Practical guidance for firefighter applicants preparing for cardiorespiratory fitness testing: A secondary analysis of self-reported physical activity levels

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Adequate cardiorespiratory fitness is critical for firefighters since an insufficient level of fitness threatens the integrity of their operations and could be dangerous for their lives. In fact, the leading cause of mortality for on-duty firefighters is not injury but sudden cardiac death. Therefore, to mitigate these risks, potential firefighter recruits are often required to perform a graded exercise test to determine their cardiorespiratory fitness as part of the recruitment process. However, there are currently limited data available to prospective firefighters on the amounts and types of exercises needed to be successful in the graded exercise test, commonly known as a $\dot{V}O_{2max}$ test. Physiological parameters for the current secondary analysis were collected on firefighter applicants who performed the graded exercise test where 72% were successful and 28% were unsuccessful to meet the

minimum standard set at 42.5 ml·kg^{-1}·min^{-1}. Prior to their test, applicants were asked to describe their exercise training routine by indicating the number of minutes per week spent exercising. Activities were then divided into one of two categories: endurance exercise or strength and power exercise training. The total exercise training describes the sum of all activities performed each week. The sum of endurance exercise activities and the sum of strength and power exercise activities were compared between the successful and the unsuccessful groups and results showed that successful applicants had a higher training volume and performed more endurance exercise training as compared to unsuccessful applicants. Therefore, practical recommendations related to exercise training regime are presented for firefighter applicants to embrace as guidance to prepare for their graded exercise test as part of their recruitment process.

Practical Guidance for Firefighter Applicants Preparing for Cardiorespiratory Fitness Testing: A Secondary Analysis of Self-reported Physical Activity Levels

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Abstract

Adequate cardiorespiratory fitness is critical for firefighters since an insufficient level of fitness threatens the integrity of their operations and could be dangerous for their lives. In fact, the leading cause of mortality for on-duty firefighters is not injury but sudden cardiac death. Therefore, to mitigate these risks, potential firefighter recruits are often required to perform a graded exercise test to determine their cardiorespiratory fitness as part of the recruitment process. However, there are currently limited data available to prospective firefighters on the amounts and types of exercises needed to be successful in the graded exercise test, commonly known as a $\dot{V}O_{2max}$ test. Physiological parameters for the current secondary analysis were collected on firefighter applicants who performed the graded exercise test where 72% were successful and 28% were unsuccessful to meet the minimum standard set at 42.5 ml·kg^{-1}·min^{-1}. Prior to their test, applicants were asked to describe their exercise training routine by indicating the number of minutes per week spent exercising. Activities were then divided into one of two categories: endurance exercise or strength and power exercise training. The total exercise training describes the sum of all activities performed each week. The sum of endurance exercise activities and the sum of strength and power exercise activities were compared between the successful and the unsuccessful groups and results showed that successful applicants had a higher training volume and performed more endurance exercise training as compared to unsuccessful applicants. Therefore, practical recommendations related to exercise training regime are presented for firefighter applicants to embrace as guidance to prepare for their graded exercise test as part of their recruitment process.

Introduction

Maintaining cardiorespiratory fitness is essential for emergency responders as this factor might seriously impact on the integrity of their operations. Firefighters represent a unique occupational group in that regard. The physiological burden of wearing bulky protective clothing, breathing through a self-contained breathing apparatus, and performing physically demanding work at the incident scene requires stamina and strength. Firefighter work environments also contain chemicals such as carbon dioxide at acutely toxic levels that alters cardiac rhythm, probably as a

45 result of the induced hypoxia (Kristensen, 1989). It is, therefore, not surprising that the leading
46 cause of mortality for on-duty firefighters is not injury but sudden cardiac death, accounting for
47 approximately 44% of USA career firefighters on-duty fatalities (Donovan et al., 2009; Fahy,
48 2005; Smith et al., 2013). While the exact mechanism for this remains unclear, low
49 cardiorespiratory fitness has been associated with increased risk of cardiovascular disease-related
50 events Donovan et al., 2009) .
51
52 The physical nature and cardiovascular strain imposed during firefighting has been well
53 documented and have led to many recommendations for minimum requirements of
54 cardiorespiratory fitness (Barnard & Duncan, 1975; Gledhill & Jamnik, 1992; Lemon &
55 Hermiston, 1977). While no universal 'fitness-for-duty' minimum standard exists, several studies
56 have recorded oxygen uptake ($\dot{V}O_2$) during simulated firefighting tasks and reported values
57 ranging from 23.0 to 43.8 ml·kg^{-1}·min^{-1}. Accordingly, recommendations for maximal oxygen
58 uptake ($\dot{V}O_{2max}$) between 39.6 and 48.5 ml·kg^{-1}·min^{-1} are available in the literature (Gledhill &
59 Jamnik, 1992; Lemon & Hermiston, 1977; Sothmann et al., 1991; Williams-Bell et al., 2010). In
60 Canada, Gledhill & Jamnik (Gledhill & Jamnik, 1992) conducted a task analysis to detail the
61 specific tasks conducted by incumbent firefighters. The aim was to evaluate the physical abilities
62 related to these tasks, determine physically demanding ones, and determine the physiological
63 requirements to complete these tasks. Based on this analysis, the most demanding tasks required
64 a mean $\dot{V}O_2$ of 41.5 ml·kg^{-1}·min^{-1} which was, on average, equivalent to 85% of the participants
65 $\dot{V}O_{2max}$. Accordingly, values between 42.5 and 45.0 ml·kg^{-1}·min^{-1} have been widely accepted
66 across Canada where Newfoundland and Labrador adopted the value of 42.5 ml·kg^{-1}·min^{-1} as
67 their minimum standard for firefighter applicants, which was used as the cutoff value in the
68 current secondary analysis. The recruitment process to become a firefighter is very competitive
69 in Canada and it consists of multiple phases including, but not limited to, a graded exercise test
70 (GXT) to assess aerobic capacity and an occupational-specific physical test where muscular
71 strength and power play a major role to achieve a positive outcome. Failure to succeed in any of
72 these tests will result in the application being rescinded. Although achieving a $\dot{V}O_2$ value of 42.5
73 ml·kg^{-1}·min^{-1} should not be problematic for young and active Caucasian males (Kaminsky et al.,
74 2015), it remains that many individuals need to prepare for the physically demanding tests as part
75 of the recruitment process. The preparation mainly involves training the cardiorespiratory system
76 and gaining muscular strength. The aim of the current project was therefore to determine the
77 potential relationship between a positive cardiorespiratory outcome on the GXT and the type of
78 exercise training regimen performed by the applicants. It further intends to provide practical
79 guidance to future firefighter applicants preparing for their GXT.
80
Materials & Methods
82
83 The current study employed a secondary data analysis of self-reported physical activity levels to
84 investigate differences in exercise training routine (type and amount) between firefighter
85 applicants who successfully achieved the minimum recruitment criteria for the GXT performed
86 on a treadmill and those who were unsuccessful. The original data were collected from male
87 firefighter applicants living in Newfoundland and Labrador who performed a GXT as part of
88 their recruitment process. All applicants were requested to include in their application package a
89 document certifying that they had recently (i.e., <3 months ago) met the minimum
90 cardiorespiratory fitness standard through a recognized evaluation site. Thus, the dataset used for

91   this secondary analysis includes 121 applicants who chose to perform their GXT at the exercise
92   physiology clinic located on Memorial University of Newfoundland campus. Prior to their
93   testing appointment, applicants completed a Physical Activity Readiness Questionnaire (PAR-Q)
94   adapted from the Canadian Society for Exercise Physiology. Their self-reported physical activity
95   and exercise habits were included in the dataset. All applicants consented to have their data used
96   for research purposes and the regional Health Research Ethics Board approved the study protocol
97   (HIC-10.201).
98
99   **Self-Reported Physical Activity and Exercise Habits**
100   The PAR-Q was used as a screening tool to reveal any contraindications to administering a
101   maximal graded exercise test (see Addendum 1). The questionnaire included, inter alia, questions
102   related to cardiovascular, respiratory, and metabolic problems. The extended version also
103   included questions about current physical activity participation and exercise habits where a list of
104   34 common sport and recreational activities were provided. Applicants were asked (i) to identify
105   if they were physically active in the past year, (ii) to identify which activities they were currently
106   participating in on a regular basis, and (iii) to indicate the number of minutes per week
107   (min/week) spent performing each activity. Applicants also had the opportunity to indicate if
108   they were participating in any activity other than the ones listed. Information collected from the
109   PAR-Q was reviewed upon arrival at the evaluation site to ensure that there were no
110   contraindications to maximal exercise testing.
111
112   **Graded Exercise Test**
113   All applicants performed a GXT to determine their maximal $\dot{V}O_2$ value. Prior to their
114   appointment, applicants were instructed (i) to refrain from strenuous exercise at least 36 hours
115   prior to the test, (ii) to avoid eating and consuming alcohol at least four hours prior to the test,
116   and (iii) to avoid caffeine, drugs, and smoking within the two hours period preceding the test.
117   The GXT was performed on a motor driven treadmill and the Léger-Boucher protocol was used
118   which involves a gradual increase in speed over time until exhaustion (Léger & Boucher, 1980).
119   The GXT consisted of three phases: the warm-up phase, the exercise phase, and the cool-down
120   phase. Prior to beginning the warm-up phase, the applicants spent two minutes on the treadmill
121   breathing normally to collect physiological values in the standing position. The warm-up phase
122   was five minutes in length and the treadmill was set to a walking speed of 4.5 km/h and 1%
123   grade. The grade remained consistent at 1% throughout the test. Once the exercise phase had
124   started, the speed of the treadmill increased to 7 km/h for the first two minutes and then
125   increased by a rate of 1 km/h every two minutes thereafter until exhaustion. Verbal
126   encouragement was given to the applicants to exercise until they reached volitional exhaustion.
127   The cool-down phase included walking at a speed of 4.5 km/h for a minimum of five minutes.
128   During the cool-down phase, the exercise physiologist decided whether or not a verification
129   phase was required and was safe to administer. A verification phase is normally used as a
130   criterion to ensure that participants reached their 'true' maximum oxygen uptake during the
131   incremental exercise phase (Rossiter et al., 2006). However, since the purpose of the GXT was to
132   provide applicants with a certificate stating that they reached the minimum standard for
133   firefighters, the verification phase was not implemented to applicants who clearly surpassed a
134   $\dot{V}O_2$ value of 42.5 ml·kg^{-1}·min^{-1} during the exercise phase. For applicants who performed the
135   verification phase, the speed of the treadmill was increased to 105% of their maximal aerobic
136   speed reached during the preceding exercise phase. The speed and the 1% grade remained the

137 same throughout the entire verification period, which lasted until volitional exhaustion once
138 again. For those who completed the verification phase, the highest value reached during any
139 phase throughout the GXT was retained as their maximal $\dot{V}O_2$ value.
140
141 **Physiological Measurements**
142 Exercise metabolic rates were recorded with an indirect calorimetry system (Oxycon Pro, Jaeger,
143 Hochberg, Germany) and heart rate (HR) was recorded using a heart rate monitor (Polar Electro
144 Canada, Lachine, Qc). Oxygen uptake ($\dot{V}O_2$), carbon dioxide ($\dot{V}CO_2$), and breathing frequency
145 (Bf) were recorded breath-by-breath via an automated open-circuit gas analysis system with O_2
146 fuel cell and CO_2 infrared cell in connection a turbine flowmeter. Respiratory exchange ratio
147 (RER) and minute ventilation ($\dot{V}_E$) were calculated as the quotient of $\dot{V}CO_2$ on $\dot{V}O_2$ and as the
148 product of breathing frequency by tidal volume, respectively. Prior to testing, volume and gas
149 analyzers were calibrated with a 3.0 L calibration syringe and certified O_2 and CO_2 calibration
150 gases at 16% and 4%, respectfully. In addition, propane gas calibration was performed to ensure
151 accuracy and linearity of the indirect calorimetry system according to Ismael et al. (Ismail et al.,
152 2019)methodology. The data were online digitized from an A/D card to a computer for live
153 monitoring of the physiological parameters.
154
155 **Data Handling**
156 Raw data from the GXT were smoothed over a 30-second moving average to determine
157 applicants' maximal physiological values (Robergs & Burnett, 2003). The data from the section
158 pertaining to physical activity and exercise habits were used to calculate total weekly activities
159 performed by each applicant. There were five observations greater than 1020 min/week which
160 was considered excessive for this population. Since the PAR-Q was filled out in February, all
161 activities that could only be performed in the summer in Newfoundland and Labrador were
162 removed on the basis that applicants did not answer the questionnaire correctly, that is, to only
163 include activities currently performed on a regular basis. In addition, although physical activity
164 plays an important role in the prevention and treatment of multiple chronic diseases, we were
165 interested in the amount of exercise applicants performed in preparation for the GXT. Physical
166 activity and exercise are often used interchangeably, but these terms are not synonymous.
167 Physical activity is defined as any bodily movement produced by the contraction of skeletal
168 muscles that results in a substantial increase in caloric requirements over resting energy
169 expenditure. Exercise is a type of physical activity consisting of planned, structured, and
170 repetitive bodily movements organized in such a way as to improve and/or maintain one or more
171 components of physical fitness (Liguori, 2021). Since the parameter of interest with firefighter
172 applicants is exercise performed with the main objective to improve or maintain physical fitness,
173 activities considered as physical activity (e.g., walking and dancing) were also removed. The
174 reader is invited to look at Addendum 2 for more details about data handling.
175
176 Next, all exercise activities were divided into one of two categories: endurance exercise or
177 strength and power exercise. Also called aerobic exercise, the term endurance exercise training
178 generally refers to training the aerobic system and includes activities that increase your breathing
179 and HR. From the PAR-Q, 31 activities were considered endurance-based (e.g., running, biking,
180 hockey, etc.) whereas three were strength and power activities (i.e., resistance training, downhill
181 skiing, and martial arts). Strength and power exercises are commonly called resistance training,
182 weight training, or power training, and improve muscular strength. For ease of readability,

183   strength and power exercises will be referred to strength exercise for the remaining of the
184   manuscript. The sum of all endurance exercises and all strength exercises in min/week were
185   calculated for each applicant. The total exercise training was the addition of self-reported
186   endurance exercises and self-reported strength exercises which describes the total training time
187   or weekly training volume.
188
189   Finally, as an additional analysis, the original dataset was divided into three fitness zones based
190   on maximal $\dot{V}O_2$ values obtained during the GXT. Maximal values on a GXT can vary from one
191   day to the next. This variability may be partitioned into technological error and biological
192   variation. Technological errors include the variable errors of the instruments, uncontrolled
193   environment factors, reading errors, and unidentified errors. Yet, attempting to single out one or
194   two major factors contributing to the biological variation in energy metabolism during maximal
195   exercise is difficult (Katch et al., 1982). The total variability is ± 5.6% with biological variation
196   accounting for ≥ 90% of this variability, while technological error only accounts for ≤10%
197   (Katch et al., 1982). In practical terms, it means that an applicant could have a higher or lower
198   maximal $\dot{V}O_2$ value by 5.6% on any given day. Applicants should therefore aim for a minimum
199    $\dot{V}O_2$ value ≥45 ml·kg^{-1}·min^{-1} (i.e., 42.5 + 5.6%) to be confident that they would succeed in the
200   GXT even if they are tested on their least biologically optimal day. Correspondingly, the three
201   fitness zones were divided according to the following $\dot{V}O_2$ values: ≤40 (i.e., 42.5 − 5.6%), 40 to
202   45, and ≥45 (i.e., 42.5 + 5.6%) ml·kg^{-1}·min^{-1}. The middle fitness zone (40 to 45) is, in essence, a
203   gambling zone because applicants could pass or fail the GXT depending on any combination of
204   factors involved in the total variability on testing day.
205

Statistical Analysis

207   Normality was inspected by examining the histograms and conducting the Shapiro-Wilk test
208   which showed that most parameters followed a normal distribution except for age and body
209   mass. However, since the central limit theorem states that the distribution of sample means
210   approximates a normal distribution as the sample size gets larger than 30, normality was
211   assumed for all parameters used for calculating the t statistic.
212

213   The complete dataset was divided into two groups, successful group (SG) and unsuccessful
214   group (UG), to assess if there was a statistical difference between the two groups. Two-sample
215   Welch's t-test was conducted on all parameters using Python 3 (Python Software Foundation,
216   Delaware, USA) to test the equality of two means from independent populations. Subsequently, a
217   one-way Welch ANOVA was performed on parameters of interest to assess the difference
218   between the mean for each of the three fitness zones and a pairwise Games-Howell post hoc test
219   was used to compare all possible combinations of fitness zone differences.
220

221   Unstandardized as well as standardized effect size (d statistic) are reported along with their
222   corresponding confidence interval (CI) when applicable. Unstandardized effect size (ES$_{M1-M2}$)
223   was calculated by subtracting the mean of UG from the mean of SG. Their CI were constructed
224   using the standard error, t-score, and degree of freedom (df) for unequal variances as suggested
225   by (Kline, 2013). The standardized d statistic effect size was calculated using the t statistic
226   (Grissom & Kim, 2012; Kline, 2013) and their CI were constructed using the standard error, t-
227   score, and df from the d statistic (Kline, 2013). At last, conventional values proposed by (Cohen,
228   1988) were used as benchmarks for what are considered to be 'small', 'medium', and 'large'

229 effects along with their potential effect (Cohen J, 1992). For more details about statistical
230 analysis, see Addendum 3.
231
Results
233
234 Table 1 tabulates the mean (± SD) for age, height, body mass, and body mass index (BMI) for all
235 applicants were as followed: (i) 26.3 (± 5.8) years where the youngest applicant was 18 years old
236 and the older was 44 years old, (ii) height of 178.6 (± 6.2) cm where the shortest applicant was
237 160.0 cm and the tallest was 194.6 cm; (iii) body mass of 84.9 (± 10.6) kg where the lightest
238 applicant was 66.5 kg and the heaviest was 122.2 kg; and (iv) BMI of 26.6 (± 2.7) ranging from
239 20.3 to 33.6.
240
241 When comparing the two groups (SG vs. UG), mean (± SD), outcomes from the t statistic, and
242 the unstandardized effect size (ES_{M1-M2}) are presented in Table 1. Statistical significance was set
243 at the 0.05 level of confidence. Out of 121 applicants, 87 (72%) were successful and 34 (28%)
244 were unsuccessful in the GXT. Figure 1 displays the d statistic effect size with the corresponding
245 CI in relation to the effect size classes and potential effects. Figure 2 illustrates the difference in
246 medians for body mass and HR recovery for each fitness zone mentioned earlier whereas Fig. 3
247 shows the median for endurance exercise and total exercise training time performed weekly by
248 applicants for each of the three fitness zones. The one-way ANOVA test indicated that at least
249 one fitness zone was statistically different and the post hoc test revealed that the red zone (≤ 40
250 $ml \cdot kg^{-1} \cdot min^{-1}$) was statistically lower than the green zone (≥ 45 $ml \cdot kg^{-1} \cdot min^{-1}$) for endurance
251 exercise in minutes ($M_{red} = 109$, $M_{green} = 235$, $t(70.4) = -4.5$, $p = .001$) and also for total exercise in
252 minutes ($M_{red} = 268$, $M_{green} = 442$, $t(44.7) = -3.5$, $p = .003$).
253
Discussion
255
256 The project was undertaken to determine whether the type of exercise training regimen impacts
257 the GXT score in individuals who prepare for the physically demanding tests as part of the
258 firefighter recruitment process. Our results confirm the relationship between a positive
259 cardiorespiratory outcome in the GXT and the exercise training regimen of firefighter applicants.
260 The statistical analyses further inferred the impacts of physical characteristics on several
261 physiological parameters. Each relationship is presented in the following paragraphs and
262 discussed in detail with support, when applicable, from our statistical analysis.
263
Physical Characteristics
265 The height of applicants was essentially identical between groups whereas SG were on average
266 three years younger. SG also included the youngest applicant while UG included the oldest
267 applicant. Although the age variable was statistically different, a delta of three years between
268 groups was not practically significant in this case as confirmed by a small effect size (Fig. 1). In
269 addition, SG was statistically lighter than UG. When the maximal $\dot{V}O_2$ value is expressed relative
270 to body mass, it is to be expected that applicants with lower body mass should reach higher $\dot{V}O_2$
271 values given the same absolute $\dot{V}O_2$ values(Basset & Boulay, 2000). Still, a higher body mass
272 does not always convert into a lower $\dot{V}O_2$ value. Applicants with a large skeletal muscle mass
273 would exhibit high maximal absolute $\dot{V}O_2$ values that would compensate for the negative body
274 mass effect on their relative $\dot{V}O_2$ values. Inversely, applicants with a high fat mass would

275   negatively impact their maximal relative $\dot{V}O_2$ value even though their absolute $\dot{V}O_2$ value is
276   within normal range; a condition that may translate into an unsuccess in the GXT. The effect size
277   computation confirmed that a difference in body mass of 7.6 kg between SG and UG had a
278   detrimental medium effect with CI ranging from trivial up to large effect size (Fig. 1). Firefighter
279   applicants typically possess a greater skeletal muscle mass than the general population. This is
280   primarily due to the resistance training they partake in to succeed in their occupational-specific
281   physical test. In fact, the applicants need to include resistant training to challenge the tasks
282   related to a job-specific simulation as part of the recruitment process. This anthropometric factor
283   adds to the set of physical assets applicants should display to be successful in a firefighting
284   career. Since skeletal muscle mass of applicants was not collected, it is therefore difficult to
285   speculate on the body composition of heavier applicants in our sample. Nevertheless,
286   scrutinizing data from applicants with body mass $\geq$ 100 kg, 7/10 applicants failed the GXT and
287   they all had an absolute maximal $\dot{V}O_2$ value below the sample mean; outcomes suggesting lower
288   muscle mass along with higher fat mass compared to applicants who were successful.
289
290   **Physiological Parameters**
291   Some may argue that successful applicants had higher maximal $\dot{V}O_2$ values because they exerted
292   themselves more during the GXT. This was not the case with our sample because both groups
293   reached similar maximal HR, RER, and breathing frequency, which are indicators of maximal
294   effort. Mean maximal $\dot{V}O_2$ value for our sample was 46.5 ± 6.4 ml·kg^{-1}·min^{-1}, which fits with a
295   previous research study on firefighters that found a mean of 46.6 ± 6.0 ml·kg^{-1}·min^{-1} Donavan et
296   al., 2009). On average, the maximal $\dot{V}O_2$ value for SG was 28% higher as compared to UG.
297   Since the cutoff to divide the two groups was based on their maximal $\dot{V}O_2$ values, maximal
298   absolute $\dot{V}O_2$, $\dot{V}CO_2$, and $\dot{V}_E$ values were also expected to be higher in the group showing a more
299   desirable cardiorespiratory fitness level (Table 1).
300
301   Heart rate recovery is defined as the rate at which HR decreases within the following minutes
302   after the cessation of physical exercise and reflects the dynamic balance between
303   parasympathetic reactivation and sympathetic withdrawal (Qiu et al., 2017). It is a simple
304   assessment of the autonomic nervous system function indicating one's ability to adjust HR to
305   match changes in exercise demands. Accordingly, HR recovery is widely used as a guide to
306   monitor changes in physical fitness and training status. Previous research demonstrated a strong
307   relationship between HR recovery and $\dot{V}O_{2max}$ among elite athletes (Suzic Lazic et al., 2017).
308   More precisely, the authors reported that HR recovered on average 58 bpm 2-minute after the
309   cessation of the GXT. In our analysis, mean HR were on average 42 and 37 bpm lower 2-minute
310   after the cessation of the GXT among applicants in the SG and UG, respectively. It is, thus, not
311   surprising that HR recovery was considered a beneficial parameter of success displaying a
312   medium effect size with CI ranging from trivial up to large effect size (Fig. 1).
313
314   **Exercise Training Regime**
315   As above-mentioned, firefighters generally possess a higher skeletal muscle mass than the
316   general population because muscular strength is required for their job. As a result, the physical
317   preparation for applicants should ideally include regular endurance exercise and strength
318   exercise training. Surprisingly, endurance exercise showed a wide range of training hours among
319   all applicants, varying from 0 to 12 h/week and, although, no endurance or total exercise training
320   systematically indicates a failure in the GXT, on average SG trained 75 more minutes (53%)

321 each week in endurance exercise than UG. This is equivalent to an extra five hours of endurance
322 exercise training each month, a behavior that should bring about a higher cardiorespiratory
323 fitness level after a few months of additional training. Total self-reported exercise was also
324 higher in SG as compared to UG. In the same trend, SG added on average 46 more minutes of
325 strength exercise per week compared to UG, even though it did not translate into a statistically
326 significant difference between groups [displaying a small effect size with half of the CI in the
327 trivial area (Fig. 1)] . Therefore, it was inferred that both groups weight trained similarly.
328 Overall, successful applicants exercised 40% (119 minutes) more each week in TE. Likewise,
329 this additional eight hours of training volume accumulates every month and should display a
330 favorable effect over time on the cardiorespiratory fitness level of applicants as a consequence of
331 concurrent training effect (Dudley & Fleck, 1987).
332
333 In addition, our results showed that applicants in the yellow zone (40-45 ml·min^{-1}·kg^{-1}) were not
334 visually and statistically different from those in the red or green zones for all parameters.
335 However, body mass and HR recovery were different between the red and green zones. Figure 2
336 shows a difference in medians of 10 kg for body mass between applicants in the red zone and
337 those in the green zone which is a substantial difference whereas HR recovery was 8 bpm higher
338 in the green zone compared to those in the red zone. Moreover, applicants in the green zone
339 displayed higher endurance exercise and total exercise training times as compared to those in the
340 red zone (Fig. 3). This can be visually confirmed by the notches between the red and green zones
341 that do not overlap, indicating a distinct difference in the medians between the two zones. The
342 median for endurance exercise in the green zone was equivalent to 4 h/week, 95% CI [3, 4.5] and
343 the median for total exercise was 7 h/week, 95% CI [6, 8]. Although it does not guarantee
344 success, aiming to train similarly to applicants in the green zone would most likely lead to a
345 higher probability of succeeding in the GXT than replicating the amount of exercise training
346 performed by the group in the red zone. In fact, 82% of all applicants who trained ≥ 7 h/week in
347 total exercise were successful and 87% of all applicants who trained ≥ 4 h/week in endurance
348 exercise reached the standard in the GXT, reinforcing the importance of endurance-based
349 activities in the exercise training regimen. Performing 4 h/week of endurance type of exercises
350 (no less than 3 h/week) within a training volume of 7 h/week (no less than 6 h/week) on a regular
351 basis is well within the capacity of many firefighter applicants and hopefully exercise training
352 will become part of their lifestyle throughout their careers.
353
354 One of the most significant aspects of the manuscript relates to the concurrent training or cross-
355 training effects. In fact, the chronic response brought about by 4 h of endurance exercise
356 performed per week by the successful applicants were clearly not hindered by the 3 h of strength
357 training. These outcomes partly concur with (Coffey et al., 2017) who report that chronic
358 response to concurrent training depends on individual's fitness status, the fitter the individual,
359 the greater the disruptive impact of strength training on cardiorespiratory fitness. However, the
360 same authors mentioned that low to moderate intensity and volume of training do bring no
361 interference effect of strength on cardiorespiratory response. They further suggest that the
362 potential of resistance training to increase oxidative metabolism might contribute to the
363 cardiorespiratory fitness of recreationally active individuals such as our firefighter applicants.
364 Somehow, they agree with (Dudley & Fleck, 1987; Loy et al., 1995) reporting that concurrent
365 training does not affect the development of oxidative capacity. Those conclusions and our
366 outcomes further confirm the benefit of strength training on cardiorespiratory fitness in

367   moderately fit individuals and that the total volume of training represents a very good indicator
368   of cardiorespiratory fitness in moderately trained individuals.
369

370   **Conclusions**

371

372   Physical exercise is an important aspect of preparation for fitness testing among firefighter
373   applicants and it usually encompasses endurance and strength type of exercise training. The main
374   objective of the current secondary analysis was to determine if there was any difference in
375   exercise training routine between successful and unsuccessful applicants and, if so, to provide
376   practical guidance to future applicants preparing for their GXT. Based on a 5.6% total
377   variability, it was determined that a good target for applicants would be to aim for a maximal
378     $\dot{V}O_2$ value ≥ 45 ml·kg^{-1}·min^{-1} that correspond to the green zone. While it does not guarantee
379   success in the GXT, future firefighter applicants are encouraged to replicate the exercise training
380   regime self-reported by successful applicants in the green zone. This suggestion is even more
381   important for those who currently have a maximal $\dot{V}O_2$ value ≤ 40 ml·kg^{-1}·min^{-1}. Our results
382   showed endurance exercise and total exercise differences between SG and UG but no statistical
383   difference in strength exercise between groups. This does not mean that strength has no effect on
384   success in the GXT, but rather that we cannot reject the null hypothesis with our sample size.
385   Thus, future applicants are encouraged to perform strength exercise regularly to be ready
386   physically for their occupational specific test, which requires a significant amount of muscular
387   strength. However, if someone must choose between the two types of exercise training, our
388   findings suggest that endurance exercise should be favored. In short, future firefighter applicants
389   should embrace the following practical recommendations as guidance to prepare for the GXT as
390   part of their recruitment process:

391

392   ✓   7 h/week of total exercise training, from which 4 h/week should be endurance-based
393   exercise training;
394   ✓   Heart rate recovery at 2-minute ≥ 43 beat per minute; and
395   ✓   Healthy body mass composition with optimal muscle mass and fat mass

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397

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492

Table 1

Anthropometrics and physical characteristics of participants

Parameters	N	Mean (all) (SD)	Mean SG (SD)	Mean UG (SD)	ES_{M1-M2} [95% CI]	Diff (%)	t statistic	df	p value
Age (years)	121	26.3 (5.8)	25.5 (4.9)	28.4 (7.3)	-2.9 [-5.7, -0.1]	-10	-2.091	44.7	.042
Height (cm)	121	178.6 (6.2)	178.4 (5.5)	179.2 (7.7)	-0.8 [-3.8, 2.2]	0	-0.548	46.3	.587
Body mass (kg)	121	84.9 (10.6)	82.7 (8.3)	90.4 (13.5)	-7.6 [-12.7, -2.5]	-8	-3.022	43.0	.004
Maximal HR (bpm)	121	195 (9)	195 (9)	194 (10)	1 [-3, 5]	0	0.363	56.4	.718
HR recovery (bpm)	121	40 (10)	42 (10)	37 (10)	5 [1, 9]	14	2.554	61.7	.013
Maximal VO_2 (ml·kg^{-1}·min^{-1})	121	46.5 (6.4)	49.6 (4.5)	38.7 (2.7)	10.9 [9.5, 12.2]	28	15.896	97.6	<.001
AbsVO_2 (ml·min^{-1})	121	3928 (588)	4099 (547)	3491 (448)	608 [413, 803]	17	6.214	72.4	<.001
VCO_2 (ml·min^{-1})	119	3802 (571)	3971 (529)	3362 (425)	609 [420, 797]	18	6.438	71.1	<.001
V_E (L·min^{-1})	119	130 (20)	135 (18)	116 (18)	19 [11, 26]	16	5.049	57.0	<.001
Bf (breath·min^{-1})	119	50 (8)	51 (8)	48 (8)	3 [0, 7]	7	2.044	55.0	.046
RER	119	1.0 (0)	1.0 (0)	1.0 (0)	0 [0, 0]	0	0.372	46.2	.711
EE (min/week)	120	195 (154)	216 (162)	141 (117)	75 [21, 128]	53	2.779	82.7	.007
SE (min/week)	119	189 (158)	202 (159)	156 (148)	46 [-16, 108]	30	1.481	64.5	.143
TE (min/week)	118	382 (239)	417 (240)	298 (213)	119 [28, 210]	40	2.612	68.0	.011

Figure 1

Figure 1

Effect size and confidence intervals for *d* statistic in relation to effect size classes and potential effects. Adapted from Cohen (1988) and Batterham & Hopkins (2006).
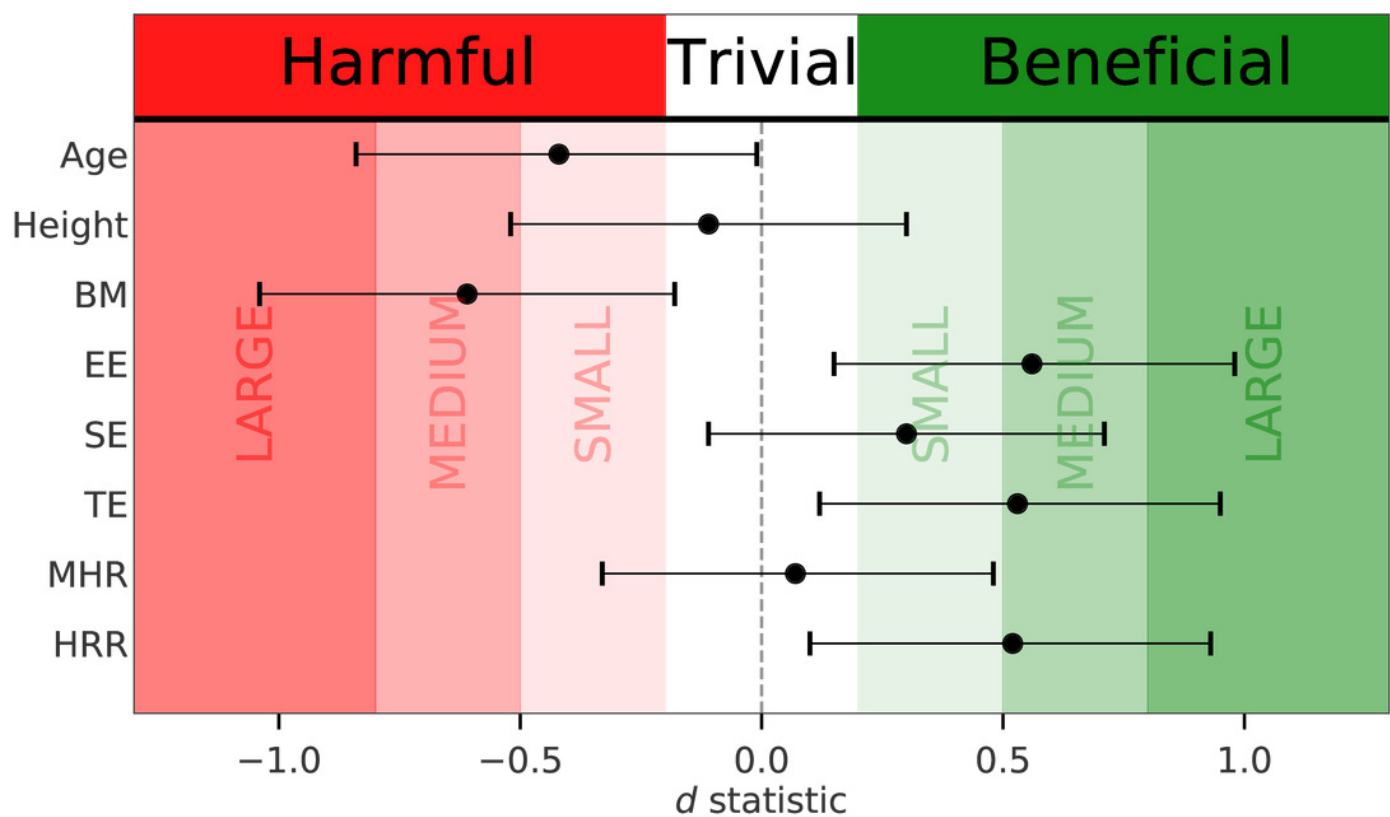
Figure 2

Figure 2

Difference in medians for body mass and heart rate recovery for each fitness zone (n_{red}= 21, n_{yellow}= 33, n_{green}= 67). The green zone includes applicants with maximal $\dot{V}O_2$ values ≥45 ml·kg^{-1}·min^{-1}, the yellow zone includes applicants with maximal $\dot{V}O_2$ values between 40-45 ml·kg^{-1}·min^{-1}, and the red zone includes applicants with maximal $\dot{V}O_2$ values ≤40 ml·kg^{-1}·min^{-1}.
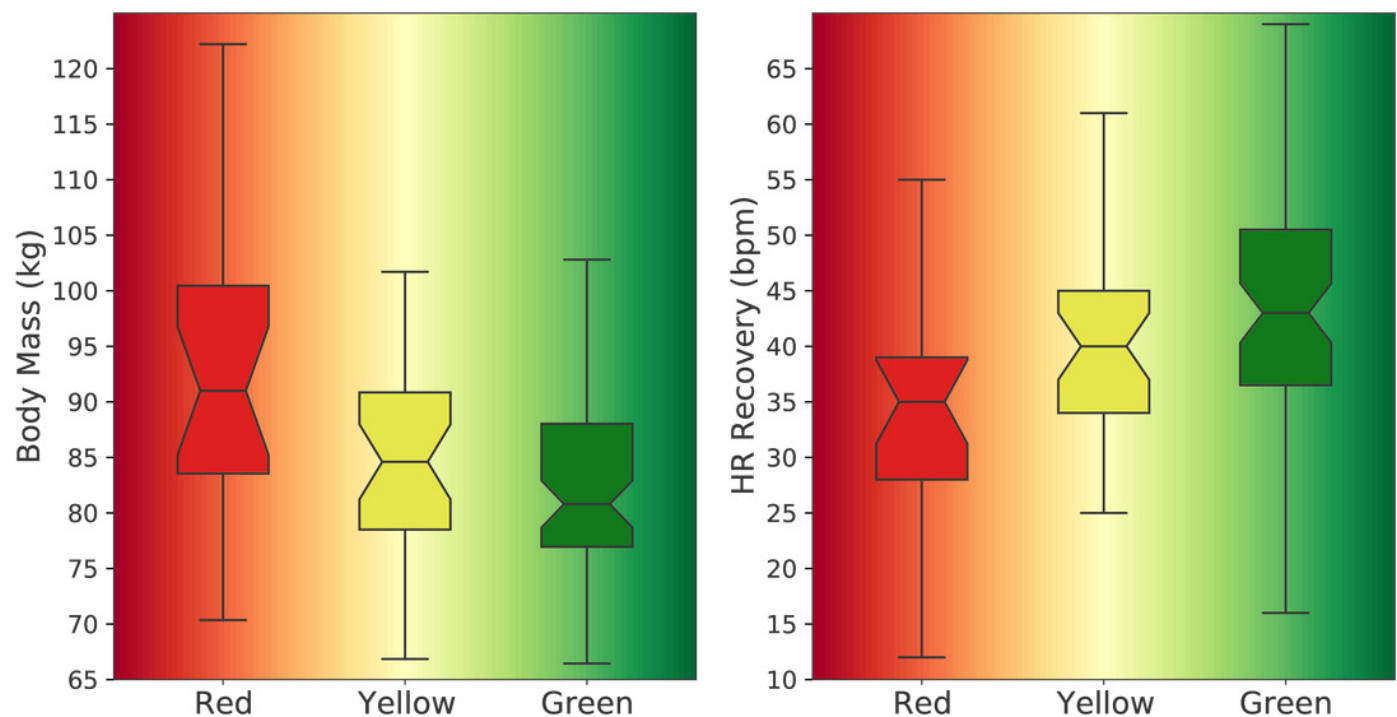
Figure 3

Figure 3

Difference in medians for endurance exercise (EE) and total exercise (TE) training time in hours per week for each fitness zone (n_{red}= 21, n_{yellow}= 33, n_{green}= 67). The green zone includes applicants with maximal $\dot{V}O_2$ values ≥45 ml·kg^{-1}·min^{-1}, the yellow zone includes applicants with maximal $\dot{V}O_2$ values between 40-45 ml·kg^{-1}·min^{-1}, and the red zone includes applicants with maximal $\dot{V}O_2$ values ≤40 ml·kg^{-1}·min^{-1}.