Sport Sci Health (2015) 11:279–285
DOI 10.1007/s11332-015-0236-y

ORIGINAL ARTICLE

Age-related changes in upper body strength and lower limb power of professional Italian firefighters

Fabrizio Perroni[1] · Laura Guidetti[2] · Lamberto Cignitti[3] · Carlo Baldari[2]

Received: 30 June 2015 / Accepted: 3 August 2015 / Published online: 21 August 2015

Abstract

Purpose Considering that the decrease in strength can be observed with ageing and that muscular endurance and strength are essential factors for firefighting effectiveness in critical situations, the purpose of this study was to evaluate the Upper Body Strength and Lower Limb Power of Professional of Italian Firefighters of 229 Italian male firefighters (age 32 ± 8 years, height 177 ± 6 cm, weight 79 ± 9 kg, BMI 24.5 ± 2.4 kg/m^2) and to compare the results in relation to the age (<30-year-old group; 31- to 35-year-old group; 36- to 40-year-old group; 41- to 45-year-old group; >45-year-old group).

Methods Upper body strength (1RM bench press), lower limb power (counter movement jump—CMJ, and sprint ability—20 m) were analysed. Descriptive statistics and an Analysis of Variance (ANOVA) were applied to anthropometric and physical fitness values to assess significant difference between age groups. When a significant effect was found, Bonferroni's post hoc analysis was used.

Results Between age groups, anthropometric values showed an age effect ($p < 0.05$) for BMI with 34 % of all firefighters in overweight and high prevalence (52 %) in >45 compared to the other age group categories. Performances values showed differences for 1RM bench press [$F_{(4,223)} = 6.17$; $p < 0.001$], CMJ [$F_{(4,223)} = 3.04$; $p < 0.05$], 20 m [$F_{(4,224)} = 8.47$; $p < 0.001$] among age groups. A decrease of 12 % for bench press, 13 % for CMJ and 5 % for 20 m between <30 and >45-year-old groups was found.

Conclusions Considering that the ability to produce strength and power movements are very important qualities to firefighters in each age, individuals and "job specific" training programs should be planned with functional work activities to improve neuromuscular function at any age.

Keywords Upper body strength · Lower limb power · Counter movement jump · Age

Introduction

Firefighters perform strenuous work in dangerous environments and chaotic conditions under time urgency. Recent studies [1, 2] have demonstrated that firefighters spend much of their working shift on standby and, on short notice, they have to respond to high-intensity emergency situations. In fact, during the first 3 min before the arrival of the full alarm assignment, a typical fire will increase in energy output approximately 400–600 % [3]. In addition, during emergencies, firefighters wear personal protective devices and use supplementary weight identified by Gledhill and Jamnik [4] as follow: ladders 25.40–61.23 kg, Hurst portable pump 56.70 kg; advancing hoses produced forces equivalent to weights ranging from 51.71 to 68.04 kg; hoisting hoses produced forces equivalent to weights ranging from 36.24 to 50.35 kg. Various studies [5–9] have shown that protective clothing and self-contained breathing apparatus have negative effects on gait, metabolic and thermal efficiency, and fatigue.

✉ Carlo Baldari
carlo.baldari@uniroma4.it

1 School of Exercise and Sport Sciences (SUISM), Department of Medical Sciences, University of Turin, Turin, Italy

2 Department of Movement, Human and Health Sciences, University of Rome "Foro Italico", P.za lauro De Bosis 15, 00135 Rome, Italy

3 Italian Fire Fighter Corp, Rome, Italy

Examining American firefighters, Karter and Molis [10] have shown that strains, sprains and muscular pain accounted for the largest portion of injuries (51.4 %), whereas Poplin et al. [11] found that 32.9 % of injuries were due to physical exercise, followed by patient transport (16.9 %), training drills (11.1 %) and fire ground operations (10.2 %). An analysis of the injury incidence by age groups [12] has revealed the lowest and less frequent values among firefighters aged 30-39 and the highest among those aged more than 50 years, whereas during compulsory physical training accidents were less frequent in the 40–49 age groups than others (age 20–29 and 50–59 years).

As can be expected, physical fitness is important to perform the duties and meet the physical demands of firefighting. Therefore, low fitness of firefighters is critical issue because of his correlation with injury risk and with the lower occupational readiness. Various studies [13–17] have shown a significant correlation between upper body muscular endurance and strength with faster times to complete a fire suspension task, and between high levels of fitness and decreased risk of injury.

Considering that the decrease in explosive strength can be observed among younger, middle-aged and older subjects of both genders [18–21] and that rapid execution of many physically demanding fire suppression tasks is essential for job effectiveness, the purpose of this study was (1) to evaluate the upper body strength and lower limb power of professional of Italian firefighters and (2) to compare the results in relation to the age.

Methods

Experimental approach to the problem

The procedures of the study, designed to investigate the differences of strength in firefighters, were approved by the local Institutional Review Board and they were carefully explained to each subject who provided their written informed consent. Firefighter's evaluations included anthropometric measurements (i.e. weight, height and body mass), strength and power test. Prior to the evaluation, each individual answered the AAHPERD exercise/medical history questionnaire (i.e. educational background, dietary and smoking habits, medication use and history of physical activity).

Weight and height were measured only in light clothes and barefoot using an electronic scale (±0.1 kg) and a fixed stadiometer (±0.1 cm), whereas body mass index (BMI) was used to assess weight relative to height and it was calculated by dividing body mass by the squared height (kg/m^2).

Prior to testing, firefighters underwent a 15-minute standardized warm-up period (i.e. jogging, strolling locomotion, stretching of the chest muscles and limb). All the experimental evaluations were performed in similar conditions (temperature 22–24 °C; humidity 50–60 %) in the morning (from 9.00 to 11.00 a.m.).

Participants

Two-hundred and twenty-nine male Italian firefighters at least 3 years of previous firefighting experience were engaged to participate in this study. The subject had the following general baseline characteristics (mean ± SD): age: 32 ± 8 years (range 22–50), height 177 ± 6 cm, weight 79 ± 9 kg, BMI 24.5 ± 2.4 kg/m^2. Previously, Perroni et al. [22] divided firefighters into 5-year age interval groups from <25 to 41–42 years, and found similarity between the <25 and 25–30 years groups. Therefore, in this study, we have divided all subjects in 5-year age interval groups from the under 30-year-old (≤30) group to the over 45-year-old (>45) group.

Italian Firefighters work in long shifts including weekends and holidays. In particular, these shifts are 12 h on followed by 24 h off, and 12 h on followed by 48 h off. This schedule requires firefighters to remain in a fire station for a 12-h period and respond to fire calls at any time during this period. During shift work, firefighters have to train their theoretical and practical firefighting skills (i.e. emergency medical procedures, check fire apparatus, simulated firefighters intervention, etc.). Since they have to respond to emergencies on short time, they have difficulty following regular physical training and eating during shift work. For these reasons, the Italian Firefighters Corp. suggests a home physical training (2 h/day, 3 days/week).

Upper body strength evaluations

Bench press test was performed on a standard bench press station using a York Olympic standard barbell and free weights to evaluate 1 repetition maximum (1RM). Firefighters were free to choose the weight, allowing to perform a maximum of ten lifts at a 30 beat/min cadence dictated by a metronome. The subject's 1RM was estimated using the formula of Wathan [23]:

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

where m_{1RM} is the 1RM-mass and m_n is the maximum mass that can be lifted n times (ICCs = from 0.96 to 0.99).

Lower limb power evaluations

The counter movement jump (CMJ) performances were evaluated using an optical acquisition system (Optojump, Microgate, Udine, Italy), and developed to measure all flying and ground contact times. The Optojump system consists of two bars (i.e. transmitting and receiving bars) that are equipped with 33 optical light-emitting diodes (LEDs) placed at 6 mm from the ground, and they are triggered by the feet of the subject at the instant of taking-off and at the contact upon landing. The calculations of the height of the jump are made by software dedicate [24]. From the standing position, the firefighters were instructed to bend their knees to a 90° angle, to perform a maximal vertical jump with hands on their hips, to keep their body vertical throughout the jump, and to land with knees fully extended. Any jump that was deviated from the required instructions was repeated. Glatthorn et al. [25] have shown very high validity (ICCs = 0.997–0.998) and excellent test–retest reliability (ICCs = from 0.982 to 0.989) of the Optojump system.

The 20 m sprint (20 m) performances were evaluated by a dual infrared reflex photoelectric cells system (Polifemo, Microgate, Udine, Italy) positioned 20 m apart with the first timing gate at 0.5 m from the starting. For each test, firefighters were allowed three trials (5-minute of recovery period between trials) and their best performance was used for statistical analysis. Gabbett et al. [26] reported high test–retest stability coefficients (ICCs = 0.96) of 20 m performances.

Statistical analyses

All results were expressed as means and standard deviations (mean ± SD) and a 0.05 level of significance ($p \leq 0.05$) was selected throughout the study. An Analysis of Variance (ANOVA) was applied to anthropometric values and to jump (cm), bench press (kg), 20 m Sprint (s) performances to assess differences among age groups (≤30 years; 31–35 years; 36–40 years; 41–45 years; >45 years). When a significant effect was found, Bonferroni's post hoc analysis was used. To provide meaningful analysis for comparisons between groups, Cohen's effect sizes (ES) were calculated considering values ≤0.2 trivial, from 0.3 to 0.6 small, <1.2 moderate and >1.2 large, respectively [27].

Results

Descriptive data are presented in Table 1.

No statistical differences emerged between age group in height and weight values, while BMI showed significant differences [$F_{(4,224)} = 3.211$; $p < 0.05$] only between >45 and <30 (ES = 0.34). Only 41–45 and >45 years group (24.9 ± 2.4 kg m^{-2} and 25.6 ± 3.0, respectively) have a mean BMI which indicates overweight [28]. In particular, 34 % ($n = 78$) of all firefighters were overweight with high prevalence in >45 (52 %) compared to the other age group categories (<30 = 20 %, 31–35 = 33 %, 36–40 = 34 %, 40–45 = 43 %).

Performances values showed differences in 1RM bench press (Fig. 1), CMJ (Fig. 2), and 20 m sprint (Fig. 3) with results systematically worse for the >45 age group. In particular, results of the test showed a decrease of 12 % for Bench press, 13 % for CMJ and 5 % for 20 m sprint between <30 and >45-year-old group.

Discussion

The aims of this study were to evaluate the Upper Body Strength and Lower Limb Power of Professional of Italian Firefighters and to compare the results in relation to the age. The main finding of this study was the decreased values for upper body strength, lower limb power and sprint in relation to the age.

According to Perroni et al. [22] in this study, the values of 1 M decline with the increase of age. Analysing all subjects, our results of the upper body strength showed strength values higher than those reported for novice fire fighters recruits [6] but lower than Henderson et al. [29]. Considering age group, we have found lower values than those reported by Perroni et al. [22] for ≤30-year-old group

Table 1 Means, standard deviations (Mean ± SD) and range of anthropometric data across age groups

Age groups (years)	No.	High (cm)		Weight (kg)		BMI (kg m^{-2})	
		Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
≤30	55	177 ± 7	166–196	74.5 ± 6.6	61.0–96.0	23.8 ± 1.7*	19.9–28.0
31–35	75	176 ± 6	165–192	76.1 ± 8.4	60.5–97.0	24.5 ± 2.4	20.1–30.3
36–40	32	177 ± 5	165–188	75.6 ± 8.0	97.0–62.0	24.2 ± 2.1	20.4–28.3
41–45	40	177 ± 6	167–192	78.5 ± 9.5	64.5–101.0	24.9 ± 2.4	21.0–31.2
>45	27	176 ± 6	165–189	79.5 ± 11.8	59.0–101.5	25.6 ± 3.0	20.9–32.3
Total	229	177 ± 6	165–192	76.5 ± 8.7	59.0–101.5	24.5 ± 2.4	19.9–32.3

* Vs. >45 = $p < 0.05$

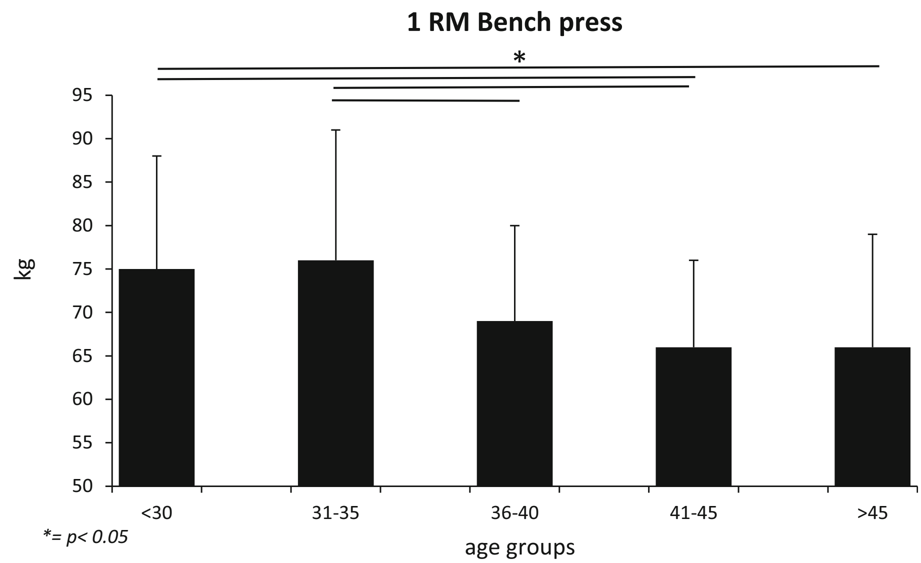


Fig. 1 Means ± standard deviations of 1RM bench press across age groups

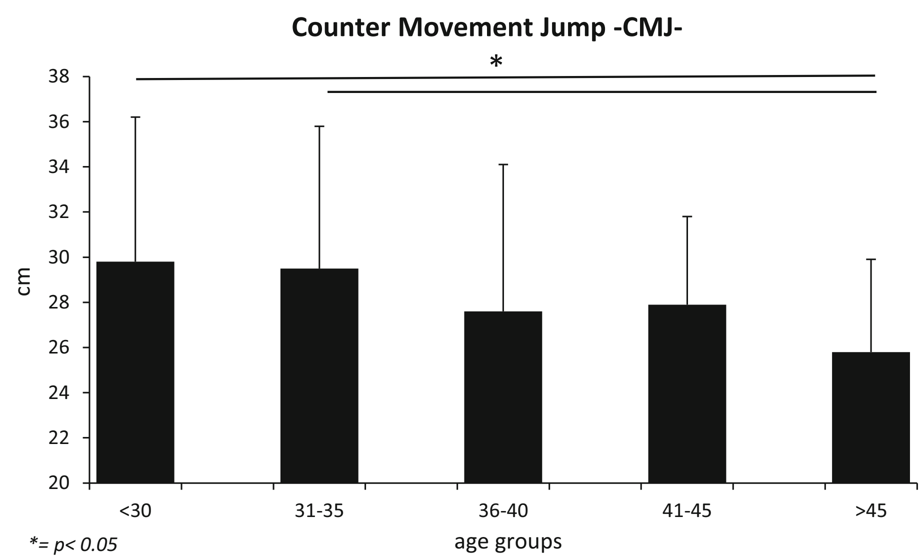


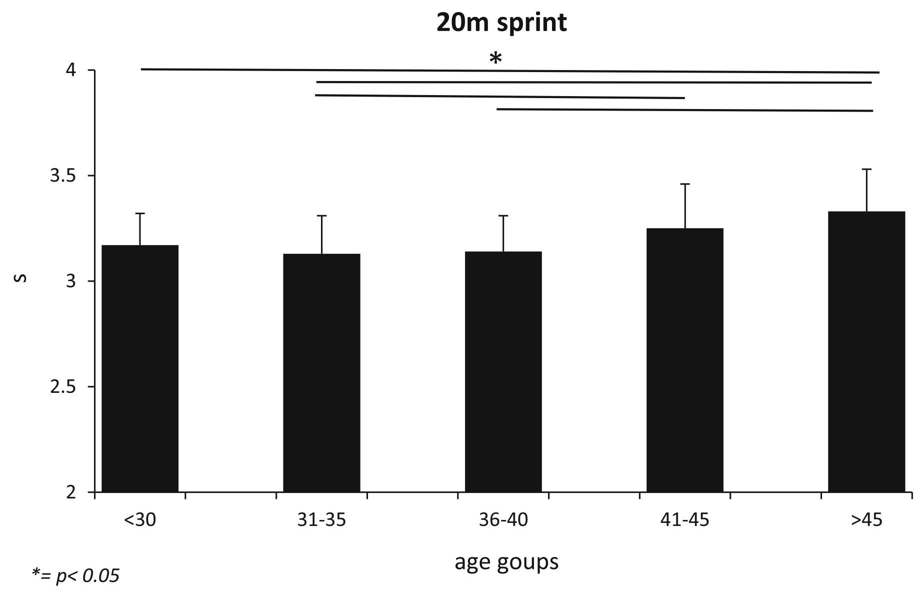
Fig. 2 Means ± standard deviations of CMJ across age groups

and higher for the other age group. Considering that previous study [30] showed a significant correlation between the bench press performances and specific firefighting performances, we agree with The American Society of Exercise Physiologists that recommended both isometric and isotonic 1-RM strength tests [31, 32] to evaluate the fitness level.

The stretch–shortening cycle is utilized in the job performance and any fatigue-induced impairment in his function could then have implications for job performance. In sport field, various studies [33–37] showed that the CMJ is amongst the most widely performed movement to assess lower limb power and, together with sprinting speed test, appears to be an interrelated predictor of explosive and accelerative capability. In this study, CMJ values have demonstrated higher values to those previously reported by Perroni and colleagues [6] for novice Italian firefighters recruits but similar to Perroni et al. [22] and lower by Perroni and colleagues [6] for volunteer Italian firefighters. In particular, we have found lower values than those reported by [22] for the ≤30-year group, and higher for the other age group. Contrarily, 20 m sprint of all subjects showed similar values to those previously reported by Perroni and colleagues [6] and by Perroni et al. [22] for Italian firefighters recruits. Considering the age groups, we found similar values for ≤30-year-old group and better values for the other age groups than those reported by Perroni et al. [22].

Previous research has shown the relationship between strength and age. It has been shown [18, 21, 38–40] that

Fig. 3 Means ± standard deviations of 20 m across age groups



ageing leads to declines in muscle mass, in maximal strength of the muscles and, in particular, greater worsening in explosive force production. Older adults show a loss in strength with ageing, but estimated maximum velocity of shortening changes little, which leads to some overall reduction of power output [41].

A number of studies in sport sciences [34, 42–44] have investigated the relationship between strength and sprint performance, demonstrating that stronger athletes perform better sprint performances. In fact, it is recognized that sprinting requires high levels of acceleration and high levels of strength to overcome the inertia of body mass.

Study of Michaelides et al. [13] demonstrated that upper muscular strength and endurance as well as low body composition were significantly related to better performances on the simulated firefighting tasks. Considering that muscle strength and muscle power are fundamental to the performance of tasks of daily living (i.e. walking, running, climbing up and down stairs, and prevention of falls), successful performance of rapid movements (i.e. jumps, sprints, and quick changes of direction) is essential in firefighter's activity. For these reasons, the influence of power and speed is important in firefighters activity and an evaluation of these physical capabilities should be a preventive measure to oppose the age-related deterioration of work ability not only for older workers.

The results of this study could provide useful information to develop appropriate specific conditioning programs to increase job performance and decrease the percentage of risks due to increased age in Italian firefighters. Various studies [21, 38, 45] have shown a decrease in maximal strength of 30–40 % from the age of 30 to the age of 80.

With the knowledge of the limiting factors of age in strength and power performance of firefighters, the strength and conditioning firefighters instructor and sport scientist can more effectively tailor the training accordingly so that a job performance increase can more likely be achieved in safety.

Previous studies [46, 47] have shown that the muscle contraction time and muscle relaxation time lengthen with age and any changes to these phases of muscle contraction influence the efficiency of the older adult to perform activities. Since muscle strength and the ability of the leg muscles to develop force rapidly are important performance characteristics contributing to several tasks of daily life, or even prevention of falls and trips [40, 48], this should be taken into consideration when constructing strength training programmes for both middle-aged and older men and women.

In general population, previous studies have shown that the loss of muscle strength in the proximal muscles of the lower extremities seems to be greater than that of the upper extremities, and Frontera et al. [38] suppose that it was presumably due to a decreasing use of lower compared with upper limb muscles in older groups. Contrarily, the results of our study have shown the same strength loss in upper body strength and lower limb power (12 and 13 %, respectively) between <30 and >45-year-old group. We hypothesize that this finding is not the result of traditional sport training but the training effect of the continues and specific ''functional'' job activities that firefighters perform during emergency simulations or of the other activities proper of their working shift (i.e. carry and climb ladders; wear weight protective clothing; drag, lift, and control fire hoses; swing an sledgehammer to gain entry; carry victims to safety).

Whereas the main limitations of this study are that the observations were obtained in only male firefighters and in a cross-sectional study, further longitudinal study is recommended to evaluate and to compare the upper body strength and power of the lower limbs of firefighters in relation to age, sex (male and female), specialization (i.e. general firefighters, drivers, helicopter pilot, diver, etc.) and rank (i.e. simply firefighters, firefighters foreman, firefighters team leader).

Conclusion

Considering that the ability to produce strength and power movements is very important qualities to firefighters in each age, we suggest that training programs should be individual and must systematically manipulate training loads (loading intensity), specificity of exercises, frequency of training sessions per week, intensity, and duration of the training period to be effective and to improve neuromuscular function at any age. In fact, to minimize the effects of ageing on the neuromuscular system, the hypertrophic strength training combined with explosive types of exercises could be recommended as an important part of an overall physical training programme to maintain the functional capacity at as high level as possible for as long as possible. A combined programme of typical heavy-resistance (with high loads and slow movement/action velocities) and explosive strength training could contribute to increase maximal force and to improve the force–velocity curves and to decrease the physiological decline of the physical capabilities related to age.

Acknowledgments The authors would like to express their gratitude to the Italian Firefighters Corp. for the support in carrying out the experimental sessions.

Compliance with ethical standards

Conflict of interest All authors declared no conflict of interest with the above work.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Dobson M, Choi B, Schnall PL, Wigger E, Garcia Rivas J, Israel L, Baker DB (2013) Exploring occupational and health behavioral causes of firefighter obesity: a qualitative study. Am J Ind Med 56:776–790
2. Taylor NA, Taylor EA (2012) How much money could fire brigades save annually simply by increasing firefighter fitness. In: Taylor NA, Billing DC (eds) 1st Australian conference on physiological and physical employment standards, Canberra, November 27–28. Australian War Memorial, Campbell ACT
3. National Fire Protection Association (2004) NFPA 1710: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments. NFPA, Quincy
4. Gledhill N, Jamnik VK (1992) Characterization of the physical demands of firefighting. Can J Sport Sci 3:207–213
5. McLellan TM, Selkirk GA (2004) Heat stress while wearing long pants or shorts under firefighting protective clothing. Ergonomics 47(1):75–90
6. Perroni F, Tessitore A, Lupo C, Cortis C, Cignitti L, Capranica L (2008) Do Italian fire fighting recruits have an adequate physical fitness profile for fire fighting? Sport Sci Health 4:27–32
7. Knapik JJ, Reynolds KL, Harman E (2004) Soldier load carriage: historical, physiological, biomechanical, and medical aspects. Mil Med 169:45–56
8. Blacker SD, Fallowfield JL, Bilzon JL, Willems ME (2010) Neuromuscular function following prolonged load carriage on level and downhill gradients. Aviat Space Environ Med 81:745–753
9. Qu X, Yeo JC (2011) Effects of load carriage and fatigue on gait characteristics. J Biomech 44:1259–1263
10. Karter MJ, Molis JL (2011) US Firefighter injuires—2010. National Fire Protection Association: Quincy
11. Poplin GS, Harris RB, Pollack KM, Wayne F, Peate WF, Jefferey L, Burgess JL (2012) Beyond the fireground: injuries in the US fire service. Injury Prev 18:228–233
12. Szubert Z, Sobala W (2002) Work-related injuries among firefighters: site and circumstances of their occurrence. Int J Occup Med Environ Health 15(1):49–551
13. Michaelides MA, Parpa KM, Thompson J, Brown B (2008) Predicting performance on a firefighter's ability test from fitness parameters. Res Q Exerc Sport 79(4):468–475
14. Rhea MR, Alvar BA, Gray R (2004) Physical fitness and job performance of firefighters. J Strength Cond Res 18:348–352
15. Williford HN, Duey WJ, Olson MS, Howard R, Wang N (1999) Relationship between fire fighting suppression tasks and physical fitness. Ergonomics 9:1179–1186
16. Knapik JJ, Sharp MA, Canham-Chervak M, Hauret K, Patton JF, Jones PH (2001) Risk factors for training-related injuries among men and women in basic combat training. Med Sci Sports Exerc 33:946–954
17. Mattila VM, Niva M, Kiuru M, Pihlajamãki H (2007) Risk factors for bone stress injuries: a follow-up study of 102, 515 person-years. Med Sci Sports Exerc 39:1061–1066
18. Hakkinen K, Kallinen M, Komi PV, Kauhanen H (1991) Neuromuscular adaptations during shortterm 'normal' and reduced training in strength athletes. Electromyogr Clin Neurophysiol 31:35–42
19. Hakkinen K, Hakkinen A (1995) Neuromuscular adaptations during intensive strength training in middle-aged and elderly males and females. Electromyogr Clin Neurophysiol 35:137–147
20. Hakkinen K, Kallinen M, Linnamo V, Pastinen UM, Newton RU, Kraemer WJ (1996) Neuromuscular adaptations during bilateral versus unilateral strength training in middle-aged and elderly men and women. Acta Physiol Scand 158:77–88
21. Hakkinen K, Kallinen M, Izquierdo M, Jokelainen K, Lassila H, Mälkiä E, Kraemer WJ, Newton RU (1985) Alen M (1998) Changes in agonist–antagonist EMG, muscle CSA, and force during strength training in middle-aged and older people. J Appl Physiol 84:1341–1349

22. Perroni F, Cignitti L, Cortis C, Capranica C (2014) Physical fitness profile of professional Italian firefighters: differences among age groups. Appl Ergon 45:456–461
23. Wathan D (1994) Load assignment. In: Baechle TR (ed) Essentials of strength training and conditioning champaign. Human Kinetics, IL, pp 435–439
24. Komi PV, Bosco C (1978) Utilization of stored elastic energy in leg extensor muscles by men and women. Med Sci Sports Exerc 10:261–265
25. Glatthorn JF, Gouge S, Nussbaumer S, Stauffacher S, Impellizzeri FM, Maffiuletti NA (2011) Validity and reliability of Optojump photoelectric cells for estimating vertical jump height. J Strength Cond Res 25(2):556–560
26. Gabbett TJ, Sheppard JM, Pritchard-Peschek KR, Leveritt MD, Aldred MJ (2008) Influence of closed skill and open skill warm-ups on the performance of speed, change of direction speed, vertical jump, and reactive agility in team sports athletes. J Strength Cond Res 22(5):1413–1415
27. Cohen J (1988) Statistical power analysis for the behavioral sciences (2nd ed). Lawrence Eribaum Associates, Hillsdale
28. World Health Organization "BMI Classification". http://www.who.int/bmi/index.isp?introPage=intro3.html
29. Henderson ND, Berry MW, Matic T (2007) Field measures of strength and fitness predict firefighter performance on physically demanding tasks. Pers Psychol 60:431–473
30. Bates JT (1987) Coronary artery disease in the Toronto Fire Department. J Occup Med 29:132–135
31. Blakely BR, Quinones MA, Crawford MS, Jago IA (1994) The validity of isometric strength tests. Pers Psychol 47:247–274
32. Brown LE, Weir JP (2001) ASEP procedures recommendation I: accurate assessment of muscular strength and power. JEPonline 4:1–21
33. Maulder P, Cronin C (2005) Horizontal and vertical jump assessment: reliability, symmetry, discriminative and predictive ability. Pys Ther Sport 6:74–82
34. Cronin JB, Hansen KT (2005) Strength and power predictors of sports speed. J Strength Cond Res 19:349–357
35. Habibi W, Shabani M, Rahimi E, Fatemi R, Najafi A, Analoei H, Hosseini M (2010) Relationship between Jump Test Results and Acceleration Phase of Sprint Performance in National and Regional 100 m Sprinters. J Human Kinetics 23:29–35
36. Kales SN, Tsismenakis AJ, Zhang C, Soteriades ES (2009) Blood pressure in firefighters, police officers, and other emergency responders. Am J Hypertens 22:11–20
37. Maulder P, Bradshaw E, Keogh J (2006) Jump kinetic determinants of sprint acceleration performance from starting blocks in male sprinters. J Sports Sci Med 5:359–366
38. Frontera WR, Hughes VA, Lutz KJ, Evans WJ (1991) A cross-sectional study of muscle strength and mass in 45- to 78-year-old men and women. J Appl Physiol 71(2):644–650
39. Bosco C, Komi PV (1980) Influence of aging on the mechanical behavior of leg extensor muscles. Eur J Appl Physiol 45:209–215
40. Izquierdo M, Aguado X, Gonzalez R, Lopez JL, Hakkinen K (1999) Maximal and explosive force production capacity and balance performance in men of different ages. Eur J Appl Physiol 79:260–267
41. Larson R (1978) Thirty years of research on the subjective well-being of older Americans. J Gerontol 33:109–125
42. Comfort P, Bullock N, Pearson SJ (2012) A comparison of maximal squat strength and 5-, 10-, and 20-m sprint times, in athletes and recreationally trained men. J Strength Cond Res 26:937–940
43. McBride JM, Blow D, Kirby TJ, Haines TL, Dayne AM, Triplett NT (2009) Relationship between maximal squat strength and five, ten, and forty yard sprint times. J Strength Cond Res 23:1633–1636
44. Wisloff U, Castagna C, Helgerud J, Jones R, Hoff J (2004) Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. Br J Sports Med 38:285–288
45. Porter MM, Vandervoort AA, Lexell J (1995) Aging of human muscle: structure, function and adaptability. Scand J Med Sci Sports 5:129–142
46. Florini JR, Ewton DZ (1989) Skeletal muscle fiber types and myosin ATPase activity do not change with age or growth hormone administration. J Gerontol 44:110–117
47. Vandervoort AA, Hayes KC, Belanger AY (1986) Strength and endurance of skeletal muscle in the elderly. Physiother Can 38:167–173
48. Bassey EJ, Fiatarone MA, O'Neill EF, Kelly M, Evans WJ, Lipsitz LA (1992) Leg extensor power and functional performance in very old men and women. Clin Sci 82:321–327