Characteristics of the Standard 12-lead Holter ECG in Professional Firefighters

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Abstract

Firefighters have twice as many cardiovascular deaths as police officers and yet there are no available high resolution continuous ECG recordings during firefighting activities. The purpose of this study was to characterize the 12-lead ECG in on-duty professional firefighters. In this prospective descriptive study, all firefighters underwent 24hr ambulatory Holter monitoring using a standard hires 12-lead ECG. Results: 112 firefighters (age 43.6 ± 8yrs, mostly white males) were enrolled over a one year period. During monitoring the average HR was 77 ± 10bpm, it range from an average minimum of 47 ± 7 to an average maximum of 143 ± 21 bpm. All were in normal sinus rhythm, however over half of the firefighters had elevated average heart rate and nearly 10% had a widened QRST angle. Conclusion: Among on-duty professional firefighters, high risk ECG markers are present including an elevated average HR and the presence of a widened QRST angle, a high risk marker for fatal cardiac events.

1. Introduction

In 2005, the National Fire Protection Association reported that 44% of on-duty firefighter fatalities were due to sudden cardiac death [1]. In a recent study, Kales and colleagues confirmed that 45% of on-duty firefighter deaths were cardiac related so that many are actually dying of cardiac disease rather than of fire-related injuries [2]. On-duty firefighters have twice as many cardiovascular deaths as police officers and four times as many as emergency medical responders. To date, despite the high cardiac risk for firefighters and its societal importance, there are no available field data recordings of the ECG during firefighting activities. Consequently, the aim of this study was to characterize the 12-lead ECG during ambulatory monitoring of on-duty professional firefighters.

2. Methods

2.1. Subject population

With Institutional Review Board approval, a convenience sample of professional firefighters was recruited from the Buffalo, New York (NY) Fire Department. To minimize sampling bias, every possible effort was made to approach all eligible firefighters until the full sample is obtained. Thus, among the 13 firehouses in the metro area the research team rotated among seven of the firehouses and recruited from all four platoons. Since professional firefighters have a physician clearance to be on-duty, no exclusion criteria applied. Of note, more than 75% of on-duty fatalities in the US were older than 45 years [3] and over 37% of Buffalo Fire firefighters and 83% of the Lieutenants are over 45 years old.

2.2. Holter acquisition

12-Lead ECGs were recorded using H12+ Holter recorders (V3.12; Mortara Instruments, Milwaukee, WI). To optimize signal quality, the firefighters' skin was shaved, rubbed with alcohol wipes until thoroughly clean, and briskly dried with gauze to stimulate capillary flow. Disposable electrodes were applied in the Mason-Likar lead configuration under the firefighters' uniformed t-shirts and the Holter secured to their uniformed belt. All leads were simultaneously acquired at a high resolution (1000 samples per second), resulting in high fidelity recordings with a frequency response of 0.05 to 60 Hz. Importantly, Holter recordings used to analyze high-frequency features like notching in the QRS complex, can be missed with the standard of 60 Hz, thus the first ECG of the monitoring period was selected to ensure a resting supine position; and with the ELI LINK program (Mortara Instruments), a single 12-lead ECG was exported into a portable document format with the standard filter setting at 0.05 to 150 Hz for subsequent analysis. Standard 12-lead ECGs were then analyzed by a reviewer blinded to all research data.

2.3. ECG variables

In addition to cardiac rhythm, 12 ECG variables were operationally defined and cut off points for cardiovascular risk identified (Table1).

3. Results

3.1. Sample characteristics

Consistent with the demographics of the Fire Department, the sample (n=112) was predominantly middle aged white males, 77% and 88%, respectively (Table 2). The firefighter's average body mass index was 29.5, the upper limit of overweight. In addition, 12% are active smokers, 4% report a history of sleep apnea and 15% had a cardiac history including a diagnosis of cardiovascular disease or an intervention.

Table 1. High Risk ECG Variables

Variable	Operational Definition	Cut off point
Heart Rate	Automated, average of all QRS complexes/ minute over 24hrs.	>75 bpm [4]
QRS duration	Automated, global (earliest onset to latest offset, all leads)	>120 ms[5]
QT interval	Automated, Bazett formula	>450ms men >470ms women [6]
LVH	Manual, sum of SV3 and RaVL, Cornell	>20 mm women, >23mm in men[7]
Left Bundle Branch Block	QRSd ≥120 ms plus broad notched R wave in I, aVL, V5-V6 and an RS in V5-V6.	Present [7]
fQRS	Any RSR notching in the nadir of the S or more than one R (R').	At least 2 leads in same region [8]
QRS-T angle	Automated, using QRS-T simple formula [9]	>135 degrees [10]
Q waves	Any Q wave that is 0.04 second wide and ¼ R wave deep	One Q wave in each region [11]
HRV	Automated	rmsSD <15 [12]
ST Event	Automated, significant J point deviation for at least 60 seconds in two leads of same region.	≥1mm ST deviation for 60 sec in 2 leads[13]
PVC	Manual, a premature QRS complex, ectopic shaped with QRSd>120ms	≥10 PVCs/hr [5]
NSVT	Manual, ≥3 consecutive PVCs	At least one NSVT / 24 hrs [5]

Abbreviations. LVH, left ventricular hypertrophy, fQRS, fragmented QRS complex, HRV, heart rate variability, PVC, premature ventricular contraction, NSVT, nonsustained ventricular tachycardia.

Table 2. Sample Characteristics (n=112)

Characteristic	Mean (±SD)
Age (years)	43.6 ±7.7
Years as a firefighter	15.5 ±7.0
Weight (lbs)	205.5 ±31.3
Systolic BP	129.3 ±14.9
Diastolic BP	81.8 ±10.6
BMI (kg/m2)	29.5 ±4.1

Abbreviations. BP, blood pressure, BMI, body mass index

3.2. ECG characteristics

Confirming our pilot study [14], the quality of the ECG data was ample for arrhythmia and myocardial ischemia interpretation. On-duty heart rates have ranged from 47±7 beats per minute (bmp) to 143 ±22bpm. Although no lethal arrhythmias occurred, nonsustained ventricular tachycardia (NSVT) did occur once.

All firefighters were in normal sinus rhythm and on-duty heart rates have ranged from minimum of 47 bpm to a maximum of 143bpm; it should be noted that in three firefighters, maximum predicted heart rate was exceeded while on-duty. Eight other ECG variables also exceeded the cut off point for cardiovascular risk (Table 3).

Table 3. Frequency of High Risk ECG Variables

	ECG Variable	Frequency (ave, SD/%)
1	*Average 24h HR (beat/min)	76.6 ±9.9
2	QRS duration (msec)	98.5 ±11.1
3	QTc interval (msec)	409.2 ±33
4	*LVH (count)	4 (3.6)
5	*Left bundle branch block (count)	1 (0.9)
6	*fQRS (count)	28 (25)
7	*Spatial QRS-T Angle (degrees)	78.1 ±37.3
8	*Q waves (count)	3 (2.7)
9	Heart Rate Variability (rmsSD)	63.9±44.3
10	*ST events (count)	14 (13.4)
11	*PVC (count)	5(4.5)
12	*NSVT (count)	1(0.9)

Abbreviations. LVH, left ventricular hypertrophy, fQRS, fragmented QRS, PVC, premature ventricular contraction, NSVT, nonsustained ventricular tachycardia. *exceeded cut off.

The spatial angle between the QRS and T axes is the angle between the directions of ventricular depolarization and repolarization. Although historically obtained from orthogonal leads, computer-derived measurements can be calculated from a standard 12-lead ECG [9]. An abnormal angle has a larger hazard ratio for fatal cardiac events than other established risk factors[10]. Nearly 10% of the firefighters had a widened QRST angle (Figure 2).
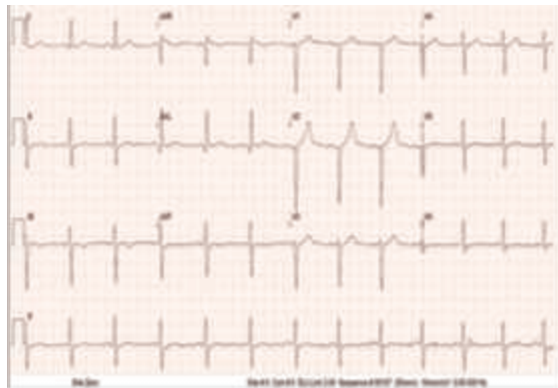
Figure 2. Resting ECG with a widened QRST angle (160°) Among the 12 high risk ECG markers analyzed in this study, NSVT occurred the least frequently while more than half of the firefighters had accelerate average heart rates over 24 hour monitoring period (Figure 3).
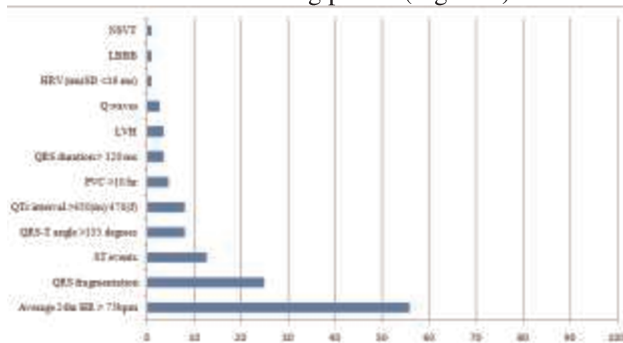

Figure 3. Prevalence of ECG markers among firefighters

4. Discussion

To our knowledge, this is the first study to record high resolution 12lead ECGs of professional firefighters. Among on-duty professional firefighters, high risk ECG markers are present including an elevated average HR in over 50% of the sample. The increased heart rate is consistent with firefighter's activities that are strenuous and often require fighters to work at their maximal heart rate for long periods or even beyond, as seen in this study. But maybe more ominous, is the presence of a widened QRST angle in nearly 10% of the sample, a high risk marker for fatal cardiac events.

This preliminary work may help develop a non-invasive risk stratification approach to better identify professional firefighters at risk for cardiovascular events. Over the longer horizon, algorithmic guidelines are needed to route at-risk firefighters for optimal and timely cardiac care.

Acknowledgements

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