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Malattie cardiovascolari tra i lavoratori dei servizi di emergenza: fattori di rischio personali e professionali, impatto e strategie preventive.

Presentata da: Dott. Andrea Farioli

Coordinatore Dottorato

Chiar.mo Prof. Nicola Rizzo

Relatore

Gent.mo Prof. Stefano Mattioli

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INDICE

PREMESSA

Nella presente tesi di dottorato sono descritti i risultati principali di sei studi pubblicati su riviste internazionali *peer-reviewed* nell'ambito di un filone di ricerca sviluppato sotto la tutela del Prof. Stefano Mattioli ed in collaborazione con il Prof. Stefanos N Kales della Harvard T.H. Chan School of Public Health (Boston, MA). Negli allegati (Appendice A-F), sono riportati gli articoli *in extenso* [Farioli et al, 2013; Farioli et al, 2014; Korre et al, 2014; Yang et al, 2013; Yang et al, 2014; Varvarigou et al, 2014]

Da oltre 20 anni il Prof. Kales conduce studi sullo stato di salute e la sicurezza dei lavoratori dei servizi di emergenza ed è oggi considerato uno dei massimi esperti di questa tematica. Nel corso dell'ultimo anno della scuola di specializzazione in Medicina del Lavoro (momento di inizio di questo dottorato di ricerca) e durante il periodo del dottorato ho avuto la possibilità di lavorare direttamente con il Prof. Kales in qualità di *visiting scientist* presso la Harvard T.H. Chan School of Public Health. Il filone di ricerca in cui si inserisce questa tesi ha la finalità di studiare le patologie cardiovascolari tra i lavoratori dei servizi di emergenza statunitensi (in particolare, vigili del fuoco ed agenti di polizia). Le ricerche condotte, e tuttora in corso, hanno lo scopo di caratterizzare l'incidenza di eventi cardiaci (in particolare, di morte cardiaca improvvisa), identificare i fattori di rischio professionali, valutare la diffusione dei comuni fattori di rischio cardiovascolare, descrivere il substrato fisiopatologico delle morti osservate ed identificare ed implementare strategie di prevenzione primaria e secondaria.

Oltre agli articoli oggetto di questa tesi, la collaborazione con il Prof. Kales ha generato altri quattro manoscritti:

1. Yang J, Farioli A, Korre M, Kales SN. Dietary preferences and nutritional Information needs among career firefighters in the United States. Glob Adv Health Med. 2015;4:16-23.
2. Korre M, Sampani K, Porto LG, Farioli A, Christiani DC, Lombardi AD, Smith D, Kales SN. Cardiac enlargement in US firefighters: prevalence estimates by

echocardiography, cardiac magnetic resonance and autopsies. [inviato a rivista *peer-reviewed* per la pubblicazione].

3. Porto LG, Nogueira R, Nogueira E, Molina G, Farioli A, Junqueira Jr LF, Kales SN. Agreement between BMI and body fat percentage definitions in a physically active population. [inviato a rivista *peer-reviewed* per la pubblicazione].
4. Shusko M, Benedetti L, Korre M, Boyd S, Farioli A, Christophi CA, Kales SN. Fitness as a predictor of police academy graduation among Massachusetts recruits. [inviato a rivista *peer-reviewed* per la pubblicazione].

Il primo articolo presenta i dati relativi ad un sondaggio sulle preferenze e conoscenze dietetiche tra i vigili del fuoco; le stime ottenute confermano la necessità di implementare interventi sul posto di lavoro atti a migliorare la condotta alimentare dei vigili del fuoco.

In Korre et al si valuta la prevalenza di cardiomegalia tra i vigili del fuoco. Lo studio compara i tassi di prevalenza dedotti usando metodiche diverse e valuta la sensibilità dello standard clinico, ecocardiografia, nel rilevare un aumento del peso cardiaco.

Il terzo studio, Porto LG et al, compara la definizione di obesità ottenuta attraverso la misura del indice di massa corporea con il dato diretto sulla percentuale di massa grassa. L'analisi, condotta tra 3,000 vigili del fuoco militari brasiliani sottolinea l'ampia prevalenza di soggetti *skinny fat*, ossia individui con basso indice di massa corporea ed alta percentuale di massa grassa. Tale dato suggerisce la necessità di misurare, durante le visite di idoneità, altri indicatori di obesità oltre al tradizionale indice di massa corporea.

In Shusko et al si descrive la condizione fisica dei cadetti di polizia del Massachussets e si valuta come i fattori antropometrici e la performance atletica influenzino le fasi inziali della carriera dei giovani poliziotti.

MORTE CARDIACA IMPROVVISA TRA I GIOVANI VIGILI DEL FUOCO STATUNITENSI: CARATTERISTICHE CLINICHE E FATTORI DI RISCHIO PERSONALI

Riferimento bilbiografico: Yang J, Teehan D, Farioli A, Baur DM, Smith D, Kalen SN. Sudden cardiac death among firefighetrs ≤ 45 years of age in the United States. Am J Cardiol. 2013;112:1962–1967. [Appendice A]

Titolo breve: MCI e fattori di rischio personali tra i giovani VdF

Introduzione

I decessi per cause cardiache rappresentano una delle principali cause di morte tra i vigili del fuoco (VdF) statunitensi [Soteriades et al, 2011; Fahy et al, 2011; Smith et al, 2013; Fahy et al, 2005]. La maggior parte di questi decessi avviene tra VDF di mezza età (≥45) e occorre in soggetti con malattia coronarica o cardiomegalia [Fahy et al, 2005; Holder et al, 2006; Kales et al, 2007; Geibe et al, 2008]. Al contrario, secondo le conoscenze attuali, le morti cardiache, in particolare le morti cardiache improvvise (MCI), tra giovani attivi sono solitamente imputabili ad alterazioni cardiache strutturali [Maron, 2003; Braunwald et al, 2001]. Tuttavia, poco è noto sui determinanti di MCI tra i giovani VdF.

Per questo motivo, abbiamo condotto uno studio caso-controllo sulla morte cardiaca improvvisa tra i giovani (≤45 anni) VdF. Scopo dello studio era studiare le cause sottostanti il decesso e valutare il ruolo dei comuni fattori di rischio cardiovascolare, quali fumo, obesità, ipertensione, obesità e dislipidemia.

Materiali e metodi

I metodi dettagliati dello studio sono presentati nell'appendice A. Abbiamo condotto uno studio caso-controllo basato sui record storici del National Istitute for Occupational Safety and Health (NIOSH). Il NIOSH conduce indipendentemente delle indagini dei decessi avvenuti tra i VdF [NIOSH, 2012]. Per individuare i casi di MCI, abbiamo rivisto tutti i record inerenti il periodo 1996–2012. I criteri usati per identificare i casi sono stati i seguenti:

1. decesso avvenuto tra il 1° gennaio 1996 ed il 31 dicembre 2012;
2. decesso avvenuto in servizio o entro 24 ore dall'ultimo turno;
3. causa del decesso MCI (causa cardiaca; sintomi non antecedenti un'ora rispetto alla perdita di coscienza; assenza di ripresa dello stato di conoscenza tra il collasso ed il decesso) [Myerburg e Castellanos, 2012];
4. età al decesso ≤45 anni;
5. disponibilità di un report autoptico o di dati clinici sufficiente a stabilire la causa della morte.

Due gruppi di controllo sono stati utilizzati per le analisi: a) decessi di VdF avvenuti per traumi esterni (periodo 2004–2010); b) dati della sorveglianza sanitaria di una coorte di VdF seguita tra il 2007 ed il 2009 [Baur et al, 2012]. I dati relativi ai decessi per trauma sono stati estratti da un database mantenuto dalla National Fallen Firefighters Foundation. Sono stati inclusi i dati relativi a soggetti di età ≤45 anni e deceduti per traumi da corpo contundente, ustioni o asfissia. Sono stati esclusi tutti i record che indicavano quale concausa un evento cardiaco. Le informazioni sul secondo gruppo di controllo (coorte in sorveglianza sanitari) sono state precedentemente pubblicate [Baur et al, 2012a; Baur et al, 2012b]. Per questo studio abbiamo selezionato soggetti di età inferiore a 45 anni e privi di limitazioni dell'idoneità alla mansione.

Due investigatori (JY e DT) hanno estratto indipendentemente le informazioni di interesse. Un terzo investigato (AF) ha svolto un controllo in cieco dei dati estratti. In caso di disaccordo, un quarto investigatore (SNK) ha preso la decisione finale sul dato da includere.

Per i casi ed i controlli campionati dalla coorte in sorveglianza sanitaria, abbiamo estratto le informazioni sul sesso, l'età, l'indice di massa corporea, il fumo di sigaretta, la presenza di

ipertensione arteriosa o dislipidemia. In aggiunta, utilizzando i dati anamnestici, abbiamo identificato i VdF con storia positiva di a) malattia coronarica o valvulopatia; b) anomalie del ritmo cardiaco; c) anomalie elettrocardiografiche o ecocardiografiche; d) dolore precordiale o dispnea ricorrente. Per quanto riguarda il gruppo di controllo costituito da morti violente, le uniche informazioni disponibili erano quelle direttamente e usualmente deducibili dal referto autoptico (età, indice di massa corporea, perso nel cuore).

Le seguenti definizioni operative sono state utilizzate nel nostro studio:

- fumo di sigaretta: consumo di una sigaretta die nell'anno precedente;
- diabete mellito: glicemia ≥ 150 mg/dl, pregressa diagnosi o in terapia ipoglicemizzante;
- ipertensione, definizione 1: pressione arteriosa sistolica ≥ 140 mmHg e/o diastolica ≥ 90 mmHg, pregressa diagnosi, o in terapia antiipertensiva;
- Ipertensione, definizione 2: come la definizione 1 o evidenza di ipertrofia ventricolare sinistra all'esame autoptico (solo deceduti);
- dislipidemia: colesterolo totale ≥ 200 mg/dl e/o colesterolo LDL ≥ 160 mg/dl, pregressa diagnosi o terapia anticolesterolemica;
- coronaropatia: pregresso infarto miocardico, angioplastica, posizionamento di stent, o diagnosi clinica basata su calcium score o test da sforzo;
- valvulopatia: pregressa diagnosi di patologie o anomalie valvolari cardiache o loro riscontro autoptico;
- dolore precordiale o dispnea persistente: storia di dolore o dispnea persistente in assenza di diagnosi di coronaropatia.

Le analisi statistiche sono state effettuare utilizzando SPSS 21.0 (IBM, Armonk, NY)e Stata 12.1 SE (Stata Corp, College Station, TX). L'associazione dei fattori di rischio di interesse con il rischio di MCI è stata studiata adattando modelli di regressione logistica. Le variabili da inserire nei modelli multivariati sono state selezionate *a priori*. La soglia di significatività statistica è stata definita con un p value a due code <0,05.

Risultati

I risultati dello studio sono riportati in esteso nell'Appendice A. Sono stati analizzati 87 decessi per MCI (casi), 915 VdF in sorveglianza sanitaria (gruppo di controllo I) e 56 VdF deceduti per traumi esterni (gruppo di controllo II).

Tabella 1 riporta il confronto tra i casi e i VdF in sorveglianza sanitaria. Dalle stime emerge che i fattori di rischio cardiovascolare tradizionali (fumo, obesità ed ipertensione) hanno svolto un ruolo determinante nel causare le MCI. L'anamnesi positiva per malattia coronarica si è mostrata fortemente associata al rischio di MCI (OR 6,89, IC95% 2,87–16,5).

In Tabella 2 è riportato il confronto tra i casi ed il gruppo di controllo rappresentato dalle morti per traumi esterni. I casi hanno mostrato una massa cardiaca nettamente aumentata rispetto ai controlli (differenza media 120g). In presenza di cardiomegalia (peso del cuore superiore a 450g), l'odds ratio di MCIè risultato essere 4.89 (IC95% 1,93–1,24). Come atteso, la maggior parte dei soggetti con cardiomegalia aveva un indice di massa corporea superiore a 30 kg/m^2 (74% tra i casi e 67% tra i controlli).

Tabella 1 Associazione tra fattori di rischio cardiovascolare e condizioni patologiche e rischio di morte cardiaca improvvisa.

	Casi NIOSH		Coorte di vigili del fuoco		Univariate analysis			Multivariate analysis					
								Model I[a]			Model II[b]		
Variabile	(n=87)		(n=919)		OR	IC95%	P	OR	IC95%	P	OR	IC95%	P
Fattori di rischio													
Età (anni), media (DS)	37,7	(6,6)	35,4	(6,1)	1,06	1,03–1,11	0,001	1,03	0,98–1,08	0,268	1,02	0,97–1,07	0,451
Sesso maschile, n (%)	85/87	(98)	886/915	(97)	0,72	0,17–3,06	0,655	/	/	/	/	/	/
IMC													
<30 kg/m^2, n (%)	25/68	(37)	582/908	(64)	1,00	Rif,		1,00	Rif,		1,00	Rif,	
≥30 kg/m^2, n (%)	43/68	(63)	326/908	(36)	3,07	1,84–5,12	<0,001	2,20	1,27–3,81	0,005	1,76	0,99–3,11	0,053
Fumo di sigaretta, n (%)	24/87	(28)	70/779	(9)	3,86	2,27–6,56	<0,001	3,53	1,87–6,65	<0,001	3,50	1,76–6,95	<0,001
Diabete mellito, n (%)	4/87	(28)	18/908	(2)	2,38	0,79–7,21	0,124	3,26	0,93–11,5	0,066	2,17	0,59–7,95	0,243
Ipertensione, definizione 1, n (%)	41/87	(5)	179/904	(20)	3,69	2,34–5,81	<0,001	3,43	2,01–5,87	<0,001	/	/	/
Ipertensione, definizione 2, n (%)	62/87	(48)	179/904	(20)	10,5	6,35–17,2	<0,001	/	/	/	11,8	6,23–22,3	<0,001
Dislipidemia, n (%)	46/87	(53)	366/908	(40)	1,66	1,07–2,58	0,024	1,47	0,86–2,51	0,157	1,53	0,88–2,68	0,134
Condizioni patologiche													
Coronaropatia o valvulopatia	18/87	(21)	29/786	(4)	6,81	3,60–12,9	<0,001	6,89	2,87–16,5	<0,001	5,72	2,40–13,6	<0,001
Ritmo irregolare	2/87	(2)	45/786	(6)	0,39	0,09–1,63	0,195	0,13	0,02–1,06	0,057	0,13	0,02–1,04	0,054
Anomalie ECG o ecocardiogramma	6/87	(7)	62/786	(8)	0,86	0,36–2,06	0,744	0,50	0,16–1,59	0,242	0,41	0,13–1,31	0,132
Dolore precordiale o dispnea	7/87	(8)	9/786	(1)	7,55	2,74–20,8	<0,001	1,92	0,46–8,01	0,372	2,15	0,50–9,29	0,307

Abbreviazioni: ECG, elettrocardiogramma; IC, intervallo di confidenza; IMC, indice di massa corporea; RIF, categoria di riferimento.

[a]Stime aggiustate per età, IMC, fumo, diabete, ipertensione (1) e dislipidemia; analisi ristretta a 68 casi e 765 controlli con informazioni complete

[b]Stime aggiustate per età, IMC, fumo, diabete, ipertensione (2) e dislipidemia; analisi ristretta a 68 casi e 765 controlli con informazioni complete

Tabella 2 Associazione tra fattori di rischio cardiovascolare e perso cardiaco e rischio di morte cardiaca improvvisa.

	Casi NIOSH di MCI		**Controlli (traumi)**		**Analisi univariata**			**Analisi multivariata**		
	(n = 87)		*(n = 56)*		*OR*	*IC95%*	*P*	*OR*	*IC95%*	*P*
Età (anni), media (DS)	37,7	(6,6)	31,2	(8,3)	1,12	1,07–1,17	<0,001	1,09[a]		<0,002
IMC										
<30 kg/m^2, n (%)	25/68	(37)	33/56	(59)	1,00	Rif,		1,00[a]	Rif,	
≥30 kg/m^2, n (%)	43/68	(63)	23/56	(41)	2,47	1,19–5,10	0,015	1,23[a]	0,50–3,07	0,650
Peso cardiaco (g), media (DS)	522	(102)	400	(91)	1,01	1,01–1,02	<0,001	1,01[c]	1,01–1,02	<0,001
Perso cardiaco										
≤450g, n (%)	22/65	(34)	42/54	(78)	1,00	Rif,		1,00[a]	Ref,	
>450g, n (%)	43/65	(66)	12/54	(22)	6,84	3,01–15,6	<0,001	4,89[a]	1,93–12,4	<0,001

Abbreviazioni: IC, intervallo di confidenza; IMC, indice di massa corporea; RIF, categoria di riferimento.

[a]Stime da modello di regressione logistica includente età, IMC e peso cardiaco dicotomizzato; analisi ristretta a 59 casi e 54 controlli.

[b]Stime da modello di regressione logistica includente età, IMC e peso cardiaco; analisi ristretta a 59 casi e 54 controlli.

Discussione

I risultati del nostro studio supportano l'ipotesi che le MCI osservate tra i giovani VdF siano principalmente imputabili a fattori di rischio modificabili. In particolare, l'epidemia di obesità (riscontrata anche nel 36% della coorte dei VdF in sorveglianza sanitaria) contribuisce in modo determinante al carico di decessi osservato.

Il data sul rischio di MCI tra i VdF obesi osservato nel nostro studio è in linea con le conoscenze generali [Tsismenakis et al, 2009; Vgontzas et al, 1994]. Inoltre, i nostri dati sono simili a quanto già riportato tra popolazioni di VdF più anziani [Geibe et al, 2008]. L'associazione tra cardiomegalia o ipertrofia ventricolare sinistra e rischio di MCI non è nuova tra i VdF o la popolazione generale [Smith et al, 2013; Levy et al, 1990; Kannel et al, 1969; Bluemke et al, 2008]. È notevole tuttavia che, anche un quinto dei deceduti per cause traumatiche presentasse un peso cardiaco superiore a 450g. Tale dato, se diagnosticato in vita, potrebbe permettere di escludere da mansioni ad alto rischio soggetti con alterazioni morfologiche notoriamente associate a MCI.

Il nostro studio presenta importanti limiti metodologici. In primo luogo, non è stato possibile ottenere dati autoptici da gruppi di deceduti per cause sicuramente non connesse a fattori di rischio cardiovascolari. Difatti, i VdF obesi potrebbero presentare un rischio maggiore non solo di morire per MCI, ma anche di andare in contro a traumi fatali [Proudfoot et al, 2006]. Se fosse così, le stime ottenute nella nostra analisi presenterebbero una distorsione verso l'ipotesi nulla, ossia avremmo osservato per i fattori di rischio cardiovascolare stime inferiori a quelli reali. Un secondo limite è legato all'assenza di procedure standardizzate obbligatori per l'esecuzione delle autopsie nei decessi occorsi tra i VdF. Di conseguenza, una misclassificazione non differenziale potrebbe affliggere le nostre stime. In aggiunta, alcuni dati (ad esempio l'altezza), erano frequentemente mancanti nei report studiati. In aggiunta, come prevedibile, non tutti i decessi per MCI tra i VdF vengono sottoposti all'esame autoptico; la popolazione studiata potrebbe essere non completamente rappresentativa del quadro generale.

In conclusione, i nostri dati sottolineano la necessità di intraprendere azioni di prevenzione primaria e secondaria per ridurre il carico di MCI tra i giovani VdF statunitensi.

MORTE CARDIACA IMPROVVISA DOVUTA ALL'ATTIVITÀ LAVORATIVA TRA I GIOVANI VIGILI DEL FUOCO STATUNITENSI

Riferimento bibliografico: Farioli A, Yang J, Teehan D, Baur DM, Smith DL, Kales SN. Duty-related risk of sudden cardiac death among young US firefighters. Occup Med (Lond). 2014;64:428–35. [Appendice B]

Titolo breve: Attività lavorativa e MCI in servizio tra i giovani VdF

Introduzione

La morte cardiaca improvvisa (MCI) è la prima causa di decesso in servizio tra i vigili del fuoco (VdF) statunitensi [Karter e Stein, 2013]. Precedenti studi hanno documentato un aumento del rischio di MCI tra i VdF durante lo svolgimento di attività emotivamente e fisicamente intense [Kales et al, 2003; Kales et al, 2007; Smith et al, 2013]. La maggior parte decessi documentati in queste ricerche aveva riguardato vigili del fuoco di mezza età e lo stressore esterno (attività lavorativa) aveva solitamente agito su di un cuore affetto da patologie croniche (principalmente malattia coronarica o ipertrofia ventricolare sinistra) [Smith et al, 2013]. Tra i giovani, la morte cardiaca improvvisa è solitamente associata ad anomalie cardiache strutturali, piuttosto che a malattia coronarica [Chandra, 2013]. Non è quindi noto se l'aumento di incidenza di MCI che colpisce i VdF durante lo svolgimento di attività a rischio riguardi anche i giovani. Per questo motivo, abbiamo condotto uno studio dei dati sulla mortalità in servizio per MCI dei giovani VdF (≤45 anni) utilizzando i dati di due registri federali gestiti dalla US Fire Administration (USFA) e dal National Institute for Occupational Safety and Health (NIOSH). Scopo dello studio era valutare l'associazione tra attività considerate a rischio e l'incidenza di MCI.

Materiali e metodi

I metodi dettagliati dello studio sono presentati nell'appendice B. Brevemente, abbiamo consultato i database USFA e NIOSH [USFA, 2013; NIOSH, 2012]. La USFA mantiene un database sistematico sui decessi in servizio tra i VdF avvenuti a partire dal 1981. Il NIOSH esegue, per finalità preventive, investigazioni mirate su un ristretto numero di eventi; il database NIOSH non comprende tutti gli eventi e non è concepito per essere rappresentativo (i decessi non sono investigati in modo casuale, ma selezionati secondo un algoritmo di priorità). I report NIOSH riportano approfondite informazioni sulle modalità dell'evento, la storia clinica della vittima ed i risultati dell'autopsia. Per questo studio abbiamo raccolto i dati di tutti i decessi accaduti tra il 1996 ed il 2012. Due medici hanno indipendentemente estratto i dati di rilievo da ogni record, classificando la causa del decesso (MCI o altro) e la mansione svolta al momento dell'evento.

Sono stati applicati i seguenti criteri di inclusione:

6. età al decesso ≤ 45 anni;
7. causa del decesso MCI;
8. a) MCI entro 24 ore dall'ultimo turno o b) arresto cardiaco improvviso entro le 24 ore dall'ultimo turno seguito da perdita di coscienza irreversibile fino al decesso;
9. decesso avvenuto tra il 1° gennaio 1996 ed il 31 dicembre 2012;
10. disponibilità di record clinici e/o autoptici (solo per il database NIOSH).

In base al compito svolto al momento dell'insorgenza dei sintomi, abbiamo raggruppato gli eventi in una delle seguenti sei categorie [Kales et al, 2003; Kales et al, 2007; Holder et al, 2006]:

1. routine e attività svolte in caserma (compiti amministrativi, attività di prevenzione, ispezione, manutenzione, meeting, seminari e corsi);
2. emergenze diverse dagli incendi (servizi medici di emergenza, salvataggi e altre operazioni di emergenza non connesse agli incendi);
3. allenamento fisico (test fisici, attività fisica, simulazioni di emergenze);
4. ritorno dalle emergenze (eventi occorsi durante il ritorno da un'emergenza)
5. risposta alle emergenze (eventi occorsi dall'allarme al momento del raggiungimento del luogo dell'emergenza);

6. soppressione di incendi (tutte le attività eseguite sul luogo dell'incendio).

Per i decessi documentati sia nel database USFA che in quello NIOSH, la classificazione della modalità del decesso e della mansione svolta si è basata sui dati forniti dagli ispettori NIOSH, ritenuti più accurati. Per i decessi indicizzati nel registro del NIOSH, è stata valutata la presenza di anamnestica delle seguenti patologie cardiache: malattia coronarica (storia clinica di infarto, angioplastica, posizionamento di stent, stress-test o calcium-score positivo); anomalie valvolari; storia autoriferita di dolore precordiale o documentate anomalie ECG. Sulla base di questa classificazione abbiamo quindi condotto un'analisi stratificata sulla presenza di precedenti cardiologici.

Per valutare la frequenza di MCI durante lo svolgimento di attività specifiche abbiamo calcolato il rischio relativo (RR) di morte utilizzando come riferimento la categoria "routine e attività svolte in caserma". I RR sono stati stimati rapportando il numero di eventi osservarti alla percentuale di tempo spesa dal vigile del fuoco medio nelle attività considerate (Tabella 1). Poiché sono note variazioni dei livelli di attività in base al tipo di distretto (municipale o metropolitano), sono state considerate tre diverse sorgenti di dati.

Tabella 1 Stime sul percentuale del turno spesa dal vigile del fuoco medio in attività specifiche. Dati da tre diverse fonti.

Attività	Dipartimento municipale, % del turno[a]	Dipartimento metropolitano, % del turno[b]	Sondaggio nazionale, % del turno[c]
Routine e attività svolte in caserma	51	29	65
Emergenze diverse dagli incendi	23	34	15
Allenamento fisico	8	8	8
Risposta alle emergenze	10	15	7
Ritorno dalle emergenze	6	9	4
Soppressione di incendi	2	5	1

[a]Stime relative al Cambridge Fire Department [Kales et al, 2007]

[b]Stime basate su un sondaggio condotto in 17 grandi dipartimenti metropolitani (L.Moore-Merrel, comunicazione personale) [Kales et al, 2007]

[c]Stime basate sul sondaggio annuale condotto dalla National Fire Protection Association [Fahy et al, 2012]

Le analisi statistiche sono state condotte con Stata 12.1 SE (Stata Corp, College Station, TX). Le distribuzione di variabili categoriche, presentate come numero e %, è stata confrontata attraverso il test del chi quadro di Pearson. L'accordo tra le informazioni riportate nei due database è stato valutato calcolando il kappa di Cohen. Per stimare i RR di MCI durante lo svolgimento di mansioni specifiche, abbiamo adattato modelli di Poisson che includevano il numero di eventi osservati quale variabile dipendente e la percentuale di tempo spesa in ogni mansione come offset. Il livello di significatività statistica è stato fissato a p value ≤ 0,05.

Risultati

I risultati dello studio sono presentati in esteso nell'appendice B. Nel periodo studiato, 206 vigili del fuoco di età ≤ 45 anni e rispettanti i criteri di inclusione del presente studio sono deceduti per MCI durante il servizio (si veda Figura 1 dell'Appendice B). Il 42% di questi decessi (n=86) sono stati investigati approfonditamente dagli ispettori NIOSH. La classificazione dell'attività svolta al momento del decesso basata sul database USFA o su quello NIOSH ha mostrato un ottimo livello di accordo (kappa di Cohen 0,90, IC95% 0,82–0,97).

Tabella 2 mostra i RR di MCI in base all'attività svolta al momento della comparsa dei sintomi. Il rischio più alto è osservabile per le attività di soppressione degli incendi, ma gli assunti utilizzati per la distribuzione dei tempi influenzano notevolmente la stima puntuale (RR variabile tra 5 e 56) I risultati mostrano anche una maggior incidenza di MCI durante l'esercizio fisico e la risposta agli allarmi. Limitata evidenza associa il ritorno dalle emergenze alla MCI, mentre lo svolgimento di attività legate alla gestione di emergenze diverse dagli incendi non sembra associabile ad un maggior numero di decessi.

Tabella 2 Rischi relativi di morte cardiaca improvvisa durante lo svolgimento di attività specifiche.

	MCI (n=206)		Stime basate sui dati municipali		Stime basate sui dati metropolitani		Stime basate sui dati nazionali	
Attività	n	(%)	RR	(IC95%)	RR	(IC95%)	RR	(IC95%)
Routine e attività svolte in caserma	52	(25)	1,0	(Rif,)	1,0	(Rif,)	1,0	(Rif,)
Emergenze diverse dagli incendi	12	(6)	0,5	(0,3–1,0)	0,2	(0,1–0,4)	1,0	(0,5–1,9)
Allenamento fisico	39	(19)	4,8	(3,2–7,2)	2,7	(1,8–4,1)	6,1	(4,0–9,2)
Risposta alle emergenze	42	(20)	4,1	(2,7–6,2)	1,6	(1,0–2,4)	7,5	(5,0–11)
Ritorno dalle emergenze	16	(8)	2,6	(1,5–4,6)	1,0	(0,6–1,7)	5,0	(2,9–8,8)
Soppressione di incendi	45	(22)	22	(15–33)	5,0	(3,4–7,5)	56	(38–84)

Abbreviazioni: IC, intervallo di confidenza; MCI, morte cardiaca improvvisa; Rif., categoria di riferimento; RR, rischio relativo.

Tabella 3 Rischi relativi di morte cardiaca improvvisa. Analisi stratificata per presenza di precedenti cardiologici e ristretta ai dati del National Institute for Occupational Safety and Health

	MCI in vigili del fuoco con precedenti cardiologici				MCI in vigili del fuoco senza precedenti cardiologici			
	MCI (n=33)		Stime basate sui dati municipali		MCI (n=54)		Stime basate sui dati municipali	
Attività	n	(%)	RR	(IC95%)	n	(%)	RR	(IC95%)
Routine e attività svolte in caserma	3	(9)	1,0	(Rif,)	13	(24)	1,0	(Rif,)
Emergenze diverse dagli incendi	1	(3)	0,7	(0,1–7,1)	4	(7)	0,7	(0,2–2,1)
Allenamento fisico	12	(36)	25	(7,2–90)	15	(28)	7,4	(3,5–15)
Risposta alle emergenze	5	(15)	8,5	(2,0–36)	4	(7)	1,6	(0,5–4,8)
Ritorno dalle emergenze	2	(6)	5,7	(1,0–34)	2	(4)	1,3	(0,3–5,8)
Soppressione di incendi	10	(30)	85	(23–308)	16	(30)	31	(15–65)

Abbreviazioni: IC, intervallo di confidenza; MCI, morte cardiaca improvvisa; Rif., categoria di riferimento; RR, rischio relativo.

Tabella 3 riporta le stime delle analisi stratificate sulla presenza di precedenti cardiologici. L'analisi include solo i decessi investigati dal NIOSH; i record USFA non recano sufficienti informazioni cliniche. L'analisi evidenzia rischi relativi maggiori per i VdF con precedenti cardiaci. Nonostante ciò, vi è un chiaro aumento dell'incidenza di MCI associata alla soppressione di incendi anche tra i giovani VdF con anamnesi cardiologica negativa (RR 31, IC95% 15–65). In entrambi i gruppi non si osserva alcun aumento del rischio di MCI durante la gestione delle emergenze diverse dagli incendi.

Discussione

Il nostro studio evidenzia un marcato aumento del rischio di MCI tra i giovani (≤45 anni) VdF durante lo svolgimento di attività fisicamente ed emotivamente intense. L'aumento, seppur di minor magnitudine, è ben osservabile anche nei soggetti con anamnesi cardiologica negativa. Lo svolgimento di attività connesse alle emergenze diverse dagli incendi non mostra associazione con il rischio di MCI.

I rischi relativi osservati nel presente studio sono minori rispetto a quelli riportati in precedenti studi condotti sull'intera popolazione dei VDF [Kales et al, 2003; Kales et al, 2007]. Questo risultato conferma l'ipotesi che l'età potrebbe modulare il rischio di MCI conferito da attività fisicamente ed emotivamente intese [Kales et al, 2007]. Sebbene le stime siano caratterizzate da alta variabilità campionaria, RR maggiori sono stati stimati per i giovani VdF con precedenti cardiovascolari. Questa osservazione conferma che limitazioni inerenti le attività più gravose dovrebbero essere prese in considerazione per i soggetti con anamnesi positiva per malattia coronarica e/o patologia strutturali cardiache [Yang et al, 2003; Soteriades et al, 2011].

La nostra analisi si basa una metodologia di confronto interno già utilizzata in precedenti ricerche [Kales et al, 2003; Kales et al, 2007]. Un vantaggio di questo metodo è l'assenza di confondimento legato alle caratteristiche personali; l'assenza di fattori di rischio cardiovascolari noti quali diabete, obesità, tabagismo ed ipertensione non dovrebbe determinare una distorsione delle stime di interesse (sebbene non si possa escludere la presenza di modificazione di effetto, non investigabile con i dati disponibili). Un particolare riflessione va fatta sul fumo di sigaretta quale trigger di eventi cardiovascolari. In questo caso, è possibile che l'assenza del dato sul consumo di sigarette immediatamente precedente l'evento di interesse abbia introdotto un *bias* verso l'ipotesi nulla (ossia abbia ridotto la magnitudine dei RR osservati). Infatti, è più verosimile che un VdF fumi durante attività di routine piuttosto che mentre conduce operazioni critiche o si allena. Una possibile sorgente di bias del presente è sono la misclassificazione non differenziale delle attività svolte al momento della comparsa dei sintomi di MCI; anche in questo caso è possibile una attenuazione delle stime di rischio. Al contrario, l'assegnazione ad attività di emergenza diverse dalla gestione degli incendi non è risultata associata ad un aumento del rischio di MCI.

Significativamente, tale dato si è confermato anche nell'analisi ristretta ai soggetti con precedenti cardiovascolari.

Diversi fattori potrebbero contribuire al rischio di MCI durante la gestione degli incendi. All'ovvio sforzo fisico, potrebbe aggiungersi il raggiungimento di temperature corporee superiori ai 38.5°C [von Klot et al,2008; Horn et al, 2014]. Questi fattori, sommati all'uso di indumenti protettivi non traspiranti e di considerevole peso (la dotazione standard tuta, autorespiratore e strumentazione ha un peso complessivo di circa 20kg) potrebbero determinare uno stato di disidratazione, determinando turbe elettrolitiche e della coagulazione [Smith et al, 2013; Smith et al, 2014]. A ciò, si aggiungerebbe l'esposizione a prodotti di combustione (in primo luogo di CO) e lo distress emotivo [Soteriades et al, 2011; Steptoe e Brydon, 2009].

In conclusione, il nostro studio conferma che le attività fisicamente ed emotivamente intense svolte dai VdF possono aumentare il rischio di MCI anche in soggetti giovani e privi di precedenti cardiologici. Tuttavia, la pregressa storia di coronaropatia o la presenza di anomalie strutturali compartono un ulteriore aumento del rischio. L'assegna ad attività di gestione delle emergenze diverse dagli incendi potrebbe rappresentare un'alternativa alla piena idoneità per i soggetti ad alto rischio.

INCIDENZA DI MORTE CARDIACA IMPROVVISA IN UNA GIOVANE POPOLAZIONE LAVORATIVA

Riferimento bibliografico: Farioli A, Christophi CA, Quarta CC, Kales SN. Incidence of sudden cardiac death in a young active population. J Am Heart Assoc. 2015;4:e001818. [Appendice C]

Titolo breve: Incidenza di MCI tra i VDF

Introduzione

La morte cardiaca improvvisa (MCI) è una morte naturale dovuta a cause cardiache [Myerburg e Castellanos, 2012]. Secondo la definizione operativa più frequentemente accettata, la MCI è anticipata da una repentina perdita di coscienza che segue di non più di un'ora i sintomi di esordio [Myerburg e Castellanos, 2012]. In assenza di testimoni, la definizione di MCI implica il riscontro di un decesso in un soggetto visto l'ultima volta nelle precedenti 24 ore in uno stato di apparente buona salute fisica.

L'eziologia della MCI è stata ampiamente studiata nella popolazione generale e tra gli atleti [Adebag et al, 2010a;Adebag et al, 2010b; Leikin et al, 2013; Pugh et al, 2012]. Nella popolazione generale la principale causa di SCD è la malattia coronarica (80% dei decessi), seguita dalle cardiomiopatie (10–15%) [Chugh et al, 2008]. Al contrario, tra gli atleti, la malattia coronarica determina solo una minima frazione delle morti (3%), mentre i principali determinanti sono la cardiopatia ipertrofica (10–51%), le miocarditi (5–22%), la displasia aritmogena del ventricolo destro (fino al 25%) e le alterazioni dei canali ionici (2–10%) [Pugh et al, 2012; Hill e Sheppard, 2010; Patel e Elliot, 2012; Schmied e Borjesson, 2014].

Purtroppo, esistono scarse conoscenze sull'incidenza di MCI improvvisa in popolazioni lavorative adulte. Gli studi sugli atleti non trovano applicabilità a causa della peculiare distribuzione dell'età anagrafica (si tratta solitamente di soggetti giovani) e del pattern caratteristico delle cause sottostanti la MCI. I tassi di incidenza calcolati per la popolazione generale sono invece probabilmente guidati da eventi occorsi in soggetti ad alto rischio (ad esempio, per la presenza di comorbidità) non facenti parte della forza lavoro.

Lo scopo del presente studio è valutare i tassi di incidenza di MCI tra i vigili del fuco (VdF) statunitensi. Per stimare il numero di eventi, sono stati consultati i database della US Fire Administration (USFA) e del National Institute for Occupational Safety and Health (NIOSH). I dati sulla popolazione a rischio (denominatori dei tassi) sono stati ottenuti consultando i dati nel Current Population Survey (CPS).

Materiali e metodi

Popolazione dello studio

Abbiamo studiato la coorte dinamica dei vigili del fuoco statunitensi in carriera e a tempo pieno (circa 300.000 unità) in servizio tra il 1° gennaio 1998 ed il 31 dicembre 2012. L'analisi è stata ristretta ai soggetti di età compresa tra i 18 ed i 64 anni.

Il CPS viene condotto mensilmente dal US Census Bureau e rappresenta la sorgente privilegiata di informazioni sulla forza lavoro negli Stati Uniti [Bureau of Labour Statistics, 2003; Bureau of Labour Statistics, 2013a]. I dettagli sulle modalità di campionamento e codifica delle informazioni sono riassunti nell'Appendice C. Per il presente studio abbiamo consultato tutti CPS condotti nel periodo 1998–2012. Sulla base dei dati disponibili, abbiamo enumerato il numero di VdF in carriera e a tempo pieno, classificandoli sulla base dell'età e del sesso (Tabella 1 dell'Appendice C).

Enumerazione dei casi

Abbiamo raccolto i dati sulle MCI occorse in servizio tra i VdF in carriera e a tempo pieno consultando i database USFA e NIOSH [NIOSH, 2012; USFA, 2013]. La USFA raccoglie attivamente tutti i dati sui decessi dei VdF in servizio, presentando informazioni su: i dati anagrafici, profilo contrattuale, data, luogo, modalità, causa e natura della morte, e un sommario narrativo delle circostanze del decesso [USFA, 2013]. Il NIOSH conduce un programma specifico per investigare a fini preventivi i decessi tra i VdF [NIOSH, 2012]. Il database NIOSH include solo parte dei decessi, peraltro non campionati al fine di essere rappresentativi sotto il profilo epidemiologico. Tuttavia, questi report presentano dettagliate informazioni sulle modalità dell'evento, sulla storia clinica e sull'esame post-mortem. Oltre due fonti principali di dati, USFA e NIOSH, sono stati consultati articoli di giornale e siti di categoria (ad esempio il *line-of-duty database* gestito dalla International Association of Firefighters) per integrare i dati mancanti di otto decessi.

Per identificare i casi di MCI abbiamo visionato tutti i record USFA etichettati come "morte cardiaca", "evento cerebrovascolare", "colpo di calore" o "altro". Abbiamo inoltre consultato tutti i rapporti sulle investigazioni di "morti dovute a cause mediche" effettuate dal NIOSH. Due medici hanno indipendentemente estratto le informazioni su: età, sesso, causa della morte (cardiaca o

altro), esordio dei sintomi (entro un'ora dal collasso), dinamica dell'evento (testimoniato direttamente o ritrovamento del corpo a 24 ore dall'ultimo contatto) e tipo di attività svolto al momento dell'evento. Solo per casi indagati dal NIOSH, abbiamo anche estratto il dato sulla presenza di un ritmo cardiovertibile al momento del collasso (identificato attraverso l'applicazione di un defribrillatore esterno automatico). Nel caso di informazioni contrastanti tra il database USFA e quello NIOSH, è stata data priorità a quest'ultimo, ritenuto maggiormente informativo.

Le MCI sono state identificate secondo la seguente definizione operativa:

1. morte per cause cardiache;
2. esordio dei sintomi entro l'ora precedente il collasso o soggetto visto l'ultima volta in apparenti buone condizioni fisiche nelle 24 ore precedenti il collasso;
3. perdita di coscienza irreversibile dopo il collasso.

Nelle analisi principali abbiamo escluso dal computo delle MCI i decessi attribuiti a patologie aortiche o a embolie polmonari. In aggiunta, sono stati esclusi i casi di annegamento, morte violenta, overdose o associati a importanti traumi esterni precedenti il collasso.

<u>Confronto con la popolazione generale e con il personale militare</u>

Abbiamo confrontato i tassi calcolati tra i VdF con quelli stimati per la popolazione generale degli Stati Uniti e per il personale militare statunitense [Eckart et al, 2011; Chugh et al, 2004].

Lo studio di Eckart e colleghi rappresenta di fatto l'unica valutazione dei tassi di incidenza di MCI in una grande popolazione lavorativa oggi disponibile. Gli autori hanno utilizzato i dati del Ministero della Difesa statunitense per monitorare il numero di eventi tra il personale in uniforme. Lo studio si basa su una solida identificazione dei casi (era spesso disponibile un referto autoptico) e la possibilità di enumerare appropriatamente la coorte (censita dal Ministero). Come nel nostro studio, Eckart e colleghi hanno escluso dal computo dei decessi le morti dovute ad embolia polmonare o dissezioni aortiche.

Lo studio Chugh e colleghi è attualmente considerato la miglior sorgente disponibile di informazioni sul tasso di MCI nella popolazione generale statunitense. Le stime, inerenti la contea di Multnomah, Oregon, si basano su di un doppio sistema di sorveglianza e supera i limiti degli studi basati sulle sole schede di morte [Chugh et al, 2004]. La definizione di caso utilizzata in

questo studio include anche gli eventi aortici; per questo motivo, per il confronto con i tassi della popolazione generale, abbiamo modificato la nostra definizione operativa di MCI, includendo anche le dissezioni aortiche.

Analisi statistica

Sulla base delle analisi preliminari, si è deciso di restringere lo studio ai soli VdF uomini; solo tre MCI sono occorse nel periodo considerato tra le VdF donne.

L'accordo tra il database NIOSH e quello USFA è stato valutato utilizzando il kappa di Cohen. Le variabili continue, presentate come mediana ed intervallo interquartile, sono state confrontate mediante il test U di Mann-Whitney; le variabili categoriche, descritte come numero e percentuale, sono state comparate mediante il test del chi quadro di Pearson.

I tassi di MCI improvvisa sono stati calcolati per classe di età (10 anni) e presentati come numero di eventi per 100,000 anni-persona a rischio. Gli intervalli di confidenza sono stati stimati con il metodo esatto di Fisher. I denominatori sono stati stimati a partire dai numeri del CPS utilizzando la seguente formula:

$$Anni - persona = \frac{2{,}080}{365{,}25 * 24} * \sum_{anno=1998}^{2012} \sum_{mese=gen}^{dic} \frac{N\ giorni\ del\ mese}{365.25} * N\ VdF$$

Nella formula, 2,080 rappresenta il numero di ore lavorate in media da un VdF in un anno [Bureau of Labour Statistics, 2013b].

Per il confronto esterno dei dati, abbiamo calcolato i rapporti standardizzati di mortalità (RSM). Sono inoltre stati calcolati i tassi standardizzati annuali di MCI (standardizzazione diretta con standard interno pari alla popolazione studiata) al fine di valutare il trend storico degli eventi. L'analisi del trend è stata condotta adattando modelli joinpoint su scala logaritmica e trattando l'eteroschedasticità attraverso la generazione di stime pesate sugli errori standard. In aggiunta, nei modelli è stata considerata la presenza di autocorrelazione. Sono stati valutati fino a due punti di flesso (*joinpoints*), testati attraverso un test delle permutazioni basato sul metodo di Monte Carlo (10000 ripetizioni).

Le analisi statistiche sono state effettuate con Stata 12.1 SE (Stata Corp, College Station, TX) e Joinpoint Regression Program 4.1 (Statistical Research and Applications Branch, National Cancer Institute). È stato definito statisticamente significativo un p value a due code < 0,05.

Risultati

Dopo l'esclusione dei decessi tra VdF volontari o part-time (n=542), delle morti per cause non cardiovascolari (n=38), degli eventi occorsi al di fuori del turno di lavoro (n=54), delle morti avvenute in età superiori ai 64 anni (n=3), dei casi registrati tra le donne (n=2), e dei decessi che non soddisfacevano la nostra definizione operativa di MCI (morti non cardiache, n=31; morti non improvvise, n=20), sono state identificate 182 MCI avvenute tra i VdF in carriera ed a tempo pieno di età compresa tra i 18 e i 64 anni, in servizio tra il 1998 ed il 2012.

I risultati dello studio sono riportati integralmente nell'Appendice C. Figura 1 presenta i tassi di incidenza di MCI specifici per età stimati per la nostra popolazione ed il confronto con i dati relativi al personale militare ed alla popolazione generale. Il tasso di incidenza complessivo di MCI nella coorte è stato pari a 18,1 per 100,000 anni-persona (IC95% 15,7–21,0). Come previsto, il tasso di incidenza più alto è stato osservato per la classe di età 55–64 anni (45,2 per 100,000 anni-persona, IC95% 31,2–65,5). Tuttavia, sia il confronto con il personale militare, sia quello con la popolazione generale evidenzia come l'aumento del tasso di MCI associato all'età sia, nella coorte dei VdF, inferiore all'atteso. Nel complesso, i VdF mostrano una mortalità ridotta rispetto al personale militare (RSM 0,60, IC95% 0,52–0,69) ed alla popolazione generale (RSM 0,62, IC95% 0,53–0,72).

Figura 2 presenta l'andamento storico (1998–2012) dei tassi standardizzati di MCI tra i VdF. In linea con le conoscenze generali, il tasso è decresciuto costantemente su scala logaritmica (-3,9% per anno, IC95% da -5,8% a -2,0%). Una sotto-analisi (Tabella 5 dell'Appendice C) ha evidenziato come questa variazione sia principalmente imputabile ad una ridotta mortalità tra i soggetti di età superiore ai 54 anni.

Tabella 1 presenta i dati sulla causa sottostante il decesso per i soggetti con referto autoptico disponibile (n=99). La malattia coronarica è stata la più frequente causa di SCD (n=77, 78%); in 57 di questi 77 casi, la coronaropatia coesisteva a cardiomegalia. Un'ipertrofia ventricolare sinistra accoppiata a cardiopatia ipertensiva è stata riscontrata in 7 autopsie (7%). 4 casi di MCI sono stati attribuiti dall'anatomopatologo a vizi valvolari. I due decessi tra i soggetti più giovani (<25 anni di età) sono stati valutati quali eventi aritmici in cuori privi di disordini strutturali.

Tabella 1 Cause di morte riportate nei referti autoptici. Analisi ristretta ai 99 casi di MCI con informazioni disponibili.

	Classe di età (anni)																	
	Tutte			18–24			25–34			35–44			45–54			55–64		
Causa di morte	n	%	IC95%	n	%	IC95%	n	%	IC95%	n	%	IC95%	n	%	IC95%	n	%	IC95%
Aritmia[a]	3	3	1–9	2	100	16–100	1	14	0–58	0	0	0–12	0	0	0–7	0	0	0–25
Sarcoidosi cardiaca	2	2	0–7	0	0	0–84	0	0	0–41	2	7	1–24	0	0	0–7	0	0	0–25
Coronaropatia	20	20	13–29	0	0	0–84	0	0	0–41	5	18	6–37	10	20	10–34	5	38	14–68
Coronaropatia e cardiomegalia	57	58	47–67	0	0	0–84	3	43	10–82	14	50	31–69	34	69	55–82	6	46	19–75
Cardiomiopatia dilatativa	1	1	0–5	0	0	0–84	1	14	0–58	0	0	0–12	0	0	0–7	0	0	0–25
Cardiopatia ipertrofica	4	4	1–10	0	0	0–84	1	14	0–58	2	7	1–24	1	2	0–11	0	0	0–25
Ipertrofia ventricolare sinistra	7	7	3–14	0	0	0–84	0	0	0–41	3	11	2–28	3[b]	6	1–17	1	8	0–36
Miocardite	1	1	0–5	0	0	0–84	0	0	0–41	1	4	0–18	0	0	0–7	0	0	0–25
Valvulopatia	4	4	1–10	0	0	0–84	1	14	0–58	1	4	0–18	1	2	0–11	1	8	0–36
Tutte	99			2			7			28			49			13		

Abbreviazione: IC, intervallo di confidenza.

[a]Decessi imputati ad eventi aritmici in assenza di alterazioni strutturali documentabili

[b]Uno dei casi presentava tossicologico positivo per intossicazione acuta da etanolo.

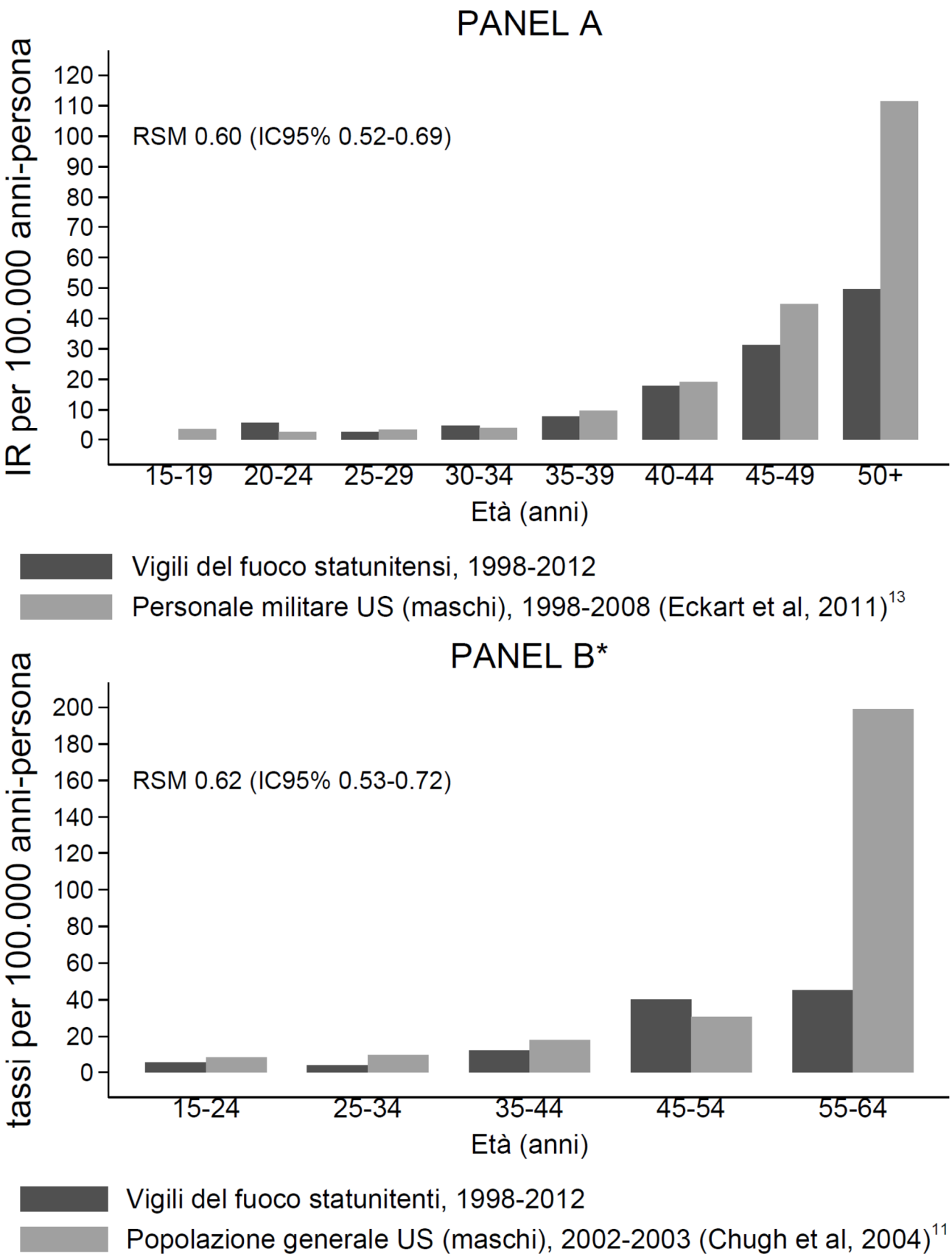

Figura 1 Incidenza di morte cardiaca nella coorte dei vigili del fuoco e confronto con popolazione generale e personale militare.

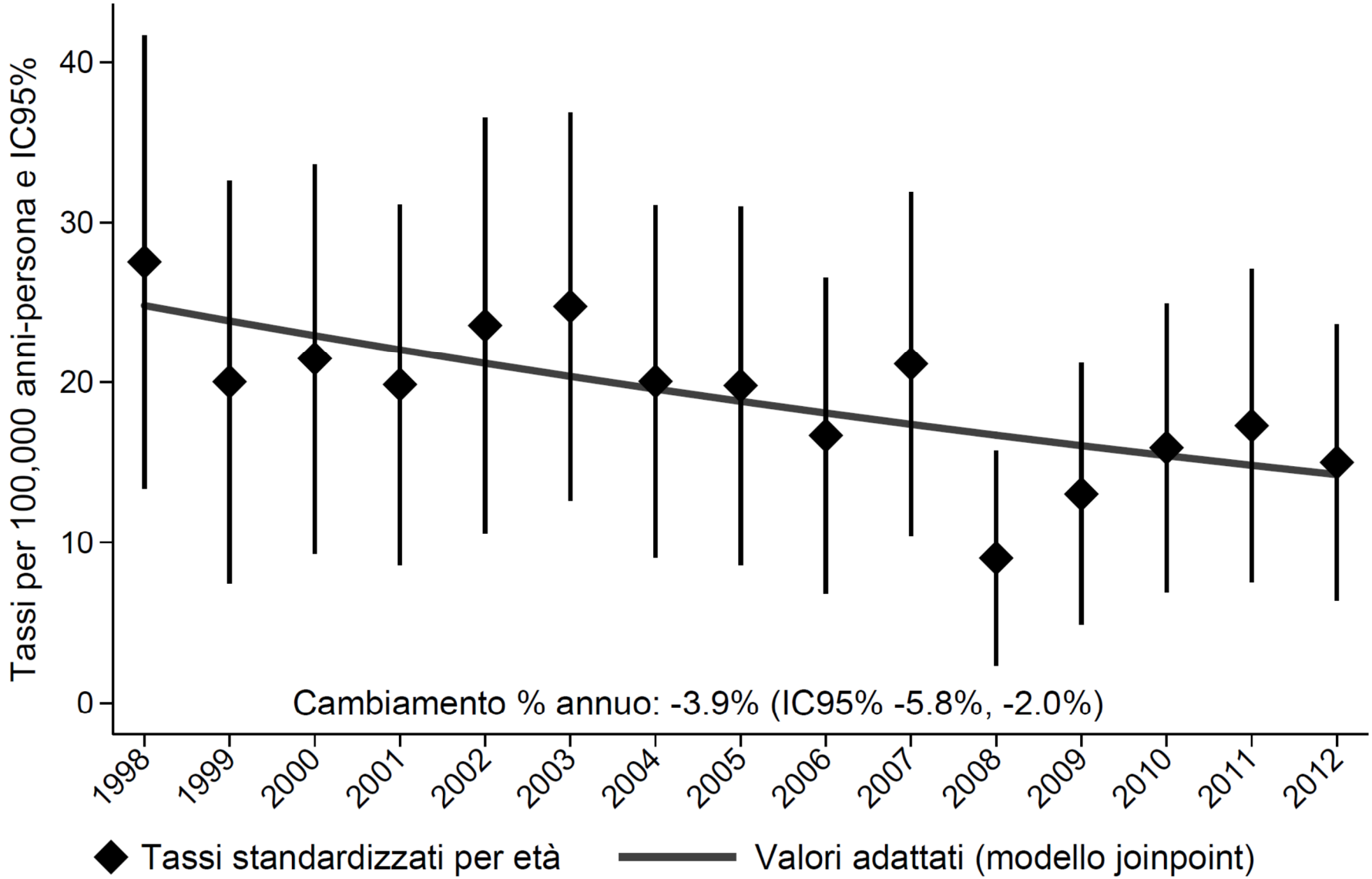

Figura 2 Trend temporale dei tassi di morte cardiaca improvvisa nella coorte dei VdF.

Discussione

In una coorte dinamica di circa 300,000 VdF statunitensi seguiti per 15 anni, abbiamo osservato un tasso di incidenza di MCI pari a 18.1 per 100,000 anni-persona. Detto tasso appare inferiore a quello della popolazione generale e quello osservato tra il personale militare statunitense. Nel periodo di osservazione il tasso si è ridotto costantemente; questo declino è principalmente imputabile ad un calo degli eventi tra i soggetti al di sopra dei 54 anni di età. La coronaropatia è risultata essere la prima causa di MCI, incidendo in modo importante anche tra soggetti di età compresa tra i 35 ed i 44 anni.

I VdF sono usualmente considerati una popolazione di lavoratori sani [Rosenstock e Olsen, 2007]. Considerati i requisiti fisici della professione e l'alto livello di attività fisica svolta, è lecito attendersi tra i VdF un'incidenza di patologie croniche inferiori alla popolazione generale (effetto lavoratore sano, in inglese *healthy worker effect*) [Rosenstock e Olsen, 2007]. Non sorprende quindi il dato osservato nel nostro studio, che ha evidenziato una ridotta mortalità (-40%) della nostra popolazione rispetto a quella generale. È però interessante notare che questa differenza nasce principalmente da una ridotta mortalità tra i VdF più anziani (>54 anni). Al contrario, i VdF di età compresa tra i 35 ed i 54 anni presentano tassi di MCI in linea con la popolazione generale; tale dato suggerisce la necessità di aumentare le attività di prevenzione primaria tra i VdF in questa fascia di età. Il confronto con il personale militare genere stime di rischio relativo probabilmente inferiori all'atteso. Le due popolazione potrebbero sembrare, a prima vista, simili per requisiti fisici e processi di selezione. Al contrario, i VdF presentano tassi di incidenza di MCI nettamente inferiori, in particolare tra i soggetti ultracinquantenni. Per interpretare correttamente tale dato occorre tenere in considerazione che molti stati americani offrono forti incentivi al pensionamento ed indennizzi per i VdF affetti da cardiopatie [Soteriades et al, 2011]. Pertanto, il dato osservato potrebbe essere frutto di una selezione spontanea.

La coronaropatia è risultata essere la prima di causa di MCI tra i VdF. Questo dato è in linea con le conoscenze disponibili per la popolazione generale e per il personale militare [Adebag et al, 2010; Eckart et al, 2011]. In aggiunta, avevamo già osservato un alta di frequenza di

coronaropatia tra in uno studio caso-controllo sui fattori di rischio cardiaci tra i giovani vigili del fuoco [Yang et al, 2013]. Le evidenze disponibili suggeriscono che l'obesità giochi un ruolo importante nel generare il carico di mortalità cardiaca oggi osservabile tra i VdF [Yang et al, 2013]. Per questo motivo, è necessario incrementare la prevenzione primaria, ad esempio implementando sul luogo di lavoro programmi finalizzati a modificare lo stile di vita.

Il declino dei tassi di MCI nel tempo osservato in questo studio è in linea con le conoscenze disponibili [Adebag et al, 2010]. Purtroppo, ad oggi sono disponibili per i VDF solo dati sui decessi per MCI e non informazioni sul numero di arresti cardiaci improvvisi. Non ci è pertanto possibile stabilire se la diminuzione della mortalità per MCI si imputabile ad una riduzione degli arresti cardiaci o ad una maggiore probabilità di sopravvivere all'evento.

Limiti e punti di forza dello studio

Lo nostro studio presenta alcuni limiti. I dati USFA presentano limitati dati medici. Tuttavia, la misura dell'accordo dei dati estratti dal database USFA e quello NIOSH, ricco di dati clinici/anatomopatologico, ha mostrato ottimi risultati (si veda l'appendice C). A causa del basso numero di decessi osservati tra i VdF donna, il nostro studio non può fornire informazioni su questa popolazione. Un altro limite dello studio è che i referti autoptici sono disponibili soltanto per i decessi indagati dal NIOSH. Nel complesso, tuttavia, la proporzione di decessi corredata di esame autoptico è risultata alta (99/182). Il nostro studio è scarsamente informativo per le fasce di età più giovani a causa del ridotto numero di eventi e, di conseguenza, dell'ampia variabilità delle stime.

Il punto di forza principale del nostro studio è la disponibilità di database affidabili per l'enumerazione dei casi. Allo stesso modo, i dati del CPS forniscono stime attendibili sul numero di soggetti a rischio. Altra forza dello studio è la buona disponibilità di dati autoptici e l'uso di più sorgenti di dati per validare la definizione di caso. In passato, gli studi basati sui soli dati di registro hanno mostrato una sostanziale tendenza a sovrastimare i tassi di MCI [Chugh et al, 2004].

Conclusioni

Il nostro studio colma un vuoto di conoscenza sui tassi di MCI improvvisa tra i VdF. In questa popolazione, il numero di decessi è inferiore a quello nella popolazione generale,

probabilmente a causa di una selezione negativa spontanea nel corso della sesta decade di vita.

Attività preventive primarie sono necessarie per ridurre il carico di coronaropatia.

DIETA MEDITERRANEA MODIFICATA E RISCHIO CARDIOVASCOLARE TRA I VIGILI DEL FUOCO STATUNITENSI

Riferimento bibliografico: Yang J, Farioli A, Korre M, Kales SN. Modified Mediterranean diet score and cardiovascular risk in a North American working population. PLoS One. 2014;9:e87539. [Appendice D]

Titolo breve: Dieta mediterranea e rischio cardiovascolare tra i VdF

Introduzione

Lo stile di vita è stato correlato ad un'importante riduzione del rischio cardiovascolare [Mozaffarian, 2011]. In particolare, la dieta mediterranea è stata più volte associata ad un minore rischio di morte per tutte le cause [Mitrou et al, 2007; Leighton, 2009; Trichopoulou 1995; Trichopoulou 2005; Trichopoulou 2009; Knoops, 2004]. In particolare, la dieta mediterranea determinerebbe una ridotta incidenza di patologie associate ad un aumento del rischio cardiovascolare quali obesità, diabete, ipertensione e sindrome metabolica [Leighton et al, 2007; Babio et al, 2009; Vincent-Baudry et al, 2005; Panagiotakos et al, 2003].

La dieta mediterranea rappresenta un pattern alimentare caratterizzato da: 1) utilizzo dell'olio d'oliva quale grasso principale in cucina; 2) alto consumo di frutta, vegetali e amidi non raffinati (provenienti da cereali); 3) moderato consumo di pesce; 4) basso consumo di latticini, carni rosse e derivati delle carni; 5) moderato consumo di vino ai pasti [Trichopoulou et al, 2005; Sofi et al, 2010].

Sebbene molti articoli siano stati pubblicati sul legame tra rischio cardiovascolare e dieta mediterranea, limitata evidenza esiste sull'efficacia di questa dieta in popolazioni giovani, attive e non mediterranee. Difatti, la maggior parte degli studi disponibili riguarda soggetti anziani, con patologie cardiovascolari o provenienti da aeree mediterranee.

Per questo motivo abbiamo condotto uno studio trasversale tra i vigili del fuoco (VdF) americani per valutare l'associazione tra l'aderenza ad una dieta simile a quella mediterranea e la presenza di fattori di rischio cardiovascolari.

Materiali e metodi

Abbiamo condotto un'analisi trasversale (*cross sectional*) usando i dati di una coorte di VdF in carriera. I partecipanti provenivano da 11 dipartimenti degli stati del Midwest. Il profilo dietetico è stato valutato attraverso un questionario. Sono stati applicati in seguenti criteri di inclusione: 1) partecipazione ad almeno una visita di sorveglianza sanitaria completa; 2) completamento del questionario; 3) assenza di limitazioni alla mansione specifica; 4) genere maschile (<97% popolazione in sorveglianza sanitaria); 5) rilascio di consenso informato.

I dati clinici ed anamnestici sono stati raccolti durante le visite di sorveglianza sanitaria. I metodi dello studio sono riportati dettagliatamente nell'Appendice D.

Valutazione del regime dietetico

Uno score delle dieta mediterranea modificato (SDMm) è stato creato sulla base delle indicazioni di letteratura e delle informazioni disponibili nel questionario (disegnato per finalità diverse dallo studio qui riportato). Per creare lo score, abbiamo identificato 15 domande inerenti la dieta ed inerenti i seguenti domini:

- numero di pasti consumati in fast-food;
- consumo di frutta e verdura;
- consumo di dolci;
- grasso primario utilizzato per cucinare a casa;
- grasso secondario utilizzato per cucinare a casa;
- grasso primario utilizzato per cucinare in caserma;
- grasso secondario utilizzato per cucinare in caserma;
- consumo di cibi fritti;
- fonte primaria di amidi nei pasti a casa;
- fonte primaria di amidi nei pasti in caserma;
- consumo pesce;
- bevande consumate durante i pasti a casa;
- bevande consumate durante i pasti in caserma;

- consumo di alcolici;
- consumo di vino.

Ogni dominio è stato associato ad un punteggio variabile da 0 a 4, con l'eccezione del consumo di frutta e verdura (0–8) e del vino (0–2). Per i domini raccolti con riferimento sia ai pasti a casa, sia a quelli in caserma, è stata generata una media pesata dei due domini sulla base della proporzione di pasti consumati in ciascun luogo.

Lo score finale è stato calcolato sommando tutti i domini. Valori alti di SDMm (valore massimo 42) rappresentano una buona aderenza a questo tipo di dieta; un SDMm di 0 simboleggia una dieta totalmente disallineata alla dieta mediterranea.

Valutazione dei fattori di rischio cardiovascolare e covariate

Abbiamo collezionato dai record clinici informazioni su età, indice di massa corporea (IMC), la percentuale di massa grassa, i valori di pressione arteriosa, la glicemia, la colesterolemia, la capacità aerobica misurata in METS (stimata con test da sforzo massimale), il numero di minuti dedicati ogni settimana all'esercizio fisico, la variazione autoriferita del peso corporeo negli cinque anni precedenti la compilazione del questionario. Utilizzando le informazioni disponibili è stato creato uno score per il rischio metabolico secondo i criteri proposti nel Join Scientific Statement [Alberti et al, 2009; Baur et al, 2012].

Analisi statistica

L'analisi statistica è stata effettuata utilizzando il software Stata 12.1 SE (Stata Corp, College Station, TX). Il trend attraverso gruppi ordinati è stato studiato mediante il test non parametrico di Cuzick. Differenze nella distribuzione media di variabili che soddisfacevano l'approssimazione alla distribuzione normale sono state valutate attraverso l'analisi della varianza. Sono stati adatti modelli di regressione logistica ordinale per studiare l'effetto della dieta mediterranea sullo score della sindrome metabolica ed il cambiamento di peso. L'assunto di proporzionalità degli odds è stato valutato applicando il test di Brant.

La soglia della significatività statistica è stata definita quale un p value a due code inferiore a 0,05.

Risultati

780 VDF in carriera maschi (pari al 97% della popolazione in sorveglianza sanitaria) hanno partecipato ad almeno una visita di sorveglianza sanitaria e compilato il questionario. Tuttavia, 26 soggetti sono stati esclusi a causa dell'alto numero di informazioni mancanti.

In tabella 1 presentiamo le informazioni descrittive sulla popolazione studiata stratificate per IMC. La media dello SDMm nella popolazione è risultata pari a 21,3 (DS 5,6); detto score è risultato più basso nei soggetti obesi (obesità di classe II/III, score medio=19,8) che nei soggetti con peso normale (score medio 21,7). Tra i singoli domini, solo le bevande consumate dei pasti hanno mostrato una differenza statisticamente significativa attraverso le classi di IMC.

La stratificazione dei valori medi dei fattori di rischio cardiovascolari attraverso i quartili di SDMm è presentata in Tabella 2. All'analisi aggiustata per età, IMC ed attività fisica, la percentuale di massa grassa, il valore di colesterolo HDL ed il rapporto colesterolo totale/HDL si sono mostrati associati allo SDMm, con i VDF più aderenti alla dieta mediterranea che mostravano un miglior profilo di rischio.

Tabella 3 mostra i dati sull'associazione tra SDMm e score della sindrome metabolica. Nell'analisi aggiustata per età ed attività fisica, si evidenzia un trend in diminuzione dello score metabolico all'aumentare dell'aderenza alla dieta mediterranea (misurata attraverso i quartili di SDMm). Un trend simile si osserva per il cambiamento del peso corporeo (stime aggiustate per età, IMC e attività fisica). In questo caso, la probabilità di aver perso peso negli ultimi cinque (o non averne acquisito) è risultata essere più alta per i soggetti con alto SDMm.

Tabella 1 Tabella descrittiva; analisi stratificata per indice di massa corporea

	Peso normale		Sovrappeso		Obesità classe I		Obesità classe II/III		
	18,5≤IMC<25		25≤IMC<30		30≤IMC<35		IMC≥35		
Caratteristica	n=108		n=401		n=203		n=85		P trend
Età (anni), media (DS)	35,6	10,0	37,2	8,4	38,9	8,0	38,6	8,1	<0,001
Percentuale di massa grassa, media (DS)[a]	16,5	7,0	21,2	4,2	27,5	3,0	32,1	3,9	<0,001
METS durante test da sforzo, media (DS)	13,7	1,6	13,1	1,5	12,2	1,8	10,9	2,0	<0,001
% massima FC in test da sforzo, media (DS)	99,0	5,2	98,8	6,2	97,5	5,7	96,5	7,1	0,001
Min esercizio aerobico/set., mediana (IIQ)	86	26-131	79	56-131	79	56-131	56	11-124	0,003
Fumatore corrente, n (%)	19	17,6	80	20,0	39	19,2	19	22,1	0,563
N pasti in caserma, mediana (IIQ)	6	3-6	6	3-6	6	3-6	6	4,5-7,5	0,018
Domini dello SDMm									
-Pasti in fast-food, media (DS)	2,8	1,2	2,7	1,1	2,6	1,1	2,3	1,2	<0,001
-Consumo frutta e verdura[b], media (DS)	2,2	1,8	2,3	1,9	2,1	1,7	2,0	1,7	0,109
-Consumo dolci, media (DS)	2,6	1,2	2,7	1,2	2,8	1,1	2,8	1,2	0,389
-Grasso primario a casa, media (DS)	2,2	1,6	2,6	1,5	2,4	1,5	2,6	1,6	0,391
-Grasso secondario casa, media (DS)	1,8	1,6	1,8	1,5	1,9	1,5	1,9	1,5	0,239
-Grasso primario in caserma, media (DS)	1,9	1,4	2,0	1,3	2,1	1,4	2,2	1,3	0,088
-Grasso secondario in caserma, media (DS)	1,7	1,7	1,7	1,6	1,8	1,5	1,7	1,6	0,952
-Consumo cibi fritti, media (DS)	2,2	0,9	2,2	0,9	2,2	0,9	2,0	1,0	0,146
-Amidi a casa, media (DS)	2,6	1,9	2,6	1,9	2,6	1,8	2,3	1,9	0,647
-Amidi in caserma, media (DS)	1,7	1,7	1,5	1,7	1,8	1,8	1,8	1,8	0,358
-Consumo pesce, media (DS)	1,6	0,9	1,5	0,7	1,5	0,8	1,5	0,7	0,829
-Bevande pasti a casa, media (DS)	2,9	1,6	2,6	1,7	2,3	1,7	2,1	1,7	<0,001
-Bevande pasti in caserma, media (DS)	2,7	1,7	2,6	1,7	2,5	1,6	1,9	1,8	0,002
-Consumo alcolici, media (DS)	2,1	1,6	2,1	1,5	2,0	1,5	1,8	1,6	0,093
-Consumo di vino, media (DS)	0,1	0,4	0,1	0,5	0,2	0,5	0,1	0,5	0,667
SDMm totale, media (DS)	21,7	5,5	21,6	5,4	21,0	5,7	19,8	5,6	0,008

Abbreviazioni: FC, frequenza cardiaca; IIQ, intervallo interquartile; IMC, indice di massa corporea; min, munuti; SDMm, score dieta mediterranea modificato; sett, settimana

[a]Dato disponibile per 244 soggetti.

[b]Punteggio raddoppiato poiché frutto della combinazione di due domini.

Tabella 2 Associazione tra variabili antropometriche e metaboliche e score dieta mediterranea modificato. Analisi di 780 maschi.

		Score dieta mediterranea modificato											
		I quartile		II quartile		III quartile		IV quartile					
		≤17,5		17,6–21,4		21,5–25,0		>25,0					
		(N=194)		(N=195)		(N=190)		(N=201)		P value (analisi della varianza)			
Caratteristica	N	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Model 1[c]	Model 2[d]	Model 3[e]	Model 4[f]
Età (anni)[a]	780	38,2	(8,6)	37,0	(9,2)	37,9	(9,2)	37,1	(8,4)	0,4195		0,5448	0,5877
IMC (kg/m^2)[a]	780	29,9	(4,7)	29,4	(4,2)	29,2	(4,2)	28,7	(4,2)	0,0756	0,0950		0,6369
% massa grassa[a]	233	25,2	(6,8)	24,4	(5,7)	22,7	(5,7)	22,2	(6,3)	0,0327	0,0372	0,0179	0,0281
PSA a riposo (mmHg)[a]	780	122,4	(12,6)	121,8	(11,8)	122,7	(11,8)	122,8	(13,3)	0,8546	0,8606	0,6013	0,9156
PDA a riposo (mmHg)[a]	780	80,4	(8,5)	79,7	(7,8)	79,2	(7,8)	79,9	(8,2)	0,5749	0,5812	0,6125	0,6219
FC a riposo (bpm)[a]	780	71,5	(11,6)	68,9	(11,3)	69,5	(11,3)	68,2	(11,5)	0,0220	0,0316	0,6887	0,4126
% massima FC in test da sforzo[a]	765	98,0	(6,5)	98,4	(6,3)	98,5	(6,3)	98,1	(5,3)	0,7963	0,7920	0,7771	0,7796
METS[b]	766	12,3	(1,2)	12,7	(1,1)	12,7	(1,1)	13,0	(1,1)	0,0002	0,0003	0,0047	0,3784
Trigliceridi (mg/dl)[b]	780	140,4	(1,8)	125,8	(1,7)	122,8	(1,7)	115,8	(1,8)	0,0065	0,0093	0,0463	0,4604
Colesterolo totale (mg/dl)[b]	780	196,5	(1,3)	191,0	(1,2)	191,4	(1,2)	186,3	(1,2)	0,0567	0,0926	0,1348	0,3275
Colesterolo LDL (mg/dl)[b]	759	120,3	(1,3)	117,0	(1,4)	115,0	(1,4)	110,2	(1,3)	0,0328	0,0427	0,0599	0,0982
Colesterolo HDL (mg/dl)[b]	780	41,7	(1,3)	43,9	(1,3)	44,2	(1,3)	46,6	(1,3)	0,0001	0,0001	0,0009	0,0258
Colesterolo totale/HDL[b]	780	4,7	(1,4)	4,4	(1,4)	4,3	(1,4)	4,0	(1,3)	<0,0001	<0,001	<0,0001	0,0035
Glicemia (mg/dl)[b]	780	93,2	(1,2)	92,6	(1,2)	92,9	(1,2)	91,1	(1,2)	0,6896	0,6896	0,8387	0,9289

Abbreviazioni: bpm, battiti per minuto; FC, frequenza cardiaca; HDL, high-density lipoprotein; IMC, indice di massa corporea; LDL, low-density lipoprotein; METS, metabolic equivalents; PDA, pressione diastolica arteriosa; PSA, pressione sistolica arteriosa.

[a]Media aritmetica e deviazione standard; [b]Media geometrica e deviazione standard

[c]valore crudo; [d]valore aggiustato per età; [e]valore aggiustato per IMC; [f]valore aggiustato per età, IMC e attività fisica

Tabella 3 Associazione tra score della sindrome metabolica e cambiamento di peso negli ultimi cinque anni e score dieta mediterranea modificata. Stime da modelli di regressione logistica ordinale.

	Score sindrome metabolica[a]											
	0	1	2	3	4	5	Stime crude			Stime aggiustate per età e attività fisica		
Quartile	N	N	N	N	N	N						
SDMm	%	%	%	%	%	%	OR	IC95%	P	OR	IC95%	P
I	26	54	49	33	22	10	1,00	Rif,		1,00	Rif,	
	13,4	27,8	25,3	17,0	11,3	5,2						
II	46	52	41	35	19	2	0,67	0,47–0,94	0,023	0,75	0,53–1,07	0.108
	23,6	26,7	21,0	18,0	9,7	1,0						
III	44	50	41	32	15	8	0,70	0,49–0,99	0,044	0,80	0,56–1,15	0.238
	23,2	26,3	21,6	16,8	7,9	4,2						
IV	59	59	32	35	10	6	0,50	0,35–0,71	<0,001	0,65	0,44–0,94	0.021
	29,4	29,4	15,9	17,4	5,0	3,0						
P trend									<0,001			0.039

	Cambiamento riferito di peso negli ultimi cinque anni (in libbre)											
	<-10	-10, -5	-5, +5	+5, +10	>+10	Stime crude			Stime aggiustate per età e attività fisica		
Quartile	N	N	N	N	N						
SDMm	%	%	%	%	%	OR	IC95%	P	OR	IC95%	P
I	9	19	59	61	42	1,00	Rif,		1,00	Rif,	
	4,7	10,0	31,1	32,1	22,1						
II	15	16	66	68	24	0,73	0,51–1,05	0,036	0,78	0,54–1,13	0,194
	7,9	8,5	34,9	36,0	12,7						
III	12	31	53	65	28	0,70	0,48–1,01	0,039	0,83	0,57–1,21	0,338
	6,4	16,4	28,0	34,4	14,8						
IV	31	20	78	54	17	0,43	0,30–0,62	<0,001	0,57	0,39–0,84	0,005
	15,5	10,0	39,0	27,0	8,5						
P trend								<0,001			0,010

Abbreviazioni: IC, intervallo di confidenza; OR, odds ratio; SDMm, score dieta mediterranea modificato.

[a]calcolato sommando un punto per ognuna delle seguenti voci: obesità (IMC≥30 kg/m^2); colesterolo HDL ridotto (<40mg/dl); ipertrigliceridemia (≥150 mg/dl); pressione arteriosa non ottimale (sistolica≥130 mmHg e/o diastolica≥85 mmHg) o terapia antipertensiva in corso; iperglicemia (glicemia≥100 mg/dl).

Discussione

Il nostro studio conferma che l'aderenza ad una dieta di tipo mediterraneo si associa ad un profilo di rischio cardiovascolare migliore rispetto alla norma anche in una popolazione nordamericana giovane e attiva.

Le nostre stime sono in linea con quanto riportato in studi precedenti [Ronksley et al, 2011; Di Daniele et al, 2013]. Al crescere dello SDMm abbiamo osservato un aumento dei valori colesterolo HDL ed una diminuzione del grasso corporeo e del rapporto colesterolo totale/HDL. Anche altri parametri studiati (indice di massa corporea, capacità aerobica, colesterolo totale, colesterolo LDL, trigliceridi e glicemia) hanno mostrato andamenti consensuali con quanto presente in letteratura, sebbene non sia stata raggiunta la soglia della significatività statistica. Allo stesso modo, lo score per la sindrome metabolica si è rivelato minore nei soggetti con SDMm alto [Wannamethee et al, 2005]. In aggiunta, i VdF con SDMm più alti hanno mostrato una maggior possibilità di non veder aumentare il loro peso nel corso dei cinque anni precedenti; anche questo dato rispecchia le evidenze disponibili [Shai et al, 2008].

Precedenti studi hanno mostrato un'influenza importante dei fattori di rischio cardiovascolari tradizionali nell'aumentare l'incidenza di morte cardiaca improvvisa tra i VdF [Smith et al, 2013]. Uno dei dati che emerge dalla nostra analisi è un'aderenza nel complesso bassa alla dieta mediterranea. Interventi condotti sul posto di lavoro e atti a migliore la dieta dei VdF potrebbero impattare positivamente lo stato di salute di questa popolazione.

Il nostro studio presenta alcuni limiti metodologici. In primo luogo, il questionario è stato disegnato per finalità diverse rispetto a quelle illustrate nel presente studio. Per questo motivo, la scelta dei domini da utilizzarsi per quantificare l'aderenza ad una dieta mediterranea è stata effettuata *ex post* ed alcuni domini potenzialmente rilevanti (come il consumo di frutta secca) non erano disponibili. Il nostro score potrebbe quindi non catturare a pieno l'essenza della dieta mediterranea; se fosse così, saremmo in presenza di una misclassificazione non differenziale e le nostre stime potrebbero sottovalutare il reale effetto di questa dieta nel modulare il profilo di rischio cardiovascolare. Un altro limite è rappresentato dalla relativa ridotta variabilità del pattern dietetico

nella nostra popolazione. Ad esempio, pochissimi soggetti hanno riferito di consumare abitualmente pesce o bere regolarmente vino. Quest'assenza di variabilità campionaria ha influenzato negativamente la potenza statistica dello studio e non permette di fare inferenza su soggetti che presentano altissima aderenza alla dieta mediterranea. I soggetti arruolati per l'analisi non erano a conoscenza delle finalità dello studio; tuttavia non possiamo escludere che i VdF intervistati non abbiano riportato abitudini di vita tendenzialmente migliori rispetto alla realtà.

In conclusione, il nostro mostra dei potenziali effetti benefici di una dieta mediterranea tra i VdF. In linea con questo dato, interventi per mutare le abitudini alimentari dei VdF potrebbero essere utili per ridurre il rischio di malattie cardiovascolari.

SONDAGGIO DEI LIVELLI DI STRESS E DELLE ATTIVITÀ SVOLTE TRA LE FORZE DI POLIZIA

Riferimento bibliografico: Korre M, Farioli A, Varvarigou V, Sato S, Kales S. A survey of stress levels and time spent across law enforcement duties: police chief and officer agreement. Policing. 2014;8:109–122. [Appendice E]

Titolo breve: Livelli di stress tra le forze di polizia

Introduzione

Le mansioni svolte dai membri dei corpi di polizia sono classificabili come gravose fisicamente, connotate da rischi specifici e caratterizzate da alti livelli di stress psicologico [Cooper et al, 1982; Anshel et al, 2000; Gershon et al, 2002; Deschamps et al, 2003; Reichard e Jackson, 2010; Yoo e Franke, 2011]. Gli stressori ai quali possono essere esposti i tutori dell'ordine includono fattori comuni ad altre professioni, come il lavoro a turni, gli straordinari eccessivi, l'alto carico di lavoro, un ritmo di lavoro variabile ed imprevedibile e la frequente interazioni con il pubblico [Violanti a Aron, 1994; Anderson et al, 2002]. Altri stressori sono invece pressoché caratteristici di questo lavoro: l'inseguimento di sospetti, le colluttazioni fisiche e la frequente esposizione diretta ad eventi traumatici (Violanti and Aron, 1994; Anderson et al, 2002; Gershon et al, 2002). Di conseguenza, l'attività di tutela dell'ordine è tra le tre professioni più frequentemente segnalata da medici del lavoro e psichiatri al Occupational Disease Intellingence Network system for Suiveillance of Occupational Stress and Mental Illness [Cherry et al, 2000; Collins ad Gibbs, 2003].

Sfortunatamente, allo stato attuale esistono solo conoscenze parziali sui livelli di stress legati allo svolgimento di specifiche attività di polizia [Anderson et al, 2002]. In aggiunta, non esistono stime affidabili sulla distribuzione media del tempo per attività tra gli agenti di polizia [gli studi disponibili descrivono realtà lavorative altamente specifiche [es, Parks et al, 1999].

Scopo del presente studio è valutare i livelli di stress percepiti dagli agenti di polizia durante lo svolgimento di attività specifiche e quantificare la percentuale media annuale spesa dal un agente tipo in queste attività ad alto stress.

Materiali e metodi

Abbiamo condotto un sondaggio tra gli agenti operativi di polizia ed i comandanti di polizia al fine di valutare i livelli di stress ed il tempo speso in specifiche attività. I metodi dello studio sono riportati dettagliatamente nell'appendice E.

Il sondaggio è stato effettuato somministrando un questionario standardizzato attraverso una piattaforma Internet (SurveyMonkey®) o invio per posta di cartaceo. Il questionario comprendeva una serie di scale di Likert (graduate da 0 a 10) con le quali l'intervistato potete identificare i livelli di stress associati all'attività in oggetto. In aggiunte, è stato chiesto al soggetto di quantificare la frequenza con cui le attività censite vengono svolte (quotidiana, settimanale, mensile, annuale) ed il numero di ore spese. Le attività da inserire nel questionario sono state selezionate a seguito di una ricerca condotta nella letteratura tecnica al fine di individuare i compiti più gravosi o fisicamente/emotivamente gravosi. È stata quindi creato un questionario preliminare che è stato testato da 17 comandanti di polizia del Massachusetts. In base ai commenti ottenuti in questa fase pilota, è stato creato il questionario finale (Supplementary Appendix 1 di Korre et al, 2014).

Il sondaggio tra gli agenti operativi è stato condotto grazie alla collaborazione dell'International Union of Police Associations e il Fraternal Order of Police. Entrambe le associazioni hanno inviato ai propri membri il link al questionario e le istruzioni per la compilazione. Ad ogni agente è stato esplicitamente richiesto di compilare il questionario secondo la propria esperienza personale. Il sondaggio tra gli agenti di polizia è iniziato il 22 Agosto 2012 e si è concluso il 2 Dicembre 2012.

Il sondaggio dei comandanti di polizia è stato condotto in prima istanza attraverso l'invio di questionario cartaceo. Una copia del questionario è stata inviata a tutti i dipartimenti di polizia nei quali era stata registrata una morte cardiaca improvvisa (dati forniti dal National Law Enforcement Officers Memorial Found) tra il personale nel periodo 1984–2010 (n=340). Una mail di sollecito è stata inviata in caso di mancata risposta. Ai comandanti di polizia è stato richiesto di compilare il

questionario facendo riferimento al turno di lavoro tipico di una agente in servizio presso il loro dipartimento.

Le analisi statistiche sono state effettuate utilizzando il software Stata 12.1 SE (Stata Corp, College Station, TX). Per il calcolo dei tempi medi per turno, si è deciso di escludere un ristretto numero di outliers (definiti secondo il metodo di Tukey), ritenuti agenti assegnati a mansioni specifiche non comuni. I livelli di stress e la percentuale di tempo spesa in ogni mansione specifica sono stati presentati come media e deviazione standard. La correlazione tra le risposte date dai comandanti e dagli agenti operativi è stata studiata stimando il coefficiente rho di Spearman. Un P value a due code minore di 0,05 è stato utilizzato quale soglia della significativa statistica.

Risultati

Hanno partecipato al sondaggio 93 comandanti e 951 agenti di polizia operativi. In media, i comandanti provenivano da distretti più piccoli rispetto agli agenti operativi (Tabella 1 dell'Appendice F). Confrontanti ai dati Federali, i distretti di provenienza dei comandanti sono risultati essere in linea con la media nazione per quanto riguarda il numero di agenti in servizio e la dimensione della popolazione servita (Appendice E). Al contrario, gli agenti operativi che hanno partecipato al sondaggio provenivano generalmente da distretti più grandi della media nazionale.

Tabella 1 presenta i livelli medi percepiti durante specifiche attività. Ad accezione di alcuni compiti routinari (ad esempio, la partecipazione a meeting), i comandanti di polizia hanno generalmente indicato livelli medi di stress superiori rispetto agli agenti operativi. Tuttavia, i ranghi delle attività quando ordinate in base al livello medio di stress erano pressoché identici tra comandanti e agenti operativi (rho di Spearman = 0,95).

Tabella 2 riporta la percentuale media del tempo lavorativo totale spesa nelle attività considerate. Anche in questo caso abbiamo osservato un'ottima correlazione tra il giudizio espresso dagli agenti operativi e quello dei comandanti (rho di Spearman = 0,91). Come atteso, entrambe le fonti hanno riportato che oltre il 70% del turno di lavoro viene speso in attività di routine. Tuttavia, percentuali di tempo non trascurabili (>1%) vengono spese anche in attività potenzialmente ad alto impatto fisico e psicologico (es. colluttazioni).

Analisi stratifica per tipologia di dipartimento (rurale/urbano/metropolitano), numero di agenti in servizio e dimensione della popolazione servita non hanno mostrato variazioni particolari dei livelli di stress percepiti o della percentuale di tempo spesa in specifiche attività (Appendice E).

Tabella 1 Confronto dei livelli percepiti dagli agenti operativi e quelli riferiti dai comandanti di polizia.

	Livelli di stress percepiti dagli agenti (N=951)		**Livelli di stress percepiti dai comandanti (N=93)**		
Compito	*Mean*	*SD*	*Mean*	*SD*	*P value*
Adunata	1,2	1,7	1,5	1,2	0,115
Servizi di scorta	2,2	2,3	2,2	1,7	<0,999
Attività in aula	2,5	2,0	2,3	1,4	0,366
Meeting	2,6	2,2	2,5	1,4	0,679
Emissione ticket sosta	2,7	2,4	3,6	1,9	<0,001
Pattuglia a piedi	2,9	2,5	3,5	1,8	0,038
Allenamento fisico	3,0	2,5	3,7	2,2	0,016
Poligono di tiro	3,3	2,4	3,4	1,7	0,710
Pattuglia in auto	3,3	2,2	3,4	1,5	0,683
Lavoro d'ufficio	3,4	2,3	3,0	1,4	0,113
Trasporto detenuti	3,9	2,4	4,8	2,0	0,002
Investigazioni	4,1	2,2	4,3	1,7	0,414
Operazioni di soccorso	4,2	3,2	6,1	2,5	<0,001
Chiamate per disturbo della quiete	4,9	2,4	5,6	1,8	0,009
Emergenze mediche	4,9	2,5	5,5	1,8	0,030
Testimoniare in tribunale	5,0	2,4	5,8	1,7	0,003
Intervenire in liti domestiche	5,7	2,4	6,6	1,8	<0,001
Eseguire mandati	6,0	2,7	6,4	1,7	0,178
Colluttazioni	7,1	2,5	8,2	1,7	<0,001
Eventi traumatici	7,5	2,6	8,6	1,6	<0,001
Inseguimenti in macchina	7,7	2,7	8,8	1,6	<0,001
Inseguimenti a piedi	7,7	2,8	8,8	1,6	<0,001
Rho di Spearman	0,95 (intervallo di confidenza 95% 0,82–0,99, p <0,001)				

Tabella 2 Percentuale del turno di lavoro spesa svolgendo compiti specifici. Confronto tra i dati riportati dagli agenti e quelli riportati dai comandati. Analisi eseguita escludendo gli outlier statistici (definiti con il metodo di Tukey).

Compito	**Dati riferiti dagli agenti**		**Dati riferiti dai comandanti**	
	% di tempo per turno	*(IC95%)*	*% di tempo per turno*	*(IC95%)*
Meeting	2.6	(2.4–2.8)	2.1	(1.3–2.5)
Attività in aula	2.7	(2.0–3.0)	1.7	(1.4–2.1)
Lavoro d'ufficio	18.5	(17.4–20.1)	12.4	(11.0–14.5)
Servizi di scorta	0.3	(0.2–0.5)	1.1	(0.6–1.9)
Poligono di tiro	1.0	(0.7–1.1)	0.7	(0.3–0.9)
Investigazioni	10.7	(9.3–11.5)	8.7	(7.2–10.6)
Emissione ticket sosta	5.4	(4.3–6.9)	5.2	(3.3–6.2)
Pattuglia a piedi	30.3	(28.8–31.7)	35.4	(31.3–37.9)
Pattuglia in auto	2.4	(1.7–2.7)	2.5	(1.9–4.1)
Adunata	3.5	(3.3–3.7)	3.0	(2.0–3.4)
Subtotale routine	77.4	(75.8–78.7)	72.8	(66.9–75.2)
Intervenire in liti domestiche	5.6	(5.2–6.1)	5.2	(3.8–6.4)
Chiamate per disturbo della quiete	4.0	(2.8–6.0)	3.6	(3.1–5.3)
Subtotale interventi	9.6	(0.1–0.2)	8.8	(7.4–11.1)
Emergenze mediche	2.8	(2.5–3.0)	2.9	(2.4–3.4)
Operazioni di soccorso	0.1	(0.1–0.2)	1.0	(0.4–1.7)
Subtotale soccorso	2.9	(2.6–3.1)	3.9	(2.9–4.8)
Inseguimenti in macchina	0.3	(0.2–0.5)	0.6	(0.3–0.9)
Inseguimenti a piedi	0.5	(0.4–0.6)	0.6	(0.5–1.0)
Subtotale inseguimenti	0.8	(0.7–1.0)	1.2	(0.9–1.8)
Allenamento fisico	2.9	(2.5–3.3)	3.1	(2.2—4.1)
Colluttazioni	1.2	(1.1–1.3)	2.3	(1.1–2.8)
Eseguire mandati	1.6	(1.2–2.1)	2.4	(1.3–2.9)
Trasporto detenuti	2.2	(2.0–2.4)	4.1	(3.1–11.9)
Testimoniare in tribunale	1.4	(1.3–1.7)	1.3	(0.8–1.6)
Rho di Spearman	0.91 (intervallo di confidenza al 95% 0.74–0.98, p <0.001)			

Discussione

Il nostro studio colma un vuoto di conoscenza sulla distribuzione delle attività svolte dall'agente di polizia medio e i livelli di stress percepito ad esse associate.

I dati ottenuti da due sondaggi indipendenti di popolazioni distinte (comandanti ed agenti di polizia) non hanno mostrato differenze sostanziali. In aggiunta, le stime ottenute da analisi stratificate per caratteristiche del dipartimento non hanno mostrato sostanziale variabilità.

I nostri dati sono compatibili con le limitate conoscenze disponibili. Secondo Anderson et al (2002), le colluttazioni, gli inseguimenti e la gestione di incidenti critici sono associati ad un importante aumento della frequenza cardiaca. In aggiunta, una precedente analisi a mostrato che, al termine di un inseguimento di auto, un agente di polizia può raggiungere frequenza cardiache superiori a 160 battiti per minuto che persistono anche durante l'arresto del sospetto (collaborativo).

Il nostro studio presenta ovvie limitazioni. In primo luogo, non è stata possibile stabilire un tasso di rispondenza per gli agenti di polizia, poiché gli indirizzari utilizzati per l'invio dei questionari non rappresenta una fonte certa di dati (includono personale non più attivo, indirizzi errati, indirizzi di portatori di interesse non operanti in polizia). In aggiunta, per gli stessi motivi, non è stato possibile studiare le caratteristiche dei non rispondenti e valutarne la loro comparabilità con i rispondenti. Tuttavia, abbiamo potuto intervistare due popolazioni indipendenti e comparare le caratteristiche dei rispondenti ai dati disponibili sulle forze di polizia operanti negli Stati Uniti. In aggiunta, le stime si sono mostrate stabili anche nelle analisi stratificate per le caratteristiche del distretto.

Riteniamo quindi che i presenti dati possano costituire una risorsa per futuri studi sullo stato di salute degli agenti di polizia.

ATTIVITÀ DI TUTELA DELL'ORDINE PUBBLICO E RISCHIO DI MORTE CARDIACA IMPROVVISA TRA LE FORZE DI POLIZIA STATUNITENSI

Riferimento bibliografico: Varvarigou V, Farioli A, Korre M, Sato S, Dahabreh IJ, Kales SN. Law enforcement duties and sudden cardiac death among police officers in United States: case distribution study. BMJ. 2014;349:g6534. [Appendice F]

Titolo breve: MCI e mansioni svolte tra le forze di polizia

Introduzione

La tutela dell'ordine è un occupazione pericolosa. Nel 2011–2012, il tasso di mortalità tra gli agenti di polizia in servizio negli USA è stato di 15–16 decessi per 100,000 lavoratori a tempo pieno, più di tre volte superiore a quello registrato tra i dipendenti del settore primato [US Department of Labour, 2012; Tiesman et al, 2013]. È stato stimato che circa il 7% dei decessi potrebbe essere imputato a cause cardiache [Zimmerman, 2012]. Sebbene lo studio delle patologie cardiovascolari sia stato inserito tra le priorità della National Occupational Research Agenda del National Institute for Occupational Health and Safety, i determinanti di morte cardiaca improvvisa tra le forze di polizia non sono stati adeguatamente studiati [NIOSH, 2014]. Studi svolti nella popolazione generale suggeriscono che esposizioni acute a stress fisico o psicologico possano determinare eventi cardiaci, in particolare tra soggetti affetti da preesistenti disordini o patologie cardiache [Mittleman et al, 1993; Albert et al, 2000; Smith et al, 2013].

Scopo del presente studio è investigare il ruolo dello stress psicofisico associato a attività specifiche nel determinare il rischio di MCI tra i poliziotti statunitensi.

Materiali e metodi

Abbiamo condotto uno studio della distribuzione dei casi di MCI tra gli agenti di polizia in servizio. I metodi dettagliati dello studio sono riportati nell'Appendice F.

Decessi tra i le forze di polizia

Il National Law Enforcement Officers Memorial Fund (NLEOMF) raccoglie informazioni su decessi avvenuti in servizio tra gli agenti di polizia statunitensi. Si tratta del più grande database disponibile che documenta più decessi di ogni altra sorgente di dati sui corpi di polizia [Tiesman, 2013]. Questo database è stato utilizzato quale sorgente primaria di dati per il nostro studio. Tuttavia, al fine di individuare altri decessi non censiti dal NLEOMF, abbiamo anche consultati i dati del Officer Down Memorial Page (ODMP) [ODMP].

Ambedue i database includono informazioni relative ai tutori dell'ordine, definiti come persone dotate di potere di arresto ed impiegati dalle agenzie deputate alla tutela dell'ordine negli Stati Uniti [NLEOMF, ODMP]. Sono considerati decessi in servizio quelli direttamente cagionati da eventi occorsi turante il turno di lavoro. Entrambi i database escludono i decessi dovuti ad abuso di sostanze tossiche, farmaci o alcol. Oltre ai database citati, abbiamo anche consultato il registro dei casi che il NLEOMF ha preso in considerazione, ma ha in ultima analisi respinto.

Tutti i record individuati attraverso la nostra procedura di ricerca, sono stati esaminati indipendentemente da due ricercatori (AF, MK); un terzo investigatore (SNK) ha risolto eventuali disaccordi. Da ogni record abbiamo estratto i seguenti dati: età, sesso, data della morte, causa presunta del decesso e descrizione narrativa dell'evento. Proprio la descrizione narrativa è stata rivista per valutare quali dei decessi per cause mediche includere nel conto delle MCI. A tal fine, stono state utilizzate procedure precedentemente descritte [Kales et al, 2003; Kales et al, 2007].

I seguenti criteri di inclusione sono stati applicati nel nostro studio:

1) decesso per cause cardiache;
2) perdita improvvisa di coscienza (massimo un'ora dopo l'esordio dei sintomi);
3) assenza di altre cause mediche identificabili;
4) collasso o comparsa dei sintomi durante un turno di lavoro.

Per ogni deceduto abbiamo identificato l'attività svolta al momento della comparsa dei sintomi. Le attività svolte sono state classificate in due macrogruppi: attività di routinarie e attività non routinarie. Le attività routinarie includevano: adunata, attività svolte in classe, meeting, lavoro d'ufficio, operazioni di scorta (parate, funerali), poligono di tiro, attività investigative, emissione di ticket per il parcheggio e pattugliamento. Le attività non routinarie sono state suddivise in 8 ulteriori gruppi: 1) interventi (liti domestiche, disturbo della quiete); 2) soccorso (emergenze mediche, operazioni di soccorso); 3) inseguimenti (inseguimenti in macchina, inseguimenti a piedi); 4) allenamento fisico; 5) colluttazioni; 6) esecuzione di mandati; 7) trasporto detenuti; 8) testimoniare in tribunale.

Per valutare la frequenza di MCI durante lo svolgimento di attività specifiche abbiamo calcolato il rischio relativo (RR) di morte utilizzando come riferimento la categoria delle attività routinarie. I RR sono stati stimati rapportando il numero di eventi osservarti alla percentuale di tempo spesa dall'agente di polizia medio nelle attività considerate (Tabella 1). Sono state condotte due analisi separate utilizzando due sorgenti di dati per le percentuali di tempo spese nelle attività considerate. Queste informazioni sono state pubblicate in Korre et al (2014) e derivano da due sondaggi indipendenti condotti tra gli agenti operativi di polizia ed i comandanti di polizia [Appendice F].

Oltre ai rischi relativi di morte, abbiamo calcolato i tassi assoluti di incidenza stratificati per età. Per i denominatori dei tassi, abbiamo utilizzato i dati dei Current Population Survey tenuti ogni mese tra il 1989 ed il 2010 [CPS, 2013a]. Per calcolare il tempo persona a rischio abbiamo assunto 2,080 ore lavorative all'anno e considerato la percentuale di tempo spesa in ogni attività specifica [CPS, 2013b]

Le analisi statistiche sono state condotte con Stata 13.1 SE (Stata Corp, College Station, TX). Per stimare i RR di MCI durante lo svolgimento di mansioni specifiche, abbiamo adattato modelli di Poisson che includevano il numero di eventi osservati quale variabile dipendente e la percentuale di tempo spesa in ogni attività come offset. Il livello di significatività statistica è stato fissato a p value $\leq 0,05$.

Risultati

Tra il 1° gennaio 1984 ed il 31 dicembre 2010 (periodo dello studio), il NLEOMF ha censito 4553 morti in servizio tra i poliziotti statunitensi; 331 di essi sono stati classificati quali MCI. Nello stesso periodo, l'ODMP ha registrato 4661 decessi, 359 dei quali classificabili come MCI. La sovrapposizione tra i due database è risultata essere, come atteso, alta (91%).Oltre ai dati inclusi ufficialmente nei due database, abbiamo identificato 78 MCI tra i decessi vagliati per l'inclusione dal NLEOMF, ma non selezionati per il database. In totale abbiamo identificato 441 casi di MCI, pari a circa il 9-10% dei decessi totali. I dettagli sul processo di inclusione sono riportati in Figura 1 dell'appendice G. L'età media al momento del decesso per i casi di MCI è risultata pari a 37 anni (DS 9). Solo nove casi (2%) erano donne.

Siamo stati in grado di identificare l'attività svolta al momento della comparsa dei sintomi per 431 casi (98%, per i restanti 10 casi non vi erano informazioni sufficienti per classificare con certezza l'attività). Ben il 25% dei decessi è risultato associabile a colluttazioni, una percentuale superiore a quella osservata per le attività routinarie (23%). Il 20% dei decessi è stato associato all'allenamento fisico, il 12% agli inseguimenti ed il restante 19% ad altre attività. Tabella 1 mostra i rischio di MCI stimati per le attività considerate, utilizzando quale riferimento le attività routinarie. RR notevolmente innalzati (>10) sono stati osservati per le colluttazioni, gli inseguimenti e l'esercizio fisico. Sono risultati associati ad un aumentato RR di MCI anche la conduzione di operazioni di soccorso ed il trasporto dei detenuti. Evidenze limitate di un aumento del rischio di MCI sono documentabili per l'esecuzione di mandati, il testimoniare in tribunale e gli interventi (disturbo alla quiete pubblica/interventi in liti familiari).

Figura 1 mostra i tassi di incidenza di MCI stratificati per attività svolta ed età. Come atteso, il rischio di MCI è risultato aumentare con l'età, sebbene in alcune mansioni (allenamento fisico, operazioni di soccorso, inseguimenti) la stima puntuale del tasso risulti più bassa per soggetti di età compresa tra i 55 ed i 64 anni, rispetto ai poliziotti di età tra i 45 ed i 54 anni.

Tabella 1 Rischio di morte cardiaca improvvisa tra gli agenti di polizia statunitensi. Casi censiti dal National Law Enforcement Officers Memorial Fund and Officer Down Memorial Page (1984–2010).

	Eventi osservati		**Denominatori basati sul sondaggio condotto tra gli agenti di polizia[a]**					**Denominatori basati sul sondaggio condotto tra i comandanti di polizia[a]**				
Attività	*N*	*%*	*% di tempo per turno*	*Eventi attesi*	*O/A*	*RR*	*IC95%*	*% di tempo per turno*	*Eventi attesi*	*O/A*	*RR*	*IC95%*
Routine	101	23,4	77,4	333,6	0,30	1,00	Rif	72,8	313,8	0,32	1,00	Rif,
Interventi	20	4,6	9,6	41,4	0,48	1,60	0,99–2,58	8,8	37,9	0,53	1,64	(1,01–2,65)
Testimoniare in tribunale	3	0,7	1,4	6,0	0,50	1,64	0,52–5,18	1,3	5,6	0,54	1,66	(0,53–5,24)
Eseguire mandati	6	1,4	1,6	6,9	0,87	2,87	1,26–6,55	2,4	10,3	0,58	1,80	(0,79–4,11)
Trasporto detenuti	18	4,2	2,2	9,5	1,90	6,27	3,80–10,4	4,1	17,7	1,02	3,16	(1,92–5,22)
Soccorso	34	7,9	2,9	12,5	2,72	8,98	6,09–13,3	3,9	16,8	2,02	6,28	(4,26–9,27)
Allenamento fisico	88	20,4	2,9	12,5	7,04	23,3	17,5–30,9	3,1	13,4	6,59	20,5	(15,4–27,2)
Inseguimenti	53	12,3	0,8	3,5	15,4	50,8	36,4–70,8	1,2	5,2	10,2	31,8	(22,8–44,4)
Colluttazioni	108	25,1	1,2	5,2	20,9	69,0	52,6–90,5	2,3	9,9	10,9	33,8	(25,8–44,4)

Abbreviazioni: IC, intervallo di confidenza; O/A, osserbati/attesi; Rif, categoria di riferimento; RR; rischio relativo.

[a]Dati sui tempi per attività tratti da Korre et al, 2014.

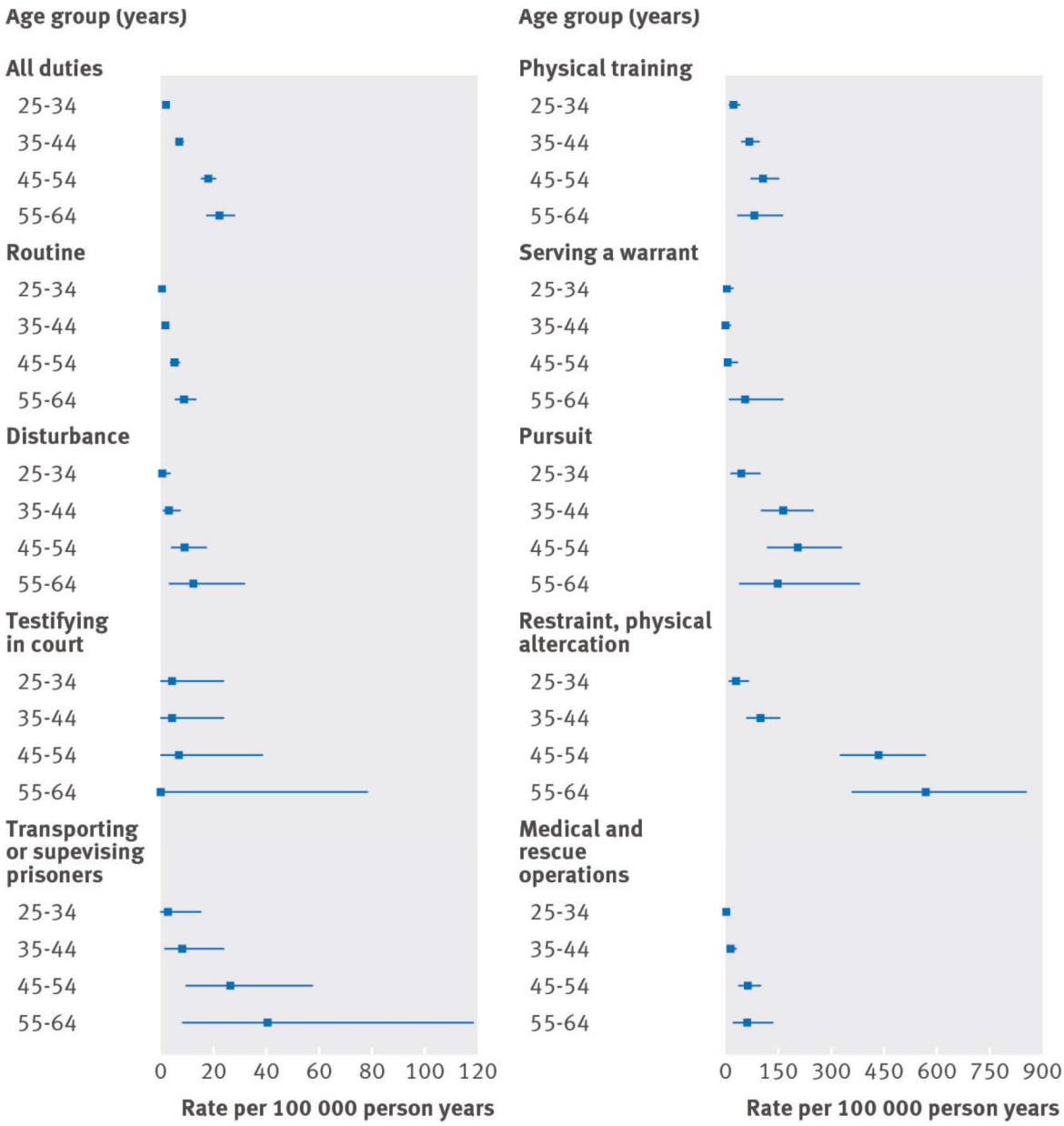

Figura 1 Incidenza di morte cardiaca improvvisa per classe di età ed attività.

Discussione

Il nostro studio è il primo a documentare un aumento del rischio di MCI tra i poliziotti imputabile allo svolgimento di attività ad alto carico emotivo e fisico. In aggiunta, abbiamo osservato che ben il 10% delle morti occorse in servizio soddisfano la definizione di MCI.

I nostri risultati sono in linea con quanto già documentato tra i vigili del fuoco (Kales et al, 2003; Kales et al, 2007]. La maggior parte dei decessi per MCI (77%) avviene durante attività non routinarie, sebbene esse rappresentino solo un quarto del tempo di lavoro [Korre et al, 2014].

Le colluttazioni fisiche e gli inseguimenti sono risultate essere attività ad altissimo rischio. Questo dato è in linea con la comune percezione che anno gli agenti di polizia dello stress legato a queste operazioni [Korre et al, 2014]. Questo innalzamento del rischio è probabilmente imputabile sia a fattori fisici (sforzo fisico con conseguente innalzamento della domanda cardiovascolare) che psichici (in linea con il modello psicologico *"fight or flight*") [Smith et al, 2013; Ramey et al, 2008].

L'allenamento fisico non è usualmente percepito come stressante dagli agenti di polizia [Korre et al, 2014]. Tuttavia, i rischi relativi osservati (20–25) sono in linea con le conoscenze acquisite tra la popolazione generale ed i vigili del fuoco [Kales et al, 2003; Kales et al, 2007]. Le attività di soccorso ed il trasporto di detenuti sono risultate associate a moderati/forti incrementi del rischio di RR. Questi risultati sono importanti poiché queste attività, ed in particolare il trasporto di detenuti, non sono generalmente considerate attività particolarmente intense.

Lo studio presenta limiti metodologici legati principalmente all'identificazione dei casi (assenza di database sicuramente completi), alla qualità delle informazioni cliniche (limitate), all'assenza di referti autoptici e alla costruzione dei denominatori (basati sui dati relativi a due sondaggi). Non è possibile escludere che queste sorgenti di distorsione abbiano influenzato i dati osservati. Tuttavia, la magnitudine dei rischi relativi osservati è notevole. Abbiamo pertanto condotto una serie di analisi di sensibilità (presentate nell'Appendice G e nei suoi allegati) che mostrano che sarebbero necessari livelli di misclassificazione dei casi e dell'esposizione non plausibili per spiegare i RR osservati. Pertanto, riteniamo che il nostro studio documenti con certezza l'evidenza di un aumento del RR associato a specifiche attività, ma ammettiamo che i RR

reali potrebbero essere diversi rispetto a quelli osservati a causa delle molteplici sorgenti di distorsione presenti nel nostro studio.

La nostra analisi si basa una metodologia di confronto interno già utilizzata in precedenti ricerche [Kales et al, 2003; Kales et al, 2007]. Un vantaggio di questo metodo è l'assenza di confondimento legato alle caratteristiche personali; l'assenza di fattori di rischio cardiovascolari noti quali diabete, obesità, tabagismo ed ipertensione non dovrebbe determinare una distorsione delle stime di interesse (sebbene non si possa escludere la presenza di modificazione di effetto, non investigabile con i dati disponibili). Un particolare riflessione va fatta sul fumo di sigaretta quale trigger di eventi cardiovascolari. In questo caso, è possibile che l'assenza del dato sul consumo di sigarette immediatamente precedente l'evento di interesse abbia introdotto un bias verso l'ipotesi nulla (ossia abbia ridotto la magnitudine dei RR osservati). Infatti, è più verosimile che un agente di polizia fumi durante attività di routine piuttosto che mentre conduce operazioni critiche o si allena.

In conclusione, il nostro studio dimostra attività di polizia fisicamente ed emotivamente gravose si associano ad un notevole aumento del rischio di MCI. Futuri studi dovranno valutare il substrato fisiopatologico di queste morti e vagliare strategie preventive su vasta scala.

CONSIDERAZIONI CONCLUSIVE

La presente tesi illustra un percorso di ricerca articolatosi nel triennio 2013-2015. I risultati degli studi mostrano che, tra i vigili del fuoco, la morte cardiaca improvvisa può essere scatenata da attività fisicamente ed emotivamente gravose anche in soggetti di giovane età. I nostri dati mostrano inoltre che la prevalenza di patologie coronariche e profili di rischio cardiovascolare sfavorevoli (obesità, dislipidemie, ipertensione, intolleranza glucidica/diabete, abitudine tabagica) è più alta di quanto ci si potrebbe aspettare in una popolazione giovane, attiva e comunemente ritenuta in buona forma fisica. Tra i determinanti dell'epidemia di obesità osservata tra i vigili del fuoco statunitensi figura sicuramente un regime dietetico caratterizzato dallo scarso consumo di vegetali e frutta e l'eccesivo uso di carni rosse ed alcolici (principalmente birra). In un filone di ricerca svolto parallelamente a quello condotto tra i vigili del fuoco, abbiamo dimostrato che la morte cardiaca improvvisa è una frequente causa di decesso tra gli agenti di polizia ed è spesso associata all'esecuzione di attività fisicamente ed emotivamente intense.

Prospettive di ricerca

Gli studi futuri tra i vigili del fuoco dovranno avere principalmente finalità preventive, essendo già ampiamente disponibili elementi che caratterizzano il rischio cardiovascolare in questa popolazione. È necessario un miglioramento delle tecniche di screening per individuare correttamente i soggetti che presentano un substrato fisiopatologico ad alto rischio di interventi cardiaci. In aggiunta, strategie di prevenzione primaria devono essere attuate sul luogo di lavoro per migliora le abitudini alimentari e lo stile di vita, al fine di ridurre la prevalenza dei comuni fattori di rischio cardiovascolare.

Tra gli agenti di polizia servono ulteriori studi per caratterizzare i determinanti delle patologie cardiovascolari in questa popolazione. Allo stato attuale, manca, e ne è raccomandabile l'implementazione, un sistema di investigazione dei decessi simile a quello messo in essere tra i vigili del fuoco ad opera nel National Institute for Occupational Safety and Health. In aggiunta, è necessario rivalutare la correttezza dei parametri utilizzati per selezionare le reclute di polizia. A tal

fine, si dovrebbe costituire un database di ampie dimensioni e recante informazioni sulle prestazioni mostrate durante l'accademia e la successiva traiettoria professionale.

Studi in corso

Sono attualmente in corso ulteriori studi sotto la coordinazione del Prof. Kales. Tra i protocolli in corso, figura un trial controllato con randomizzazione a *cluster* per valutare l'efficacia di un intervento mirato a cambiare le abitudini dietetiche dei vigili del fuoco. Un altro progetto in corso si basa sui dati provenienti da una coorte di vigili del fuoco seguita per oltre 12 anni. Lo scopo principale dello studio è valutare la presenza di comuni parametri di forma fisica in grado di fornire indicazioni sulla appropriatezza di restrizioni dell'attività fisica. In aggiunta, sono in corso ulteriori studi basati sui dati autoptici disponibili per i vigili del fuoco e la costituzione di una coorte dei cadetti di polizia da seguire nel tempo.

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Appendice A. Yang et al. Am J Cardiol. 2013;112:1962-7.

Sudden Cardiac Death Among Firefighters ≤45 Years of Age in the United States☆

Justin Yang, MD, MPH[a,b], Dennis Teehan, MD, MPH[a,b], Andrea Farioli, MD[a,b,c], Dorothee M. Baur, MD, MS[a,d], Denise Smith, PhD[e], and Stefanos N. Kales, MD, MPH[a,b,*]

Sudden cardiac death (SCD) is the leading cause of death in firefighters. Although on-duty SCD usually occurs in older victims almost exclusively because of coronary heart disease, no studies have examined causation across the career span. In the present retrospective case-control study, cases of SCD in young (aged ≤45 years) firefighters from the National Institute for Occupational Safety and Health fatality investigations (n = 87) were compared with 2 age- and gender-matched control groups: occupationally active firefighters (n = 915) and noncardiac traumatic firefighter fatalities (n = 56). Of the SCD cases, 63% were obese and 67% had a coronary heart disease–related cause of death. The SCD victims had much heavier hearts (522 ± 102 g) than noncardiac fatality controls (400 ± 91 g, p <0.001). Cardiomegaly (heart weight >450 g) was found in 66% of the SCD victims and conveyed a fivefold increase (95% confidence interval [CI] 1.93 to 12.4) in SCD risk. Furthermore, hypertension, including cases with left ventricular hypertrophy, increased SCD risk by 12-fold (95% CI 6.23 to 22.3) after multivariate adjustment. A history of cardiovascular disease and smoking were also independently associated with elevated SCD risk (odds ratio 6.89, 95% CI 2.87 to 16.5; and odds ratio 3.53, 95% CI 1.87 to 6.65, respectively). In conclusion, SCD in young firefighters is primarily related to preventable lifestyle factors. Obesity entry standards, smoking bans, and improved screening and/or wellness program are potential strategies to reduce SCD in younger firefighters. © 2013 The Authors. Published by Elsevier Inc. All rights reserved. **(Am J Cardiol 2013;112:1962–1967)**

The leading mode of duty-related death among US firefighters is sudden cardiac death (SCD), which accounts for about 50% of on-duty firefighting fatalities.[1–4] About 90% of these SCD cases will be attributable to coronary heart disease (CHD) and usually occur in firefighters aged >45 years.[4–7] In addition, emerging evidence has suggested that obesity and left ventricular (LV) hypertrophy and/or cardiomegaly are present in a large proportion of all those with SCD (with and without CHD) in firefighters[8] and the general population.[9] Although SCD causation in younger subjects, such as athletes, is usually due to non-CHD structural pathologic features,[10,11] little is known about SCD in young firefighters. We conducted a case-control study of SCD among firefighters aged ≤45 years to examine the associated cardiovascular disease (CVD) risk factors and underlying pathologic features. Our aims were to (1) describe the specific pathologic-anatomic causes of on-duty SCD in these cases, (2) compare the prevalence and severity of CVD risk factors in SCD fatalities with those in healthy, occupationally active firefighter controls, and (3) compare the cardiac findings from the SCD cases at autopsy with those of firefighters who died of on-duty noncardiac causes.

Methods

We conducted a retrospective case-control study that serially reviewed and selected as cases all SCD fatalities (aged ≤45 years) from 1996 to 2012 investigated by the National Institute for Occupational Safety and Health (NIOSH).[12] Two other firefighter groups were chosen as controls: (1) age-matched, career firefighters examined from 2007 to 2009[13] and (2) age-matched, noncardiac, traumatic fatalities (2004 to 2010) with autopsy reports available.

NIOSH conducts independent investigations of firefighter line-of-duty deaths, and the completed fatality reports are publicly available for download from NIOSH's Firefighter Fatality Investigation and Prevention Program website.[12] Two physician investigators (J.Y. and D.T.) examined in detail all fatality reports published online from January 1996

[a]Environmental and Occupational Medicine and Epidemiology Program, Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts; [b]Cambridge Health Alliance, Harvard Medical School, Cambridge, Massachusetts; [c]Department of Medical and Surgical Sciences (DIMEC), University of Bologna, Bologna, Italy; [d]II. Medizinische Klinik, Klinikum rechts der Isar, Technische Universitaet, Munich, Germany; and [e]Health and Exercise Sciences Department, Skidmore College, Saratoga Springs, New York. Manuscript received June 24, 2013; revised manuscript received and accepted August 14, 2013.

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*Corresponding author: Tel: (617) 665-1580; fax: (617) 665-1672.
E-mail address: skales@challiance.org (S.N. Kales).

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Table 1
Descriptive results of sudden cardiac death (SCD) cases aged ≤45 years from the National Institute for Occupational Safety and Health (NIOSH) investigations

Variable	Age <35 yrs (n = 22)	Age 35–45 yrs (n = 65)	Total (n = 87)
Age (yrs)	28.0 ± 4.1	41.0 ± 3.1	37.7 ± 6.6
Men (%)	21 (96)	64 (99)	85 (98)
BMI (kg/m^2)	31.6 ± 6.5 (n = 18)	32.1 ± 6.1 (n = 50)	32.0 ± 6.2 (n = 68)
Obesity category			
BMI ≥30 kg/m^2 (obese)	12 (67)	31 (62)	43 (63)
BMI ≥30 but <35 kg/m^2	7 (39)	17 (34)	24 (35)
BMI ≥35 but <40 kg/m^2	3 (17)	7 (14)	10 (15)
BMI ≥40 kg/m^2	2 (11)	7 (14)	9 (13)
Smoker	4 (18)	20 (31)	24 (28)
Career status			
Career	11 (50)	41 (63)	52 (60)
Volunteer	11 (50)	24 (37)	35 (40)
Autopsy findings			
CHD only	1 (5)	11 (17)	12 (14)
Hypertrophic cardiomyopathy	3 (14)	2 (3)	5 (6)
LV hypertrophy or hypertension heart disease	1 (5)	3 (5)	4 (5)
CHD + cardiomegaly	7 (32)	39 (60)	46 (53)
Arrhythmia because of idiopathic dilated cardiomyopathy	3 (14)	1 (2)	4 (5)
Coronary anomaly	1 (5)	1 (2)	2 (2)
Valvular disease (acquired)	3 (14)	3 (5)	6 (7)
Congenital heart disease other than coronary anomaly	0	1 (2)	1 (1)
WPW, long QT, and other primary arrhythmia without structural disease	1 (5)	0	1 (1)
Cardiac sarcoidosis	0	2 (3)	2 (2)
Commotio cordis	0	0	0
Myocarditis	0	0	0
Other cardiovascular causes	1 (5)	1 (2)	2 (2)
Cause of SCD not confirmed*	1 (5)	1 (2)	2 (2)
Heart weight (g)	490 ± 84 (n = 18)	534 ± 107 (n = 47)	522 ± 102 (n = 65)
Heart weight group			
>450 g	11 (61)	32 (68)	43 (66)
>550 g	5 (28)	22 (47)	27 (42)

Data are presented as mean ± SD or n (%).
BMI = body mass index; WPW = Wolff-Parkinson-White syndrome.
* Cause of SCD could not be confirmed because of lack of autopsy and previous medical records.

to December 2012 to determine whether each case met our inclusion criteria as listed in the following paragraph. A third physician investigator (A.F.) then reviewed the NIOSH database and previously selected cases again, with final decisions on inclusion resolved by the senior investigator (S.N.K.). SCD case data were extracted using a standardized electronic template[5,8] by 2 of us (D.T. and J.Y.) independently and then were verified for completeness and accuracy (by J.Y.). Any disagreements among the investigators on data extraction were resolved by the senior physician investigator (S.N.K.).

The inclusion criteria for the NIOSH SCD fatality cases were (1) NIOSH investigated cases published on the website from January 1996 to December 2012, (2) firefighters who experienced SCD and died within 24 hours of their last fire service duty or experienced a sudden cardiac event within 24 hours of their last duty and the event was associated with loss of consciousness within 1 hour of onset, and, subsequently, the firefighter never regained consciousness before biologic death, (3) age ≤45 years, and (4) autopsy report or sufficient medical findings available to determine the underlying cause of death.

An existing database previously assembled from career fire departments was reviewed for occupationally active control firefighters. The cohort's cardiovascular and health status were comprehensively characterized by baseline fire department medical examinations.[13,14] The inclusion criteria for the occupationally active firefighter controls were (1) age ≤45 years, and (2) no medical restrictions or physical limitations on duty.

Potential age-matched, noncardiac traumatic fatalities (deaths due to blunt trauma, burns, or asphyxiation) were identified for 2004 to 2010 from a firefighter autopsy research data bank maintained by 1 of us (D.S.) and the National Fallen Firefighters Foundation. The inclusion criteria for the National Fallen Firefighters Foundation noncardiac traumatic controls were (1) age ≤45 years, (2) death while on duty, and (3) cause of death determined by autopsy to be due to blunt trauma, burns, or asphyxiation and not related to any cardiovascular pathologic entity.

Table 2
Statistical analyses of cardiovascular disease (CVD) risk factors comparing sudden cardiac death (SCD) cases aged ≤45 years from National Institute for Occupational Safety and Health (NIOSH) investigations with occupationally active firefighter controls

Variable	NIOSH Cases (n = 87)	Active Controls (n = 915)	Univariate Analysis			Multivariate Analysis					
						Model I*,†			Model II†,‡		
			OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Risk factor											
Age (yrs)	37.7 ± 6.6	35.4 ± 6.1	1.06	1.03–1.11	0.001	1.03	0.98–1.08	0.268	1.02	0.97–1.07	0.451
Men	85/87 (98)	886/915 (97)	0.72	0.17–3.06	0.655	—	—	—	—	—	—
BMI (kg/m^2)											
<30	25/68 (37)	582/908 (64)	1.00	Ref		1.00	Ref		1.00	Ref	
≥30	43/68 (63)	326/908 (36)	3.07	1.84–5.12	<0.001	2.20	1.27–3.81	0.005	1.76	0.99–3.11	0.053
Smoker§	24/87 (28)	70/779 (9)	3.86	2.27–6.56	<0.001	3.53	1.87–6.65	<0.001	3.50	1.76–6.95	<0.001
Diabetes mellitus‖	4/87 (5)	18/908 (2)	2.38	0.79–7.21	0.124	3.26	0.93–11.5	0.066	2.17	0.59–7.95	0.243
Hypertension¶	41/87 (48)	179/904 (20)	3.69	2.34–5.81	<0.001	3.43	2.01–5.87	<0.001	—	—	—
Hypertension 2#	62/87 (72)	179/904 (20)	10.5	6.35–17.2	<0.001	—	—	—	11.8	6.23–22.3	<0.001
Dyslipidemia**	46/87 (53)	366/908 (40)	1.66	1.07–2.58	0.024	1.47	0.86–2.51	0.157	1.53	0.88–2.68	0.134
History of CVD											
CHD, CHD equivalent, or valvular disease††	18/87 (21)	29/786 (4)	6.81	3.60–12.9	<0.001	6.89	2.87–16.5	<0.001	5.72	2.40–13.6	<0.001
Irregular rhythm	2/87 (2)	45/786 (6)	0.39	0.09–1.63	0.195	0.13	0.02–1.06	0.057	0.13	0.02–1.04	0.054
Abnormal findings on ECG or echocardiogram	6/87 (7)	62/786 (8)	0.86	0.36–2.06	0.744	0.50	0.16–1.59	0.242	0.41	0.13–1.31	0.132
Chest pain or shortness of breath‡‡	7/87 (8)	9/786 (1)	7.55	2.74–20.8	<0.001	1.92	0.46–8.01	0.372	2.15	0.50–9.29	0.307

Data are presented as mean ± SD or n (%), unless otherwise noted.
CI = confidence interval; ECG = electrocardiogram; hypertension 2 = second definition of hypertension; OR = odds ratio; Ref = reference category.
* Adjusted by age, BMI (dichotomous), smoking, diabetes mellitus, hypertension, and dyslipidemia.
† Analysis restricted to 68 cases and 765 controls with complete information.
‡ Adjusted by age, BMI (dichotomous), smoking, diabetes mellitus, hypertension 2, and dyslipidemia.
§ Subject was smoking within previous 12 months.
‖ Cases: evidence of diabetes mellitus in report; controls: blood glucose ≥150 mg/dl, previous diabetes mellitus diagnosis, and/or taking medication.
¶ Systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg, previous hypertension diagnosis, and/or taking medication.
# Included all cases of hypertension defined in previous footnote plus those with findings of LV hypertrophy on autopsy.
** Evidence of dyslipidemia mentioned (total cholesterol ≥200 mg/dl or low-density lipoprotein ≥160 mg/dl), previous diagnosis of hyperlipidemia, and/or taking medication.
†† CHD, CHD equivalent: previous myocardial infarction, angioplasty, stent placement, or clinical diagnosis of CHD because of abnormal calcium score or exercise tolerance test findings; valvular disease: previous diagnosis of valvular abnormalities or disease or presence of appropriate autopsy findings.
‡‡ Episodes of chest pain or shortness of breath documented but without a CHD diagnosis.

Among the occupationally active controls, firefighters were considered active smokers if they self-reported smoking within the previous 12 months. Diabetes mellitus was defined using the Framingham criteria (random blood glucose ≥150 mg/dl, previous diagnosis of diabetes, and/or requiring diabetes mellitus medications).[5,8] Hypertension was considered present if firefighters had a systolic blood pressure of ≥140 mm Hg and/or diastolic blood pressure of ≥90 mm Hg at rest, a previous hypertension diagnosis, and/or required hypertension medication. Firefighters with a total cholesterol level of ≥200 mg/dl, low-density lipoprotein of ≥160 mg/dl, a previous diagnosis of hyperlipidemia, and/or requiring lipid-lowering medications were considered to have dyslipidemia.

In the NIOSH SCD cases, the determinations were according to the same criteria or a description of the risk factors as presented by the NIOSH investigators anywhere in the case report. We also considered a second definition of hypertension that included those with hypertension as defined plus those with LV hypertrophy found on autopsy.[8] Any firefighter was considered to have a history of CHD or CHD equivalent if the NIOSH report or medical record reported previous myocardial infarction, angioplasty, stent placement, or a clinical diagnosis of CHD on the basis of an abnormal calcium score or exercise tolerance test findings. A history of valvular disease was considered present if a previous diagnosis of valvular abnormalities and/or disease or appropriate autopsy findings of valvular disease were present. A "history of chest pain or shortness of breath" was considered present if the firefighter had had episodes of chest pain and/or shortness of breath documented without a CHD diagnosis. We conservatively coded the CVD risk factors in the SCD cases as negative when these were undeterminable or ambiguous from the investigation report.

The use of de-identified data from the occupationally active firefighter controls was previously approved by the institutional review board of Harvard School of Public Health and local institutional review boards, as appropriate. The investigations and autopsy reports from NIOSH and the National Fallen Firefighters Foundation were exempt from institutional review board review (deceased, nonliving subjects).[15]

autopsies.[3,5,8] In our study, 70% of cases had evidence of LV hypertrophy. The autopsy findings from our trauma controls (22% prevalence of heart weight >450 g) indicated that LV hypertrophy and/or cardiomegaly could be fairly common among firefighters aged ≤45 years. Additional research is needed to develop more sensitive screening methods for cardiomegaly in the fire service.

Our observation of high body mass indexes, heavier heart weights, and a fivefold risk increase associated with cardiomegaly in SCD cases, although already significant, were actually likely to be conservative. This resulted from the greater obesity we observed in the traumatic controls compared with the occupationally active cohort. Because it is not possible to obtain the heart weight from the active controls, an excess of extreme obesity in noncardiac fatalities potentially biased our findings toward the null hypothesis, because obesity usually increases the heart weight. We hypothesized that traumatic fatalities occur more frequently in obese firefighters because they are more inclined to be physically trapped during a fire secondary to their body size and relative physical immobility.[21]

Our study had several minor limitations. First, the NIOSH investigation program might have underrepresented volunteer firefighters. Only about 23% of volunteer firefighter deaths were examined by NIOSH from 2004 to 2009 compared with 55% of career fatalities.[22] However, although volunteers account for most (about 70%) of the United States fire service,[23] we also know that the volunteers were older as a group and 93% of the SCD victims who were aged >60 years were volunteers.[4] These statistics suggest a skewed distribution of SCD fatalities toward older volunteers, whose cases the NIOSH is less likely to review. Therefore, any selection bias would have been limited to the NIOSH investigations of younger firefighters.

Another limitation of our study was that we were only able to extract the autopsy results provided in the NIOSH investigations, and no standardized reporting formats were used. Thus, it is possible that our results underestimated the true magnitude of obesity or cardiomegaly in young firefighters. Regardless, our significant findings, combined with the results from previous studies, strongly suggest that obesity and cardiomegaly increase the odds of SCD.[3,5,16,24,25]

Our study also had major methodologic strengths. We created a statistically rigorous case-control design with 2 age-matched control groups from the same occupation whose medical data were derived from similar periods. Also, although we conservatively coded the incomplete reports from the NIOSH as negative, we adopted broad definitions for the risk factors in the active control group. Our near complete risk factor data from the controls would have most likely biased our results toward the null hypothesis.

The present results continue to support previous recommendations[1,3,12,16,22,26–29] for mandating medical screening and wellness programs for firefighters, because these remain relatively uncommon within the United States fire service.[1,22] In particular, imposing an entry-level obesity standard should be strongly supported because of (1) the prevalence of obesity reported in the present study and in previous studies,[2,16,28] and (2) our present findings that obesity is strongly associated with an increased risk of cardiomegaly and SCD.

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Disclosures

Stefanos N. Kales, MD, MPH, reports serving as a paid expert witness or independent medical examiner, or both, in Workers' compensation and disability cases, including cases involving firefighters. Denise Smith, PhD, reports serving as a paid expert witness in cases involving firefighter fatalities. No other potential conflicts of interest relevant to our study exist.

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Table 3
Statistical analyses comparing sudden cardiac death (SCD) cases aged ≤45 years from National Institute for Occupational Safety and Health (NIOSH) investigations and traumatic fatality controls

Variable	NIOSH SCD Cases (n = 87)	Trauma Controls (n = 56)	Univariate Analysis			Multivariate Analysis		
			OR	95% CI	p	OR	95% CI	p
Age (yrs)	37.7 ± 6.6	31.2 ± 8.3	1.12	1.07–1.17	<0.001	1.09*	1.03–1.15*	0.002
BMI (kg/m^2)								
<30	25/68 (37)	33/56 (59)	1.00	Ref		1.00	Ref	
≥30	43/68 (63)	23/56 (41)	2.47	1.19–5.10	0.015	1.23*	0.50–3.07*	0.650
Heart weight (g)	522 ± 102	400 ± 91	1.01	1.01–1.02	<0.001	1.01†	1.01–1.02†	<0.001
Heart weight group								
≤450	22/65 (34)	42/54 (78)	1.00	Ref		1.00	Ref	
>450	43/65 (66)	12/54 (22)	6.84	3.01–15.6	<0.001	4.89*	1.93–12.4*	0.001

Data are presented as mean ± SD or n (%).
CI = confidence interval; OR = odds ratio; Ref = reference category.
* Estimates from logistic regression model that included age, BMI, and dichotomized heart weight; analysis restricted to 59 cases and 54 controls with complete information.
† Estimates from logistic regression model that included age, BMI, and heart weight; analysis restricted to 59 cases and 54 controls with complete information.

Statistical analyses were performed using SPSS, version 21.0 (IBM, Armonk, New York) and Stata, version 12.1 SE (StataCorp, College Station, Texas). Categorical variables were compared using Fisher's exact test and normally distributed continuous variables using Student's *t* test. Associations of risk factors with SCD were characterized by odds ratios and associated 95% confidence intervals. Variables to be introduced in the multivariate logistic regression models were selected a priori. p Values <0.05 were considered statistically significant, and all statistical tests were 2-sided.

Results

A total of 87 SCD fatality cases, 915 occupationally active controls, and 56 trauma deaths met the inclusion criteria. The SCD cases dichotomized by age are listed in Table 1. Cases with cardiomyopathy and/or cardiomegaly in the absence of CHD were most often associated with hypertrophic cardiomyopathy or nonspecific cardiomyopathies. Overall, 67% of SCD cases had CHD as a contributing factor (categories 1 and 4).

The CVD risk factor prevalence between the NIOSH SCD cases and occupationally active firefighter controls is presented in Table 2. The odds ratios for obesity, smoking, and hypertension were all statistically significant for an association with SCD after multivariate adjustment. A history of CHD, CHD equivalent, or valvular disease diagnosed before death was associated with a sevenfold increase in the risk of SCD, even after multivariate adjustment (95% confidence interval 2.87 to 16.5).

Data from the SCD cases and noncardiac trauma controls are listed in Table 3. Our SCD cases had significantly larger hearts (mean difference >120 g) compared with the trauma controls (p <0.001). Furthermore, the odds of SCD increased almost fivefold in the presence of cardiomegaly (heart weight >450 g) after multivariate adjustment (95% confidence interval 1.93 to 12.4). Finally, in both groups we observed cardiomegaly primarily in obese victims: 74% of cases and 67% of controls with an enlarged heart were obese.

Discussion

The results from the present study support the finding that on-duty SCD in younger US firefighters, even those aged <35 years, is primarily related to preventable lifestyle factors, which culminate in obesity, CHD, and LV hypertrophy and/or cardiomegaly. Our study also identified several important risk factors for SCD. Those with SCD were more likely to be obese, hypertensive, and smokers and to have a history of significant CVD than were active controls. Furthermore, when the SCD autopsy results were compared with those from other firefighters who died of noncardiac causes, the SCD cases were more obese, had significantly greater heart weights, and had an increased risk of cardiomegaly (heart weight >450 g). Two thirds of the SCD cases had a heart weight >450 g and >40% weighed >550 g.

In strong agreement with data from the general population,[9] we found that the most common underlying pathologic reason for SCD in younger firefighters was CHD, together with cardiomegaly (53%). Most remaining SCD cases were due to either CHD or some type of cardiomegaly alone. These results for cardiomegaly and obesity were also consistent with an earlier study of SCD in the fire service that was limited to CHD deaths, in which the average age of those dying was 50 years and >75% of the subjects were >45 years old.[8]

In our present study, 63% of those with SCD were obese compared with 36% of the active firefighter controls. This yielded a twofold increased risk of SCD after adjustment for covariates. Also, 28% of the SCD cases had class II or III obesity compared with only 10% of our occupationally active control firefighters. Our results can most likely be explained by obesity's well-known associations with the clustering of cardiometabolic risk factors, especially hypertension and obstructive sleep apnea, which increase the risk of both CHD and cardiomegaly, as well as death.[16,17]

Accordingly, LV hypertrophy was another powerful predictor of SCD, in agreement with previous studies.[3,18–20] In previous investigations of CHD fatalities among firefighters, LV hypertrophy was found in 60% to 76% of

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Duty-related risk of sudden cardiac death among young US firefighters

A. Farioli[1,2,3], J. Yang[1,2], D. Teehan[1,2], D. M. Baur[1,4], D. L. Smith[5] and S. N. Kales[1,2]

[1]Department of Environmental Health (Environmental & Occupational Medicine & Epidemiology), Harvard School of Public Health, Boston, MA 02115, USA, [2]The Cambridge Health Alliance, Harvard Medical School, Cambridge, MA 02139, USA, [3]Department of Medical and Surgical Sciences (DIMEC), University of Bologna, Bologna 40138, Italy, [4]Interdisciplinary for Hormone and Metabolic Disorders, Endokrinologikum ULM, 89073 Ulm, Germany, [5]Department of Health and Exercise Sciences, Skidmore College, Saratoga Springs, New York, NY 12866, USA.

Correspondence to: S. N. Kales, Cambridge Hospital Macht Building 427, 1493 Cambridge Street, Cambridge, MA 02139, USA. Tel: +617 665 1580; fax: +617 665 1672; e-mail: skales@hsph.harvard.edu

Background	Little is known regarding duty-related risks for sudden cardiac death (SCD) among young firefighters.
Aims	To investigate duty-related SCD among US firefighters aged 45 or younger.
Methods	We collected data on duty-related SCD from the US Fire Administration (USFA) and the US National Institute for Occupational Safety and Health (NIOSH). Two physicians independently reviewed each record. The proportions of time spent by firefighters performing specific duties were estimated from a municipal department, 17 large metropolitan departments and a national database. We estimated the duty-specific relative risks (RRs) and 95% confidence intervals (95% CI) of SCD relative to non-emergency duties based on the observed deaths and the expected average proportions of time per duty.
Results	The USFA recorded 205 age-eligible on-duty SCDs between 1996 and 2012; 86 (42%) of these deaths and one additional SCD were investigated by NIOSH (total n = 206). NIOSH was more likely ($P < 0.001$) to report on SCD associated with physical training (69% of cases were investigated) and fire suppression (57%). Compared with non-emergency duties, the risk of SCD was increased for fire suppression (RR 22.1, 95% CI 14.8–32.9), alarm response (RR 2.6, 95% CI 1.5–4.6), alarm return (RR 4.1, 95% CI 2.7–6.2) and physical training (RR 4.8, 95% CI 3.2–7.2). RRs for SCD were higher among firefighters with a pre-existing history of a cardiac condition. All 16 SCDs associated with alarm response occurred among volunteer firefighters.
Conclusions	The performance of strenuous emergency duties is strongly associated with an increased risk of SCD among young firefighters, particularly among those with a history of cardiovascular disease.
Key words	Firefighters; longitudinal study; occupational disease; occupational exposure; sudden cardiac death.

Introduction

Despite the high risk of trauma during fires and other emergency activities, sudden cardiac death (SCD) is the leading cause of on-duty death among the 1 100 000 firefighters in the USA [1,2]. An increased incidence of SCD among firefighters has been documented during certain emergency and strenuous duties, which can trigger SCD among individuals affected by underlying coronary heart disease (CHD) and/or left ventricular hypertrophy (LVH) [3–6]. It is unknown whether these findings, mainly observed among middle-aged firefighters with CHD, also apply to younger firefighters. SCD among young and apparently healthy subjects is often associated with a structural cardiac abnormality, rather than CHD [7]. Nevertheless, a recent study of US firefighters aged 45 or younger found a major role for traditional cardiovascular risk factors (obesity, cigarette smoking and hypertension) in conveying an increased risk of SCD through the development of CHD and LVH/cardiomegaly [8].

Since little is known about the occupational determinants of on-duty SCD among younger firefighters, we investigated the duty-related risks of SCD among

firefighters aged ≤45 using data from two US national databases maintained by the US Fire Administration (USFA) and the National Institute for Occupational Safety and Health (NIOSH).

Methods

We collected death records from USFA and NIOSH. The USFA maintains a systematic database of all deaths associated with firefighting in the USA since 1981 [9]. Each record includes name, age, rank, classification (e.g. volunteer, career), dates of incident and death, location, cause and nature of death, duty (type, specific activity, emergency context) and a description of the event (systematically available from 1993). The NIOSH program investigates firefighter line-of-duty deaths for prevention purposes, analysing all putative determinants of the events [10]. The NIOSH database is neither representative nor comprehensive [3,6,8], but all reports comprehensively describe the event and, whenever relevant, contain a summary of the pre-morbid clinical history and findings of the post-mortem examination. From 1994, the USFA has recommended performing an autopsy for all fatalities possibly associated with firefighting [11]. However, the final decision to undertake a necropsy is at the discretion of local coroners.

The protocol for data extraction from the two databases has been described elsewhere [6,8]. Briefly, for this study, we collected all fatality reports published between 1996 and 2012 from both databases. Two physicians independently examined each summary report for possible inclusion and data extraction. The senior physician investigator (S.N.K.) resolved any disagreements.

We applied the following inclusion criteria:

1. age at death ≤45 years;
2. cause of death SCD;
3. (a) SCD within 24 hours of last fire service duty or (b) sudden cardiac event within 24 hours of last duty followed by permanent loss of consciousness until death;
4. death occurred between 1 January 1996 and 31 December 2012;
5. medical history and/or autopsy report available (NIOSH database only).

Based on the duty performed at the time of the onset of the symptoms, we grouped SCD events into one of six categories [3,4,12]:

1. fire station tasks and non-emergency duties (administrative and fire station tasks, fire prevention, inspection, maintenance, meetings and classroom activities);
2. non-fire emergencies (emergency medical services (EMS) rescues and other non-fire operations);
3. physical training (physical fitness tests, fitness activities, simulated or live fire, rescue emergency and search drills);
4. alarm return (all events occurred upon returning from an emergency);
5. alarm response (all events after an emergency dispatch and prior to reaching the emergency scene);
6. fire suppression (including all operational activities on the fireground).

For the SCD cases reported both from USFA and NIOSH, we crosschecked blindly the classification of the duties in the two databases. For non-concordant cases, we relied on the more comprehensive information provided by the NIOSH reports. We classified volunteer, paid on-call and part-time firefighters together as 'volunteers' and full-time firefighters working in career fire departments as 'career' firefighters. We evaluated pre-existing cardiovascular conditions based on the NIOSH reports. We did not extend this analysis to the USFA database due to the lack of information on pre-existing medical conditions. We included the following when present: CHD (pre-morbid myocardial infarction, angioplasty, stent placement, positive calcium score or positive exercise tolerance test); valvular abnormalities/diseases; pre-morbid self-reported history of chest pain or shortness of breath or a previous history of an abnormal electrocardiogram (as reported by NIOSH investigators based on clinical records). Since the NIOSH database does not seek to be comprehensive (the deaths investigated are identified through an algorithm designed to address prevention priorities [13]), we conducted a secondary analysis to assess how the selection process might bias the study of relative risks (RR) associated with specific duties. We used three independent estimates to approximate the proportional time that an average firefighter spends in each duty (Table 1). These estimates have been previously described in detail [3,4].

We performed statistical analyses using Stata 12.1 SE (Stata Corp., College Station, TX). We defined a two-sided P value ≤ 0.05 as statistically significant. We compared continuous variables, expressed as median and interquartile range (IQR), using the Mann–Whitney U-test. We used Cohen's κ to study agreement on duty at time of death between the two databases. Assuming independence between duties and the risk of SCD, we calculated the expected deaths based on the relative time per duty. We estimated the duty-specific RR and the associated 95% confidence intervals (95% CIs) of SCD by fitting Poisson regression models including observed counts as the dependent variable and the logarithm of the proportion of time per duty as the offset. As this study involved only deceased subjects, it was exempt from institutional review board review, which by US Federal law classifies research on deceased subjects as exempt non-human subjects investigation [14]. All data were extracted from freely available electronic databases maintained in the public domain by US Federal agencies. To preserve the anonymity of the study population,

Table 1. Estimated proportion of time spent in specific firefighting duties by various fire service estimates[a]

Duty	Municipal fire department[b] % of time	Large metropolitan fire department[c] % of time	National data[d] % of time
Fire station and other non-emergency duties	51	29	65
EMS and other non-fire emergencies	23	34	15
Physical training	8	8	8
Alarm return	10	15	7
Alarm response	6	9	4
Fire suppression	2	5	1

[a]Adapted from Kales *et al.* [4].
[b]Estimates based on municipal data from the Cambridge Fire Department, Cambridge, MA [2].
[c]Estimates based on a survey of 17 large metropolitan fire departments conducted by the International Association of Fire Fighters (L. Moore-Merrell, personal communication) [2].
[d]Estimates based on annual national surveys conducted by the National Fire Protection Association [3].

our final database did not include any personal identifiers and we only presented aggregated data.

Results

Figure 1 presents the process for identifying on-duty SCDs among firefighters aged 45 or younger. The USFA database included 205 SCDs occurring between 1996 and 2012 among firefighters aged 45 or younger and meeting the study's inclusion criteria. The NIOSH investigated 86 of these deaths (42%) and one case from 2012 that was not yet included in the USFA database at the time of data extraction, bringing the total number of unique SCDs to 206. All deaths classified as SCD according to the USFA records were confirmed by the more informative NIOSH reports. Among the 86 deaths included in both data sets, the agreement between the two databases on the duty at the time of the death was extremely robust (Cohen's κ 0.90, 95% CI 0.82–0.97). Among cases investigated by NIOSH, we observed similar distributions of hypertension, heart mass and past cardiovascular history by duty performed at the time of the death (Supplementary Table 1, available as Supplementary data at *Occupational Medicine* Online). Victims dying during physical training tended to be younger and less frequently smokers. Firefighters dying during fire station and other non-emergency duties or EMS and other non-fire emergencies tended to have a lower body mass index.

In Table 2, we show the proportion of SCD reported by the USFA and also investigated by NIOSH as a function of the duty associated with the fatalities. NIOSH was more likely to investigate SCD associated with physical training (69%) and fire suppression (57%) compared with 42% of overall SCD ($P < 0.001$). Career firefighters' deaths were investigated in 55% of cases, while only 31% of deaths occurring among volunteers were studied ($P < 0.05$). The age distribution of the cases investigated by NIOSH (median 39, IQR 34–43 years) and of those that were not investigated (median 40, IQR 36–43) did not differ significantly.

In Table 3, we present the RRs for duty-related SCD risk based on USFA data. We observed the highest risks for fire suppression duties regardless of the exposure assessment assumptions. However, the choice of the estimates influenced the magnitude of the RR point estimates. Physical training and alarm return were also associated with increased risks of SCD. Evidence was more limited for alarm response and limited to volunteer firefighters. We did not find an increased risk for SCD for EMS and other non-fire emergencies in any of the three exposure assessment scenarios.

In Supplementary Table 2, available as Supplementary data at *Occupational Medicine* Online, we present the RR for duty-related SCD risk based on NIOSH data. The patterns of RRs were similar but higher for physical training and fire suppression than using USFA data.

In Table 4, we stratify the duty-related risk of SCD according firefighters' job status, that is career or volunteer. The risk estimates were similar with the exception of alarm response, which was markedly elevated among volunteers, while we observed no such deaths among career firefighters.

Among SCDs investigated by NIOSH, 38% (95% CI 28–49%) had a history of any cardiovascular condition; and as many as 21% of SCD cases (95% CI 13–31%) had a pre-morbid history of CHD or CHD equivalent. In Table 5, we stratify the duty-related risk of SCD according to firefighters' pre-morbid cardiovascular history using NIOSH cases. The RRs associated with fire suppression, alarm return and response, and physical training were consistently higher among firefighters with a history of cardiovascular diseases or conditions.

Discussion

Our study provides definitive evidence that performing strenuous emergency duties is a risk factor for

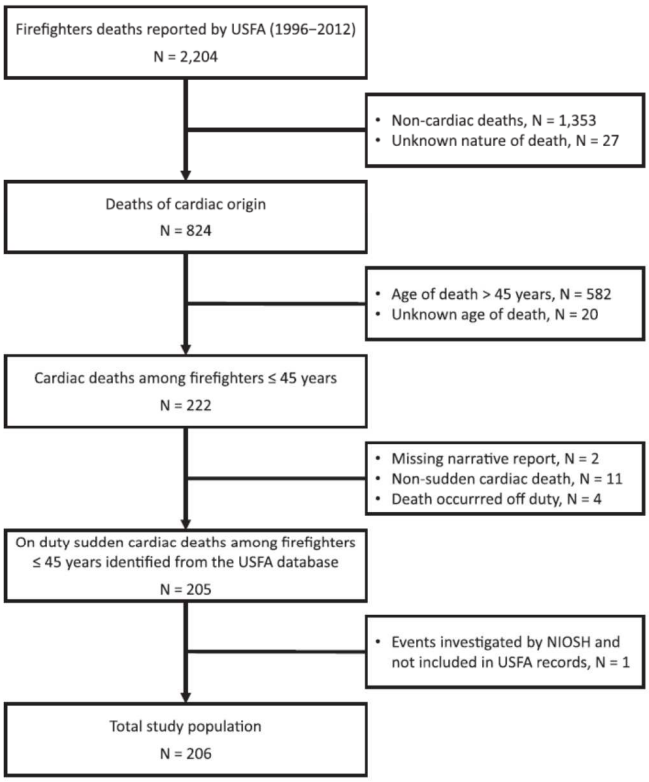

Figure 1. Flow chart of the study population. Identification of on-duty SCDs among US firefighters aged 45 or younger.

SCD among young firefighters. We demonstrate that the duty-specific risks of SCD were higher among subjects with a pre-morbid history of cardiovascular conditions. Both of these findings are consistent with previous studies of exclusively CHD-related SCD among mostly older firefighters [3,4]. We are the first to report that alarm response is associated with an increased risk of SCD only among volunteer firefighters.

The main strength of our study is the use of an internal comparison group; indeed, we estimated the expected death counts based on fire service data. We believe that the three sets of duty-time estimates cover all plausible exposure scenarios [3,4]. Despite the variations in the magnitude of the RRs, the analysis conducted using different assumptions consistently identified increased risks of SCD for physical training, alarm return and fire suppression. Our analysis, based on expected deaths, eliminate the healthy worker effect, which hampered the study of cardiovascular disease among emergency workers in many previous investigations [15].

Our study does have limitations. Although the USFA provides a comprehensive database of deaths among US firefighters, it presents only limited medical information. However, we found that the identification of SCD was highly reliable: all 86 cases also analysed by NIOSH were confirmed as SCD by the more detailed clinical and autopsy reports. Another limitation of our study is the potential for misclassification of the last duty as the USFA database presents only a brief summary of the event. However, we found almost perfect agreement between the duties assessed using the USFA records and those based on NIOSH reports. Because the NIOSH investigations present detailed descriptions of the circumstances of deaths and of underlying medical causes, we believe that exposure misclassification and case ascertainment bias are not major concerns. The NIOSH criteria for investigation are likely to bias the estimates of the duty-related RRs based on NIOSH reports. Thus, it is not surprising that the RR associated with physical training and fire suppression were higher in this sub-selection of cases.

Table 2. Proportion of 205 USFA reported SCD cases (1996–2012) investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program[a]

Duty	Investigated by NIOSH Fire Fighter Fatality Investigation and Prevention Program		Pearson's χ^2
	No *n* (%)	Yes *n* (%)	*P* value
Fire station and other non-emergency duties	37 (71)	15 (29)	
EMS and other non-fire emergencies	7 (58)	5 (42)	
Physical training	12 (31)	27 (69)	
Alarm return	32 (76)	10 (24)	
Alarm response	12 (75)	4 (25)	
Fire suppression	19 (43)	25[b] (57)	
Total	119 (58)	86 (42)	<0.001

[a]Data stratified by type of duty.
[b]One case from 2012 investigated by NIOSH was not included in the US Fire Administration Database at the study date.

Table 3. Risk of SCD among young firefighters (age ≤ 45) engaged in emergency and strenuous duties compared with firefighters engaged in non-emergency duties[a]

Duty	Observed deaths (N = 206)	Expected deaths											
		Municipal department				Large metropolitan fire department				National data			
	n (%)	*E*[b]	O/E	IRR	95% CI	*E*[c]	O/E	IRR	95% CI	*E*[d]	O/E	IRR	95% CI
Fire station and other non-emergency duties	52 (25)	105.1	0.5	1.0	Ref.	59.7	0.9	1.0	Ref.	133.9	0.4	1.0	Ref.
EMS and other non-fire emergencies	12 (6)	47.4	0.3	0.5	0.3–1.0	70.0	0.2	0.2	0.1–0.4	30.9	0.4	1.0	0.5–1.9
Physical training	39 (19)	16.5	2.4	4.8	3.2–7.2	16.5	2.4	2.7	1.8–4.1	16.5	2.4	6.1	4.0–9.2
Alarm return	42 (20)	20.6	2.0	4.1	2.7–6.2	30.9	1.4	1.6	1.0–2.4	14.4	2.9	7.5	5.0–11.3
Alarm response	16 (8)	12.4	1.3	2.6	1.5–4.6	18.5	0.9	1.0	0.6–1.7	8.2	1.9	5.0	2.9–8.8
Fire suppression	45 (22)	4.1	10.9	22.1	14.8–32.9	10.3	4.4	5.0	3.4–7.5	2.1	21.8	56.2	37.7–83.8

E, expected; IRR, incidence rate ratio; O, observed; Ref, reference category.
[a]Data from the US Fire Administration (1996–2012) and NIOSH Fire Fighter Fatality Investigation and Prevention Program (1996–2012).
[b]Expected deaths based on municipal data from the Cambridge Fire Department, Cambridge, MA [2].
[c]Expected deaths based on a survey of 17 large metropolitan fire departments conducted by the International Association of Fire Fighters (L. Moore-Merrell, personal communication) [2].
[d]Expected deaths based on a national survey conducted by the National Fire Protection Association [3].

Information on personal cardiovascular risk factors was not available in the USFA database. However, personal risk factors are not confounders in our analysis. Indeed, we did not compare different populations, but the risk of SCD as a proportion of time spent in each duty. It is reasonable to assume that personal risk factors (such as obesity, hypertension and diabetes) are stable within the same subject over multiple work shifts, while job-related psycho-physiological stressors vary across work shifts. Tobacco smoking, an exogenous trigger of cardiovascular events, might bias our estimates towards the null hypothesis. Indeed smoking is much more frequent during downtime on routine duties and unlikely to occur in the heat of performing emergency/strenuous tasks.

Our risk estimates are lower than those reported in a previous study of duty-specific risk of SCD among firefighters of all ages [4]. This finding confirms age as an effect modifier of duty-specific SCD triggering [4]. Importantly, we observed higher duty-specific risks of SCD among firefighters with a positive history of cardiovascular diseases or conditions. This finding provides further support for the suggestion that firefighters with known CHD, other clinically significant atherosclerotic endpoints and/or considerable structural heart disease should be restricted from participating in fire emergencies

Table 4. Risk of SCD among young firefighters (age ≤ 45) engaged in emergency and strenuous duties compared with firefighters engaged in non-emergency duties: Analysis stratified on job position[a]

Duty	Volunteer firefighters					Career firefighters[b,c]				
	Observed deaths (N = 112)	Statistic				Observed deaths (N = 93)	Statistic			
	n (%)	E[c]	O/E	IRR	95% CI	n (%)	E[c]	O/E	IRR	95% CI
Fire station and other non-emergency duties	24 (21)	57.1	0.4	1.00	Ref.	28 (30)	47.4	0.6	1.00	Ref.
EMS and other non-fire emergencies	8 (7)	25.8	0.3	0.74	0.3–1.7	4 (4)	21.4	0.2	0.3	0.1–0.9
Physical training	15 (13)	9.0	1.7	3.98	2.1–7.6	24 (26)	7.4	3.3	5.5	3.2–9.4
Alarm return	25 (22)	11.2	2.2	5.31	3.0–9.3	17 (18)	9.3	1.8	3.1	1.7–5.7
Alarm response	16 (14)	6.7	2.4	5.67	3.0–10.7	0 (0)	5.6	0.7[e]	0.0	0.0–1.2[f]
Fire suppression	24 (21)	2.2	10.7	25.5	14.5–44.9	20 (22)	1.9	10.8	18.2	10.3–32.3

E, expected; IRR, incidence rate ratio; Ref, reference category.
[a]Data from the US Fire Administration (1996–2012) and NIOSH Fire Fighter Fatality Investigation and Prevention Program (1996–2012).
[b]Including two trainees.
[c]The death of one wildland firefighter was excluded.
[d]Expected deaths based on municipal data from the Cambridge Fire Department, Cambridge, MA [2].
[e]Upper bound of the 95% confidence limit.
[f]Exact confidence interval.

Table 5. Risk of SCD among young firefighters (age ≤ 45) engaged in emergency and strenuous duties compared with firefighters engaged in non-emergency duties: Analysis stratified on history of cardiovascular condition[a]

Duty	Firefighters with a positive history of cardiovascular condition[b]					Firefighters without a history of cardiovascular condition[b]				
	Observed deaths (N = 33)	Statistic				Observed deaths (N = 54)	Statistic			
	n (%)	E[c]	O/E	IRR	95% CI	n (%)	E[c]	O/E	IRR	95% CI
Fire station and other non-emergency duties	3 (9)	16.8	0.2	1.0	Ref.	13 (24)	22.4	0.6	1.0	Ref.
EMS and other non-fire emergencies	1 (3)	7.6	0.1	0.7	0.1–7.1	4 (7)	10.1	0.4	0.7	0.2–2.1
Physical training	12 (36)	2.6	4.6	25.5	7.2–90.4	15 (28)	3.5	4.3	7.4	3.5–15.5
Alarm return	5 (15)	3.3	1.5	8.5	2.0–35.6	4 (7)	4.4	0.9	1.6	0.5–4.8
Alarm response	2 (6)	2.0	1.0	5.7	1.0–33.9	2 (4)	2.6	0.8	1.3	0.3–5.8
Fire suppression	10 (30)	0.7	15.2	85.0	23.4–308	16 (30)	0.9	18.2	31.4	15.1–65.2

E, expected; IRR, incidence rate ratio; O, observed; Ref, reference category.
[a]Data from NIOSH Fire Fighter Fatality Investigation and Prevention Program (1996–2012).
[b]Includes history of irregular rhythm, CHD or equivalent, valvular disease, abnormal electrocardiogram, chest pain or shortness of breath.
[c]Expected deaths based on municipal data from the Cambridge Fire Department, Cambridge, MA [2].

and certain forms of strenuous physical training [8,15]. Additionally, firefighters with cardio-respiratory symptoms or abnormal electrocardiogram findings should receive sufficient evaluation to exclude underlying disease.

EMS and other non-fire emergencies did not convey increased SCD risk in this and in previous studies [3,4]. This was also true for firefighters with pre-existing disease. Therefore, we suggest that restricted EMS duties might offer a safer alternative for carefully selected firefighters with known heart disease. All deaths related to alarm response were observed among volunteer, paid on-call or part-time firefighters. Greater sympathetic stimulation due to use of personal vehicles to reach the site of the emergency, a lesser frequency of calls or a combination of both could explain the observed difference. It is also possible that volunteers spend different proportions

of time in each duty compared with career firefighters. However, we did not observe major differences for the estimates of duty-related risks other than alarm response.

Several factors could contribute to the risk of SCD observed for emergency duties. The risk of SCD increases considerably in presence of moderate or strenuous exertion [16]. Core temperatures over 38.5°C have been documented during fire ground activities[17] and working in a hot environment while wearing heavy protective clothing may result in severe dehydration leading to volume depletion, alterations of plasma electrolyte concentrations, hyperviscosity and coagulatory changes [5,18]. Exposure to toxic substances (e.g. carbon monoxide, cyanides and particulates) could be another contributory factor during fire emergencies [15], as could psychological stress [19]. Previous studies have highlighted a substantial increase in heart rate responses immediately following an initial alarm [20,21]. Finally, shift work is associated with an increased risk of cardiac events, probably due to the disruption of circadian rhythms [22].

We previously reported that traditional cardiovascular risk factors (hypertension, obesity and cigarette smoking) are associated with SCD among young firefighters by contributing to atherosclerosis and cardiac hypertrophy [8]. These findings were based on the NIOSH database and included the 87 SCD events analysed in this study. Notably the prevalence of obesity was found to be as high as 63%, 48% of subjects had a diagnosis of hypertension, 28% of firefighters were current smokers at the time of the death and 66% of SCD occurred among firefighters with a heart weight >450 g [8]. Among the 87 SCD cases investigated by NIOSH, it was surprising to discover that when we stratified the distribution of cardiovascular risk factors by duty associated with the death we observed a lower median body mass index among subjects deceased during less stressful duties [8]. This finding could be an artefact driven by selective investigations. Unexplained deaths, for example, during resting periods among subjects assumed to have been healthy, naturally attract investigators' attention. It is not surprising that death during physical training was more common among non-smokers and younger firefighters because these individuals probably spend more time in physical training.

Previous studies have already highlighted that the prevalence of obesity, hypertension and low aerobic capacity among US firefighter recruits is surprisingly high [23–26]. There is also growing evidence that LVH is common among active US firefighters [3,6,8]. These observations support the hypothesis that the cardiovascular strain associated with firefighting may trigger SCD in susceptible individuals with underlying heart disease (most often CHD and LVH) [5]. Prevention strategies aimed at modifying traditional risk factors might be effective in reducing the burden of SCD among young firefighters [26]. Dietary interventions may be particularly promising. A recent study of US firefighters described low compliance to a Mediterranean-like diet [27], which would probably be effective in decreasing CVD risk [28]. Interventions aimed at improving physical fitness could be effective as well, as it is known that increasing cardio-respiratory fitness has beneficial effects on cardiovascular disease risk factor profiles among firefighters [29,30].

In conclusion, our study provides evidence that performing emergency duties increases the risk of SCD among young firefighters with underlying heart disease. Less strenuous restricted EMS duties should be considered as a safer alternative for firefighters with a significant history of cardiovascular disease. Prevention strategies aimed at reducing the burden of traditional cardiovascular risk factors among young firefighters are needed [30].

Key points

- Performing strenuous duties is associated with an increased risk of sudden cardiac death among young firefighters, particularly those with a pre-existing history of a cardiovascular condition.
- Firefighters with symptoms or abnormal electrocardiogram findings should receive sufficient evaluation to exclude underlying heart disease.
- Restricted emergency medical service duties might be considered for selected firefighters with known cardiovascular disease.

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Conflicts of interest

S.N.K. and D.L.S. report serving as paid expert witnesses, independent medical examiners or both in cases involving firefighters. No other potential conflict of interest relevant to this article was reported.

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Appendice C. Farioli et al. J Am Heart Assoc. 2015;4:e001818.

ORIGINAL RESEARCH

Incidence of Sudden Cardiac Death in a Young Active Population

Andrea Farioli, MD; Costas A. Christophi, PhD; Candida Cristina Quarta, MD, PHD; Stefanos N. Kales, MD, MPH

Background—Little is known about the burden of sudden cardiac death (SCD) among active, presumably healthy persons. We investigated the incidence of SCD among US male career firefighters.

Methods and Results—All on-duty SCDs among US male career firefighters between 1998 and 2012 were identified from the US Fire Administration and the US National Institute for Occupational Safety and Health databases. Age-specific incidence rates (IRs) of SCD with 95% CIs were computed. A joinpoint model was fitted to analyze the trend in IR and to help estimate the annual percentage change of SCD rates over the years. The effects of seasonality were assessed through a Poisson regression model. We identified 182 SCDs; based on 99 available autopsy reports, the leading underlying cause of death was coronary heart disease (79%). The overall IR was 18.1 SCDs per 100 000 person-years. The age-specific IRs of SCD ranged between 3.8 (for those aged 18 to 24 years) and 45.2 (for those aged 55 to 64 years) per 100 000 person-years. The annual rate of SCD steadily declined over time (annual percentage change −3.9%, 95% CI −5.8 to −2.0). SCD events were more frequent during January (peak-to-low ratio 1.70; 95% CI 1.09 to 2.65). In addition, the IR was 3 times higher during high-risk duties compared with low-risk duties. IRs among firefighters were lower than those observed among the US general population and US military personnel.

Conclusions—SCD risk in this active working population is overestimated using statistics from the general population. To address public health questions among these subpopulations, more specific studies of active adults should be conducted. (***J Am Heart Assoc.* 2015;4:e001818 doi: 10.1161/JAHA.115.001818**)

Key Words: death • epidemiology • men • registries • statistics • sudden

Sudden cardiac death (SCD) is a natural death resulting from cardiac causes.[1] According to the widely accepted definition, SCD is heralded by abrupt loss of consciousness within 1 hour of the onset of the symptoms.[1] When the event is unwitnessed, the definition of SCD is extended to deaths occurring in normally functioning persons last seen alive and well within 24 hours.[1]

From the Department of Environmental Health (Environmental & Occupational Medicine & Epidemiology), Harvard TH Chan School of Public Health, Boston, MA (A.F., C.A.C., S.N.K.); The Cambridge Health Alliance, Harvard Medical School, Cambridge, MA (A.F., S.N.K.); Department of Medical and Surgical Sciences (DIMEC), University of Bologna, Italy (A.F.); Cyprus International Institute for Environmental and Public Health in association with Harvard School of Public Health, Cyprus University of Technology, Limassol, Cyprus (C.A.C.); Cardiovascular Division, Brigham and Women's Hospital, Harvard Medical School, Boston, MA (C.C.Q.); Institute of Cardiology, University of Bologna and S.Orsola-Malpighi Hospital, Bologna, Italy (C.C.Q.).

Correspondence to: Stefanos N. Kales, MD, MPH, Cambridge Hospital Macht Building 427, 1493 Cambridge Street, Cambridge, MA 02139. E-mail: skales@hsph.harvard.edu

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The etiology of SCD has been investigated thoroughly in 2 different groups: the general population and young athletes.[2–5] The leading cause of SCD in the general population is coronary heart disease (CHD), which accounts for 80% of the deaths, followed by cardiomyopathies (10% to 15% of the SCDs).[6] In contrast, among young athletes, CHD is responsible for only 3% of SCDs.[7] In this group, most SCDs are attributable to hypertrophic cardiomyopathy (10% to 51%), myocarditis (5% to 22%), arrhythmogenic right ventricular cardiomyopathy (up to 25%), and ion channel diseases (ie, long QT syndrome, short QT syndrome, Brugada syndrome, catecholaminergic polymorphic ventricular tachycardia; 2% to 10%).[5,8,9]

The incidence of SCD among athletes is 1 to 2 deaths per 100 000 person-years.[5,8] As expected, estimates of SCD incidence in the general population are much higher, ranging from 40 to 100 deaths for 100 000 person-years.[2,6] Statistics on SCD are useful to inform policy makers and scientists about the global burden of SCD and the need for prevention efforts, including screening protocols, identification of risk-stratification tools, availability of public-access defibrillators, and implementation of primary prevention strategies.[2,6]

Unfortunately, little is known about the incidence of SCD in active adult populations. SCD rate estimates in the general population are probably driven by incidence among high-risk subjects, such as those with a long history of chronic disease.

At the same time, current knowledge about competitive or young athletes cannot be easily translated to other settings because of the significant differences in the age distributions and underlying etiology.[10]

The study of the active workforce would present a valuable source of information on the incidence of SCD among presumably "healthy" adults. Unfortunately, previous studies have demonstrated that the retrospective assessment of SCD based on death certificates alone is not as accurate, and SCD rates may be largely overestimated.[11,12] Only a few occupational cohorts have sample sizes adequate to study the incidence of SCDs. At present, the only study of SCD incidence among young active male adults was conducted among US military personnel.[13]

The US Fire Administration (USFA) collects data on all on-duty firefighter fatalities occurring in the United States, and reliable estimates of the number of US career firefighters are available from the Current Population Survey (CPS).[14,15] In addition, the National Institute for Occupational Safety and Health (NIOSH) performs independent investigations of firefighter line-of-duty deaths[16]; the investigative reports have already proven to be a valuable source of information for etiologic studies.[17–20]

The aim of the present study is to investigate the rate of SCD among US male career firefighters using data from the USFA, to compare this rate with the corresponding rates among military personnel and the general population, and to assess the change in incidence rate (IR) over the study period and the effects of seasonality on SCD.

Methods

Study Population

The study population is the dynamic cohort of ≈300 000 US full-time male career firefighters employed between January 1, 1998, and December 31, 2012. Only firefighters aged 18 to 64 years were included in the cohort.

The CPS, conducted by the US Census Bureau for the Bureau of Labor Statistics, is the primary source of labor statistics in the United States. The CPS uses a complex stratified sampling technique that identifies 824 (formerly 754 until July 2004) geographic sample areas and then selects clusters of households within each area.[21] Of the roughly 72 000 households selected each month, about 60 000 are occupied and eligible for interview; among eligible households, the response rate is ≈92.5%.[21] On average, information is collected from around 112 000 persons aged ≥16 years every month.[21] The survey inquires about the calendar week that includes the 12th day of the month. Since January 2003, occupational titles have been classified according to the 2002 Census Industry and Occupation Classification Codes[21]; the 1990 version of the classification was used through December 2002. Persons who usually work ≥35 hours per week are defined as full-time workers.

Table 1 presents the study population at risk for SCD and the corresponding person-years. We estimated the number of US career firefighters based on the CPS surveys conducted monthly between January 1998 and December 2012. We included as career firefighters all full-time workers classified as *first-line supervisors/managers firefighting and fire prevention workers* (1990 classification: code 413/2002 classification: code 3720), *fire inspectors* (code 416/3750), and *firefighters* (code 417/3740). Of note, the number of active firefighters ascertained through the CPS databases was very close to the figures reported annually by the National Fire Protection Agency.[22] Because ascertainment of SCD is virtually complete only for on-duty events, we considered only working time as the exposure or time for being at risk.

Firefighting duties have been associated with an increased risk of SCD.[23,24] In particular, studies showed an increased risk of SCD during physical training, alarm response, alarm return, and fire suppression (including all operational activities on the fire ground).[17,18,25,26] In contrast, the risk of SCD during emergency medical services, rescues, and other nonfire emergencies has been consistently reported to be in line with the risk associated with nonemergency or routine duties.[17,18,25,26] Furthermore, increased rates of SCD during stressful duties have been reported among other emergency-worker categories, such as law enforcement officers.[27] Moreover, we distinguished between SCDs that occurred during low-risk duties (eg, fire station tasks and other nonemergency or routine duties, emergency medical services, rescues, and other nonfire emergencies) and those that occurred during high-risk duties (eg, physical training, alarm response, alarm return, and fire suppression). Estimates of the average time spent by firefighters in low- and high-risk duties have been reported in previous studies[17,25]; therefore, we assumed that 74% of the total observed person-years had been spent on low-risk duties (23% emergency medical services and other nonfire emergencies and 51% fire station and other nonemergency duties) and that the remaining 26% of the observed person-years was spent on high-risk duties (8% physical training, 6% alarm response, 10% alarm return, and 2% fire suppression).

The present study, involving only deceased persons, was exempt from institutional review board review, based on US federal law, which classifies research on deceased, nonliving subjects as exempt non–human subjects investigation.[28] All data were extracted from publicly available electronic databases maintained by US federal agencies. We created a database that excluded any personal identifiers, and to

Table 1. Career Firefighters in the United States (1998–2012)

	SCD	Firefighters*	Person-Time†	Crude Estimates		Age-Adjusted Estimates	
Year	n	n	pyrs	IR	95% CI	IR	95% CI
1998	15	248 509	58 966	25.4	15.3 to 42.2	27.5	13.4 to 41.7
1999	10	244 192	57 942	17.3	9.3 to 32.1	20.0	7.5 to 32.6
2000	12	240 183	56 991	21.1	10.7 to 34.9	21.5	9.3 to 33.7
2001	12	257 545	61 110	19.6	11.2 to 34.6	19.9	8.6 to 31.1
2002	13	256 179	60 786	21.4	12.4 to 36.8	23.6	10.6 to 36.6
2003	16	277 004	65 728	24.3	14.9 to 39.7	24.8	12.6 to 36.9
2004	13	280 625	66 587	19.5	11.3 to 33.6	20.0	9.0 to 31.1
2005	12	260 689	61 856	19.4	11.0 to 34.2	19.8	8.6 to 31.0
2006	11	269 062	63 843	17.2	9.5 to 31.1	16.7	6.8 to 26.6
2007	15	305 439	72 475	20.7	12.5 to 34.3	21.2	10.4 to 31.9
2008	7	317 734	75 392	9.3	4.4 to 19.5	9.0	2.3 to 15.7
2009	10	310 675	73 717	13.6	7.3 to 25.2	13.0	4.9 to 21.2
2010	12	312 019	74 036	16.2	9.2 to 28.5	15.9	6.9 to 25.0
2011	12	315 725	74 915	16.0	9.1 to 28.2	17.3	7.5 to 27.1
2012	12	332 732	78 951	15.2	8.6 to 26.8	15.0	6.4 to 23.6

IR indicates incidence rate; pyrs, person-years; SCD, sudden cardiac death.
*The yearly number of career firefighters was estimated as the average of the firefighters reported by the monthly Current Population Survey.
†Person-time for each year was estimated as the total number of working hours.

preserve the anonymity of the study population, we present only aggregate data.

Databases on Firefighter Fatalities

We collected on-duty SCD data from the USFA and from the NIOSH Fire Fighter Fatality Investigation and Prevention Program. The USFA maintains a systematic database of all deaths associated with firefighting in the United States since 1981.[14] Of note, identifying and reporting cardiac death among firefighters is mandatory in the United States (section 1201 of the Omnibus Crime Control and Safe Streets Act of 1968 [42 U.S.C. 3796] and Hometown Heroes Survivors Benefits Act of 2003). The USFA actively collects information of firefighter deaths directly from fire services and from many external sources, including the USFA Public Safety Officers' Benefits program administered by the US Department of Justice, NIOSH, the Occupational Safety and Health Administration, the US Department of Defense, the National Interagency Fire Center, and other federal agencies. Furthermore, the USFA exchanges information with fire service organizations. Each USFA record includes the deceased person's name, age, rank, and classification (volunteer versus career) and the date of incident, date of death, type of location (eg, residential, street), cause and nature of death, duty (type, specific activity, emergency context), and a narrative summary of the event (systematically available after 1993). For the years 1998–2000, we cross-validated the information contained in the USFA databases with the records included in the Firefighters Fatality Retrospective Study.[29]

The NIOSH program aims to investigate firefighter line-of-duty deaths for prevention purposes.[16] The NIOSH database is neither representative nor comprehensive; however, all reports present a detailed description of the event and, if relevant, a summary of the clinical history (including emergency medical services records) and postmortem examination findings. Since 1994, the USFA has recommended the performance of an autopsy for all fatalities possibly associated with firefighting[14]; however, the final decision to undertake an autopsy is at the discretion of the local coroners.

Eight records included only in the USFA database presented missing or insufficient information on age, cause and dynamic of death, or career status. We were able to retrieve missing information through an Internet search for data from newspapers, firefighters associations (eg, the line-of-duty deaths database of the International Association of Firefighters, http://www.iaff.org/hs/LODD), and obituaries. To validate the accuracy of the data retrieved with the above methods, we cross-checked the name, date and circumstances of death, and firefighter employment in the retrieved

information against the USFA database records. In this way, we were able to retrieve all missing data.

Identification of SCD Cases and Data Extraction

We examined all USFA records for on-duty fatalities that occurred between January 1998 and December 2012 that were listed as heart attacks, cerebrovascular accidents, heat exhaustion, or "other." We also reviewed all "medical related" deaths from the NIOSH database. Two physicians independently examined the summary report of each record. We extracted the following information: age, sex, cause of death (cardiac or noncardiac), onset of symptoms (within 1 hour of collapse or not), dynamic of the event (directly witnessed versus subject last seen alive and symptom free within 1 hour or 24 hours before death), and the type of duty performed during the onset of the symptoms. From NIOSH records, we were also able to retrieve information on the presence of a shockable rhythm during resuscitation efforts (as assessed through the use of automated external defibrillators). We classified an event as *on duty* if the onset of the symptoms occurred during the firefighter's work shift. For cases in which the information extracted from the USFA and NIOSH reports were not in agreement, we relied on the more comprehensive narrative information provided by the NIOSH reports.

SCD was defined as an unexpected death of cardiac origin that occurred within 1 hour of the onset of symptoms (witnessed) or within 24 hours of having been seen alive and without symptoms (unwitnessed). In our analysis, we included only cardiovascular deaths in which, after the collapse, the person never regained consciousness prior to biological death. We excluded pulmonary embolisms and cerebrovascular and aortic events and deaths associated with trauma, violent death, overdose, or drowning.

Comparison With the General Population and Military Personnel

We compared the rates of SCD registered in our study population with those reported for the US male general population and US male military personnel.

The military study by Eckart and colleagues represents the only source of information on the incidence of SCD in a large working population.[13] Like firefighters, military personnel represent a highly selected population undergoing pre-employment screening and health surveillance. Eckart and colleagues reported solid findings based on high autopsy rates and reliable identification of the source population. Moreover, their case definition, like ours, included only SCD of cardiac origin, excluding pulmonary embolisms and aortic dissections.

Highly reliable estimates of the incidence of SCD in the US general population are available from multiple-source surveillance of inhabitants of Multnomah County, Oregon[11,30]; however, the case definition of SCD in this study also included thoracic aortic dissection. Consequently, when comparing our figures with those reported by Chugh and colleagues, we extended our case definition to include thoracic aortic dissections.

Statistical Analysis

We assessed the agreement between the USFA and the NIOSH databases with Cohen's κ. We compared non-normally distributed continuous variables, expressed as median and interquartile range, between groups using the Mann–Whitney *U* test and categorical variables, described as number and percentage, with Pearson's chi-square test.

We calculated the age-specific (10-year categories) IRs of SCD per 100 000 person-years and computed the 95% CI associated with each rate. Assuming a full-time equivalent of 2080 work hours per year,[30] we estimated the total at-risk person-years (ie, the total amount of working hours among full-time career firefighters) using the following formula:

$$\text{Person-years} = \frac{2,080}{365.25 \times 24} \times \sum_{\text{year}=1998}^{2012} \left[\sum_{\text{month}=\text{Jan}}^{\text{Dec}} \frac{\text{N of days of the month}}{365.25} \times \text{N of firefighters} \right]$$

For purposes of external comparison, we calculated age-standardized mortality rates with exact CI. We also calculated age-adjusted (10-year classes) monthly and annual rates of SCD through direct standardization using the entire study population as the reference standard.

To estimate the seasonal intensity of SCD based on monthly counts, we fitted the following Poisson model[31]:

$$\log E(Y) = \beta_0 + \beta_1 \times \sin(2\pi \times \text{month}/12) + \beta_2 \times \cos(2\pi \times \text{month}/12),$$

We modeled monthly counts adjusted for the size of the denominators and rescaled to sum up to the total number of observed events. Periodic models are used to study seasonal effects through standard regression models adapting a sine curve to a time series of frequencies. Consequently, through the inclusion of sine and cosine terms (the number of terms introduced determines the number of peaks allowed by the model), it is possible to fit the observed data using traditional maximum likelihood estimators (usually a Poisson regression model for counts). Overdispersion in our data was assessed

through the likelihood ratio test for the overdispersion parameter. A simple parameterization of the model including only 1 sinusoid was chosen based on the observed data and a previous report that highlighted only a very small secondary peak of CHD deaths among firefighters in the late summer.[32] The single sinusoid parameterization allowed a closed-form estimation of the peak-to-low ratio (a measure that compares the periods with the highest and lowest incidence) with CI.[31]

To estimate the annual percentage change in age-standardized SCD rates, we applied joinpoint regression models.[33] A joinpoint represents a knot at which an important change in the temporal trend occurs; joinpoints are estimated iteratively and do not require the specification of an a priori hypothesis about the location of the knots to be tested. We fitted a log-linear joinpoint model maximized on standard error–weighted least squares to account for heteroscedasticity. We also allowed for autocorrelation of the residuals to account for the fact that the observed rates are not independent. We tested for up to 2 joinpoints through a Monte Carlo permutation test based on 10 000 repetitions.

Statistical analyses were performed using Stata 12.1 SE (Stata Corp) and the Joinpoint Regression Program 4.1 (Statistical Research and Applications Branch, National Cancer Institute). We defined statistical significance as a 2-sided *P* value of <0.05.

Results

Figure 1 summarizes the flowchart for the 182 SCD cases included in the analysis. Using the deaths included in the USFA database from 1998 onward, we selected 872 records of potential cardiovascular deaths. After the exclusion of events that did not meet our case definition, we ended up with 182 SCD events that occurred among full-time male career firefighters aged 18 to 64 years during the study period (1998–2012). In 143 of these cases (79%), the deceased person was reported to be symptom-free 1 hour before a witnessed collapse.

After examining all medical-related deaths among firefighters from the NIOSH databases (n=255), we identified 141 potential SCD cases. All of these deaths were included among the 872 events listed by USFA as "heart attacks, cerebrovascular accidents, heat exhaustions, or other." After further assessment, we excluded 12 of these deaths because they did not satisfy our case definition and 9 additional deaths that occurred off duty; therefore, the NIOSH reports included 120 (66%) of the SCDs reported by the USFA database. The assessment of SCD cases, events occurring on duty, and duty at the time of the death (high or low risk) showed a very high level of agreement between the 2 databases (all Cohen's κ 0.95). An autopsy report was available for 99 (83%) of the cases investigated by NIOSH (corresponding to 54% of the total study population).

Table 2 presents several characteristics of the SCD events by the availability of an autopsy report. The ages of the firefighters and the years of events were comparable between the 2 groups; however, autopsy reports were more likely to be available for SCDs that occurred during high-risk duties, during the daytime, and in the presence of a witness.

The IRs of SCD in groups of 10-year increments are reported overall and separately for low- and high-risk duties in Table 3. The overall IR in the study population is 18.1 per 100 000 person-years (95% CI 15.7 to 21.0); as expected, the IR is lower for low-risk duties (IR 11.0 per 100 000 person-years, 95% CI 8.9 to 13.7) compared with high-risk duties (IR 38.3 per 100 000 person-years, 95% CI 31.5 to 46.6). We observed the highest IR among firefighters aged 54 to 64 years (IR 45.2 per 100 000

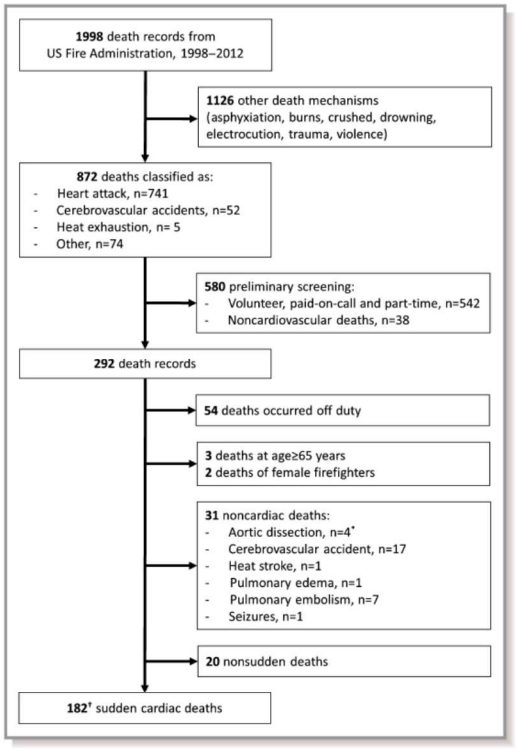

Figure 1. Identification of the sudden cardiac deaths from the US Fire Administration records (1998–2012). *One aortic dissection satisfied the definition of sudden death; †183 sudden cardiac deaths when applying the broader case definition also including thoracic aortic dissection.

Table 2. Characteristics of Sudden Cardiac Death Events by Availability of an Autopsy Report

Characteristic	Autopsy Report		*P* Value
	Not Available (n=83)	Available (n=99)	
Age, y, median (IQR)	49 (44 to 53)	48 (43 to 52)	0.08*
Duty at the time of the death			
Low-risk duty, n (%)	51 (61)	31 (31)	
High-risk duty, n (%)	32 (39)	68 (69)	<0.001†
Time of the death			
Night (00:00 to 05:59), n (%)	22 (29)	16 (16)	
Morning (06:00 to 11:59), n (%)	18 (24)	25 (25)	
Afternoon (12:00 to 17:59), n (%)	19 (25)	36 (36)	
Evening (18:00 to 23:59), n (%)	17 (22)	22 (22)	0.008†,‡
Unknown, n (%)	7	0	
Witnessed event			
No, n (%)	22 (27)	14 (14)	
Yes, n (%)	58 (72)	85 (86)	0.027†,‡
Unknown, n (%)	3	0	
Year			
1998–2002, n (%)	23 (28)	39 (39)	
2003–2007, n (%)	32 (39)	35 (35)	
2008–2012, n (%)	28 (34)	25 (25)	0.218†

*Mann–Whitney *U* test.
†Pearson's chi-square test.
‡Test performed excluding the "unknown" category.

person-years, 95% CI 31.2 to 65.5) and the lowest IR in the group aged 25 to 34 years (IR 3.8 per 100 000 person-years, 95% CI 2.1 to 6.9).

Table 4 presents the causes of deaths as reported in the available autopsy reports (n=99). CHD was the most common underlying cause of death (n=77, 78%); in 57 of 77 cases, CHD was accompanied by an enlarged heart (58%). Left ventricular hypertrophy coupled with hypertensive heart disease was the underlying cause of death in 7 events (7%). Four cases of SCD were attributed to valvular heart diseases. The 2 cases of SCD in persons aged <25 years were determined to be due to cardiac arrhythmias (in both cases, the specific etiopathogenesis remained undetermined). CHD accounted for 43% of the SCDs in the group aged 25 to 34 years and for 68% in the group aged 35 to 44 years.

Figure 2 shows the annual age-standardized rates of SCD (also reported in Table 1). The joinpoint model highlighted a constant decline of SCD during the study period (annual percentage change −3.9%, 95% CI −5.8 to −2.0). The decrease in SCD incidence was driven mainly by a decline of rates among firefighters aged ≥55 years (Table 5).

The monthly counts of SCD presented seasonal variation over the study period (Figure 3A). The incidence peaked in January, with a peak-to-low ratio of 1.70 (95% CI 1.09 to 2.65). The distribution of SCD events by period of day is also reported in Figure 3B, indicating that the higher number of events occurred during the afternoon (31%), followed by the morning (25%).

Figure 4 presents a comparison between the incidence of SCD events among US firefighters and data reported in the medical literature on other populations. The age-specific IRs observed among US firefighters are similar to those reported for the US military personnel for subjects aged up to 49 years (Figure 4A); however, among people aged >50 years, the US firefighters do not show the sharp increase in IR that was documented among military personnel. This finding is confirmed when looking at the ratios between the observed numbers of SCD among firefighters and the expected numbers of SCD calculated based on the rates presented by Eckart and colleagues (Table 6). Indeed, only the ratios for

Table 3. Incidence of Sudden Cardiac Death Among US Male Career Firefighters

Age	All Duties				Low-Risk Duties*				High-Risk Duties*			
	SCDs	pyrs†	IR	95% CI	SCDs	pyrs†	IR	95% CI	SCDs	pyrs†	IR	95% CI
Overall rate	182	1 003 296	18.1	15.7 to 21.0	82	742 439	11.0	8.9 to 13.7	100	260 857	38.3	31.5 to 46.6
18 to 24 years	3	55 888	5.4	1.7 to 16.6	2	41 357	4.8	1.2 to 19.3	1	14 531	6.9	1.0 to 48.9
25 to 34 years	11	286 989	3.8	2.1 to 6.9	7	212 372	3.3	1.6 to 6.9	4	74 617	5.4	2.0 to 14.3
35 to 44 years	45	360 067	12.5	9.3 to 16.7	14	266 450	5.3	3.1 to 8.9	31	93 618	33.1	23.3 to 47.1
45 to 54 years	95	238 430	39.8	32.6 to 48.7	49	176 438	27.8	21.0 to 36.7	46	61 992	74.2	55.6 to 99.1
55 to 64 years	28	61 921	45.2	31.2 to 65.5	10	45 822	21.8	11.7 to 40.6	18	16 100	111.8	70.4 to 177.5

Data are from the US Fire Administration (1998–2012). IR indicates incidence rate; pyrs, person-years; SCD, sudden cardiac death.
*The proportion of time spent in low- or high-risk duty was estimated based on the Cambridge (Massachusetts) Fire Department.[17,25]
†Estimates based on the Current Population Survey (1998–2012).[15]

Table 4. Cause of Death as Presented in Autopsy Reports

	Age Category																	
	Total			18 to 24			25 to 34			35 to 44			45 to 54			55 to 64		
Cause of Death	n	%	95% CI	n	%	95% CI	n	%	95% CI	n	%	95% CI	n	%	95% CI	n	%	95% CI
Arrhythmia*	3	3	1 to 9	2	100	16 to 100	1	14	0 to 58	0	0	0 to 12	0	0	0 to 7	0	0	0 to 25
Cardiac sarcoidosis	2	2	0 to 7	0	0	0 to 84	0	0	0 to 41	2	7	1 to 24	0	0	0 to 7	0	0	0 to 25
CHD	20	20	13 to 29	0	0	0 to 84	0	0	0 to 41	5	18	6 to 37	10	20	10 to 34	5	38	14 to 68
CHD and cardiomegaly	57	58	47 to 67	0	0	0 to 84	3	43	10 to 82	14	50	31 to 69	34	69	55 to 82	6	46	19 to 75
Dilated cardiomyopathy	1	1	0 to 5	0	0	0 to 84	1	14	0 to 58	0	0	0 to 12	0	0	0 to 7	0	0	0 to 25
HCM	4	4	1 to 10	0	0	0 to 84	1	14	0 to 58	2	7	1 to 24	1	2	0 to 11	0	0	0 to 25
LVH/HHD	7	7	3 to 14	0	0	0 to 84	0	0	0 to 41	3	11	2 to 28	3†	6	1 to 17	1	8	0 to 36
Myocarditis	1	1	0 to 5	0	0	0 to 84	0	0	0 to 41	1	4	0 to 18	0	0	0 to 7	0	0	0 to 25
Valvular disease	4	4	1 to 10	0	0	0 to 84	1	14	0 to 58	1	4	0 to 18	1	2	0 to 11	1	8	0 to 36
Total	99			2			7			28			49			13		

Data are from the NIOSH Fire Fighter Fatality Investigation and Prevention Program (1998–2012). CHD indicates coronary heart disease; HCM, hypertrophic cardiomyopathy; HHD, hypertensive heart disease; LVH, left ventricular hypertrophy; NIOSH, National Institute for Occupational Safety and Health.
*Presumed arrhythmic event in the absence of structural disease.
†One subject presented acute ethanol intoxication.

subjects aged 45 to 49 or ≥50 years demonstrate a decrease in SCD for firefighters compared with military personnel. When we compared our figures with those from the US male general population, we documented a lower incidence of SCD in almost all age categories, with the only exception being those aged 45 to 54 years (Figure 4B and Table 4). Nevertheless, we observed the most dramatic difference between the 2 populations among those aged 55 to 64 years, for whom the observed-to-expected ratio was as low as 0.23 (95% CI 0.15 to 0.33).

Using data on witnessed events investigated by NIOSH (N=102), we estimated the proportion of deceased persons that presented a shockable rhythm during their collapse. Four cases were excluded from this analysis because of insufficient information in the NIOSH reports (n=2) or late assessment of cardiac rhythm (n=2). Among 98 subjects with complete information, 78 (80%, 95% CI 70% to 87%) presented a shockable rhythm; 96 received 1 or more series of shocks, whereas in 2 cases, defibrillator use was not possible because of device malfunction or the presence of very wet conditions.

Discussion

In a dynamic cohort of about 300 000 US firefighters followed between 1998 and 2012, we observed an IR of SCD of 18.1 per 100 000 person-years; the rate was lower when considering low-risk duties (11.0 per 100 000 person-years). We documented a decline of SCD incidence over the study period, driven mainly by a decrease in the rates among firefighters aged ≥55 years. As expected, the incidence of SCD peaked in January, whereas we did not observe the typical excess of morning deaths compared with other periods of day. Based on NIOSH reports, CHD was the main cause of SCD; this finding also applies to relatively young (aged 25 to 44 years) firefighters. Taken together, hypertrophic cardiomyopathy,

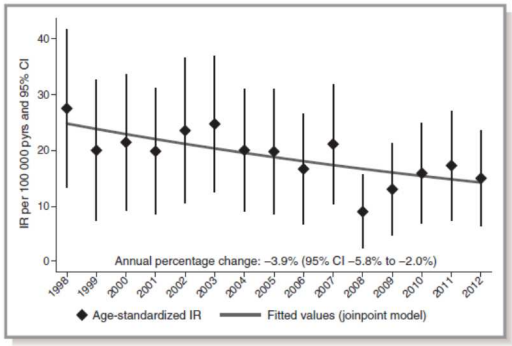

Figure 2. Age-adjusted incidence rates of sudden cardiac death by year for US male career firefighters, 1998–2012. IR indicates incidence rates; pyrs, person-years.

Table 5. Incidence Rates of Sudden Cardiac Death by Calendar Period and Age

	1998–2002				2003–2007				2008–2012			
Age	SCDs	pyrs*	IR	95% CI	SCDs	pyrs*	IR	95% CI	SCDs	pyrs*	IR	95% CI
Overall rate	62	295 796	21.0	16.3 to 26.9	67	330 489	20.3	16.0 to 25.8	53	377 011	14.1	10.7 to 18.4
18 to 24 years	0	17 002	0.0	0.0 to 21.7	2	17 761	11.3	2.8 to 45.0	1	21 126	4.7	0.7 to 33.6
25 to 34 years	6	79 897	7.5	3.4 to 16.7	2	98 843	2.0	0.5 to 8.1	3	108 250	2.8	0.9 to 8.6
35 to 44 years	13	115 764	11.2	6.5 to 19.3	17	115 385	14.7	9.2 to 23.7	15	128 919	11.6	7.0 to 19.3
45 to 54 years	28	69 326	40.4	27.9 to 58.5	40	77 967	51.3	37.6 to 69.9	27	91 136	29.6	20.3 to 43.2
55 to 64 years	15	13 807	108.6	65.5 to 180.2	6	20 533	29.2	13.1 to 65.0	7	27 581	25.4	12.1 to 53.2

IR indicates incidence rate; pyrs, person-years; SCD, sudden cardiac death.
*Estimates based on the Current Population Survey (1998–2012).

myocarditis, and arrhythmias accounted for only 6% of the observed SCDs. We observed a high proportion (80%) of shockable rhythms among SCDs investigated by NIOSH.

Firefighters are generally regarded as a selected group of healthy workers.[34] By the very nature of their presumably high levels of fitness and health, they are expected to show a lower risk of cardiac events compared with the general population ("healthy worker effect").[34] The healthy worker effect is determined by 2 main components: the initial selection process and the continuing employment of healthy persons.[35] Both components seem to contribute to the decreased risk of SCD observed when we compared our population with the US

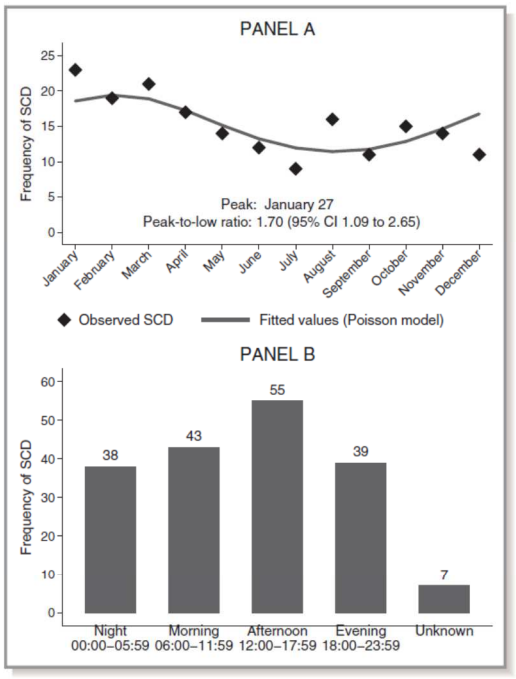

Figure 3. Distribution of sudden cardiac deaths events by month (A) and time of day (B) for US male career firefighters, 1998–2012. SCD indicates sudden cardiac death.

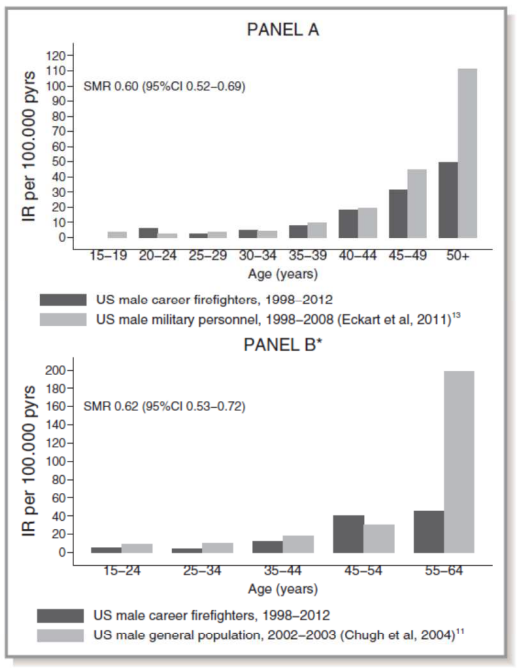

Figure 4. Comparison of the incidence of sudden cardiac death among US firefighters with the rates reported among the US general population (A) and among US military personnel (B). *Includes 1 sudden death caused by thoracic aortic dissection. IR indicates incidence rates; pyrs, person-years; SMR, standardized mortality ratio.

Table 6. Observed to Expected Ratios of Sudden Cardiac Death

Age	Person-Years	Obs SCD	Exp SCD	Obs/Exp	95% CI
Comparison with US male military personnel (Eckart et al[13])					
18 to 19 years	3936	0	0.13	0.00	0.00 to 27.81
20 to 24 years	51 952	3	1.27	2.37	0.49 to 6.92
25 to 29 years	122 261	3	4.06	0.74	0.15 to 2.16
30 to 34 years	164 729	8	6.57	1.22	0.53 to 2.40
35 to 39 years	191 975	15	18.60	0.81	0.45 to 1.33
40 to 44 years	168 092	30	32.31	0.93	0.63 to 1.33
45 to 49 years	140 929	44	62.92	0.70	0.51 to 0.94
≥50 years	159 422	79	177.68	0.44	0.35 to 0.55
Comparison with US male general population (Chugh et al[11])					
18 to 24 years	55 888	3	4.87	0.62	0.13 to 1.80
25 to 34 years	286 989	11	28.64	0.38	0.19 to 0.69
35 to 44 years	360 067	45	65.28	0.69	0.50 to 0.92
45 to 54 years	238 430	96*	72.86	1.32	1.07 to 1.61
55 to 64 years	61 921	28	123.20	0.23	0.15 to 0.33

Exp indicates expected; Obs, observed; SCD, sudden cardiac death.
*Includes 1 sudden death caused by thoracic aortic dissection.

male general population. Indeed, even though we analyzed events occurring during strenuous duties characterized by an increased risk of SCD,[17,18,25,26] we observed IRs of SCD lower than those previously reported by Chugh and colleagues among almost all age categories.[11,36] Furthermore, we did not observe any dramatic rise in the incidence of SCD that usually characterizes the group aged 55 to 64 years.[11,36] Compared with military personnel, the incidence of SCD among career firefighters was similar among younger persons, but important differences were observed after the age of 45 years. The pattern of SCD incidence that we observed in firefighters is similar to that reported for sports-related sudden death in the general population, although firefighters experience higher rates of SCD compared with athletes.[10] Selection processes explain the similarities in the incidence of SCD in a healthy working population and among adult noncompetitive athletes, resulting in a lower proportion of high-risk subjects in the older age classes. Less fit persons are more likely to retire early from firefighting with age. In addition, many US states have laws entitling firefighters with heart disease to receive publicly funded disability benefits[23]; this fact likely contributes to underrepresentation of subjects at high risk for cardiovascular events among occupational active firefighters aged 55 to 64 years. Our findings suggest that applying the rates of SCD estimated in the general population to a working population may lead to overestimation of the incidence of SCD, particularly in age groups characterized by high absolute risk. Our observation is consistent with previous studies of aging workers that showed both early retirement and unemployment are associated with a remarkable increase in the risk of cardiovascular diseases.[37,38]

CHD, often coupled with cardiomegaly, was the main cause of SCD death in our study population. This finding is in line with current knowledge of the incidence of SCD in the general population.[3,11,36] CHD has also been documented as a major cause of death among young (aged ≤45 years) firefighters, probably due to the obesity epidemic.[20] Eckart et al reported that CHD is a frequent cause (>20%) of SCD among military personnel aged <35 years and the main cause (>70%) among subjects aged ≥35 years.[13] The available evidence suggests the need for preventive strategies aimed at reducing the prevalence of modifiable CHD risk factors.

It is well established that SCD events vary by time of day and by season of the year.[39,40] We did not observe the typical excess of SCD events occurring in the morning and the low rate generally documented during the night[39]; however, our findings are in line with current knowledge of SCD among firefighters and could be attributed to the shift work schedule and the daily distribution of emergency dispatches, which is higher from noon to midnight.[17,41,42] With respect to season, we found that SCD among firefighters was most frequent in the winter (peaking in January), in agreement with the general population and a previous study on CHD deaths among firefighters.[32,40]

Interestingly, we observed a constant decline of SCD between 1998 and 2012. This observation is consistent with

previous epidemiological studies on temporal trends of SCD.[3] This significant decrease in SCD rates over the past decade has been attributed to improvements in the primary and secondary prevention of CHD and other underlying causes and to progress in acute treatment strategies.[3]

The proportion of shockable rhythms observed in our study population was higher than expected[43,44]; however, previous studies showed that the probability of registering a shockable rhythm in a sudden cardiac arrest is higher when the event is witnessed and bystanders practice cardiopulmonary resuscitation.[43,44] According to NIOSH reports, in our study population, cardiopulmonary resuscitation was performed promptly in most cases, and an automated external defibrillator was usually available. This is not surprising considering that firefighters are trained and equipped to face health emergencies. The timely availability of advanced life-support resources might also contribute to the reduced incidence of SCD documented when comparing US male firefighters with US male military personnel.

Study Strengths and Limitations

Our study has several limitations. Although the USFA provides a comprehensive database of all deaths among US firefighters, it presents only limited medical information. Nevertheless, we found that the identification of SCD based on USFA records was highly reliable when compared with the much more detailed NIOSH reports. In addition, our study is limited to only male firefighters; however, only 2 cases of SCD were observed among female firefighters. Specific firefighting activities have been previously associated with an increased risk of SCD.[17–19,25] Consequently, the risk of SCD among firefighters might be higher when compared with other occupations, even those characterized by a high level of physical demand. For perspective on the magnitude of the incidence of SCD during low-effort, low-risk activities, we stratified our analyses based on the duty performed at the time of the onset of symptoms; we observed a 3-fold lower risk of SCD during low-effort duties compared with high-effort, high-risk activities. Another limitation of our study is that autopsy reports were available for our review only for the events reported by NIOSH. The NIOSH investigators selected the cases to be examined based on a priori criteria, and we found that reports were more often available for SCDs that occurred during high-risk duties. We cannot exclude the possibility that the underlying cause of SCD may vary according to the presence of an external trigger (eg, physical effort, psychological stress). Nonetheless, it is hard to hypothesize that the selection criteria adopted by NIOSH introduced a bias strong enough to explain the high proportion (76%) of SCD with underlying CHD observed in our study population. Finally, both the USFA and the NIOSH databases provide information only on SCD and do not report data on survivors of cardiovascular events. Consequently, we could not evaluate whether the observed decline in annual SCD rates was determined by a decreasing number of sudden cardiac arrests or by an increased survival rate over the years. An obvious limitation of our study is the low number of deaths observed among young subjects; therefore, age-specific rates and proportions estimated among subjects aged <35 years present considerable levels of statistical uncertainty.

The main strength of our study is the comprehensive assessment of on-duty deaths provided by the USFA database and the availability of accurate denominators from the CPS. As expected for SCD occurring at the workplace, a high proportion of the events included in the present study were witnessed. This fact, combined with the noninclusion of persons affected by chronic and disabling conditions—a population in which a sudden cardiac arrest is likely to be explained by the underlying conditions—have likely limited any overestimation of SCD that usually characterizes the assessment of SCD events in the absence of autopsy reports.[6] Furthermore, the NIOSH reports provide detailed information on the dynamics and details of the deaths, and thus we could use this second source of data to validate the analysis based on the USFA database. The use of multiple sources of ascertainment and information for the study of SCD has been highly recommended.[11] Our study, like those performed by Chugh et al and Eckart et al,[11,13] was based on the retrieval of available postmortem examination reports and did not rely solely on death certificates. This fact ensures comparability between our estimates and those previously reported for US male military personnel and the US male general population.

Conclusions

We demonstrated that the incidence of SCD among US career firefighters is lower than among the general population and more comparable to rates among military personnel. Active, presumably healthy populations may show a reduced risk of SCD, particularly at ages characterized by high absolute risk, and have unique characteristics (eg, work shift) that make them quite different from the general population. To address relevant public health issues such as the need for preventive strategies in large working populations, more studies specific to these populations should be conducted.

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Disclosures

Dr Kales reported serving as a paid expert witness, independent medical examiner, or both in cases involving firefighters. No other potential conflict of interest relevant to this article was reported.

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Modified Mediterranean Diet Score and Cardiovascular Risk in a North American Working Population

Justin Yang[1,2], Andrea Farioli[1,3], Maria Korre[1,2], Stefanos N. Kales[1,2]*

1 Department of Environmental Health, Environmental & Occupational Medicine & Epidemiology, Harvard School of Public Health, Boston, Massachusetts, United States of America, **2** The Cambridge Health Alliance, Harvard Medical School, Cambridge, Massachusetts, United States of America, **3** Department of Medical and Surgical Sciences, University of Bologna, Bologna, Italy

Abstract

Introduction: Greater adherence to a Mediterranean diet is linked to lower risk for cardiovascular morbidity/mortality in studies of Mediterranean cohorts, older subjects, and/or those with existing health conditions. No studies have examined the effects of this dietary pattern in younger working populations in the United States. We investigated the effects of Mediterranean diet adherence on cardiovascular disease (CVD) biomarkers, metabolic syndrome and body composition in an occupationally active, non-Mediterranean cohort.

Methods: A cross-sectional study in a cohort of 780 career male firefighters, ages 18 years or older, from the United States Midwest. No dietary intervention was performed. A modified Mediterranean diet score (mMDS) was developed for assessment of adherence to a Mediterranean dietary pattern from a previously administered life-style questionnaire that examined pre-existing dietary habits. Clinical data from fire department medical examinations were extracted and analyzed.

Results: Obese subjects had significantly lower mMDS, and they reported greater fast/take-out food consumption ($p<0.001$) and intake of sweetened drinks during meals ($p=0.002$). After multivariate adjustment, higher mMDS was inversely related to risk of weight gain over the past 5 years (odds ratio [OR]: 0.57, 95% confidence interval [CI]: 0.39–0.84, p for trend across score quartiles: 0.01); as well as the presence of metabolic syndrome components (OR: 0.65, 95% CI: 0.44–0.94, p for trend across score quartiles: 0.04). Higher HDL-cholesterol ($p=0.008$) and lower LDL-cholesterol ($p=0.04$) were observed in those with higher mMDS in linear regression after multivariate adjustment for age, BMI and physical activity.

Conclusions: In a cohort of young and active US adults, greater adherence to a Mediterranean-style dietary pattern had significant inverse associations with metabolic syndrome, LDL-cholesterol and reported weight gain, and was significantly and independently associated with higher HDL-cholesterol. Our results support the potential effectiveness of this diet in young, non-Mediterranean working cohorts, and justify future intervention studies.

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Competing Interests: Dr. Kales reports serving as a paid expert witness, independent medical examiner, or both, in workers' compensation and disability cases, including cases involving firefighters. No other disclosures were reported. This does not alter the authors' adherence to all the PLOS ONE policies on sharing data and materials.

* E-mail: skales@hsph.harvard.edu

Introduction

Lifestyle behaviors have long been correlated with lowering cardiovascular disease (CVD) risk. [1] In particular, the Mediterranean diet has consistently been associated with better health status, decreased all-cause mortality and protective/ameliorative effects on chronic diseases. [2–7] Specifically, this type of diet is associated with benefits regarding cardiovascular risk factors such as obesity, hypertension, diabetes mellitus and metabolic syndrome [3,8–11], as well as on the relative risks of CVD-related morbidity and mortality [2,9,12–14].

The Mediterranean diet is collection of similar eating habits traditionally followed in at least 16 countries bordering the Mediterranean Sea. [15] It is characterized by high consumption of olive oil, fruits, vegetables, non-refined breads and cereals, potatoes, legumes and nuts; moderate consumption of fish and poultry; a low intake of dairy products, red meat, processed meats and sweets; and moderate wine intake with meals. [6,12,15].

Although several studies have measured Mediterranean diet adherence with a scoring system and have reported inverse associations with CVD morbidity and mortality, those investigations were primarily conducted on older subjects, those with existing health conditions and/or among Mediterranean populations. [2,4,6,7,12,15–17] Little is known about the effects of Mediterranean-style diet among young working groups in non-Mediterranean countries. To the best of our knowledge, no studies have examined this dietary pattern in a North American occupational cohort. We investigated a modified Mediterranean diet score (mMDS) to assess Mediterranean diet adherence and its associations in a population of United States (US) Midwestern

firefighters. No intervention was performed. Rather, we investigated the association between cardiovascular risk markers and the extent to which the firefighters' reported dietary habits conformed to a Mediterranean diet pattern using the mMDS.

Subjects and Methods

Study Population and Study Design

We conducted a cross-sectional analysis within an ongoing longitudinal study of a young, occupationally active cohort of career male firefighters. The participants were age 18 years or older from 11 fire departments in two Midwestern states. Mediterranean diet adherence was assessed from responses to a life-style questionnaire, and CVD biomarkers were measured during the firefighters' baseline medical evaluations. The cohort and data collection have been described in detail elsewhere. [18,19] Inclusion criteria for the mMDS investigation were: 1) completion of a fire department-sponsored medical examination including a maximal exercise test; 2) completion of the life-style questionnaire; 3) absence of work-restrictions at examination; and 4) signed informed consent.

Ethics Statement

The study was approved by the Institutional Review Board (IRB) of the Harvard School of Public Health and by local IRBs (Chesapeake IRB and National Development and Research Institute [NDRI] IRB).

Assessment of Adherence to Mediterranean Diet

A modified Mediterranean diet score (mMDS) was developed by examining questions from our existing life-style questionnaire for relevance to Mediterranean diet components and adherence to traditional Mediterranean eating patterns based on previous studies. [4,6,12,13] To construct the scoring system, we identified fifteen question areas including the following food domains: frequency of consuming fast/take-out food; weekly serving(s) of fruit and vegetables; frequency of sweet dessert consumption; cooking oil/fat use (olive oil versus others); weekly fried food consumption; type of breads/starches eaten with meals (refined versus whole grain); frequency of consuming ocean fish; and beverage consumption which included wine/alcohol drinking frequency and type of drink(s) consumed with most meals. **Figure 1** shows the generalized Mediterranean diet component categories and score ranges we developed using our questionnaire.

For each Mediterranean diet-associated question, a 4-point scale was developed where a score of 4 is given to the response that best represents a Mediterranean-style diet, and 0 is assigned to the choice that least conforms to a Mediterranean-style diet. A detailed description of how question responses were coded and mMDS scores were attributed for each item is provided in **Table S1 and Method S1**. For questions on "drinks with most meals" we assigned scores for different types of beverages based on likely calorie intake and antioxidant components per serving. In a working population, meals at the workplace and at home may differ substantially. Hence, we surveyed separately cooking oil use, breads/starches and beverages at home and at work, and then weighted each item's consumption by the proportion of weekly meals each participant reported that he consumed at the workplace or at home, respectively. We scored overall alcohol intake because moderate ethanol consumption is consistently associated with a reduced risk of CVD outcomes. [20] Furthermore, additional points for wine intake were also scored separately because authorities consider wine to be an integral part of Mediterranean diet. [21–23] We then obtained each individual's final total mMDS by summing the scores across all items. The total mMDS score has a possible range of 0 (no conformity to a Mediterranean-style diet) to 42 (maximal conformity to a Mediterranean-style diet based on our scoring system).

Assessment of CVD Risk Factors and Covariates

Detailed descriptions of the collection of anthropometric, clinical and laboratory data from this cohort are summarized in previous studies. [24,25] Briefly, body mass index (BMI, kg/m^2) was recorded for all study subjects from measured height and weight. Body fat (%) was estimated by Bioelectrical Impedance Analyzer (BIA) or with skin fold measures, and was added to the medical evaluation protocol while the study was in progress. Cardio-respiratory fitness was measured using symptom- limited maximal treadmill exercise testing with estimation of oxygen consumption (metabolic equivalents [METS]) according to the Bruce protocol. The prevalence of metabolic syndrome and its individual components among the study population were determined using modified criteria from the Joint Scientific Statement. [26,27].

Reports of weight change over the last 5 years and physical activity were extracted from the lifestyle questionnaire. The following question was used to assess weight change: "In the last 5 years, my body weight has gone…". Possible answers included: down a lot (>10 pounds [>4.54 kg]); down a little (5–10 pounds [2.27–4.54 kg]); not changed (<5 pounds [<2.27 kg]); up a little (5–10 pounds [2.27–4.54 kg]); and up a lot (>10 pounds [>4.54 kg]). Weekly physical activity was estimated from average reported exercise frequency and the average reported duration of aerobic/cardio sessions each week. The product of these two responses yielded the average duration of total weekly aerobic exercise expressed in minutes. [19].

Statistical Analysis

Statistical analyses were carried out using Stata 12.1 SE (Stata Corp, College Station, TX, US). Trends across ordered groups were analyzed with the Cuzick nonparametric test (continuous variables) or with a score test for linear trend of the log odds (dichotomous variable). Differences in the mean distribution of continuous variables were tested with univariate and multivariate analysis of variance. Linear regression models were fitted to study the effect of a unitary increase in mMDS. We explored the distribution of continuous variables by plotting histograms. We then transformed the following right-skewed variables (METS, triglycerides, total cholesterol, LDL-cholesterol, HDL-cholesterol, total cholesterol/HDL, and blood sugar) by taking their natural logarithm. Finally, we assessed the normality assumption for log-transformed variables by applying the skewness and kurtosis test for normality [28]. We fitted ordered logistic regression models to study naturally ordered dependent variables (i.e. metabolic syndrome score and weight change over the past five years). Parallel regression assumption was tested via the Brant test. A P value of less than 0.05 (two-sided) was considered statistically significant.

Results

In this study, 780 (97% of the total eligible database) male firefighters met the inclusion criteria and were selected for the main analyses. Twenty-six subjects were excluded due to incomplete information. In **Table 1**, we present the distribution of personal characteristics by stratifying our study population into four BMI categories. The mean mMDS in the study population was 21.3 (SD 5.6) (**Figure 2**). Normal weight subjects had

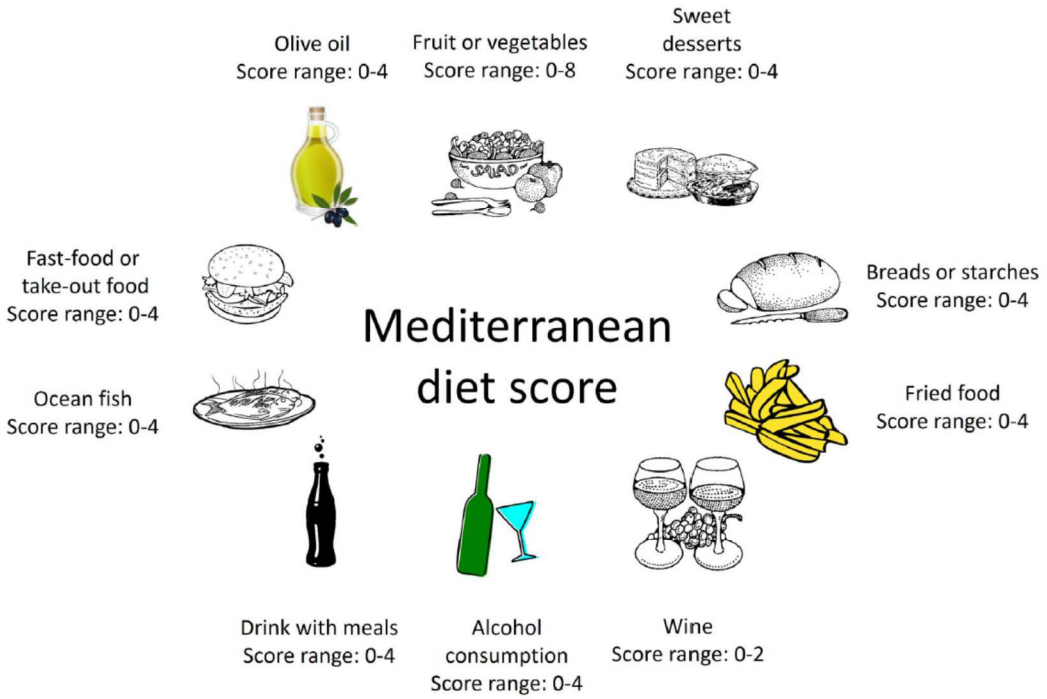

Figure 1. Mediterranean diet food domains and ranges of modified Mediterranean diet item scores (mMDS) among different categories.
doi:10.1371/journal.pone.0087539.g001

significantly higher mMDS than obese firefighters (p for trend 0.008). Beverages taken with meals, both at home and at work, as well as the frequency of eating fast/take-out food were significant determinants for the observed differences in mMDS across BMI categories.

In **Table 2**, we show CVD risk factors stratified by mMDS quartiles. After adjusting for age and BMI, significant inverse associations with mMDS were observed for body fat percentage ($p = 0.0179$), triglycerides ($p = 0.0463$), and total cholesterol to high-density lipoprotein-cholesterol (HDL-c) ratio (TC/HDL-c, $p < 0.0001$), while HDL-c ($p = 0.0001$) and METS ($p = 0.0047$) were positively associated with mMDS. When further adjusted by physical activity, body fat percentage, HDL-c, and TC/HDL-c remained significantly associated with mMDS.

In **Table 3**, we present fully adjusted linear regression models of CVD risk factors and mMDS. For every unit increase of mMDS, we observed a decrease of 0.4% in the geometric mean of low-density lipoprotein-cholesterol (LDL-c), an increase of 0.4% in the geometric mean of HDL-c, and a 0.7% decrease in the TC/HDL-c. Maximal METS achieved were also positively associated with compliance to the Mediterranean diet (0.2% increase per unit increase in mMDS).

The distribution of metabolic syndrome score also varied by mMDS (**Table 4**). In ordered logistic regression analysis, subjects in the highest quartile of mMDS had a 35% lower risk of a one unit increase in metabolic syndrome score (Odds ratio [OR]: 0.65 after adjusted for age and physical activity, 95% confidence interval [CI]: 0.44–0.94, p for trend across mMDS quartiles: 0.039).

Subjects with a high mMDS were also less likely to report weight gain over the last 5 years. Using ordered logistic regression, participants in the highest quartile of mMDS showed a significantly reduced odds of weight gain (OR adjusted by age, BMI and physical activity: 0.57, 95%CI: 0.39–0.84, p for trend across mMDS quartiles: 0.01).

Discussion

This study provides comprehensive evidence of statistically significant beneficial associations between higher mMDS and CVD risk factors among a young and occupationally active North American cohort. Subjects who were obese had a significantly lower mMDS score. This difference was primarily because obese participants were more inclined to have sweetened drinks or beverages with less nutritional value during meals, and they were more likely to consume fast/take-out foods. We observed higher HDL-c and lower LDL-c in those with better mMDS, which persisted after multivariable adjustment. Furthermore, metabolic syndrome score was inversely associated with Mediterranean-style diet in our study. We also observed a consistent beneficial trend in reported weight gain over the past 5 years among those with lower mMDS, which remained significant after multivariate adjustment. Because we examined the associations of adherence to a Mediterranean dietary pattern based on pre-existing habits without any intervention, our study likely underestimates the

Table 1. Descriptive results of characteristics and modified Mediterranean diet scores (mMDS) among 780 subjects.

	Normal weight	Overweight	Obese class I	Obese class II/III	
	(18.5≤BMI≤24.9)	*(25.0≤BMI≤29.9)*	*(30.0≤BMI≤34.9)*	*(BMI≥35.0)*	
Characteristics and mMDS results	**(N = 108)**	**(N = 401)**	**(N = 203)**	**(N = 85)**	***P* trend**
Age, mean (SD)	35.6 (10.0)	37.2 (8.4)	38.9 (8.0)	38.6 (8.1)	<0.001
Body fat percentage, mean (SD)[2]	16.5 (7.0)	21.2 (4.2)	27.5 (3.0)	32.1 (3.9)	<0.001
Max. METS achieved during ETT, mean (SD)	13.7 (1.6)	13.1 (1.5)	12.2 (1.8)	10.9 (2.0)	<0.001
Percentage of max. HR achieved during ETT, mean (SD)	99.0 (5.2)	98.8 (6.2)	97.5 (5.7)	96.5 (7.1)	0.001
Total weekly aerobic exercise (min*wk^{-1}), median (IQR)	86 (26–131)	79 (56–131)	79 (56–131)	56 (11–124)	0.003
Current smoker, n (%)	19 (17.6)	80 (20.0)	39 (19.2)	19 (22.1)	0.563
Number of meals at the firehouse, median (IQR)	6 (3–6)	6 (3–6)	6 (3–6)	6 (4.5–7.5)	0.018
Single-item mMDS					
-Fast/take-out food consumption, mean (SD)	2.8 (1.2)	2.7 (1.1)	2.6 (1.1)	2.3 (1.2)	<0.001
-Fruit and vegetable consumption[3], mean (SD)	2.2 (1.8)	2.3 (1.9)	2.1 (1.7)	2.0 (1.7)	0.109
-Sweet desserts consumption, mean (SD)	2.6 (1.2)	2.7 (1.2)	2.8 (1.1)	2.8 (1.2)	0.389
-Primary cooking oil/fat use at home, mean (SD)	2.2 (1.6)	2.6 (1.5)	2.4 (1.5)	2.6 (1.6)	0.391
-Secondary cooking oil/fat used at home, mean (SD)	1.8 (1.6)	1.8 (1.5)	1.9 (1.5)	1.9 (1.5)	0.239
-Primary cooking oil/fat use at work, mean (SD)	1.9 (1.4)	2.0 (1.3)	2.1 (1.4)	2.2 (1.3)	0.088
-Secondary cooking oil/fat used at work, mean (SD)	1.7 (1.7)	1.7 (1.6)	1.8 (1.5)	1.7 (1.6)	0.952
-Fried food consumption, mean (SD)	2.2 (0.9)	2.2 (0.9)	2.2 (0.9)	2.0 (1.0)	0.146
-Breads/starches consumed at home, mean (SD)	2.6 (1.9)	2.6 (1.9)	2.6 (1.8)	2.3 (1.9)	0.647
-Breads/starches consumed at work, mean (SD)	1.7 (1.7)	1.5 (1.7)	1.8 (1.8)	1.8 (1.8)	0.358
-Ocean fish consumption, mean (SD)	1.6 (0.9)	1.5 (0.7)	1.5 (0.8)	1.5 (0.7)	0.829
-Drinks taken with meals at home, mean (SD)	2.9 (1.6)	2.6 (1.7)	2.3 (1.7)	2.1 (1.7)	<0.001
-Drinks taken with meals at work, mean (SD)	2.7 (1.7)	2.6 (1.7)	2.5 (1.6)	1.9 (1.8)	0.002
-Quantity of alcoholic beverages, mean (SD)	2.1 (1.6)	2.1 (1.5)	2.0 (1.5)	1.8 (1.6)	0.093
-Wine consumption, mean (SD)	0.1 (0.4)	0.1 (0.5)	0.2 (0.5)	0.1 (0.5)	0.667
Total mMDS, mean (SD)	21.7 (5.5)	21.6 (5.4)	21.0 (5.7)	19.8 (5.6)	0.008

[1]Nonparametric test for trend (Cuzick) performed for all columns except current smokers, where score test for trend was performed.
[2]Information available for 244 subjects.
[3]Score doubled due to combining two different domains.
Abbreviations: BMI, body mass index (kg/m^2); ETT, exercise treadmill test; IQR, interquartile range; max, maximum; METS, metabolic equivalents; SD, standard deviation.
doi:10.1371/journal.pone.0087539.t001

benefits of a traditional, fully compliant Mediterranean diet. In other words, the effects of an intervention study that educated the participants and prescribed a specific Mediterranean diet might be expected to be even greater.

HDL-c and LDL-c are well-established independent risk factors for CVD. [29] Although previous research has observed positive changes in lipid profiles in groups adhering to Mediterranean diet, those studies were primarily conducted in older subjects, those with pre-existing conditions, and/or Mediterranean cohorts; and most of them did not observe significant findings in HDL-c after covariate adjustment. [3,9,16,17,30] In our cohort, we observed significantly higher HDL-c and lower LDL-c in those with greater mMDS, in both multivariate analyses of variance and liner regression models after covariate adjustment. Our study is the first to observe these relationships with Mediterranean-style diet in a group of young working adults in the U.S.

The potential protective effect of a higher mMDS on metabolic syndrome, which has been well correlated with increased CHD and overall mortality [31], was another significant finding in this study. Participants in the highest quartile of mMDS compared to the lowest quartile had a 35% lower risk for the presence of an

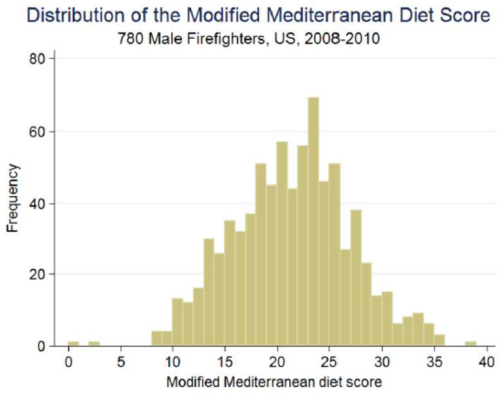

Figure 2. Distribution of the modified Mediterranean diet score (mMDS) among 780 male subjects.
doi:10.1371/journal.pone.0087539.g002

Table 2. Statistical analyses of anthropometric and metabolic variables associated with cardiovascular disease risk by quartiles of modified Mediterranean diet score (mMDS) in 780 male subjects.

		I quartile ≤17.5 (N = 194)	II quartile 17.6–21.4 (N = 195)	III quartile 21.5–25.0 (N = 190)	IV quartile ≥25.0 (N = 201)	P value (analysis of variance)			
Risk factor	**N**	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Unadjusted*	*Adjusted by age*	*Adjusted by age and BMI*	*Adjusted by age, BMI and physical activity*
Age[1] (years)	780	38.2 (8.6)	37.0 (8.2)	37.9 (9.2)	37.1 (8.4)	0.4195		0.5448	0.5877
BMI[1]	780	29.9 (4.7)	29.4 (4.6)	29.2 (4.2)	28.7 (4.2)	0.0756	0.0950		0.6369
Body fat[1] (%)	233	25.2 (6,8)	24.4 (7.0)	22.7 (5.7)	22.2 (6.3)	0.0327	0.0372	0.0179	0.0281
Resting SBP[1] (mmHg)	780	122.4 (12.6)	121.8 (12.7)	122.7 (11.8)	122.8 (13.3)	0.8546	0.8606	0.6013	0.9156
Resting DBP[1] (mmHg)	780	80.4 (8.5)	79.7 (7.6)	79.2 (7.8)	79.9 (8.2)	0.5749	0.5812	0.6125	0.6219
Resting HR[1] (bpm)	780	71.5 (11.6)	68.9 (11.2)	69.5 (11.3)	68.2 (11.5)	0.0220	0.0316	0.0887	0.4126
Percentage of max. HR achieved during ETT[1]	765	98.0 (6.5)	98.4 (6.2)	98.5 (6.3)	98.1 (5.3)	0.7963	0.7920	0.7771	0.7796
METS[2]	766	12.3 (1.2)	12.7 (1.1)	12.7 (1.1)	13.0 (1.1)	0.0002	0.0003	0.0047	0.3784
Triglycerides[2,3] (mg/dL)	780	140.4 (1.8)	125.8 (1.7)	122.8 (1.7)	115.8 (1.8)	0.0065	0.0093	0.0463	0.4604
Total cholesterol[2,3] (mg/dL)	780	196.5 (1.3)	191.0 (1.2)	191.4 (1.2)	186.3 (1.2)	0.0567	0.0926	0.1348	0.3275
LDL-cholesterol[2,3] (mg/dL)	759	120.3 (1.3)	117.0 (1.4)	115.0 (1.4)	110.2 (1.3)	0.0328	0.0427	0.0599	0.0982
HDL-cholesterol[2,3] (mg/dL)	780	41.7 (1.3)	43.9 (1.3)	44.2 (1.3)	46.6 (1.3)	0.0001	0.0001	0.0009	0.0258
Total cholesterol/HDL[2,3]	780	4.7 (1.4)	4.4 (1.3)	4.3 (1.4)	4.0 (1.3)	<0.0001	<0.0001	<0.0001	0.0035
Blood sugar[2,3] (mg/dL)	780	93.2 (1.2)	92.6 (1.2)	92.9 (1.2)	91.1 (1.2)	0.5690	0.6896	<0.8387	0.9289

[1]Arithmetic mean and standard deviation.
[2]Geometric mean and standard deviation.
[3]Analysis of variance performed using log-transformed dependent variable.
Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; bpm, beats per minute; ETT, exercise treadmill test; HDL, high-density lipoprotein; HR, heart rate; LDL, low-density lipoprotein; METS, metabolic equivalents; SD, standard deviation, SBP, systolic blood pressure.
doi:10.1371/journal.pone.0087539.t002

Table 3. Effect of a unitary increase in the modified Mediterranean diet score (mMDS) on anthropometric and metabolic variables related to cardiovascular disease risk and in 780 male subjects. B coefficient from linear regression models[1].

		Linear regression models											
		Unadjusted			*Adjusted by age*			*Adjusted by age and BMI*			*Adjusted by age, BMI and physical activity*		
Dependent variable	*Mean (SD)*	β	**Change**	*P*	β	**Change**	*P*	β	**Change**	*P*	β	**Change**	*P*
BMI[2,5]	29.3 (4.4)	−0.087	−0.3%	0.002	−0.082	−0.3%	0.004				−0.051	−0.2%	0.093
Body fat[2,5] (%)	23.6 (6.6)	−0.248	−1.1%	0.002	−0.216	−0.9%	0.006	−0.075	−0.3%	0.121	−0.042	−0.2%	0.404
Resting SBP[2,5] (mmHg)	122.3 (12.7)	0.041	0.0%	0.612	0.061	0.0%	0.452	0.113	+0.1%	0.156	0.055	0.0%	0.515
Resting DBP[2,5] (mmHg)	80.0 (8.1)	−0.047	−0.1%	0.368	−0.036	0.0%	0.494	0.008	0.0%	0.874	0.007	0.0%	0.899
Resting HR[2,5] (bpm)	69.4 (11.5)	−0.259	−0.4%	<0.001	−0.246	−0.4%	0.001	−0.200	−0.3%	0.006	−0.107	−0.2%	0.157
% Maximum HR during ETT[2,5]	98.3 (6.1)	0.002	0%	0.957	0.004	0.0%	0.926	−0.010	0.0%	0.806	0.011	0.0%	0.796
METS[3,4,6]	12.7 (1.1)	0.005	+0.5%	<0.001	0.004	+0.4%	<0.001	0.003	+0.3%	<0.001	0.002	+0.2%	0.028
Triglycerides[3,4,6] (mg/dL)	125.1 (1.8)	−0.013	−1.3%	<0.001	−0.013	−1.3%	<0.001	−0.010	−1.0%	0.005	−0.005	−0.5%	0.189
Total cholesterol[3,4,6] (mg/dL)	191.1 (1.2)	−0.004	−0.4%	0.003	−0.003	−0.3%	0.007	−0.003	−0.3%	0.014	−0.003	−0.3%	0.055
LDL-cholesterol[3,4,6] (mg/dL)	115.6 (1.4)	−0.006	−0.6%	0.004	−0.005	−0.5%	0.010	−0.005	−0.5%	0.018	−0.004	−0.4%	0.040
HDL-cholesterol[3,4,6] (mg/dL)	44.1 (1.3)	0.007	+0.7%	<0.001	0.007	+0.7%	<0.001	0.006	+0.6%	<0.001	0.004	+0.4%	0.008
Total cholesterol/HDL[3,4,6]	4.3 (1.4)	−0.011	−1.1%	<0.001	−0.011	−1.1%	<0.001	−0.009	−0.9%	<0.001	−0.007	−0.7%	0.001
Blood sugar[3,4,6] (mg/dL)	92.4 (1.2)	−0.001	−0.1%	0.310	−0.001	−0.1%	0.544	0.000	0.0%	0.926	0.000	0.0%	0.672

[1]Number of subjects with complete data: 780, except for body fat % (n = 233), % maximum HR during ETT (n = 765), METS (n = 766) and LDL-cholesterol (n = 759).
[2]Arithmetic mean and standard deviation.
[3]Geometric mean and standard deviation.
[4]Linear regression model conducted on a log-transformed dependent variable.
[5]Percent change in the arithmetic mean of the dependent variable per unitary increase in the Mediterranean diet score.
[6]Percent change in the geometric mean of the dependent variable per unitary increase in the Mediterranean diet score.
Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; bpm, beats per minute; ETT, exercise treadmill test; HDL, high-density lipoprotein; HR, heart rate; LDL, low-density lipoprotein; METS, metabolic equivalents; SD, standard deviation, SBP, systolic blood pressure.
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additional metabolic syndrome component after adjustment for age and physical activity. Therefore, our results suggest adherence to a Mediterranean-pattern diet in a young and active cohort could potentially reduce CVD-risk clustering and metabolic syndrome prevalence.

A trend in reduction of total mMDS associated with obesity was also observed. This finding is in agreement with previous studies suggesting subjects with better adherence to Mediterranean diet were less likely to be obese. [32–34] In this study, we expanded this inverse relation with the observation of a consistent trend in reported weight gain over the past 5 years among those with lower mMDS even after multivariate adjustment that included physical activity. We also observed significantly higher maximal METS achieved in the entire cohort, as well as lower body fat with higher mMDS in the subgroup of 233 participants who had this assessed. Therefore, we hypothesize that adherence to the Mediterranean diet can positively influence fitness and body composition.

Our study also revealed interesting findings regarding beverage consumption. The intake of sweetened beverages, which are not traditionally part of a Mediterranean diet, are well known to be correlated with obesity and increased cardiovascular risk. [1,35–37] Sugary drinks are considered the greatest contributor to added-sugar intake in the U.S. [36,38,39] Therefore, we believe sweetened beverage consumption is an important dietary determinant and should be incorporated into the Mediterranean diet scoring systems. Additionally, contrary to patterns observed in traditional Mediterranean countries, we observed very low wine consumption. This was likely the result of socio-cultural preferences, where 60% of our participants reported beer as their drink-of-choice. Educating existing drinkers in similar groups of workers on avoiding alcoholic beverages lacking important antioxidant properties might be an area of interest.

The finding that subjects with lower body fat/BMI and higher physical activity level had lower scores in fast/take-out food consumption further agrees with studies that associated fast-food consumption with obesity [40–42] and cardiometabolic risk. [43] While consumption of fast/take-out foods is very prevalent among the U.S. working population, [44,45] further research on educating employees about healthier food and introducing Mediterranean-style choices at work in different occupational cohorts could be a way to curtail the current obesity epidemic in the U.S. [46,47].

Our study has several limitations. First, our life-style questionnaire was originally designed to obtain general dietary information, rather than assess a specific diet pattern. Therefore, information on total energy intake and certain traditional Mediterranean food domains (e.g. nuts and legumes) were not collected and accounted for in the analyses. However, we believe that these two food groups are not highly consumed in the population studied and therefore, would not have influenced scores very much. We were also limited in our ability to assess the associations of ocean fish consumption by the very low consumption observed in our cohort likely due to its geographic setting in U.S. Midwest. Similarly, only a small proportion of our study population were regular wine drinkers. Thus, we had limited statistical power to study the possible beneficial effects of moderate wine consumption. Nonetheless, our questionnaire did address the majority of the essential components of a traditional

Table 4. Associations of 1) metabolic syndrome score and 2) reported body weight change to modified Mediterranean Diet Score (mMDS) in 780 male subjects by estimates from ordered logistic regression models.

METABOLIC SYNDROME SCORE [1]

	0	1	2	3	4	5	Unadjusted estimates			Estimates adjusted by age			Estimates adjusted by age and physical activity		
mMDS quartiles[2]	N	N	N	N	N	N									
	(%)	(%)	(%)	(%)	(%)	(%)	OR	(95% CI)	P	OR	(95% CI)	P	OR	(95% CI)	P
I	26	54	49	33	22	10	1.00	Ref.		1.00	Ref.		1.00	Ref.	
	(13.4)	(27.8)	(25.3)	(17.0)	(11.3)	(5.2)									
II	46	52	41	35	19	2	0.67	(0.47–0.94)	0.023	0.71	(0.50–1.00)	0.052	0.75	(0.53–1.07)	0.108
	(23.6)	(26.7)	(21.0)	(18.0)	(9.7)	(1.0)									
III	44	50	41	32	15	8	0.70	(0.49–0.99)	0.044	0.72	(0.50–1.03)	0.070	0.80	(0.56–1.15)	0.238
	(23.2)	(26.3)	(21.6)	(16.8)	(7.9)	(4.2)									
IV	59	59	32	35	10	6	0.50	(0.35–0.71)	<0.001	0.52	(0.36–0.74)	<0.001	0.65	(0.44–0.94)	0.021
	(29.4)	(29.4)	(15.9)	(17.4)	(5.0)	(3.0)									
P trend									<0.001			0.001			0.039

REPORTED WEIGHT CHANGE IN THE LAST 5 YEARS

	Down >10 lbs.	Down 5–10 lbs.	Stable	Up 5–10 lbs.	Up>10 lbs.	Unadjusted estimates			Estimates adjusted by age and BMI			Estimates adjusted by age, BMI and physical activity		
mMDS quartiles[2]	N	N	N	N	N									
	(%)	(%)	(%)	(%)	(%)	OR	(95% CI)	P	OR	(95% CI)	P	OR	(95% CI)	P
I	9	19	59	61	42	1.00	Ref.		1.00	Ref.		1.00	Ref.	
	(4.7)	(10.0)	(31.1)	(32.1)	(22.1)									
II	15	16	66	68	24	0.73	(0.51–1.05)	0.036	0.73	(0.51–1.05)	0.089	0.78	(0.54–1.13)	0.194
	(7.9)	(8.5)	(34.9)	(36.0)	(12.7)									
III	12	31	53	65	28	0.70	(0.48–1.01)	0.039	0.72	(0.50–1.05)	0.087	0.83	(0.57–1.21)	0.338
	(6.4)	(16.4)	(28.0)	(34.4)	(14.8)									
IV	31	20	78	54	17	0.43	(0.30–0.62)	<0.001	0.44	(0.31–0.65)	<0.001	0.57	(0.39–0.84)	0.005
	(15.5)	(10.0)	(39.0)	(27.0)	(8.5)									
P trend								<0.001			<0.001			0.010

[1]Determined adding one point for each of the following: obesity (BMI≥30 kg/m^2); reduced HDL-cholesterol (<40 mg/dL); hypertriglyceridemia (≥150 mg/dL); elevated blood pressure (systolic ≥130 mmHg or diastolic ≥85 mmHg) or antihypertensive drug treatment; or hyperglycemia (blood glucose ≥100 mg/dL).
[2]mMDS quartiles definitions: I quartile: total mMDS score ≤17.5, II quartile: total mMDS score between 17.6–21.4, III quartile: total mMDS between 21.5–25.0, IV quartile: total mMDS ≥25.0.
NB Brant test was used to explore violations of the proportional odds assumption.
Abbreviations: 95%CI, 95% confidence intervals; OR, odds ratio.
doi:10.1371/journal.pone.0087539.t004

Mediterranean diet. Additionally, our survey more accurately reflected dietary patterns in a working U.S. population with additional categories tailored to "American" eating habits inconsistent with a Mediterranean diet, as well as questions that assessed potential differences for consumption patterns at work compared to in the home. As our participants were only informed that the study was related to heart disease, they were not aware that Mediterranean diet or any other specific diet was of interest to the overall study. This fact likely decreased reporting bias; although we cannot completely rule out bias based on widespread popular knowledge of more and less "heart healthy" foods. [32].

To the best of our knowledge, this study is the first to assess Mediterranean-style diet adherence and CVD risk factors in a young, working cohort in the U.S. The main strength of our study is the homogeneous population that minimized confounding factors such as gender or socioeconomic differences (e.g., educational level, income or occupation). Also, the study of dietary patterns within a well-defined occupational group allows indirect control for job-related psychosocial factors, which are known to be determinants of eating awareness. [48] Another strength is our data collection procedures: anthropometric, clinical and laboratory data were collected using standardized procedures, and the biological plausibility of the observed relationships across different CVD risk parameters in this cohort has been verified in previous studies of physical activity, obesity and physical fitness. [25,26,49] Thus, it is very unlikely that our findings are due to chance or bias.

In conclusion, in a cohort of young working North American male adults, metabolic syndrome score, LDL-cholesterol and reported weight gain had significant inverse associations with increasing mMDS, while higher HDL-cholesterol was found to be significantly and independently associated with higher mMDS. The observed relationships support the potential effectiveness of a Mediterranean-style diet in younger, working cohorts in non-Mediterranean countries, and justify future intervention studies.

Supporting Information

Table S1 Questions extracted from the life-style questionnaire that constructed the modified Mediterranean diet score (mMDS) system.
(DOC)

Method S1 Calculation of the modified Mediterranean diet score (mMDS).
(DOC)

Author Contributions

Conceived and designed the experiments: SNK. Analyzed the data: AF. Wrote the paper: JY AF MK. Interpretation of the results: JY AF MK SNK. Revised the article critically for important intellectual content: JY AF MK SNK. Approved the final version to be published: JY AF MK SNK.

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Appendice E. Korre et al. Policing. 2014;8:109–122.

Article

A Survey of Stress Levels and Time Spent Across Law Enforcement Duties: Police Chief and Officer Agreement

Maria Korre*, Andrea Farioli*, Vasileia Varvarigou*, Sho Sato* and Stefanos N. Kales*

Abstract Health issues are commonly reported by law enforcement officers (LEOs) and often associated with stress. This study is the first to investigate the time spent and perceived stress encountered across the diverse variety of LEO activities. We developed a questionnaire to assess an average police officer's experience across 22 different duties. We then conducted two independent national surveys: one of police chiefs' views of their typical officer and the other of frontline officers' personal perspectives. Police chiefs and frontline officers perceived the same duties as the most stressful (e.g. suspect pursuit, witnessing traumatic events and physical altercations) and least stressful (e.g. certain routine duties). Additionally, chiefs' and frontline officers' absolute and relative stress rankings of all 22 duties were strikingly similar (Spearman's rho 0.95, 95% confidence interval (CI) 0.82–0.99). Moreover, chiefs and frontline officers estimated very similar relative annual durations of duty-specific exposures for frontline officers (rho: 0.91, 95% CI 0.74–0.98, $P < 0.0001$).

Introduction

Law enforcement has been consistently regarded as highly demanding, dangerous and stressful (Cooper *et al.*, 1982; Anshel, 2000; Gershon *et al.*, 2002; Deschamps *et al.*, 2003; Reichard and Jackson, 2010; Yoo and Franke, 2011). Work-related stressors in law enforcement include those common to other professions, such as shift work, excessive overtime, heavy workload, variable and intermittent work pace, and frequent interaction

*Maria Korre, Environmental & Occupational Medicine & Epidemiology, Harvard School of Public Health, Boston, MA, USA; Occupational Medicine, The Cambridge Health Alliance, Harvard Medical School, Cambridge, MA, USA
*Andrea Farioli, Environmental & Occupational Medicine & Epidemiology, Harvard School of Public Health, Boston, MA, USA; Occupational Medicine, The Cambridge Health Alliance, Harvard Medical School, Cambridge, MA, USA; Department of Medical and Surgical Sciences, DIMEC, University of Bologna, Bologna, Italy
*Vasileia Varvarigou, Environmental & Occupational Medicine & Epidemiology, Harvard School of Public Health, Boston, MA, USA; Department of Internal Medicine, St Elizabeth's Medical Center, Tufts Medical School, Brighton, MA, USA
*Sho Sato, Occupational Medicine, The Cambridge Health Alliance, Harvard Medical School, Cambridge, MA, USA
*Stefanos N. Kales, Environmental & Occupational Medicine & Epidemiology, Harvard School of Public Health, Boston, MA, USA; Occupational Medicine, The Cambridge Health Alliance, Harvard Medical School, Cambridge, MA, USA. E-mail: skales@hsph.harvard.edu

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with the public (Violanti and Aron, 1994; Anderson *et al.*, 2002). Other stressors are more specific to policing such as suspect pursuits and altercations, as well as, first-hand exposure to traumatic events (Violanti and Aron, 1994; Anderson *et al.*, 2002; Gershon *et al.*, 2002). In fact, policing is among the top three professions most commonly reported by occupational physicians and psychiatrists to the Occupational Disease Intelligence Network system for Surveillance of Occupational Stress and Mental Illness (Cherry *et al.*, 2000; Collins and Gibbs, 2003).

Diverse evidence indicates that stress contributes to physiological, psychological, and behavioural problems among police officers and affects health and work performance (Franke et al., 2002; Collins and Gibbs, 2003). Moreover, potentially stress-related psychological and physical problems may be increasing among police officers (Anderson *et al.*, 2002; Collins and Gibbs, 2003; Zimmerman, 2012). Health problems such as cardiovascular disease, musculoskeletal disorders, depression, and maladaptive and anti-social behaviours are highly prevalent in law enforcement (Gyi and Porter, 1998; Anderson *et al.*, 2002; Kohan and O'Connor, 2002; Collins and Gibbs, 2003; Yoo and Franke, 2011). In addition, there is an increased risk of suicidal ideation and alcohol abuse among police officers (Violanti et al., 1996; Violanti, 2004a,b). Police stress may also affect law enforcement officers' (LEOs') performance and thus public safety; resulting in poor productivity, high turnover, recruitment difficulties, high absenteeism, health-care utilization, and workers' compensation costs (Martelli *et al.*, 1989; Brown *et al.*, 1996; Anshel, 2000).

Despite widespread recognition of stress' impact on LEOs, there is relatively little information available to quantify and qualify sources of police stress. Policing consists of diverse law enforcement and public safety activities both within and among officers. Time and stress across duties may also vary by department/jurisdiction size and geographic location. Consequently, greater knowledge about how officers spend their work time across different law enforcement duties and the perceived stress experienced in each type of duty could improve efforts to study stress and mitigate its effects. However, there is currently very limited knowledge regarding the time spent across different law enforcement duties, as well as the stress perceived or experienced in each type of task among police officers.

Several investigations have provided some insight regarding variations in stress as a function of duty. Anderson *et al.* (2002) measured stress reactivity in 121 British Columbia police officers using heart rate monitoring. This study clearly demonstrated that certain police tasks and physical activities are more stressful than others as documented by greater heart rate increases (compared to officers' resting heart rates) after engaging in these activities. They also found that officers had anticipatory increases in heart rates at the onset of their shifts and do not recover to resting heart rates before leaving their shifts.

Hickman *et al.* (2011) also examined heart rate, but employed a more detailed methodology that monitored heart rate using direct, real-time and spatially anchored (GPS) measurements to estimate officer stress response during police work. This allowed the 'mapping' of the officer's relative stress over the course of the shift in both time and geographic location across a variety of duties and encounters. While a valuable endeavour, this pilot investigation was limited to a single officer in one department during one shift.

Other investigations have provided some qualitative and quantitative information regarding how police officers spend their time. For example, Parks *et al.* (1999) explored 'community policing' officers in two cities. They examined how patrol officers spent their time relative to the characteristics of the citizens encountered during community patrols. Another survey conducted by Amendola *et al.* (2009), provided information on law enforcement shift schedules.

Notwithstanding the above, to the best of our knowledge, no studies have specifically examined

the relative duration of exposure to different duties (and thus, varying stress levels) over the course of a typical work year. In the past decade, the development of duty-time estimates for the US fire service made rigorous epidemiologic investigations of on-duty risk of heart disease events possible in fire-fighting (Kales *et al.*, 2003, 2007). Those findings constituted an important methodological advance and stimulated further studies contributing to improved scientific knowledge regarding health outcomes among fire-fighters (Soteriades *et al.*, 2011). Therefore, the parallel development of such duty-time-stress 'exposure assessments' in law enforcement could serve as the future methodological basis needed for additional investigations of duty-specific relative risks of line-of-duty health events among police officers such as cardiovascular events and traumatic injuries.

Thus, the aim of our current study was to address this important knowledge gap in an attempt to estimate the average work distribution of a typical frontline police officer across relevant law enforcement duties; and the perceived stress levels encountered in each type of task. Therefore, we conducted two national surveys investigating the typical frontline officer's experience using two independent populations. Our first survey examined the opinions of police chiefs regarding duty time and the relative stress levels encountered by an average or typical officer while working frontline duties in each chief's department. Our second survey was carried out directly with frontline officers regarding their own average experiences. By using both chiefs' and frontline officers' perceptions, we sought to produce two independent estimates of the research questions. By comparing independently derived management and labor perspectives of frontline police work, our goal was to provide some measure of the reliability and validity of our findings. We hypothesized that police chief and frontline officer estimates of duty time and relative stress levels would demonstrate similar patterns and significant statistical agreement.

Methods

Study design and data sources

We conducted literature and internet searches to generate a preliminary list of law enforcement duties. Based on that list, we drafted a survey to estimate the time spent by an average police officer across different law enforcement duties. We also included a section for rating the average perceived stress level encountered during each duty by a typical or average officer on a Likert scale of 0–10 (Fig. 1). An experienced police chief then reviewed the draft survey, and we revised it accordingly.

We subsequently piloted the survey anonymously in a group of 17 Massachusetts police chiefs. Based on the pilot, we sought further comments and suggestions from members of several large national law enforcement organizations, and then edited and formatted the questionnaire into its final electronic and print formats (Supplementary Appendix 1).

Using the questionnaire described above, we conducted two independent surveys: one among police chiefs; and one among frontline police officers. In cover letters (police department chiefs) or emails (to police union members), we informed the potential participants the survey regarded both physical and psychological stressors in law enforcement and would require 15–30 minutes for completion. We also informed potential participants that the survey was voluntary, anonymous and the individual participants would not be identified. We further advised them that they could withdraw their participation at any time and skip those items they did not wish to complete.

In the chiefs' survey, chiefs were asked to answer the questionnaire based on the experience of an average patrol officer in their department. Survey instructions to the chiefs read as follows: 'We are undertaking a study of stress in law enforcement. For the purposes of this survey, please consider both physical (e.g. exertion) and mental aspects of stress/strain or exertion that officers may encounter in their work. In order to assist with this research, we request that you complete the following brief

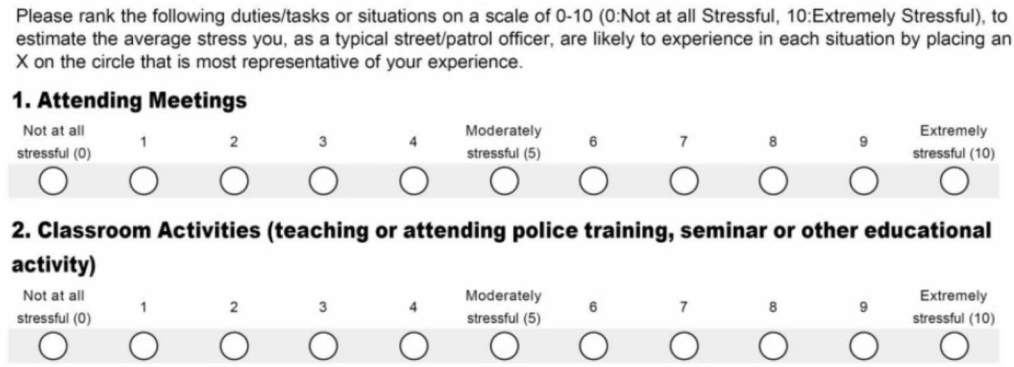

Figure 1: Survey instructions and Likert scale for stress ratings.

survey using your expertise as a Police Chief, Sheriff, or other Law Enforcement Official/ Administrator.' With respect to duties and time spent and duties and stress, we instructed the chiefs as follows: 'Please answer the following based on the experience of an average Patrol Officer in YOUR department.'

For the police union surveys, we asked the frontline officers to complete the survey based on their own experiences with the following instructions: 'We are undertaking a study of stress in law enforcement. For the purposes of this survey, please consider both physical stress (e.g. physical exertion) and mental aspects of stress/strain that you may encounter in your work. In order to assist with this research, we request that you complete the following brief survey using your experiences as a law enforcement officer.' With respect to duties and time spent and duties and stress, we instructed the frontline officers as follows: 'Please answer the following based on your experience as an officer in your department.'

The Institutional Review Board (IRB) of the Cambridge Health Alliance gave prior approval of the survey instruments and conduct. As above, we assured potential respondents that study participation was voluntary and individual respondents would not be identified. In order to guarantee anonymity and confidentiality, we did not collect internet protocol (IP) addresses, e-mails or other personal identifiers via the online surveys. For survey replies returned by mail, we assigned a unique numeric identifier to the enclosed completed survey and then immediately shredded the envelopes and to destroy any sender addresses or postmarks that might provide potential linkage to the respondents.

Sample selection and recruitment

Survey #1 among police chiefs

We had previously assembled a composite database including all reported US police sudden cardiac death (SCD) cases in the line of duty for the period 1984–2010 ($n = 369$, total SCD deaths) from two national databases ([O.D.M.P.], [N.L.E.O.M.F.]). The 340 distinct police departments employing the SCD victims provided a sample that was geographically representative of the USA with more departments concentrated in more populous areas (Fig. 2). The eligible departments included at least one police jurisdiction in 45 US states and the District of Columbia. Moreover, we plotted the number of SCD cases in each state (1984–2010) against national data for the number of LEOs working in each state (U.S.D.J., 2009) and found a strong linear correlation (data not shown).

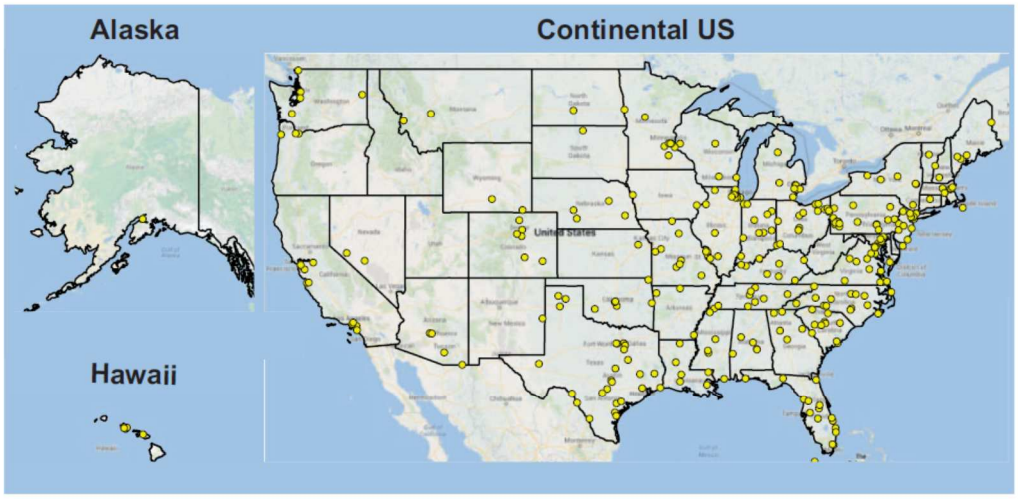

Figure 2: Geographic distribution of police departments eligible for the police chief survey.

This ensured that we surveyed more police departments in states employing a greater number of police officers.

For the purposes of the chiefs' survey, in August 2012, we mailed the paper questionnaire with a pre-addressed return envelope to all 340 US police departments represented in the composite SCD database. Our survey invitations and questionnaire did not mention how the departments were selected; nor did they mention any interest in SCD. Therefore, the potential chief participants and their departments were blinded from the both method of department selection, as well as our research interest in SCD events. After two months, we performed a follow-up mailing with an invitation to complete an online version of the same survey via an electronic survey link (SurveyMonkey®) (we advised in our letter that this invite was only applicable to those departments who had not previously completed the paper survey). The completed questionnaires were returned electronically to a database via SurveyMonkey®. We opened the chiefs' online survey on 21 October 2012 and closed it on 2 December 2012. We then merged the two databases (electronic and hard copy questionnaire responses) into a single database for the chiefs.

Survey #2: among frontline officers

We sent a separate electronic survey link (SurveyMonkey®) to the International Union of Police Associations (IUPA) and the Fraternal Order of Police (FOP) after both organizations agreed to solicit survey participation from their members. The two police unions repeatedly emailed the electronic link to members with available email addresses. The completed questionnaires were returned electronically to a database via SurveyMonkey. The officer online survey was opened on 22 August 2012 and closed on 2 December 2012.

Statistical analyses

Statistical analyses were carried out using Stata 12.1 SE (Stata Corp, College Station, TX, USA). For estimates of time spent on each duty, we converted all possible responses (e.g. hours per day, hours per week, hours per month or hours per year) to hours per year. Using information on actual police work schedules (Amendola *et al.*, 2009), we made the

following assumptions: an average of 4 days or shifts per week; and 48 weeks or 11 months working yearly to account for vacation and holidays. Accordingly, we used the following conversions: hours per day were multiplied by 192 (4 work days weekly for 48 work weeks); hours per week by 48; hours per month by 11; and hours per year by one.

We grouped some similar duties in broader categories. More specifically, the category of routine/non-emergency duties included: attendance of meetings, classroom activities, desk duty, paperwork and filing reports, roll call, escorting (e.g. funerals, parade, other event or dignitary), firing range practice, investigation, issuing parking or traffic tickets, and patrolling by car or foot. We classified responding to domestic disturbance calls and disturbing the peace calls as disturbance duties, while we classified the duties of providing emergency medical assistance and rescue operations as medical/rescue duties. In addition, we classified suspect pursuit by car and by foot as pursuit duties. We summarized percentages of time by duty types into mean, inter-quartile mean, and mean without outliers—that is, observations 1.5 inter-quartile ranges below the 25th percentile or 1.5 inter-quartile ranges above the 75th percentile. We then constructed percentile bootstrap 95% CI for these summary measures.

We compared categorical data using the Pearson's chi-square test and continuous variables using the Student's *t*-test or the Mann–Whitney U-test. We measured correlations between paired variable responses with the Spearman's rank correlation coefficient (Spearman's rho). We also used Bland–Altman difference plots to explore the agreement between frontline police officers and police chiefs. A *P*-value of less than 0.05 (two-tailed) was considered statistically significant for all analyses.

Results

A total of 93 police departments (27% of those surveyed) participated in the chiefs' survey: 73 (78%) by mail and 20 (22%) online. A total of 951 frontline officers responded to the officers' online questionnaire using the links sent by their unions. Data on the total number of police union members who received the email were not available from IUPA and FOP. Therefore, we could not calculate a response rate for the frontline officers.

As expected, chiefs were older and more experienced (greater seniority) than frontline officers. The chiefs who participated were more likely to belong to relatively smaller police districts located in rural areas or in smaller towns than the frontline officers (Table 1). When categorized by the number of officers in their respective police departments, the chiefs who responded to the survey were distributed in a fashion that was highly comparable to all US state and local law enforcement (Supplementary Appendix 2) (Reaves, 2011). Based on national data, the union members who participated as frontline officers under-represented jurisdictions with less than 100 officers (22% compared to 36% nationally) and over-represented departments with 500 or more officers (51% compared to 37% nationally) (Supplementary Appendix 2).

In Table 2, we present the average perceived levels of stress for each type of duty. With the exception of certain routine duties, chiefs reported higher average levels for officer stress than officers did for themselves. However, officers and chiefs produced very similar relative rankings of duties by stress level (Fig. 3), and we observed a highly significant correlation between the paired reported mean values (Spearman's rho 0.95, 95% CI 0.82–0.99, $P < 0.0001$). We also found excellent agreement between the two groups using the Bland–Altman difference plot, with only one duty (rescue operations) falling outside the 95% confidence limits of agreement (data not shown). The perceived stress levels were not influenced by the degree of urbanization (metropolitan, suburban, or rural area) of the police district for both chiefs and officers (Fig. 4).

All three different approaches—mean, inter-quartile mean, and mean without outliers—for

Table 1: Characteristics of the survey populations

	Frontline police officers		Police chiefs		
	(*N* = 951)		(*N* = 93)		*P*-value
Personal characteristic					
Age,[a] mean (SD)	40.8	(9.0)	49.0	(9.3)	<0.0001[b]
Seniority in service,[a] mean (SD)	15.3	(8.4)	25.6	(9.5)	<0.0001[b]
Characteristics of the department					
Size (number of officers), median (IQR)	500	(130–785)	125	(38–500)	<0.0001[c]
Location, % (95% CI)					
Metropolitan	60.8	(57.6–63.9)	42.9	(32.5–53.7)	
Suburban	28.3	(25.4–31.3)	31.9	(22.5–42.5)	
Rural	10.9	(9.0–13.1)	25.3	(16.7–35.5)	<0.0001[d]
Population of department's town, city or county, % (95% CI)					
0–10,000	5.6	(4.2–7.2)	10.9	(5.3–19.1)	
10,001–50,000	10.0	(8.2–12.1)	28.3	(19.4–38.6)	
50,001–100,000	15.4	(13.1–17.9)	15.2	(8.6–24.2)	
100,001–250,000	13.5	(11.3–15.8)	15.2	(8.6–24.2)	
250,001–500,000	26.6	(23.8–29.6)	10.9	(5.3–19.1))	
500,000–1,000,000	18.3	(15.8–20.9)	9.8	(4.6–17.6)	
>1,000,000	10.7	(8.8–12.8)	9.8	(4.6–17.6)	<0.0001[d]

IQR, inter-quartile range; SD, standard deviation.
[a]Calculations were based on 5-year categories and their mid-points (e.g. 33 for the category 31–35).
[b]*P*-value of Student's *t*-test for unpaired data.
[c]*P*-value of Mann–Whitney U-test.
[d]*P*-value of Pearson's chi-squared test.

estimating the relative proportions of time spent in each duty produced similar point estimates for both officers and chiefs (data not shown). However, we found narrower CIs for the frontline officers after the exclusion of the statistical outliers (Table 3). We found routine duties to comprise the majority of annual professional time (78% according to officers and 73% according to chiefs). However, survey respondents reported that moderately stressful duties such as disturbance and medical/rescue operations duties represented a considerable proportion of the working time. Average time estimates provided by officers and chiefs demonstrated a highly significant correlation using the Spearman's rho: 0.91 (95% CI 0.74–0.98, $P < 0.0001$). Likewise, using the Bland–Altman difference plot, we found evidence of good agreement between officers and chiefs, with only two duties—desk duty and patrol by car—following outside the 95% limits of agreement.

In Table 4, we present the proportions of professional time across duties for an average police officer based on characteristics of the department. Police from departments considered as 'rural' reported a higher proportion of time performing routine duties and less time dealing with various disturbances compared to those from 'metropolitan' departments. The duty-time or duty-exposure estimates for other tasks did not differ substantially. When departments were stratified by the size of the population served by a department or the number of officers in each department, we found this did not affect the estimates of professional time across duties.

Discussion

To the best of our knowledge, our surveys, which used two independent national populations, are the first to provide duty-time-stress 'exposure

Table 2: Comparison of duty-specific perceived stress levels by duty (sorted by mean values for frontline police officers)

Duty	Frontline police officers ($N = 951$) Perceived stress level		Police chiefs ($N = 93$)[a] Perceived stress level		P-value[b]
	Mean	(SD)	Mean	(SD)	
Roll call	1.2	(1.7)	1.5	(1.2)	0.115
Escorting	2.2	(2.3)	2.2	(1.7)	>0.999
Classroom activities	2.5	(2.0)	2.3	(1.4)	0.366
Attending meetings	2.6	(2.2)	2.5	(1.4)	0.679
Parking and traffic tickets	2.7	(2.4)	3.6	(1.9)	**<0.001**
Patrol by foot	2.9	(2.5)	3.5	(1.8)	**0.038**
Physical training	3.0	(2.5)	3.7	(2.2)	**0.016**
Firing range practice	3.3	(2.4)	3.4	(1.7)	0.710
Patrol by car	3.3	(2.2)	3.4	(1.5)	0.683
Desk duty, paperwork, filing reports	3.4	(2.3)	3.0	(1.4)	0.113
Transporting/supervising prisoners	3.9	(2.4)	4.8	(2.0)	**0.002**
Investigation/inspection	4.1	(2.2)	4.3	(1.7)	0.414
Rescue operations	4.2	(3.2)	6.1	(2.5)	**<0.001**
Disturbing the peace call	4.9	(2.4)	5.6	(1.8)	**0.009**
Emergency medical assistance	4.9	(2.5)	5.5	(1.8)	**0.030**
Testifying in court	5.0	(2.4)	5.8	(1.7)	**0.003**
Domestic disturbance call	5.7	(2.4)	6.6	(1.8)	**<0.001**
Serving a warrant	6.0	(2.7)	6.4	(1.7)	0.178
Restraint, physical altercation	7.1	(2.5)	8.2	(1.7)	**<0.001**
Witness a traumatic event	7.5	(2.6)	8.6	(1.6)	**<0.001**
Suspect pursuit by car	7.7	(2.7)	8.8	(1.6)	**<0.001**
Suspect pursuit by foot	7.7	(2.8)	8.8	(1.6)	**<0.001**
Spearman's rho	0.95 95% CI[c] 0.82–0.99 $P < 0.0001$				

[a]Police chiefs were asked to provide information for an average police officer in their department.
[b]P-value of Student's t-test for unpaired data.
[c]Percentile bootstrap CIs.
The bold mentioned in this table correspond to these results that are statistically significant, meaning a P-value less than 0.05.

assessments' by investigating the average relative time spent and mean perceived stress experienced across the wide variety of duties typically encountered in law enforcement. For both duty exposure time and duty-related stress, we found highly significant correlations between the respective estimates of the chiefs and of the officers for a typical officer's experience. However, chiefs reported higher average levels of stress for their subordinate officers compared to officers for themselves.

Our findings that both chiefs and officers rated altercations, witnessing traumatic events and pursuits as the three most stressful duties are supported by previous studies of heart rate monitoring among on-duty police officers. Consistent with our findings, Anderson *et al.* (2002) found the highest heart rates among officers during: physical altercations, major pursuits and during critical incidents. Additionally, another study, documented a rapid increase in heart rate during a pursuit of a drunken driver, which peaked at over 160 beats per minute when the officer confronted the non-complaint suspect (Hickman *et al.*, 2011). Both the agreement between chiefs and officers and physiologic

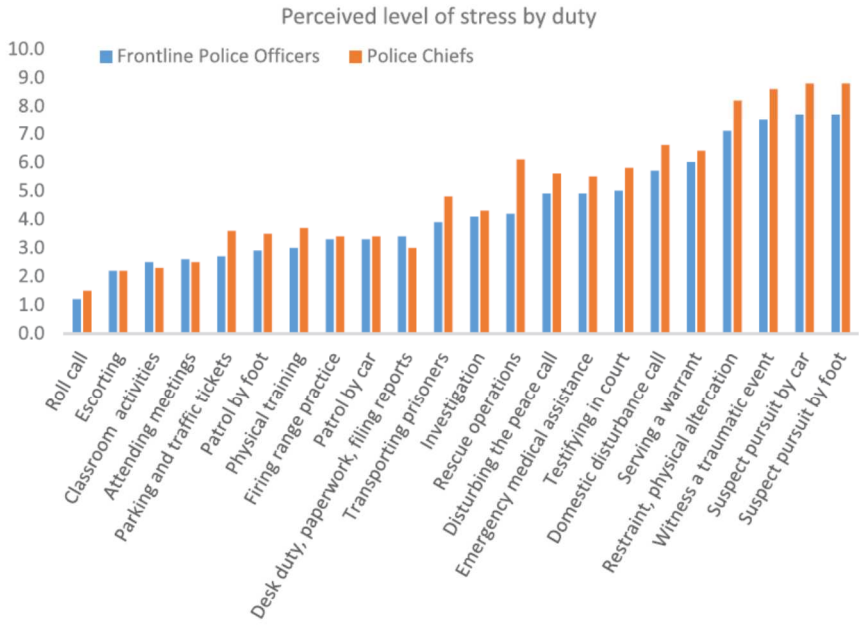

Figure 3: Perceived level of stress by duty: mean values reported by frontline police officers and police chiefs.

monitoring data support the validity of our survey findings regarding relative stress levels across different duties.

Similarly, our findings that the majority of police officers' time is spent in more routine duties and relatively small proportions of their time in direct confrontations or altercations with suspects are consistent with a previous investigation which explored the way officers spend their time in the community (Parks *et al.*, 1999). Nonetheless, we cannot directly compare the results because, Parks *et al.* study used very different methods; was limited to only two cities; and focused only on officers involved in 'community policing' rather than dispatch or '911' directed policing.

Our study does have several limitations. Because the survey populations we had available were convenience samples, they could not provide systematic or random samplings of all US police forces. On the other hand, we are able to present data above (see Methods and Fig. 2) that the police departments eligible for the chief survey were geographically representative of the USA and its relative population density distribution. Also, the participating chiefs' departments were representative of jurisdictions nationally with respect to department size as measured by number of officers employed (Supplementary Appendix 2).

Another limitation regards the response rates to the survey. While far from ideal, the response rate we observed for the police chief survey (27%) is very consistent with contemporary response rates for similar field surveys(Sheehan, 2001). According to Sheehan (2001), even though the number of studies using email to collect survey data has been increasing over the past years, the average response rate to these surveys appears to be decreasing; with a mean response rate of 24% in 2000. More recent national surveys by our research group among physicians who are members of the American College of Occupational and Environmental Medicine yielded similar response rates ranging

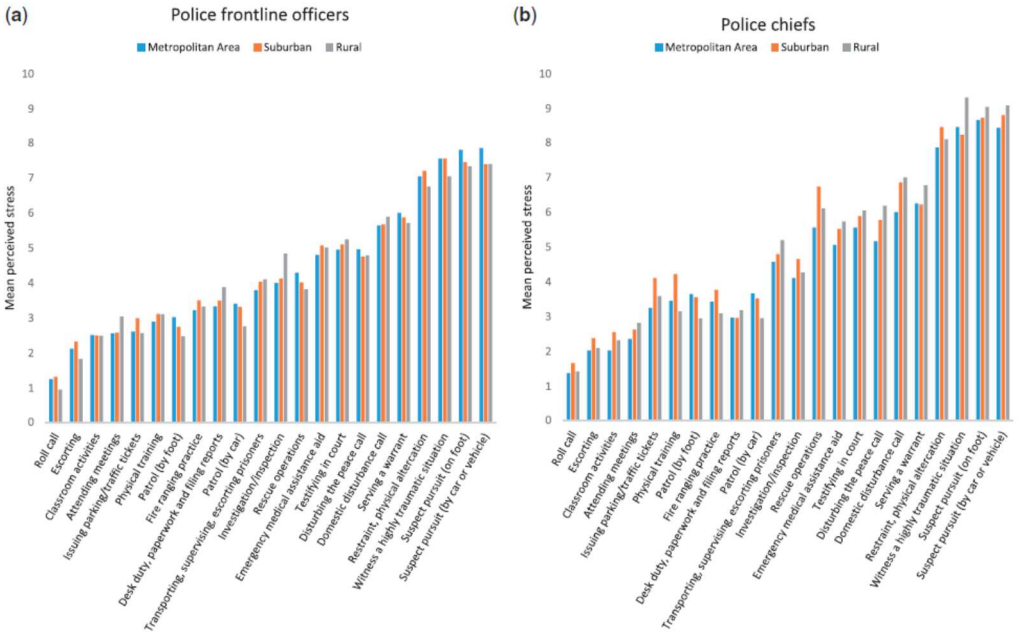

Figure 4: Perceived level of stress by location of department and duty: mean values reported by frontline police officers and police chiefs.

from 15% to 31% (Durand and Kales, 2009; Soteriades *et al.*, 2013).

Regarding the frontline officer survey, we could not calculate a response rate because data on the total number of police union members who received the email were not available from IUPA and FOP. We also cannot say with certainty whether union members who received email from these unions are representative of all IUPA and FOP members. However, we have no reason to believe they are not. We do know that our frontline officer participants under-represented very small departments and over-represented larger departments. Nonetheless, we did not find significant differences in our findings, when departments were stratified by the number of officers in each department. Moreover, although there were some differences in the departments represented by our two independent surveys, we found substantial statistical agreement in the findings from chiefs and officers.

Another limitation was that our study protocol and IRB approval did not allow us to trace the identity of survey respondents and non-respondents. Therefore, we could not conduct any head- to head comparison analyses of respondents versus non-respondents for either the chief or frontline officer survey. We did, however, perform an analysis of the police department characteristics of participating chiefs (based on survey responses) compared to the entire eligible chief survey population (based on publically available information). We found that, compared to the departments of the chiefs participating in our survey, the proportion of the entire sample of survey eligible departments belonging to metropolitan departments was comparable (43% for participants versus 47% for the total eligible sample).

Our study also has several strengths. The major strength of our study was the use of two independent survey populations: one representing

Table 3: Percentage of professional time across duties for an average police officer

Duty	Outliers excluded[a]			
	Officers		Chiefs	
	Percentage of time per duty	(95% CI)	Percentage of time per duty	(95%CI)
Attending meetings	2.6%	(2.4–2.8)	2.1%	(1.3–2.5)
Classroom activities	2.7%	(2.0–3.0)	1.7%	(1.4–2.1)
Desk duty, paperwork and filing reports	18.5%	(17.4–20.1)	12.4%	(11.0–14.5)
Escorting	0.3%	(0.2–0.5)	1.1%	(0.6–1.9)
Fire ranging practice	1.0%	(0.7–1.1)	0.7%	(0.3–0.9)
Investigation/inspection	10.7%	(9.3–11.5)	8.7%	(7.2–10.6)
Issuing parking/traffic tickets	5.4%	(4.3–6.9)	5.2%	(3.3–6.2)
Patrol (by car)	30.3%	(28.8–31.7)	35.4%	(31.3–37.9)
Patrol (by foot)	2.4%	(1.7–2.7)	2.5%	(1.9–4.1)
Roll call	3.5%	(3.3–3.7)	3.0%	(2.0–3.4)
Subtotal routine	77.4%	(75.8–78.7)	72.8%	(66.9–75.2)
Domestic disturbance call	5.6%	(5.2–6.1)	5.2%	(3.8–6.4)
Disturbing the peace call	4.0%	(2.8–5.0)	3.6%	(3.1–5.3)
Subtotal disturbance	9.6%	(8.3–10.9)	8.8%	(7.4–11.1)
Emergency medical assistance aid	2.8%	(2.5–3.0)	2.9%	(2.4–3.4)
Rescue operations	0.1%	(0.1–0.2)	1.0%	(0.4–1.7)
Subtotal medical and rescue operations	2.9%	(2.6–3.1)	3.9%	(2.9–4.8)
Suspect pursuit (by car or vehicle)	0.3%	(0.2–0.5)	0.6%	(0.3–0.9)
Suspect pursuit (on foot)	0.5%	(0.4–0.6)	0.6%	(0.5–1.0)
Subtotal pursuit	0.8%	(0.7–1.0)	1.2%	(0.9–1.8)
Physical training	2.9%	(2.5–3.3)	3.1%	(2.2–4.1)
Restraint, physical altercation	1.2%	(1.1–1.3)	2.3%	(1.1–2.8)
Serving a warrant	1.6%	(1.2–2.1)	2.4%	(1.3–2.9)
Transporting/supervising prisoners	2.2%	(2.0–2.4)	4.1%	(3.1–11.9)
Testifying in court	1.4%	(1.3–1.7)	1.3%	(0.8–1.6)
Spearman's rho	0.91 95% CI[b] 0.74–0.98 $P < 0.0001$			

[a]Estimates based on mean values after the exclusion of statistical outliers. Outliers were defined as observations 1.5 inter-quartile ranges below the 25th percentile or 1.5 inter-quartile ranges above the 75th percentile.
[b]Percentile bootstrap CIs (10,000 repetitions).

management and supervisors, and the other representing labour and frontline police officers. The complete independence of the two sampling strategies coupled with the strong consistency of the results increase the validity of our findings. Even though chief and officer participants differed somewhat with respect to jurisdiction characteristics (size and location), on average, they gave similar answers to the questionnaire. The two surveys provided very similar patterns of proportional time spent in each duty and strikingly similar relative stress ratings for more than 20 law enforcement duties. We found highly robust statistical agreement for both stress and time estimates (Spearman's rho, both $P < 0.0001$).

Another major strength of our study was the careful development of the survey instrument in the absence of a previously published and validated

Table 4: Percentage of professional time across duties for an average police officer by characteristics of the department: analysis of frontline police officers

Duty	Outliers excluded[a]					
	Percentage of time per duty	(95% CI)	Percentage of time per duty	(95% CI)	Percentage of time per duty	(95% CI)
Location	**Metropolitan**		**Suburban**		**Rural**	
Subtotal routine	75.2	(73.6–77.0)	79.6	(77.4–81.3)	82.3	(77.7–84.9)
Subtotal disturbance	11.1	(9.7–12.2)	8.1	(7.0–9.8)	4.7	(3.1–7.2)
Subtotal medical and rescue operations	2.7	(2.4–3.0)	3.1	(2.6–3.7)	2.9	(2.2–4.9)
Subtotal pursuit	0.9	(0.7–1.2)	0.5	(0.3–0.8)	1.5	(0.5–4.3)
Physical training	3.1	(2.5–3.7)	2.5	(1.7–3.2)	2.7	(1.0–3.7)
Restraint, physical altercation	1.2	(1.1–1.8)	1.2	(1.0–1.4)	0.9	(0.6–2.5)
Serving a warrant	1.8	(1.1–2.2)	1.4	(1.2–1.9)	1.9	(1.2–3.3)
Testifying in court	1.6	(1.2–1.9)	1.4	(1.1–1.7)	1.3	(0.9–2.8)
Transporting/supervising prisoners	2.3	(2.0–3.3)	2.3	(1.5–2.7)	1.8	(1.3–3.7)
Served population (inhabitants)	**Less than 100,000**		**100,000–500,000**		**More than 500,000**	
Subtotal routine	78.3	(76.0–80.7)	77.0	(74.3–78.7)	78.2	(74.9–80.6)
Subtotal disturbance	8.6	(6.4–10.2)	11.2	(8.9–12.6)	8.2	(6.4–11.1)
Subtotal medical and rescue operations	3.3	(2.9–3.8)	2.5	(2.2–2.9)	2.7	(2.3–3.2)
Subtotal pursuit	0.7	(0.4–1.3)	0.6	(0.5–1.1)	0.8	(0.6–1.7)
Physical training	2.8	(2.1–3.4)	2.8	(2.0–3.4)	3.3	(2.4–4.0)
Restraint, physical altercation	1.0	(0.7–1.5)	1.2	(1.1–1.8)	1.2	(1.0–2.1)
Serving a warrant	1.9	(1.2–2.4)	1.1	(1.0–2.2)	1.6	(1.1–2.1)
Testifying in court	1.3	(1.1–2.0)	1.3	(1.1–1.7)	1.7	(1.3–2.1)
Transporting/supervising prisoners	2.1	(1.8–2.5)	2.2	(1.9–3.5)	2.4	(1.9–3.3)
Number of officers	**Less than 200**		**200–700**		**More than 700**	
Subtotal routine	78.5	(76.9–82.1)	75.9	(73.6–77.9)	76.9	(74.4–79.6)
Subtotal disturbance	8.6	(5.5–9.8)	11.2	(9.5–12.6)	9.6	(7.3–11.6)
Subtotal medical and rescue operations	3.3	(2.9–4.0)	2.5	(2.2–2.9)	2.7	(2.3–3.1)
Subtotal pursuit	0.7	(0.3–1.0)	0.9	(0.5–1.2)	0.9	(0.6–1.5)
Physical training	3.1	(2.3–3.5)	2.2	(1.3–2.9)	2.8	(2.5–4.0)
Restraint, physical altercation	1.1	(0.7–1.7)	1.2	(1.0–1.4)	1.7	(1.0–2.2)
Serving a warrant	1.4	(1.2–2.1)	2.1	(1.1–2.5)	1.6	(1.1–2.1)
Testifying in court	1.3	(1.0–1.6)	1.7	(1.3–2.1)	1.4	(1.1–1.9)
Transporting/supervising prisoners	2.1	(1.3–2.4)	2.3	(2.0–4.2)	2.3	(1.9–2.8)

[a]Estimates based on mean values after the exclusion of statistical outliers. Outliers were defined as observations 1.5 inter-quartile ranges below the 25th percentile or 1.5 inter-quartile ranges above the 75th percentile.
[b]Percentile bootstrap CIs (10,000 repetitions).

questionnaire. We created the original draft survey based on a literature search; sought revisions from an experienced police chief; and then conducted a pilot survey using Massachusetts police chiefs. We then sought additional input and refinements from members of national law enforcement organizations before finalizing the questionnaire.

A third important strength of our study was the ability to perform analyses stratified on the police departments' characteristics (location, population served, and number of employed officers). Because we did not observe major differences in terms of the proportions of professional time spent across different duties or in perceived stress across duties, this provides reassurance that our

sampling strategies and response rates did not bias the results.

Conclusion

Police chiefs and frontline police officers, independently surveyed using the same questionnaire, provided similar estimates of the relative time spent by officers annually across different law enforcement duties. The duty-specific average stress levels reported by the two groups were also highly correlated. Both police chiefs (management) and frontline officers (labour) agreed that routine duties constituted over 70% of police officers' professional time. They were also in agreement that witnessing traumatic events, physical altercations and suspect pursuits were the three most stressful duties, although the latter two account for less than 5% of work time combined.

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Supplementary Data

Supplementary Data is available at *Policing* online.

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RESEARCH

Law enforcement duties and sudden cardiac death among police officers in United States: case distribution study

Vasileia Varvarigou *visiting scientist and medical resident*[1 2], Andrea Farioli *postdoctoral research fellow*[1 3 4], Maria Korre *PhD student*[1 3], Sho Sato *undergraduate student)*[3], Issa J Dahabreh *assistant professor*[5 6], Stefanos N Kales *associate professor*[1 3]

[1]Environmental and Occupational Medicine and Epidemiology, Harvard School of Public Health, Boston, MA, USA; [2]Department of Internal Medicine, St Elizabeth's Medical Center, Tufts Medical School, Brighton, MA, USA; [3]Occupational Medicine, Cambridge Health Alliance, Harvard Medical School, Cambridge, MA, USA; [4]Department of Medical and Surgical Sciences, DIMEC, University of Bologna, Bologna, Italy; [5]Center for Evidence-based Medicine, School of Public Health, Brown University, Providence, RI, USA; [6]Department of Health Services, Policy and Practice, School of Public Health, Brown University, Providence, RI, USA

Abstract

Objective To assess the association between risk of sudden cardiac death and stressful law enforcement duties compared with routine/non-emergency duties.

Design Case distribution study (case series with survey information on referent exposures).

Setting United States law enforcement.

Participants Summaries of deaths of over 4500 US police officers provided by the National Law Enforcement Officers Memorial Fund and the Officer Down Memorial Page from 1984 to 2010.

Main outcome measures Observed and expected sudden cardiac death counts and relative risks for sudden cardiac death events during specific strenuous duties versus routine/non-emergency activities. Independent estimates of the proportion of time that police officers spend across various law enforcement duties obtained from surveys of police chiefs and front line officers. Impact of varying exposure assessments, covariates, and missing cases in sensitivity and stability analyses.

Results 441 sudden cardiac deaths were observed during the study period. Sudden cardiac death was associated with restraints/altercations (25%, n=108), physical training (20%, n=88), pursuits of suspects (12%, n=53), medical/rescue operations (8%, n=34), routine duties (23%, n=101), and other activities (11%, n=57). Compared with routine/non-emergency activities, the risk of sudden cardiac death was 34-69 times higher during restraints/altercations, 32-51 times higher during pursuits, 20-23 times higher during physical training, and 6-9 times higher during medical/rescue operations. Results were robust to all sensitivity and stability analyses.

Conclusions Stressful law enforcement duties are associated with a risk of sudden cardiac death that is markedly higher than the risk during routine/non-emergency duties. Restraints/altercations and pursuits are associated with the greatest risk. Our findings have public health implications and suggest that primary and secondary cardiovascular prevention efforts are needed among law enforcement officers.

Introduction

Law enforcement is a dangerous occupation. In 2011-12, the fatality rate among patrol officers in the United States was 15-16 per 100 000 full time workers, about 3-5 times the national average for private sector employees.[1 2] Most of these on duty fatalities are traumatic.[2] Statistics for deaths of police on duty that are attributable to cardiovascular disease events are not well documented but are estimated to account for 7% of fatalities.[3] Cardiovascular events among police officers on duty are perceived with increasing concern by the law enforcement community and the general public.[4] Though cardiovascular disease among police has received a high priority from the National Occupational Research Agenda of the National Institute for Occupational Health and Safety,[5] it has not been adequately studied.

Correspondence to: S N Kales, Department of Environmental Health, Cambridge Hospital, Macht Building 427, 1493 Cambridge Street, Cambridge, MA 02139, USA skales@hsph.harvard.edu

Extra material supplied by the author (see http://www.bmj.com/content/349/bmj.g6534?tab=related#datasupp)

Appendix 1: Supplementary methods
Appendix 2: Supplementary tables A-C
Appendix 3: Supplementary figures A and B

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Some evidence suggests that cardiovascular morbidity is greater among police than the general population; and some jurisdictions provide benefits to police officers or their families after cardiovascular events.[3 6] Studies of "triggering" in the general population show that acute exposure to physical or psychological stress is associated with a short term increase in the risk of acute cardiovascular events, including sudden cardiac death.[7-9] Chronic exposure to established risk factors for cardiovascular disease (such as hypertension, dyslipidemia, obesity, and tobacco smoking) can lead to underlying coronary heart disease or cardiomegaly, providing the pathophysiologic substrate for acute sympathetic arousal and cardiovascular strain to precipitate acute cardiovascular events, including sudden cardiac death.[10] It is thought that stress triggers the final steps in a pathophysiologic cascade, culminating in an acute cardiovascular event.

Evidence indicates that the prevalence of traditional risk factors for cardiovascular disease among the police is high (often higher than the general population).[3] Moreover, law enforcement work involves various acute physical and psychological stressors.[6-13] It is therefore plausible that certain law enforcement tasks could serve as an occupational trigger in susceptible police officers, leading to an increased frequency of sudden cardiac death during stressful duties. This association is indirectly supported by epidemiologic studies of firefighters that have documented a markedly increased risk of acute death from heart disease (10-fold to over 100-fold) during fire suppression compared with non-emergency duties.[14-17] On the basis of studies of triggering and surveys of police officers and chiefs regarding job stress,[13] we hypothesized that stressful law enforcement duties are likely to be associated with increased risk of sudden cardiac death while on duty compared with routine/non-emergency duties.

Methods

We conducted a case-distribution study[18] by combining a case series of sudden cardiac death events among police officers with survey information on the proportion of time on duty that officers spend on different activities. We provide additional information on study design in appendix 1.

Deaths among law enforcement officers

The National Law Enforcement Officers Memorial Fund tracks US police deaths in the line of duty. It is the only major database to systematically consider fatalities arising from medical conditions, such as cardiovascular disease, and consistently documents a larger number of annual fatalities than other databases.[2] This was the primary database we selected for the current study.[19] Because it uses similar inclusion criteria, we also reviewed the Officer Down Memorial Page to identify additional cases of sudden cardiac death.[20]

Both databases define "law enforcement officers" as persons with arrest powers employed by a US law enforcement agency and "death in the line of duty" as a fatality occurring "as a direct and proximate result of a personal injury sustained in the line of duty."[19 20] Regarding on duty deaths from "natural causes," both databases require the medical condition to have arisen out of physical exertion or a specific stressful activity while on duty. Cases deemed related to alcohol, drug, or other substance abuse or intoxication are not included in either database.

Because our goal was to identify sudden cardiac deaths among US police occurring during law enforcement activities independent of their association with specific tasks, we obtained and reviewed an additional database from the National Law Enforcement Officers Memorial Fund with all deaths related to cardiovascular disease among law enforcement officers during the study period that had been submitted for possible inclusion but were ultimately rejected by the fund's board.

Ethical approval

The use of publicly available fatalities databases is exempt from institutional review board evaluation under US law ("deceased, non-living subjects").[21]

Ascertainment of on duty sudden cardiac death events

We selected for further evaluation all non-traumatic fatalities from the two databases and all deaths related to cardiovascular disease but rejected for inclusion in the memorial fund (fig 1⇓). Cases were reviewed to determine eligibility and to extract data. A physician (VV) identified all deaths explicitly labeled as related to cardiovascular disease and selected additional cases consistent with on duty sudden cardiac death. Two additional reviewers (AF, MK) independently assessed the accuracy of the selected cases and re-examined the remaining non-traumatic fatalities for further case inclusions. A board certified occupational physician (SNK) resolved any discrepancies about classifications of cause of death.

We extracted the following information for each fatality: age, sex, date of death, listed cause of death, and the narrative case summary. Case summaries provide a short description for each law enforcement officer fatality; these were reviewed for possible inclusion as sudden cardiac death cases following established procedures.[15 23]

We selected for analysis only those cases determined to be sudden cardiac deaths on duty. We defined sudden cardiac death as a fatality characterized by a sudden loss of consciousness (within one hour of the onset of acute symptoms, if present) in the absence of other compatible explanations (such as cerebrovascular event, pulmonary embolism, aortic aneurysm, etc).[22 24] We excluded deaths that occurred more than 24 hours after the on duty event unless the law enforcement officer had sudden loss of consciousness while on duty and then never regained it before a later biologic death (for example, cardiac arrest followed by a period of maintenance on life support without the patient regaining consciousness).

Police duties at the time of the death

Based on each sudden cardiac death case summary, we classified deaths according to the specific duty being performed at onset of symptoms or immediately preceding death. Duties were categorized as routine/non-emergency or non-routine/stressful based on independent national surveys of police stress in relation to a wide spectrum of different law enforcement duties.[13] "Routine/non-emergency duties" included the following activities: attending meetings; classroom activities; desk duty, office, and paperwork; escorting (such as funerals, dignitaries); firing range practice; investigation/inspection; issuing parking/traffic tickets; and patrol and roll call. "Non-routine duties" were defined as "disturbance" (domestic disturbance calls and disturbance of peace calls); medical and rescue operations; physical training (on duty exercise, physical training or drills related to employment, and law enforcement fitness tests); physical restraints/physical altercations (with suspects, prisoners, other detainees, or other uncooperative members of the public, etc); serving a warrant; suspect pursuits; testifying in court; and transporting/supervising prisoners.[13]

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Time spent on specific duties

We estimated the proportion of time spent across different law enforcement duties from national surveys of frontline police officers and police chiefs.[13] The first set of estimates was based on data from 951 frontline officers contacted through the International Union of Police Associations and the Fraternal Order of Police (response rate not available). The second set of estimates was based on data from 93 police chiefs (27% response rate) who completed the survey based on the experience of typical patrol officers in their respective departments. The two surveys provided similar patterns of the proportion of time on duty spent on different activities. We also obtained information on officer age, location of police department (rural, suburban, or urban), jurisdiction size (based on covered population), and size of police department (based on number of officers).

Statistical analysis

If the duties performed were unrelated to the risk of sudden cardiac death, the number of deaths associated with each duty would be proportional to the time officers spend performing that duty. For example, if police officers spend 75% of their time on routine/non-emergency duties, we would expect 75% of sudden cardiac deaths to be associated with such duties. Thus, using survey results and the total number of sudden cardiac death events, we derived the expected number of sudden cardiac death events associated with each duty and calculated ratios of observed to expected (O:E) events. We then estimated duty specific relative risks for sudden cardiac death and corresponding 95% confidence intervals by fitting a Poisson regression model with the observed count of sudden cardiac deaths as the response and the logarithm of the proportion of time per duty as the offset.

We conducted stability analyses using different exposure estimates of the proportional time spent across law enforcement duties. These included stratification of the officer and chief surveys based on jurisdiction size and use of only the survey responses of frontline law enforcement officers with a similar age distribution as the cases.

We estimated the age specific incidence rate of sudden cardiac death per 100 000 person years at risk. Assuming an average of 2080 worked hours a year,[25] we obtained person time estimates based on the number of law enforcement officers at risk according to the Current Population Survey (1989-2010)[26] and the proportion of on duty time spent in each duty.

Additionally, to evaluate robustness[27] to potentially unreported cases of sudden cardiac death during routine/non-emergency duties, we repeated our analyses after hypothetically assuming a number of missing sudden cardiac deaths ranging from 0 (that is, equivalent to our main analysis) to 1000 (that is, more than twice the observed total number of events). We also repeated our analyses after hypothetically assuming that a proportion of time considered as routine/non-emergency activities ranging from 0% (that is, equivalent to our main analysis) to 20% (that is, a fifth of on duty time) should have been classified as a specific strenuous duty.

We performed all statistical analyses using Stata 13.1/SE (StataCorp, College Station, TX). $P<0.05$ was considered to indicate significance, and all tests were two sided.

Results

The National Law Enforcement Officers Memorial Fund included records for 4553 on duty police fatalities between 1 January 1984 and 31 December 2010 of which we categorized 331 as sudden cardiac deaths. The Officer Down Memorial Page database included records on 4661 deaths during the same period, with 359 classified as sudden cardiac deaths. Overlap between the two databases was high (91% of all unique cases of sudden cardiac death were included in both databases). During the study period the memorial fund rejected 126 events related to cardiovascular disease, of which we categorized 78 as on duty sudden cardiac deaths after review. Thus, we identified at total of 441 unique sudden cardiac deaths (fig 1⇓) or roughly 9-10% of all on duty police fatalities. The mean age at the time of death was 47 years (SD 9 years). Only nine of the cases (2%) were in women.

We were able to identify the duty associated with the sudden cardiac death for 431 of the cases (98%). Sudden cardiac death was most commonly associated with restraints/physical altercations (25%), followed by routine/non-emergency activities (23%), physical training (20%), and pursuits (12%); 19% of events were associated with other duties (table 1⇓).

Table 1⇓ shows the estimated proportion of time spent on each duty, expected events, and ratios of observed to expected events based on the frontline officer and chief surveys. It also summarizes the relative risk estimates for the association of specific duties with sudden cardiac death compared with routine/non-emergency activities. Higher risks of sudden cardiac death (relative risk >10) were observed for restraints and physical altercations, suspect pursuits, and physical training. We also found evidence supporting an association between sudden cardiac death risk and transporting/supervising prisoners, medical and rescue operations, and less consistent evidence for associations with serving a warrant and responding to disturbances.

Figure 2⇓ shows the incidence rates of sudden cardiac death among law enforcement officers by duty and age group. The total and duty specific risk of sudden cardiac death increased with age.

Stability analyses conducted to explore the impact of jurisdiction size (population served; table 2⇓) and age of the officer (table 3⇓ and table C in appendix 2) produced results that were qualitatively similar to the main analyses presented above. Sensitivity analyses showed that our main findings remained robust across hypothetical scenarios varying the number of missing sudden cardiac death reports and the magnitude of misclassification of strenuous duty times (figs A and B in appendix 3). During restraints/physical altercations, suspect pursuits, and physical training, the relative risk point estimates and the lower bound of the 95% confidence interval remained greater than 1.0, supporting a significantly increased risk of sudden cardiac death even under the most extreme hypothetical scenarios.

Discussion

Principal findings

Physically and psychologically stressful law enforcement duties are associated with large increases in the risk of sudden cardiac death compared with routine/non-emergency policing activities. To our knowledge our study is the first to show an association between specific law enforcement duties and risk of sudden cardiac death—a finding that supports the hypothesis that stressful work related activities can "trigger" sudden cardiac death and is consistent with our previous studies of on duty acute cardiac deaths among firefighters.[14-16] In addition, our finding that up to 10% of all on duty deaths during law enforcement are sudden cardiac deaths represents the most

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accurate estimate to date of the proportionate mortality from sudden cardiac death in this population.

While routine/non-emergency duties constituted about 75% of police work time, 77% of sudden cardiac deaths occurred during non-routine tasks. Physical restraints and altercations comprised about 1-2% of a police officer's annual professional time but accounted for 25% of on duty sudden cardiac deaths. Therefore, restraints and altercations were associated with a sudden cardiac death risk about 30-70 times higher than the risk during routine/non-emergency law enforcement duties. Similarly, pursuits of suspects also comprised less than 2% of on duty time but were associated with 12% of sudden cardiac deaths and risks 30-50 times higher than during routine/non-emergency duties. The most likely explanation for these findings is a sudden increase in cardiovascular demand because of a combination of physical exertion and psychological stress, consistent with "fight or flight" physiology.[10 28] These results are also consistent with police chief and frontline officer ratings of altercations and pursuits as the most stressful duties,[13] as well as prior investigations of heart rate monitoring among on duty police officers, documenting pronounced tachycardia during these confrontational situations.[29 30]

Although police do not perceive physical training as particularly stressful,[13] we found that training activities were associated with about 20-25 times higher risk of sudden cardiac death when compared with routine/non-emergency law enforcement duties. These findings are compatible with evidence linking physical exertion to cardiovascular event triggering in the general population, particularly among physically inactive persons,[7-31] as well as findings on the association of physical training with sudden cardiac death in the US fire service.[15]

Medical and rescue operations, supervising and transporting prisoners, and other potentially stressful interactions with the public (such as serving warrants and responding to various civil disturbances) were associated with an increased risk of sudden cardiac death. These findings are important because currently the law enforcement community does not usually consider these duties as strenuous.[19 20] The considerable psychological stress of these activities and their potential to trigger cardiovascular events has implications for related workers' compensation, disability retirement, and death benefit claims.

Applicability of research findings

We believe that our findings are also applicable to law enforcement work outside the US. Law enforcement duties show substantial variation across jurisdictions in the US, rendering our findings more broadly representative. Furthermore, triggering of sudden cardiac death by acute exposure of susceptible individuals to physical or psychological stress is a pathophysiological mechanism shared by other occupations characterized by short bursts of stressful and physically demanding tasks.[3-17] For many law enforcement officers, most on duty time is spent on relatively sedentary activities, punctuated by unpredictable short periods of stressful activities.[28] In addition, officers have a relatively high prevalence of risk factors for cardiovascular disease, such as hypertension, obesity, dyslipidemia, and subclinical atherosclerosis.[3 6] In the general population, bursts of physical exertion or emotional stress have been associated with myocardial infarction and sudden cardiac death, particularly among individuals with low physical fitness and underlying cardiovascular disease.[7-32] It seems that similar mechanisms are operating during strenuous duties in susceptible officers with underlying disease.

Study limitations

Our work has some limitations. First, there are no large scale studies of how US law enforcement officers in different locations spend their time. We used nationwide survey data from police chiefs and front line officers, and we were able to account for variation in officer rank, size of population served, and department location when estimating the proportion of time officers spent on various duties.[13]

Second, no single database catalogues all on duty law enforcement fatalities related to cardiovascular disease, and databases that do track such cases selectively include events that occur during stressful situations. We were, however, able to obtain all cases related to cardiovascular disease denied by the National Law Enforcement Officers Memorial Fund after submission for consideration. There is good reason to believe that most cases of sudden cardiac death in police officers would be submitted for consideration based on the desire to honor the dead officers and to establish eligibility for financial benefits available to officers' families after on duty deaths from cardiovascular disease.[3 6] This is supported by the fact that we had to exclude numerous submitted cases in which the cardiovascular event obviously occurred while off duty. Furthermore, sensitivity analyses showed that the association of most duties with sudden cardiac death would persist, unless the number of missing cases was implausibly large. Therefore, missing event reports are unlikely to account for our results.

Third, to identify cases of sudden cardiac death and the associated duties, we relied on information abstracted from brief summaries without prior medical records and often lacked corroboration by autopsy results. Therefore, we used only those cases verified by multiple independent reviewers and limited our analyses to cases for which the cause of death could be ascertained with certainty. We have recently shown high agreement between identification of sudden cardiac death through brief case histories from public safety databases and comprehensive investigative reports conducted by health personnel contracted by the US National Institute for Occupational Safety and Health.[33] Furthermore, with respect to time spent on different duties, sensitivity analyses showed that for most emergency duties, exposure misclassification would have to be extreme to explain away our findings.

Fourth, we could not assess the contribution of risk factors for cardiovascular disease (such as obesity, hypertension, and diabetes) to the sudden cardiac death events because data were not available in the case summaries we reviewed. Existing evidence, however, supports that "triggering" occurs almost exclusively on a substrate of underlying disease.[6-23] The case summaries also did not include information on the time of death; therefore, we could not assess the impact of work shift on risk of sudden cardiac death.

Implications for future research and policy

The limitations of our study reflect the fact that, at present, the "best available data" are imperfect. Our results are best interpreted as indicative of the direction and relative magnitude of the associations between stressful police duties and sudden cardiac death, rather than an exact quantification of the magnitude of these associations. That said, the consistency of our results across stability and sensitivity analyses suggests that these associations are valid and merit further study. Future research could obtain officer level information on daily activities, use data from medical records and autopsies to identify cardiac deaths, and implement self controlled study

designs to more accurately quantify the association between stressful policing activities and sudden cardiac death.

Our findings have public health implications for prevention of cardiovascular disease among law enforcement officers and call for the implementation of prevention efforts for primary and secondary cardiovascular disease. Management of risk factors for cardiovascular disease—including interventions to increase physical activity, promote smoking cessation, maintain a healthy weight, and treat hypertension and dyslipidemia—could be used to protect police officers from the triggering effects of stressful duties and also reduce rates of long term cardiovascular disease. Our results support the US National Institute for Occupational Safety and Health research agenda that prioritizes research on cardiovascular disease among law enforcement officers, similar to efforts in firefighters.[5]

Conclusions

Using nationwide data on sudden cardiac death in law enforcement officers on duty and survey data on the proportion of time spent on specific duties, we found that stressful and physically demanding law enforcement activities were associated with large increases in the risk of sudden cardiac death, compared with routine/non-emergency policing activities.

We thank the National Law Enforcement Officers Memorial Fund and Officer Down Memorial Page for providing information on police officer deaths. We thank William J Johnson (National Association of Police Organizations), Stephen Fender, George Sherrill, Kevin Summers (Fraternal Order of Police), Sam Cabral, and the International Union of Police Associations for supporting surveys of time spent on law enforcement duties. We also thank Byron Wallace (University of Texas at Austin) for providing help with data abstraction and coding. We express our deepest appreciation to the police chiefs, police departments, and frontline police officers for their collaboration with the surveys and their service to the public.

Contributors: VV contributed to the design of the study, acquisition of data, interpretation of data, and drafting the manuscript. AF contributed to the analysis and interpretation of data. MK contributed to the analysis and interpretation of data, and drafting the manuscript. SS contributed to the design of the study and acquisition of data. IJD contributed to the design of the study, acquisition of data, analysis and interpretation of data, and drafting the manuscript. SNK conceived the idea and the design of the study, contributed to obtaining funding, acquisition of data, analysis and interpretation of data, and drafting the manuscript. All authors had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. All authors revised the manuscript critically for important intellectual content. SNK is guarantor.

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Competing interests: All authors have completed the ICMJE uniform disclosure form and declare that SNK served as paid expert witness, independent medical examiner, or both, in workers' compensation and disability cases, including cases involving law enforcement.

Ethical approval: Not required.

Data sharing: The data on police officer deaths and case histories are available online. Statistical code is available from the corresponding author.

Transparency declaration: The corresponding author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; no important aspects of the study have been omitted; and any discrepancies from the study as planned have been explained.

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What is already known on this topic

Epidemiologic studies in fire fighters suggest that the risk of sudden cardiac death is increased during stressful duties compared with non-emergency duties

Data about the impact of specific on duty activities on cardiovascular deaths among police officers are not available

What this study adds

Among US police officers, stressful duties were associated with large increases in the risk of sudden cardiac death compared with routine/non-emergency policing activities

Restraints and altercations were associated with about 30-70 times the risk of sudden cardiac death compared with routine/non-emergency law enforcement duties

Training activities were associated with about 20-25 times the risk of sudden cardiac death compared with routine/non-emergency law enforcement duties

Tables

Table 1| **Risk of sudden cardiac death among law enforcement officers engaged in emergency and strenuous duties compared with officers engaged in routine/non-emergency duties. Combined data from National Law Enforcement Officers Memorial Fund and Officer Down Memorial Page (1984-2010)***

		Frontline police officers survey				Police chiefs survey			
Duty	Observed events (%)	% time per duty†	Expected events	O:E	Relative risk (95% CI)	% time per duty†	Expected events	O:E	Relative risk (95% CI)
Routine/non-emergency	101 (23.4)	77.4	333.6	0.30	Reference	72.8	313.8	0.32	Reference
Disturbance	20 (4.6)	9.6	41.4	0.48	1.60 (0.99 to 2.58)	8.8	37.9	0.53	1.64 (1.01 to 2.65)
Testifying in court	3 (0.7)	1.4	6.0	0.50	1.64 (0.52 to 5.18)	1.3	5.6	0.54	1.66 (0.53 to 5.24)
Serving warrant	6 (1.4)	1.6	6.9	0.87	2.87 (1.26 to 6.55)	2.4	10.3	0.58	1.80 (0.79 to 4.11)
Transporting or supervising prisoners	18 (4.2)	2.2	9.5	1.90	6.27 (3.80 to 10.4)	4.1	17.7	1.02	3.16 (1.92 to 5.22)
Medical and rescue operations	34 (7.9)	2.9	12.5	2.72	8.98 (6.09 to 13.3)	3.9	16.8	2.02	6.28 (4.26 to 9.27)
Physical training	88 (20.4)	2.9	12.5	7.04	23.3 (17.5 to 30.9)	3.1	13.4	6.59	20.5 (15.4 to 27.2)
Pursuit	53 (12.3)	0.8	3.5	15.4	50.8 (36.4 to 70.8)	1.2	5.2	10.2	31.8 (22.8 to 44.4)
Restraint, physical altercation	108 (25.1)	1.2	5.2	20.9	69.0 (52.6 to 90.5)	2.3	9.9	10.9	33.8 (25.8 to 44.4)

O/E=observed over expected number of events.

*Results ordered by magnitude of estimated relative risk based on frontline police officers survey.

†Based on data from Korre et al[13]; see table A in appendix 2.

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Table 2| **Analyses of risk of sudden cardiac death among law enforcement officers engaged in emergency and strenuous duties compared with officers engaged in routine/non-emergency duties, combined data from National Law Enforcement Officers Memorial Fund and Officer Down Memorial Page (1984-2010), stratified by size of population served by officers' department. Figures are relative risk (95% confidence interval)***

	Population served		
Duty*	**<10 000**	**10 001-100 000**	**>100 000**
Routine /non-emergency	1.00 (reference)	1.00 (reference)	1.00 (reference)
Physical training	7.80 (2.22 to 27.4)	28.9 (13.6 to 61.4)	18.3 (9.44 to 35.5)
Pursuit	46.8 (22.3 to 98.3)	79.7 (33.0 to 192.3)	52.9 (26.5 to 105.6)
Restraint, physical altercation	187.2 (93.7 to 373.8)	119.5 (59.5 to 240.3)	51.9 (27.4 to 98.3)

*Estimates based on survey responses from officers whose departments serve populations of indicated size.

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Table 3| **Analyses of risk of sudden cardiac death among law enforcement officers engaged in emergency and strenuous duties compared with officers engaged in routine/non-emergency duties, using combined data from National Law Enforcement Officers Memorial Fund and Officer Down Memorial Page (1984-2010). Sensitivity analyses restricted to survey responses from law enforcement officers with similar age distribution (individual matching based on 5 year age classes) as cases of sudden cardiac death**

Duty	Relative risk (95% CI)
Routine/non-emergency	1.00 (reference)
Disturbance	1.64 (1.00 to 2.68)
Testifying in court	1.63 (0.52 to 5.13)
Serving a warrant	2.17 (0.95 to 4.94)
Transporting and supervising prisoners	3.79 (2.27 to 6.35)
Medical and rescue operations	7.36 (4.97 to 10.9)
Physical training	27.8 (20.9 to 37.1)
Pursuit	25.8 (18.4 to 36.2)
Restraint, physical altercation	40.6 (30.9 to 53.3)

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Figures

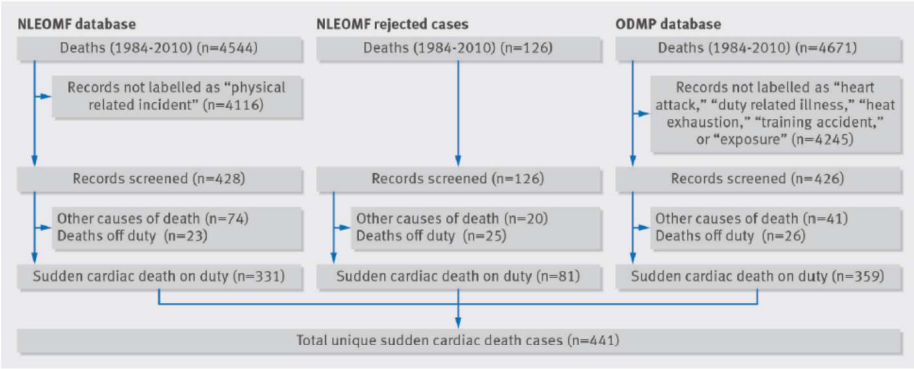

Fig 1 Review of police fatality databases and selection of cases of sudden cardiac death leading to final study population

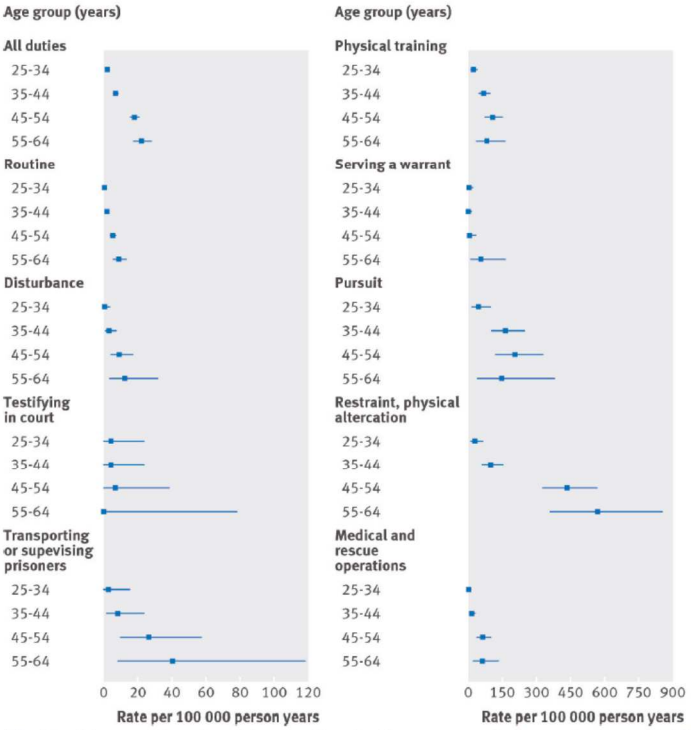

Fig 2 Incidence rates of sudden cardiac death among male law enforcement officers (1989-2010), by age and type of duty