

Age and physical activity status of Australian volunteer firefighters: a cross-sectional study

David N. Borg^{A,*} , Daniel Moore^B and Ian B. Stewart^A 

For full list of author affiliations and declarations see end of paper

*Correspondence to:

David N. Borg
School of Exercise and Nutrition Sciences,
Faculty of Health, Queensland University of
Technology, Brisbane, Qld, Australia
Email: dn.borg@qut.edu.au

Received: 11 September 2023

Accepted: 24 March 2024

Published: 18 April 2024

Cite this: Borg DN *et al.* (2024) Age and physical activity status of Australian volunteer firefighters: a cross-sectional study. *International Journal of Wildland Fire* **33**, WF23146. doi:[10.1071/WF23146](https://doi.org/10.1071/WF23146)

© 2024 The Author(s) (or their employer(s)).
Published by CSIRO Publishing on behalf of
IAWF.

This is an open access article distributed
under the Creative Commons Attribution-
NonCommercial-NoDerivatives 4.0
International License ([CC BY-NC-ND](https://creativecommons.org/licenses/by-nc-nd/4.0/))

OPEN ACCESS

ABSTRACT

Background. There have been concerns of an aging Australian volunteer firefighter workforce. **Aims.** To (1) determine the age distribution of Australian volunteer firefighters; (2) estimate the proportion of volunteer firefighters who met the Australian physical activity guidelines; (3) investigate the relationship between age and physical activity and exercise in volunteer firefighters. **Methods.** An online survey was electronically distributed to Rural Fire Service volunteers in Queensland, Australia. The survey included demographic and physical activity questions. National guidelines were used to determine whether respondents met the Australian physical activity recommendations. The relationships between age and weekly physical activity and weekly exercise minutes were modelled using Bayesian methods. **Key results.** The median age of responders ($n = 480$) was 54 years. Compared with Australian population data, volunteer firefighters were four times more likely to meet the physical activity guidelines and the exercise-only guidelines, but 1.4 times more likely to not meet the strength-based activity guidelines. Number of weekly physical activity minutes declined with age, by 61 min each decade. **Conclusions.** Volunteers were more likely to meet the national physical activity and exercise-only guidelines, but less likely to meet the strength-based activity guidelines. **Implications.** Volunteer firefighters could benefit from outreach programs that promote participation in strength-based training.

Keywords: bushfire, climate, emergency, exercise, firefighter, fitness, natural disaster, physical activity, resistance, strength-based training, training, wildfire.

Introduction

Wildfire frequency and severity are increasing globally (Hennessy *et al.* 2005; Liu *et al.* 2010). Recent wildfire devastation has been witnessed across Europe, Asia, the Americas and Australia (Liu *et al.* 2010; Aisbett *et al.* 2012; Bowman *et al.* 2017). Beyond the destruction of millions of hectares of land, wildfires present a significant threat to the economy and human life. In the 2019–2020 Australian fire season, wildfires directly claimed 33 lives (Filkov *et al.* 2020), and were indirectly responsible for an estimated 171 deaths due to reduced air quality (Graham *et al.* 2021). In the same season, Australian insurers paid out more than AU\$6.1 billion owing to wildfire damage and destruction (Insurance Council of Australia 2021). The negative impacts of Australian wildfires are predicted to worsen over the next decade (Ademi *et al.* 2022).

The increasing number and severity of wildfires have placed greater demands on Australian firefighters, including the volunteer population. Australia had an estimated 220,000 volunteers in 2004 (McLennan 2004), which was similar to 2012 estimates (Productivity Commission 2023). The volunteer population has steadily declined since 2012, to an estimated 193,000 volunteers in 2021 (Productivity Commission 2023). Volunteer firefighters assist in firefighting activities within their local community without receiving financial compensation. Volunteers play a crucial role in providing firefighting services and supporting professional firefighters during emergency situations, particularly in rural Australian areas where the population density and resources are low.

As volunteers typically hold a full-time occupation, they have less time for physical and firefighting training compared with salaried personnel (Malinen and Mankkinen 2018). Nonetheless, the value of volunteers cannot be overestimated, and they have an increasingly critical role in combating Australian wildfires as the duration and intensity of the fire season increase.

Volunteer firefighters are required to undertake physically demanding tasks (Phillips *et al.* 2012) in hazardous environments (Guidotti 1992; Navarro 2020). A 2012 study by Phillips *et al.* identified that the physically demanding tasks undertaken by volunteers primarily relied on strength-endurance and could be broadly categorised as either hose work or hand tool work. Tasks may take anywhere from 3 to 30 min per repetition, and in some cases, are performed up to 700 times across a fire season (Phillips *et al.* 2012). Owing to these physical demands, the fitness of volunteers is critical, not only because increased strain could decrease an individual's operational effectiveness, but also because of the increased risk of cardiovascular events, which are estimated to account for 26% of line of duty deaths in Australian volunteer firefighters (Glass *et al.* 2017). From a workforce perspective, the fitness of volunteers is important as a lack of fitness may deter new recruits, and could contribute to difficulties in retaining volunteers (Birch 2011).

There have been recent concerns regarding an aging volunteer firefighter population and its capability to handle the demands of a hotter and longer fire season (Colibaba *et al.* 2021), particularly in light of other challenges such as decreasing volunteering rates (McLennan *et al.* 2016; Productivity Commission 2023). Unfortunately, there is a lack of recent literature on the demographics of Australian volunteer firefighters, with the largest study on volunteers including data up until the early 2010s (Glass *et al.* 2017) and other commissioned work dating back to the 2000s (McLennan and Birch 2005). Although an aging workforce can be positive in that it brings invaluable experience and oversight, which may reduce volunteering-related mental stress (Moran and Colless 1995), the relative physical demands of volunteering can become greater with age, owing to decreased muscular power and strength endurance, and a decline in cardiovascular fitness (Perroni *et al.* 2014). For example, in Australian salaried firefighters, maximal aerobic capacity, grip strength and performance in fire-specific tasks (e.g. hose drag) were found to decrease with increase in age (Walker *et al.* 2014). Intense exercise training can assist in minimising age-associated declines in physical capacity (Walker *et al.* 2014); however, evidence suggests that older firefighters are less likely to engage in such activity (Phillips *et al.* 2012). There are limited published data on physical activity behaviours in volunteer firefighters, with existing studies involving American volunteers only (Martin *et al.* 2019; Amodeo and Nickelson 2020).

To meet the Australian physical activity and sedentary behaviour guidelines, adults 18–62 years of age must

accumulate at least 150 min of combined workplace activity and exercise-only minutes per week (Department of Health and Aged 2021). To meet the strength-training guidelines, adults must participate in strength-based training activities at least twice per week. No guidance on exercise duration is provided for strength-based training activities. No previous study of Australian volunteer firefighters has investigated the proportion of active volunteers that meet these guidelines.

This study aimed to: (1) determine the age distribution of Australian volunteer firefighters; (2) estimate the proportion of volunteer firefighters who met the national physical activity guidelines; and (3) investigate the relationship between age and physical activity and exercise in volunteer firefighters.

Methods

The survey was developed for volunteer firefighters and included demographic, anthropometric and service questions, in addition to physical activity questions from the 2016–2018 Australian National Health Survey (Australian Bureau of Statistics 2018). National guidelines (Department of Health and Aged 2021) were used to determine whether respondents met the Australian recommendations for weekly physical activity and strength-based training, enabling comparison with population estimates (Australian Bureau of Statistics 2018).

Reporting of the survey and results was guided by the STROBE reporting guidelines for cross-sectional studies (Von Elm *et al.* 2014) and the CHERRIES reporting guidelines for online questionnaires (Eysenbach 2004).

Sample and recruitment

The survey was distributed to active volunteer firefighters in Queensland, Australia. Queensland is Australia's second-largest state, with an area of 1,852,642 km². Queensland has diverse geographical features and climates, including tropical rainforests, mountain ranges, tropical and sub-tropical coastal regions, and deserts and savanna in the semi-arid and desert climatic regions of its interior.

The survey was individually distributed to 20,169 Rural Fire Service volunteers via direct correspondence through the Queensland Fire Service intranet. The survey was open from November 2020 to September 2021. Participation was voluntary with no incentives. The method of survey collection was non-random. The survey response rate was 2.38%. A comparison of characteristics between respondents and non-respondents cannot be made. All respondents provided consent before completing the survey.

Survey questions

The survey comprised 37 closed questions. The consent form was on the first page. All questions could be skipped. In pilot testing, the survey took 15–20 min to complete.

Respondents were asked demographic (age, gender) and anthropometric (body mass, height without shoes and participants' acceptability with their body weight) questions. Information about volunteer firefighting service duration was collected. Respondents were also asked to indicate their service region.

The physical activity questions were designed by the Australian Bureau of Statistics, as part of the Australian National Health Survey (Australian Bureau of Statistics 2018). The National Health Survey obtains data on a range of health-related indicators from the Australian population. The physical activity questions asked about typical physical activity in the workplace and the frequency and duration of physical activity and exercise behaviours in the past week. Respondents were asked their typical workday activities, with responses recorded as mostly sitting, standing, walking or heavy labour or physically demanding work. Any physical activity referred to the combination of workplace activity and exercise-only activity. Exercise-only activity consisted of four domains: (1) walking for transport, (2) walking for fitness, sport, or recreation, (3) moderate intensity exercise, and (4) vigorous intensity exercise. Weekly totals (in minutes) were calculated for workplace activity and the four exercise-only domains. Respondents were also asked the number of days they undertook strength or toning activities in the last week.

Physical activity guidelines

The Australian physical activity and sedentary behaviour guidelines for 18–62 year olds (Department of Health and Aged 2021) were used to determine whether respondents met the national recommendations for weekly physical activity and exercise-only minutes, and strength-based training days. To have met the guidelines for physical activity, individuals must have accumulated at least 150 min of combined workplace activity and exercise-only (i.e. walking, and moderate and vigorous intensity activity) minutes in the past week. To have met the exercise-only activity guidelines, individuals must have accumulated at least 150 min of walking, and moderate and vigorous intensity activity in the past week. In this calculation, vigorous intensity exercise accounts for double minutes (Australian Bureau of Statistics 2018). To have met the strength activity guidelines (herein strength-based activity guidelines), respondents must have participated in strength training at least twice in the past week. These same criteria were used by 2016–2018 Australian National Health Survey to determine estimates of the Australian population (Australian Bureau of Statistics 2018).

Data analysis

All analyses were performed in R (R Core Team 2022). The data and R code needed to reproduce the analyses are available at the doi: <https://www.doi.org/10.5281/zenodo.8145705>. There were missing values for anthropometric

variables ($\leq 1\%$) but not physical activity time variables. Eight respondents (1.67%) indicated they completed more than 7 days of exercise in the past week, which is not possible. These responses were changed to missing values. No values were imputed for missing data (Borg *et al.* 2022).

A histogram plot was used to describe the distribution of age for our sample. The mean age of volunteer firefighters was estimated using a bootstrap procedure, which provides a distribution-free method for estimating the uncertainty in the mean (Davison and Hinkley 1997). We ran 2000 replicates and generated a mean and 95% bootstrap confidence interval (CI) for age.

The proportion of volunteer firefighters who met the Australian physical activity guidelines was calculated and compared with population data. Respondents who undertook more than 150 min were considered to have met the physical activity and exercise-only guidelines. Vigorous intensity exercise minutes were multiplied by a factor of two for this analysis. Respondents who participated in strength training on at least 2 days were considered to have met the strength-based activity guidelines. Proportions were compared with population estimates (Australian Bureau of Statistics 2018) from the year our survey data were collected. We also compared typical workday physical activity between our respondents and the Australian population. Comparisons were made using chi-squared tests (χ^2), with *P* values computed by Monte Carlo simulation. Tests were implemented using the base R function *chisq.test*. The Type I error rate for all tests was set at 5%. Relative risks and their 95% CIs were also computed.

The relationship between age and physical activity minutes, and between age and exercise-only minutes, was examined using separate generalised linear models with a negative binomial response distribution. The models included age as a fixed variable. We did not consider gender in our modelling as the physical activity guidelines are not gender-specific. Models were implemented in a Bayesian framework, using Stan with the *brms* interface (Bürkner 2017).

The contribution of each physical activity domain (walking for travel, walking for exercise, moderate intensity exercise, vigorous intensity exercise and workplace activity) to total weekly physical activity minutes was calculated for each respondent and expressed as a proportion. These variables were separately modelled using zero- or zero-and-one-inflated beta regression (Liu and Kong 2015). A beta regression can model values between 0 and 1 (exclusive). Zero- and one-inflated beta extends beta regression by allowing exact 0s and 1s to be observed with some unknown probability. The mean of the beta distribution and the probability of observing an exact 0 were each modelled with a distinct intercept and coefficient for the age covariate (on the linear scale). The walking for travel, walking for exercise and workplace activity models included only an intercept term for the probability of observing an exact 1 owing to a fairly small number of observed 1s (2.1, 2.5 and 2.8%; see Supplementary Appendix S1). The vigorous intensity exercise

model did not include a 1 component. Moderate intensity proportions of exactly 1 (1.25%) were shifted slightly off the boundary by subtracting 0.0001 because the model did not converge when modelled with a 1 component. Subtracting 0.0001 has no effect on proportions when rounded to two decimal places. In all models, the shape of the beta distribution was estimated without covariates.

Weakly informative prior distributions were specified for the regression coefficients and variance components (Supplementary Appendix S2). Monte Carlo Markov Chain (MCMC) methods were used to generate posterior estimates for all Bayesian models (10,000 iterations, eight chains, 50% iteration burn-in, no thinning). The convergence of the MCMC to the posterior distribution was assessed using trace plots. Results from Bayesian models were interpreted using estimation methods (Kruschke and Liddell 2018). To substantiate evidence of relationships, we calculated the posterior probability that the regression coefficient (β) was greater or less than zero, denoted as $\Pr \beta > 0$ or $\Pr \beta < 0$, depending on the direction of the relationship. Posterior estimates are summarised as the mean and 66 and 95 credible interval (CrI). Descriptive statistics are reported as count and percentage or median and first and third quartile.

Ethics

Ethical approval for the study was granted by the Queensland University of Technology Human Research Ethics Committee.

Results

Sample

Table 1 provides a summary of the study sample. Survey respondents were mostly male (83.8%). The median body mass index was 27.8 kg/m², which falls in the 'overweight' range. The median number of years served as a volunteer firefighter was 13 years. Approximately 9% of respondents had previously served as a permanent firefighter, with a median number of years served of 10 years.

Age

Fig. 1 shows the age distribution of the sample. The median age of respondents was 54 years. The interquartile range spanned from 40 to 64 years and the central 90% quantile spanned from 23 to 72 years. The mean age was 51.4 years (95% bootstrap CI = 50.0–52.8).

Physical activity

The proportion of volunteer firefighters who met the Australian guidelines for: physical activity, χ^2 ($N = 17,193,480$) = 1533.00, $P < 0.001$; exercise-only activity, χ^2 ($N = 17,195,980$) = 1390.80, $P < 0.001$; and strength-based activity, χ^2 ($N = 21,340,480$) = 49.61,

Table 1. Sample demographic and anthropometric characteristics and service information.

Variable	<i>n</i> = 480
Age (years)	54 (40–64)
Gender	
Male	402 (83.8%)
Female	75 (15.6%)
Indeterminate/intersex	3 (0.6%)
Body mass (kg)	86.5 (77.0–99.2)
Height (cm)	171 (178–183)
Body mass index (kg/m ²)	27.8 (27.8–31.1)
Underweight (<18.5 kg/m ²)	3/475 (0.6%)
Normal weight (18.5–24.99 kg/m ²)	132/475 (27.8%)
Overweight (25–29.99 kg/m ²)	185/475 (38.9%)
Obese (≥ 30 kg/m ²)	155/475 (32.6%)
Acceptable body weight	
Acceptable	327 (68.1%)
Overweight	146 (30.4%)
Underweight	7 (1.5%)
Brigade region	
Brisbane	40 (8.3%)
Central	57 (11.9%)
Far Northern	34 (7.1%)
Northern	34 (7.1%)
North Coast	135 (28.1%)
South Eastern	121 (25.2%)
South Western	59 (12.3%)
Service experience	
Years served as a volunteer firefighter	13 (5–22)
Previously served as a permanent firefighter	42 (8.8%)
Number of years served	10 (4–18)

Note: gender, body mass index categories, acceptable body weight, brigade region and previous permanent firefighter service are reported as count (percent). All other variables are presented as the median and first and third quartile.

$P < 0.001$, was different to the Australian population. Compared with the Australian population, volunteer firefighters were 4.87 times more likely to meet the physical activity guidelines, 4.96 times more likely to meet the exercise only guidelines, but 1.26 times more likely to not meet the strength-based activity guidelines (Table 2).

Volunteer firefighters were 2.1 times more likely to be involved in heavy labour or physically demanding work on a typical workday compared with the Australian population, and less likely to be involved in work mostly sitting or standing, χ^2 (d.f. = 3, $N = 11,120,633$) = 90.71, $P < 0.001$ (Table 2).

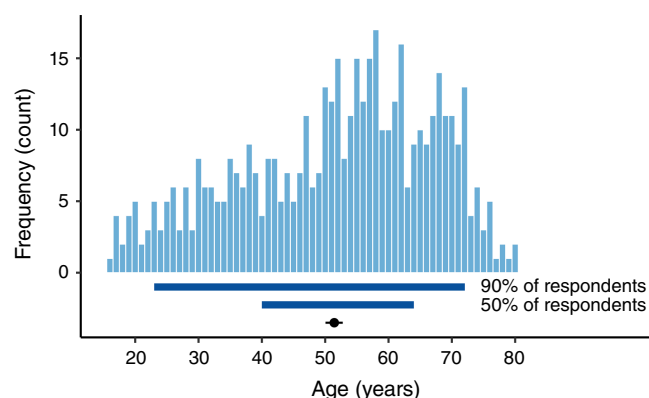


Fig. 1. The distribution of age, using 1-year bin widths. The central 90% interval spanned from 23 to 72 years (wide horizontal line) and the interquartile range spanned from 40 to 64 years (narrow horizontal line). The dark black circle indicates the mean age (51.4 years), and the error bars indicate the 95% bootstrap confidence interval, which spanned from 50.0 to 52.8 years.

Physical activity duration and frequency are displayed in Fig. 2. The median daily physical activity time was 111 min (first and third quartile = 51–235), and the median daily exercise-only time was 60 min (first and third quartile = 26–119). The median daily moderate intensity exercise time was 9 min (first and third quartile = 0–21). Forty-two percent ($n = 200/480$) of respondents had not participated in moderate intensity exercise in the past week. The median daily vigorous intensity time was 0 min (first and third quartile = 0–17). Fifty-nine percent ($n = 284/480$) of respondents had not participated in vigorous intensity exercise in the past week. Sixty-one percent ($n = 295/480$) of respondents had not participated in strength-based activity in the past week.

Relationship between age and physical activity

The number of weekly physical activity minutes declined with age ($\beta = -0.0055$, 95% CrI = -0.0115 , 0.0006 ; Pr

Table 2. The percentage of volunteer firefighters who met the physical activity guidelines and physical activity on a typical workday compared with Australian population estimates from the 2017 to 2018 National Health Survey.

Variable	Australian population ^A	Volunteer firefighters	RR	RR 95% CI lower, upper
Any physical activity ^B				
Met guidelines ^C	3,023,600 (17.6%)	411 (85.6%)	4.87	4.69, 5.05
Did not meet guidelines	14,169,400 (82.4%)	69 (14.4%)	0.17	0.14, 0.22
Exercise only ^B				
Met guidelines ^C	2,677,400 (15.6%)	371 (77.3%)	4.96	4.73, 5.21
Did not meet guidelines	14,518,100 (84.4%)	109 (22.7%)	0.27	0.23, 0.32
Strength-based activity ^B				
Met guidelines ^C	8,278,000 (38.8%)	111 (23.1%)	0.60	0.51, 0.70
Did not meet guidelines	13,062,000 (61.2%)	369 (76.9%)	1.26	1.20, 1.32
Type of physical activity on a typical workday ^D				
Mostly sitting	4,876,400 (43.9%)	164 (37.9%)	0.86	0.76, 0.98
Mostly standing	2,164,900 (19.5%)	54 (12.5%)	0.64	0.50, 0.82
Mostly walking	2,557,100 (23.0%)	89 (20.1%)	0.89	0.74, 1.08
Mostly heavy labour or physically demanding work	1,521,800 (13.7%)	126 (29.1%)	2.13	1.82, 2.48

Note: CI, confidence interval; RR, relative risk. Percentages may not sum exactly to 100 owing to rounding. Boldface indicates the 95% confidence interval of the relative risk does not include the null value of one.

^AAustralian adult (18–74 years) population data sourced from published 2017–2018 National Health Survey results.

^BAny physical activity refers to a combination of exercise-only and workplace activity. Exercise-only consists of four domains: walking for transport, walking for fitness, sport or recreation, moderate exercise and/or vigorous exercise undertaken in the last week. Workplace activity is physical activity undertaken in the workplace, which consists of two domains: moderate and/or vigorous workplace activity undertaken on a typical workday.

^CPer Australia's Physical Activity and Sedentary Behaviour Guidelines, adults should: (1) accumulate at least 150 min of moderate intensity physical activity or at least 75 min of vigorous intensity physical activity, or an equivalent combination of both moderate and vigorous activities each week; and (2) undertake muscle strengthening activities on at least 2 days of each week.

^DMissing data ($n = 47$) for the volunteer firefighter group; not accounted for by calculated percentages.

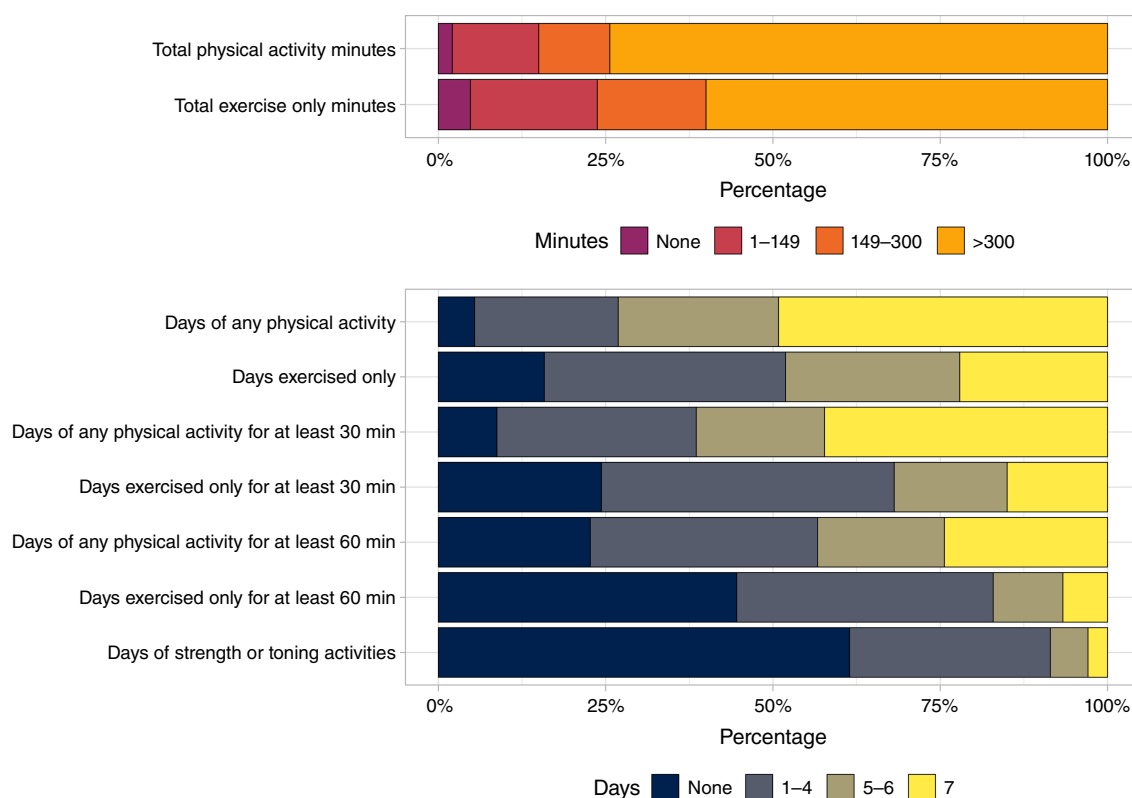


Fig. 2. Physical activity and exercise-only minutes (top panel), and days of physical activity, exercise-only and strength-based activities undertaken in the past week (bottom panel). Any physical activity refers to a combination of exercise-only and workplace activity. Exercise only consists of four domains: walking for transport, walking for fitness, sport or recreation, moderate exercise and/or vigorous exercise undertaken in the last week. Workplace activity is physical activity undertaken in the workplace, which consists of two domains: moderate and/or vigorous workplace activity undertaken on a typical workday.

$\beta < 0 = 0.963$), by on average 61 min with each decade increase in age (Fig. 3a). We did not find any evidence that age was associated with a decline in weekly exercise-only minutes ($\beta = -0.001$, 95% CrI = -0.008 , 0.005 ; $\text{Pr } \beta < 0 = 0.64$; Fig. 3b).

Walking for travel accounted for a higher proportion of weekly physical activity minutes with increases in age ($\beta_{(0,1)} = 0.0064$, 95% CrI = 0.0005 , 0.0123 ; $\text{Pr } \beta > 0 = 0.983$), by on average 0.81% with each decade increase in age (Fig. 3c). Walking for exercise accounted for a higher proportion of weekly physical activity minutes with increases in age ($\beta_{(0,1)} = 0.008$, 95% CrI = 0.002 , 0.014 ; $\text{Pr } \beta > 0 = 0.996$), by on average 0.83% with each decade increase in age (Fig. 3d).

Moderate activity accounted for a larger proportion of weekly physical activity minutes with increases in age ($\beta_{(0,1)} = 0.009$, 95% CrI = 0.001 , 0.017 ; $\text{Pr } \beta > 0 = 0.988$), by on average 0.60% with each decade increase (Fig. 3e). Vigorous intensity exercise accounted for a lower proportion of weekly physical activity minutes with increases in age, decreasing by on average 1.19% with each decade increase (Fig. 3f). This was due to an increase in respondents doing no

vigorous activity ($\beta_{\{0\}} = 0.02$, 95% CrI = 0.01 , 0.03 ; $\text{Pr } \beta > 0 = 1$), rather than a reduction in vigorous activity minutes being undertaken ($\beta_{(0,1)} = -0.002$, 95% CI = -0.009 , 0.005 ; $\text{Pr } \beta < 0 = 0.688$).

Work activity accounted for a lower proportion of weekly physical activity minutes with increases in age, decreasing by on average 1.44% with each decade increase in age (Fig. 3g). This was due to an increase in respondents doing no work activity ($\beta_{\{0\}} = 0.010$, 95% CrI = -0.002 , 0.022 ; $\text{Pr } \beta > 0 = 0.941$), rather than a reduction in work activity minutes being undertaken ($\beta_{(0,1)} = -0.003$, 95% CrI = -0.010 , 0.004 ; $\text{Pr } \beta < 0 = 0.785$).

Discussion

There are several insights from this survey of Australian volunteer firefighters. The mean age of the Queensland volunteer population was estimated to be between 50.0 and 52.8 years. Compared with the general Australian population, volunteer firefighters were: (1) twice as likely to perform physically demanding work in their career occupation;

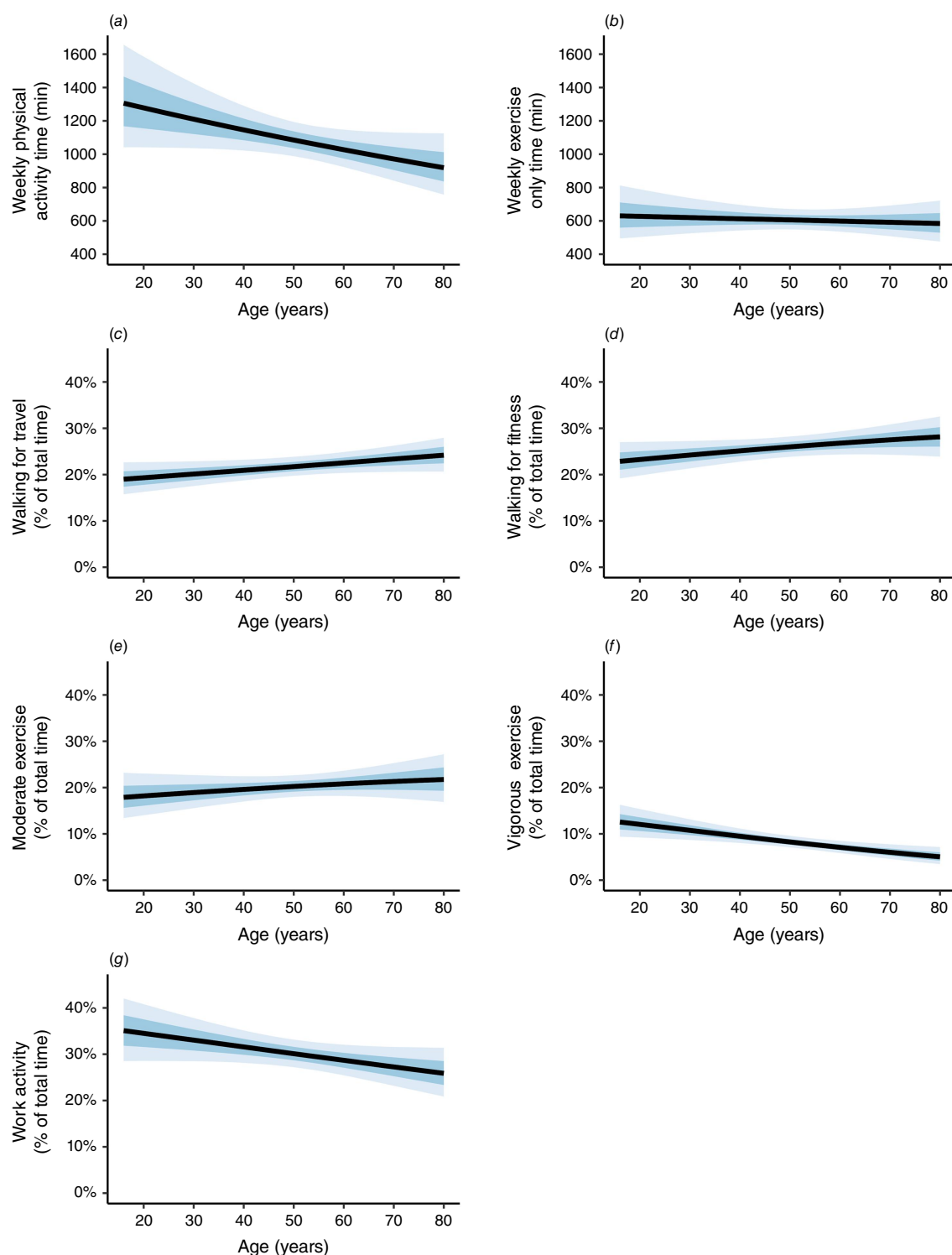


Fig. 3. The relationship between age and weekly physical activity minutes (a), and between age and weekly exercise only minutes (b); and the contribution of walking for travel (c), walking for fitness (d), moderate intensity exercise (e), vigorous intensity exercise (f), and workplace activity (g) to weekly physical activity minutes. The dark line indicates the posterior mean. The shaded ribbon indicates the 66% (blue inner ribbon) and 95% (light blue outer ribbon) credible interval. There was a decline in weekly physical activity minutes with aging, but no change in weekly exercise-only minutes. Walking for travel, walking for fitness and moderate intensity exercise accounted for a higher proportion of weekly physical activity minutes with aging. Vigorous intensity exercise and workplace activity accounted for a lower proportion of weekly physical activity minutes with aging.

(2) over four times more likely to meet the physical activity guidelines in addition to the exercise-only guidelines; and (3) 1.4 times more likely to not meet the strength-based activity guidelines. We found that the number of physical activity minutes, but not exercise-only minutes, declined with age. Future studies should review current organisational approaches to the fitness of Australian volunteer firefighters. It is possible that volunteer firefighters could benefit from outreach programs that promote and/or facilitate exercise participation, particularly in strength-based training. A multi-site trial of such a program and its effect on volunteer fitness may be warranted.

The mean age of volunteers was estimated to be 51.4 years (Fig. 1), which is 12 years older than a 2017 study of 160,000 male volunteers (Glass *et al.* 2017) and 7.8 years older than the Queensland State Emergency Service volunteer population in 2019 (Queensland Government 2019). Exactly why the volunteer firefighter population would be older than State Emergency Service volunteers is unclear; yet it does raise concerns about age-related health issues, particularly in the context of evidence that 28% of volunteer resignations are due to age or health issues (McLennan *et al.* 2009). Although the recruitment of younger volunteers is important, of equal importance is the ability to retain young recruits. There is a lack of data on the propensity of younger volunteers to be retained. Time and financial costs have been indicated as significant deterrents to volunteering (O'Halloran and Davies 2020), secondary to decreased volunteerism (McLennan *et al.* 2016). These factors are likely to contribute to lower rates of younger Australians volunteering, particularly those with young families or multiple paid employments.

In 2018, it was estimated that only 17.6% of Australians met the national physical activity guidelines, with 15.6% meeting the exercise-only guidelines (Table 2). We found that volunteer firefighters were nearly five times more likely to meet these guidelines compared with the Australian population. There is a lack of data on physical activity behaviours of Australian volunteer firefighters. A study of 74 American male volunteers found that 46% were considered sedentary – defined as not achieving at least 30 min of moderate intensity physical activity on 3 or more days a week (Martin *et al.* 2019). Using this definition, 55% of our sample would be considered sedentary. An additional 8% of our sample met the weekly time requirement but did not exercise on 3 or more days, which would otherwise mean that 47% of our sample were considered sedentary, which is comparable with the American study (Martin *et al.* 2019). A separate study of 123 American volunteers found that 14% did not participate in any moderate intensity exercise and 41% did not participate in vigorous intensity exercise (Amodeo and Nickelson 2020), compared with 42 and 59% in our sample. This suggests that Australian volunteers undertake substantially less moderate and vigorous intensity exercise compared with their American counterparts. The

generalisability of these estimates should be treated with caution owing to the small sample sizes of the comparison studies.

Decreased participation in moderate and vigorous intensity exercise is likely to increase the relative demands of firefighting independently of age, therefore increasing the associated risk of cardiac events (Walker *et al.* 2015). Worryingly, but not unexpectedly (Caspersen *et al.* 2000), we found that vigorous intensity activity accounted for a lower proportion of weekly physical activity minutes with aging (Fig. 3f). Aging was also associated with a decline in weekly physical activity minutes (Fig. 3a) but encouragingly, not exercise-only minutes (Fig. 3b). Our findings further support calls for the implementation of outreach programs that target physical activity behaviours in volunteer firefighter settings (Day *et al.* 2019; Martin *et al.* 2019). Although such programs may assist in ensuring volunteers maintain moderate and vigorous activity, they are no panacea, owing to the complexity of physical activity intention (Amodeo and Nickelson 2020). Programs should also include dietary education and support (Day *et al.* 2019), particularly when considering the high prevalence of overweight or obesity in volunteer firefighters (Martin *et al.* 2019) (71.5% in the current sample) and evidence that the risk of coronary heart disease risk is greater in volunteer firefighters compared with other volunteer and paid emergency services (Wolkow *et al.* 2014).

Despite the importance of strength endurance capacity when fighting wildfires (Phillips *et al.* 2012), 61% of respondents had not participated in strength-based activities in the past week and 77% did not meet the Australian strength activity guidelines (Table 2). Volunteers were 1.4 times more likely to not meet the guidelines compared with the Australian population. This result may be explained by volunteers being twice as likely to undertake heavy labour or physically demanding activities on a typical workday compared with the Australian population. Working in a physically demanding occupation such as farming, agriculture or construction could, at least in part, offset the need to participate in strength-based training. Nonetheless, participation in structured strength and conditioning training is still important (Westcott 2012; Bennie *et al.* 2020), particularly to offset the negative effects of age on strength (Westcott 2012), and this result should be further investigated. Sixty-one percent of volunteers did not participate in any strength-based training, which is higher than estimates of 45.2% in American volunteer firefighters (Amodeo and Nickelson 2020). Volunteer firefighters could benefit from outreach programs that promote and/or facilitate participation in strength-based training activities (Day *et al.* 2019).

The survey response rate was 2.38%, and therefore, caution should be taken when generalising from our findings. It is possible that our findings do not extend to volunteers from other Australian states. Further, the study results should be interpreted in the context of the cross-sectional

design, such that the causal relationships between age and physical activity, and between age and exercise-only minutes, are unknown. New recruits may be over-represented in our sample, as nearly a quarter of respondents (23.8%) had 3 or less years of volunteering experience. We are unable to compare demographic data between survey responders and non-responders. Questionnaire-based measures of physical activity are known to overestimate activity levels, sometimes by as much as 170% (Lee *et al.* 2011). Using a conservative approach and halving the weekly activity minutes for each respondent, 75.8% of the sample still met the physical activity guidelines and 48.3% met the exercise-only guidelines. Using these values, volunteers were still 4.3 times (95% CI = 4.1–4.5) and 3.1 times (95% CI = 2.8–3.4) more likely to meet the physical activity and exercise-only guidelines compared with the Australian population. A summary of age (as a continuous variable) and body mass index could not be provided for the Australian population data, as age data were reported categorically only, and body mass index data were reported in a different age bracket (18 and older) to the physical activity data (18–74 years) used in our study. Females represented 50.7% of individuals in the Australian population data.

Conclusion

We estimated the mean age of Queensland volunteer firefighters to be 51.4 years, which is nearly 8 years older than the mean age of Queensland State Emergency Service volunteers. Compared with general the Australian population, volunteers were more likely to meet the national physical activity and exercise only guidelines, but less likely to meet the strength-based activity guidelines. Expected age-related declines in vigorous intensity exercise minutes were observed. There is a need to review the current organisational approaches to the fitness of Australian volunteer firefighters and consider whether volunteer firefighters could benefit from outreach programs that promote and/or facilitate exercise participation, particularly from strength-based training.

Supplementary material

Supplementary material is available [online](#).

References

- Ademi Z, Zomer E, Marquina C, Lee P, Talic S, Guo Y, Liew D (2022) The hospitalizations for cardiovascular and respiratory conditions, emergency department presentations and economic burden of bushfires in Australia between 2021 and 2030: a modelling study. *Current Problems in Cardiology* 48, 101416. doi:10.1016/j.cpcardiol.2022.101416
- Aisbett B, Wolkow A, Sprajcer M, Ferguson SA (2012) 'Awake, smoky, and hot': providing an evidence base for managing the risks associated with occupational stressors encountered by wildland firefighters. *Applied Ergonomics* 43, 916–925. doi:10.1016/j.apergo.2011.12.013
- Amodeo KL, Nickelson J (2020) Predicting intention to be physically active among volunteer firefighters. *American Journal of Health Education* 51, 1–13. doi:10.1080/19325037.2019.1687368
- Australian Bureau of Statistics (2018) National Health Survey: First results – 2017–18 financial year. Available at <https://www.abs.gov.au/statistics/health/health-conditions-and-risks/national-health-survey-first-results/latest-release>
- Bennie JA, De Cocker K, Pavey T, Stamatakis E, Biddle SJH, Ding D (2020) Muscle strengthening, aerobic exercise, and obesity: a pooled analysis of 1.7 million US adults. *Obesity* 28, 371–378. doi:10.1002/oby.22673
- Birch A (2011) 'Recruiting and retaining volunteer firefighters in australia: an integrative summary of research (synopsis).' (Bushfire Cooperative Research Centre) Available at https://www.bushfirecrc.com/sites/default/files/managed/resource/volunteerism_int_rpt_synopsis_final_2.pdf
- Borg DN, Nguyen R, Tierney NJ (2022) Missing data: current practice in football research and recommendations for improvement. *Science & Medicine in Football* 6, 262–267. doi:10.1080/24733938.2021.1922739
- Bowman DMJS, Williamson GJ, Abatzoglou JT, Kolden CA, Cochrane MA, Smith AMS (2017) Human exposure and sensitivity to globally extreme wildfire events. *Nature Ecology & Evolution* 1, 0058. doi:10.1038/s41559-016-0058
- Bürkner PC (2017) brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software* 80, 1–28. doi:10.18637/jss.v080.i01
- Caspersen CJ, Pereira MA, Curran KM (2000) Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Medicine & Science in Sports & Exercise* 32, 1601–1609. doi:10.1097/00005768-200009000-00013
- Colibaba A, Russell E, Skinner MW (2021) Rural volunteer fire services and the sustainability of older voluntarism in ageing rural communities. *Journal of Rural Studies* 88, 289–297. doi:10.1016/j.jrurstud.2021.08.016
- Davison AC, Hinkley DV (1997) 'Bootstrap methods and their application.' (Cambridge University Press)
- Day RS, Jahnke SA, Haddock CK, Kaipust CM, Jitnarin N, Poston WSC (2019) Occupationally tailored, web-based, nutrition and physical activity program for firefighters: cluster randomized trial and weight outcome. *Journal of Occupational & Environmental Medicine* 61, 841–848. doi:10.1097/JOM.0000000000001685
- Department of Health and Aged (2021) 'Physical activity and exercise guidelines for all Australians.' (Australian Government Department of Health and Aged Care) Available at <https://www.health.gov.au/topics/physical-activity-and-exercise/physical-activity-and-exercise-guidelines-for-all-australians>
- Eysenbach G (2004) Improving the quality of web surveys: the checklist for reporting results of internet e-surveys (CHERRIES). *Journal of Medical Internet Research* 6, e34. doi:10.2196/jmir.6.3.e34
- Filkov AI, Ngo T, Matthews S, Telfer S, Penman TD (2020) Impact of Australia's catastrophic 2019/20 bushfire season on communities and environment. Retrospective analysis and current trends. *Journal of Safety Science and Resilience* 1, 44–56. doi:10.1016/j.jnlssr.2020.06.009
- Glass DC, Del Monaco A, Pircher S, Vander Hoorn S, Sim MR (2017) Mortality and cancer incidence among male volunteer Australian firefighters. *Journal of Occupational & Environmental Medicine* 74, 628–638. doi:10.1136/oemed-2016-104088
- Graham AM, Pringle KJ, Pope RJ, Arnold SR, Conibear LA, Burns H, Rigby R, Borchers-Arriagada N, Butt EW, Kiely L, Reddington C, Spracklen DV, Woodhouse MT, Knotte C, McQuaid JB (2021) Impact of the 2019/2020 Australian megafires on air quality and health. *GeoHealth* 5, e2021GH000454. doi:10.1029/2021GH000454
- Guidotti TL (1992) Absence experience of career firefighters reaching mandatory retirement age. *Journal of Occupational Medicine* 34, 1018–1022.
- Hennessy K, Lucas C, Nicholls N, Bathols J, Suppiah R, Ricketts J (2005) 'Climate change impacts on fire-weather in south-east Australia.' (Climate Impacts Group, CSIRO Atmospheric Research and the Australian Government Bureau of Meteorology: Spendale) Available at http://www.cmar.csiro.au/e-print/open/hennessykj_2005b.pdf
- Insurance Council of Australia (2021) Insurance Catastrophe Resilience Report: 2020–21. Available at https://insurancecouncil.com.au/wp-content/uploads/2021/09/ICA008_CatastropheReport_6.5_FA1_online.pdf

- Kruschke JK, Liddell TM (2018) The Bayesian new statistics: hypothesis testing, estimation, meta-analysis, and power analysis from a Bayesian perspective. *Psychonomic Bulletin & Review* 25, 178–206. doi:10.3758/s13423-016-1221-4
- Lee PH, Macfarlane DJ, Lam TH, Stewart SM (2011) Validity of the international physical activity questionnaire short form (IPAQ-SF): a systematic review. *International Journal of Behavioral Nutrition & Physical Activity* 8, 115. doi:10.1186/1479-5868-8-115
- Liu F, Kong Y (2015) Zoib: an R package for Bayesian inference for beta regression and zero/one inflated beta regression. *The R Journal* 7, 34–51. doi:10.32614/RJ-2015-019
- Liu Y, Stanturf J, Goodrick S (2010) Trends in global wildfire potential in a changing climate. *Forest Ecology & Management* 259, 685–697. doi:10.1016/j.foreco.2009.09.002
- Malinen S, Mankinen T (2018) Finnish firefighters' barriers to volunteering. *Nonprofit and Voluntary Sector Quarterly* 47, 604–622. doi:10.1177/0899764017749890
- Martin ZT, Schlaff RA, Hemenway JK, Coulter JR, Knous JL, Lowry JE, Ode JJ (2019) Cardiovascular disease risk factors and physical fitness in volunteer firefighters. *International Journal of Exercise Science* 12, 764–776.
- McLennan J (2004) Recruitment and retention of volunteers: rural fire services' issues and initiatives. (Bushfire Cooperative Research Centre (CRC), La Trobe University) Available at https://www.bushfirecrc.com/sites/default/files/managed/resource/report_4_lit_reviewd3.pdf
- McLennan J, Birch A (2005) Estimates of the likely impact on TFS operational volunteer fire fighter numbers of introducing mandatory fitness standards. (Bushfire CRC) Available at https://www.bushfirecrc.com/sites/default/files/managed/resource/tfs_report_2005_1_agefitness-2.0.pdf
- McLennan J, Birch A, Cowlshaw S, Hayes P (2009) Maintaining volunteer firefighter numbers: adding value to the retention coin. *Australian Journal of Emergency Management* 24, 40–47.
- McLennan B, Whittaker J, Handmer J (2016) The changing landscape of disaster volunteering: opportunities, responses and gaps in Australia. *Natural Hazards* 84, 2031–2048. doi:10.1007/s11069-016-2532-5
- Moran CC, Colless E (1995) Perceptions of work stress in Australian firefighters. *Work & Stress* 9, 405–415. doi:10.1080/02678379508256889
- Navarro K (2020) Working in smoke: wildfire impacts on the health of firefighters and outdoor workers and mitigation strategies. *Clinics in Chest Medicine* 41, 763–769. doi:10.1016/j.ccm.2020.08.017
- O'Halloran M, Davies A (2020) A shared risk: Volunteer shortages in Australia's rural bushfire brigades. *Australian Geographer* 51, 421–435. doi:10.1080/00049182.2020.1813949
- Perroni F, Cignitti L, Cortis C, Capranica L (2014) Physical fitness profile of professional Italian firefighters: differences among age groups. *Applied Ergonomics* 45, 456–461. doi:10.1016/j.apergo.2013.06.005
- Phillips M, Payne W, Lord C, Netto K, Nichols D, Aisbett B (2012) Identification of physically demanding tasks performed during bush-fire suppression by Australian rural firefighters. *Applied Ergonomics* 43, 435–441. doi:10.1016/j.apergo.2011.06.018
- Productivity Commission (2023) 9 Emergency services for fire and other events - Report on Government Services 2023. (Australian Government Productivity Commission) Available at <https://www.pc.gov.au/ongoing/report-on-government-services/2023/emergency-management/emergency-services>
- Queensland Government (2019) State Emergency Service Quarterly Figures. Available at <https://www.data.qld.gov.au/dataset/state-emergency-service-quarterly-figures>
- R Core Team (2022) 'R: A language and environment for statistical computing.' (R Foundation for Statistical Computing: Vienna, Austria) Available at <https://www.R-project.org/>
- Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP STROBE Initiative (2014) The Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *International Journal of Surgery* 12, 1495–1499. doi:10.1016/j.ijsu.2014.07.013
- Walker A, Driller M, Argus C, Cooke J, Rattray B (2014) The ageing Australian firefighter: an argument for age-based recruitment and fitness standards for urban fire services. *Ergonomics* 57, 612–621. doi:10.1080/00140139.2014.887790
- Walker A, Keene T, Argus C, Driller M, Guy JH, Rattray B (2015) Immune and inflammatory responses of Australian firefighters after repeated exposures to the heat. *Ergonomics* 58, 2032–2039. doi:10.1080/00140139.2015.1051596
- Westcott WL (2012) Resistance training is medicine: effects of strength training on health. *Current Sports Medicine Reports* 11, 209–216. doi:10.1249/JSR.0b013e31825dabb8
- Wolkow A, Netto K, Langridge P, Green J, Nichols D, Sergeant M, Aisbett B (2014) Coronary heart disease risk in volunteer firefighters in Victoria, Australia. *Archives of Environmental & Occupational Health* 69, 112–120. doi:10.1080/19338244.2012.750588

Data availability. The data and R code are available at <https://www.doi.org/10.5281/zenodo.8145705>.

Conflicts of interest. The authors have no conflicts of interest to declare.

Declaration of funding. No specific funding was awarded for this project.

Acknowledgements. The authors acknowledge the role of Queensland Fire and Emergency Services (QFES) in the review of the questionnaire's use of appropriate terminology and in its subsequent distribution to those listed on their volunteer fire service database. QFES had no role in the collection, analysis, or interpretation of the data, or in the writing of the final manuscript.

Author contributions. David N. Borg: methodology, formal analysis, data curation, writing – original draft, writing – review and editing, visualisation. Daniel Moore: conceptualisation, methodology, investigation, writing – original draft, writing – review and editing. Ian B. Stewart: conceptualisation, methodology, formal analysis, investigation, writing – review and editing, supervision.

Author affiliations

^ASchool of Exercise and Nutrition Sciences, Faculty of Health, Queensland University of Technology, Brisbane, Qld, Australia.

^BInstitute for Physical Activity and Nutrition (IPAN), School of Exercise and Nutrition Sciences, Deakin University, Geelong, Vic., Australia.