco smoking and alcohol consumption, and medication and history of physical activity. Then, firefighters underwent a 15-minute standardized warm-up period, which consisted of jogging (40–60% of maximal heart rate), strolling locomotion, stretching of the chest muscles and limb (upper and lower). To eliminate circadian rhythms, nutrition and climate-related factor, all the experimental evaluations were performed in the morning (from 9.30 to 11.00 am), in similar conditions (temperature: 22–24 °C; humidity: 50–60%).

2.2.1. Strength evaluations

Strength evaluations included a bench-press test performed on a bench press station using a standard Olympic weightlifting bar and free weights. Firefighters were free to choose the weight to perform a maximum of ten lifts at a 30 beat min⁻¹ frequency dictated by a metronome. The

subject's 1 repetition maximum (1RM) was estimated using the equations of Wathan (1994) who showed an intraclass correlation coefficients ranging from 0.96 to 0.99:

$$m_{1RM} = m_n / (0.985 - 0.025n) \text{ for } 2 \leq n \leq 10$$

where m_{1RM} is the 1RM-mass and m_n is the maximum mass that can be lifted in n times.

2.2.2. Anaerobic evaluations

Measurements of anaerobic performance included countermovement jump (CMJ) (Fig. 1) and 20 m sprint (20 m) tests.



Fig. 1. Countermovement jump (CMJ): starting position (a), stretch-shortening cycle (b), flight (c), arrive (d).

High test-retest stability coefficients have been found for CMJ (range 0.80–0.98) and 20 m sprint (0.96) performances (Slinde et al., 2008; Gabbett et al., 2008).

The CMJ performances were evaluated using an optical acquisition system (Optojump, Microgate, Udine, Italy), developed to measure with 10–3 s precision all flying and ground contact times. The optical system is placed at 6 mm from the ground and is triggered by the feet of the subject at the instant of taking-off and at contact upon landing. Then, calculations of the height of the jump are made in real time by a specific software (Komi and Bosco, 1978). From the standing position, the firefighters were required to bend their knees to a freely chosen angle and perform a maximal vertical thrust with hands on their hips. They were instructed to keep their body vertical throughout the jump, and to land with knees fully extended. Any jump that was perceived to deviate from the required instructions was repeated.

A dual infrared reflex photoelectric cells system (Polifemo, Microgate, Udine, Italy), positioned 20 m apart, was used to evaluate 20 m performances. The first timing gate was positioned at 0.5 m from the start. For each test the firefighters had to perform three trials (receiving a verbal encouragement) with a 5-minute recovery period between trials. Their best performance was used for statistical analysis.

2.2.3. Aerobic evaluation

Maximal aerobic power (VO_{2max}) of firefighters was evaluated by the Queen's College Step Test (McArdle et al., 1972). To perform the Queen's College Step Test the firefighters were required to step up and down a 40 cm step at a 24 steps min^{-1} frequency for a total of 3 min. At the end of the test, HR was recorded from 5 to 20 s of the recovery phase. To estimate VO_{2max} ($r = 0.76$) the following formula was used:

Variables	Age group (yr)					Total
	<25	26–30	31–35	36–40	41–42	
	<i>n</i> = 34	<i>n</i> = 48	<i>n</i> = 30	<i>n</i> = 31	<i>n</i> = 18	<i>n</i> = 161
	Range: 22–25	Range: 26–30	Range: 31–35	Range: 36–40	Range: 41–42	Range: 22–42
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Weight (kg)	74.6 ± 7.7	74.6 ± 6.9	76.4 ± 8.4	78.8 ± 9.4	74.9 ± 10.4	75.8 ± 8.4
High (cm)	177 ± 0.06	178 ± 0.06	175 ± 0.05	177 ± 0.06	175 ± 0.07	176 ± 0.06
BMI (kg m ⁻²)	23.8 ± 1.7 ^a	23.7 ± 2.0 ^{abc}	25.0 ± 2.5	25.3 ± 2.5	24.5 ± 2.7	24.4 ± 2.3
Counter movement jump (cm)	30.1 ± 4.8 ^{bc}	30.7 ± 5.4 ^{bc}	28.7 ± 4.6 ^c	26.8 ± 4	25.7 ± 3.1	28.9 ± 5.0
Bench press (kg)	76.1 ± 10.3 ^{abc}	77.1 ± 15.7 ^{abc}	68 ± 11	67.3 ± 9.3	63.3 ± 11.9	71.8 ± 13.2
20 m (sec)	3.1 ± 0.1	3.1 ± 0.2 ^{bc}	3.2 ± 0.2 ^c	3.3 ± 0.2	3.3 ± 0.2	3.2 ± 0.2
Queen's College Step Test (ml kg ⁻¹ min ⁻¹)	52.3 ± 6.5	52.0 ± 6.8	51 ± 7.9	51.1 ± 7.1	53.2 ± 4.8	51.8 ± 6.8
Queen's S.C.B.A. (ml kg ⁻¹ min ⁻¹)	42.7 ± 3.4	41.9 ± 4.7 ^a	43 ± 4.8	44 ± 6.2	43.1 ± 6.1	42.8 ± 4.9

a

Vs. 31–35 = $p < 0.05$.

b

Vs. 36–40 = $p < 0.05$.

c

Vs. 41–42 = $p < 0.05$.

Anthropometric values showed differences ($p < 0.05$) among ages for height and BMI, while performances values showed differences ($p < 0.05$) for 1RM bench-press, CMJ, 20 m sprint tests and the Queen's College Step Test performed with protective garments and S.C.B.A.

The results of the physical fitness tests were systematically better for the younger categories (<25 yr; 26–30 yr) than the older age group (41–42 yr), except the test for the Queen's College Step Test. Bench-press test, used to evaluate muscle strength, showed a decrease of 18% among ages with best results in the 26–30 yr (77 ± 16 kg). Anaerobic performance measured by the countermovement jump and 20 m sprint tests was 18%, and 5% better between the younger firefighters (<25 yr) and the older group (41–42 yr). Comparing the average values of VO₂max without (VO₂max = 51.8 ± 6.8) and with (VO₂max = 42.8 ± 4.9) protective garments and S.C.B.A. of all firefighters, we can notice a sharp decrease (21%) between the two. No differences among ages emerged in Queen's College Step Test performed without protective garments and S.C.B.A., while the values of VO₂max in a test with protective clothing and S.C.B.A. were linear among the ages. Moreover, despite aerobic capacity of tests with protective garments and S.C.B.A. considerably decreased from the 36–40 yr (44.6 ml kg min⁻¹) to the 41–42 yr (41.8 ml kg min⁻¹) results showed a main effect ($F(4,156) = 1.369$, $p = 0.029$, $ES = 0.5$) only for 26–30 yr with 36–40 yr.

A correlation coefficient of 0.4 ($p < 0.0001$) was found between V_O2max recorded during test performed with and without S.C.B.A. Wearing the S.C.B.A., 14% of 161 firefighters failed to complete the endurance test (Table 2).

Table 2.

Participants (*N*^o), number (*N*^o Failed) and percentage (%) of firefighters who did not complete the Queen's College Step Test with protective garments and Self Contained Breathing Apparatus (S.C.B.A.).

Age group (yr)	Participants		
	<i>N</i> ^o	<i>N</i> ^o failed	%

Age group (yr)	Participants		
	N°	N° failed	%
<25	34	3	9
26–30	48	3	6
31–35	30	6	20
36–40	31	6	19
41–42	18	5	28
Total	161	23	14

4. Discussion

The results showed a statistical differences in anthropometric and performances values in Italian firefighters recruits with better values for younger categories (<25 yr; 26–30 yr) compared to the older age group (41–42 yr). According to the international BMI classifications (Overweight = BMI ≥ 25 kg m⁻²), the average BMI of the 161 firefighters was 24.4 ± 2.3 (kg m⁻²) and it could be classified as normal (World Health Organization, 2012). In particular, 68% (n = 117) of all firefighters was of normal weight, 31% (n = 41) was overweight, and 1% (n = 2) was obese. This study suggests that the percentage (33%) of overweight and obesity among Italian firefighters is lower than that was documented for the US firefighters (Kales et al., 1999, Tsismenakis et al., 2009 and Poston et al., 2011). In particular Poston et al. (2011) showed a high prevalence rates of overweight + obesity among career (79.5%) and volunteer (78.4%) firefighters. Soteriades et al. (2008) showed that firefighters above 28.5 value of the BMI had a significantly increased risk of 70% of work disability, compared to those below the average. In this study, firefighter's BMI value of the 36–40 yr was lower than to those reported by Bauer et al. (2011) and by Bennett et al. (2011) for same age firefighters (29.3 and 27.8, respectively). In addition, firefighter's BMI values of the 41–42 yr increases (+5%) compared to <25 yr. Despite the BMI is considered a fast and simple test for body mass, it is a biometric quantitative value. In fact, firefighters with a high BMI may have more muscle mass and body fat low, but they are still classified as overweight or obese.

In this study, the aerobic power of 41–42 yr firefighters, measured without protective clothing and S.C.B.A., showed higher values than the values investigated by Lemon and Hermiston (1977). Studying the aerobic power of professional firefighters (average age of 32.3 yr) measured on a cycle ergometer, O'Connell et al. (1986) reported values similar (48.4 ml kg⁻¹ min⁻¹) to those found in this study for their Italian counterparts. Our results are in line with those obtained by Davis et al. (1982) who studied professional firefighters with an average age of 33 years (range: 21–57 years), they found the VO₂max of 39.6 ml kg⁻¹ min⁻¹ measured using a treadmill protocol. Despite the expected 20% reduction in the protective clothing and S.C.B.A. condition, all ranges of age of firefighters were still within the suggested range of 35–42 ml kg⁻¹ min⁻¹ for VO₂max to perform firefighting task for an extended period of time (National Fire Protection Association, 2007 and McArdle et al., 1972). Differences between the values recorded during the step test performed without S.C.B.A. and that carried out with S.C.B.A. showed a decrease of 13.4% for the range <25 yr up to 20.5% for those aged 41–42 yr. During the test, the values obtained in each year-old group have shown to be above average (85–90 percentile) without and slightly above average (50–60 percentile) with protective clothing and S.C.B.A comparable to values for same age and sex (ACSM, 2010). Considering that 14% of firefighters failed to complete the step test when wearing their protective garments and S.C.B.A., it is conceivable that this decrease is due to premature lower extremity muscular fatigue rather than to a deficit in cardiovascular disease. In fact, fatigued muscles may affect lifting techniques and may increase the risk of injury (Trafimov et al., 1993).

Another consideration is related to the incidence rate of body weight compared with protective clothing and S.C.B.A. The heaviest protective clothing and S.C.B.A at 23 kg can represent 39% of body weight in subjects weighing 59 kg, while only 23% in a subject of 101 kg. Protective clothing and S.C.B.A. determine overload of the musculoskeletal system and affect thermoregulation and hydro-saline balance, so they can have consequences on the actual performance. Thus, because firefighters perform many tasks wearing the protective clothing and S.C.B.A., the present results imply that personal and public safety could be compromised progressively with increasing age. These results confirm Punakallio's et al. (2012) studies on the importance of functional assessment of workers.

Over the years, several studies have shown the importance of muscle strength and muscle power on the performance of tasks of daily living (i.e. walking, climbing up and down stairs) and the effects of several factors (i.e. reduction in muscle mass, changes in hormone balance, slow nervous system's capacity) on their decline related to age in general population. Few data are currently available in the literature on strength capacity of firefighters. Given the nature of their employment, firefighters rely on upper- and lower-body muscles strength to carry out their activities (i.e., carrying ladders, advancing charged hose lines, and using heavy equipment) safely and quickly. Several authors (Michaelides et al., 2008 and Rhea et al., 2004) showed a significant correlation between muscular strength and the work ability index while Punakallio et al. (2011) explained a good muscular capacity as a protective factor against decreased perceived physical work ability. In fact, various authors (Rhea et al., 2004 and Bates, 1987) showed bench press strength significantly correlated ($r = 0.66$) to specific firefighting performance. Despite firefighters have been observed to maintain muscular strength with age (Davis et al., 2002), in this study the values of 1RM decline with the increase of age. In fact, <25 yr of firefighters showed strength values higher than those reported by Pollach et al. (1994) for young general population (72.5 kg), but lower for volunteer firefighters recruits (80.5 kg) reported by Perroni et al. (2008). Consequently, with increasing age (31–35 yr), firefighters showed muscular strength values lower than those reported for same age firefighters (Perroni et al., 2008 and Rhea et al., 2004). This study showed firefighters with 1RM values around the average, comparable to same age and sex (ACSM, 2010), and with lower values found in firefighters aged between 36 and 40 yr (percentile 35). On the other hand, the significantly lower values of the firefighters indicate that they need further training to improve their upper limb strength.

In this study, firefighters in their twenties and thirties showed worse values for CMJ and similar value for 20 m sprint compared to those previously reported by Perroni et al. (2008) for the same age Italian firefighters recruits. High variability and unpredictability of the demands of work (Bos et al., 2004) force firefighters to perform their tasks very quickly to help people in difficulty. So, further research is needed to verify the influence of power and speed on the job performance and firefighters' safety.

The findings of this study may provide useful information for the organization, implementation and development of periodic assessment of physical fitness necessary to perform this job decreasing the percentage of risks due to increased age. Strengths of our study include the large number of firefighters examined and prospective follow-up. Limitations of investigation include the use of a sample of convenience, the measurements of the field study, and the estimate rather than a direct measurement of the parameters of strength and of VO₂max. Predictive tests typically have an error of 10–15%, but they can be used to evaluate the firefighters by reducing the cost and time required to evaluate (Gledhill and Jamnik, 1992 and Gledhill and Jamnik, 1992b). A further advantage of field trials is the specificity of the movement that is similar to that used for the performance at work of the subject (i.e. climbing stairs, jumping, press), compared to non-specific test (i.e. running on a treadmill). On the basis of these results, future studies of motor control, coordination, reaction time,

agility, balance and posture must be made in order to have a complete picture of the physical characteristics of the firefighter and to create a specific test.

Firefighters need to maintain a high degree of physical fitness, not only to perform their demanding occupational activities safely (O'Connell et al., 1986), but also to reduce their risk for cardiovascular diseases and musculoskeletal injuries (Szubert and Sobala, 2002). A report from the Federal Emergency Management Agency (2001) concluded that achieving and maintaining physical health and fitness is important for reducing on duty firefighter fatality rates. Malley et al. (1999) showed a negative relationship between age and VO₂max, while various authors (Eglin and Tipton, 2005) demonstrated the importance of physical fitness as one of the most significant predictors of work ability and his importance in firefighters' abilities. Bennett et al. (2011) showed that older personnel were significantly less likely to participate in intense exercise and perceived work ability is exacerbated by indicators of overweight. Thus, combination of an adequate degree of cardiovascular fitness, joint range of motion, and muscular strength is important to facilitate the completion of the work without risk, improving the quality of life. Given that high levels of physical fitness affect the performance, the security and the age-related decline, the Italian Firefighting Corp should encourage the practice of regular physical activity during working hours and introduce annual evaluation to ensure the physical capacity of firefighters. Moreover, for promoting work ability, periodic health examinations and fitness testing should be conducted as a preventive measure. Occupational fitness evaluation should be applied in ergonomic studies, preventive health programs, and individual health and fitness screening focused on recruitment, training, and work-preventing injuries. Bennett et al. (2011) demonstrated that health and lifestyle factors can moderate the effects of aging on work capacity in firefighters.

These present results may also represent the basis for creating appropriate specific conditioning programs (Budziarek et al., 2008) to improve the fitness level of Italian firefighters and minimum standards of suitability as an alternative to mandatory retirement. In this direction, Kenney and Landy (1998) proposed and developed initiatives concerning the suitability of all firefighters and proposed the establishment of a working group (i.e. exercise physiologists, psychologists, doctors and administrators) for the implementation of standard procedures for fitness health for all firefighters. It is not difficult to imagine that an adequate financial investment focused on the assessment of physical capabilities of firefighters as well as improvement of their work could effectively reduce the health risks linked to a hypokinetic lifestyle (Pate et al., 1995).

5. Conclusion

Our results show that there are significant differences among different age groups in firefighters, particularly in trials in which the ability of muscle strength was required (CMJ, 20 m, bench press, Queen's tested with the S.C.B.A). Therefore, given the nature of the real emergencies and physiological processes of aging, we propose to firefighters to follow individualized training programs that focus on strengthening muscle steadily (at least 3 times a week), not only during the work shift and with methods that reflect gestures performed while on the job. In addition, we recommend a systematic and periodic assessment of work ability with the S.C.B.A. (overload of ~23 kg) and prevention measures before the age-related deterioration of the physical form.

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