Markers of Fitness, Stress, and Cardiometabolic Disease Risk Among Law Enforcement Officers

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Objective: Law enforcement officers (LEOs) face numerous stressors that exacerbate cardiometabolic disease (CMD) risk. The current study examined novel and classic risk factors among a cohort of LEOs to better understand relationships between biomarkers of stress, oxidative stress, inflammation, and CMD risk. **Methods:** Associations between measures of cardiorespiratory and muscular fitness, body composition, and cardiometabolic health with novel/classic CMD risk factors were assessed among 66 male LEOs. **Results:** Muscular fitness and cardiorespiratory fitness were significantly associated with reduced insulin resistance. Moreover, higher fat mass and body fat percentages were significantly associated with increased markers of inflammation and insulin resistance. **Conclusions:** Maintaining high cardiorespiratory and muscular fitness levels and improving body composition profiles can ameliorate cardiometabolic health.

Keywords: cortisol, testosterone, cardiovascular, cardiovascular disease, police officers

LEARNING OUTCOMES

- Our study investigated cardiometabolic disease risk among law enforcement officers using results from a comprehensive physical health assessment that included fitness, anthropic, and biological measurements.
- Using composites of fitness, body composition, and lipid metrics, we found expected associations between classic and novel risk factors for cardiometabolic disease.
- This study finds evidence supporting the possible role of oxidative stress in the cardiometabolic disease process among law enforcement personnel, but future work is needed to establish levels of risk relative to other populations.

Law enforcement officers (LEOs) face physical and mental stress[1,2] and occupation-specific challenges that demand robust muscular and cardiorespiratory fitness. However, some studies have demonstrated LEOs exhibit low cardiorespiratory fitness[3–6] and poor health profiles.[7,8] In addition, Ramey and colleagues[9] identified the risk of cardiometabolic disease (CMD) as 1.7 times higher among a cohort of Milwaukee LEO retirees compared to the general public. Furthermore, Poirier et al[10] demonstrated that occupational stress is linked to physical inactivity and the prevalence of CMD risk factors among LEOs. Despite limited research, the physically and psychologically demanding nature of law enforcement is believed to induce physiological stress, oxidative stress, and inflammation, which contribute to the development and progression of CMD and premature mortality.[11,12]

Largely, cardiac-related deaths occur during nonroutine occupational tasks (77%) and are characterized by sudden spikes in cardiovascular demand.[12] Acute exposure to stress results in increased neuroendocrine response and elevated heart rate and blood pressure (ie, cardiovascular reactivity)[13]; however, chronic stress exposure can alter cardiovascular reactivity and increase CMD risk.[14] In addition, high-stress occupational groups, such as first responders, have increased risk for being overweight and obese. For instance, Hartley and colleagues[15] conducted a Buffalo Cardio-Metabolic Occupational Police Stress study and noted that ≈40.5% of LEOs in the United States may be considered obese. Furthermore, a high body mass index has been associated with poor health and performance outcomes among tactical and occupational athletes—particularly when the individual falls under a higher classification than overweight.[16] Data among similar occupational personnel (ie, firefighters) suggest that individuals classified as overweight or obese, or who have lower cardiorespiratory fitness, exhibit higher levels of oxidative stress, inflammation, and indices of CMD risk.[17,18] However, data examining these factors among LEOs are lacking.

Previous work has suggested that oxidative stress and inflammation measured using blood-based biomarkers may predict CMD risk,[17] providing better insights into overall health than conventional cardiovascular disease biomarkers.[19–21] Both advanced oxidation protein products (AOPP) and C-reactive protein (CRP) have been assessed for their role in CMD progression.[19,22–24] McAllister and colleagues[17] demonstrated that AOPP concentrations were significantly related to blood triglyceride (TAG) concentrations, time to exhaustion on a maximal cardiopulmonary treadmill stress test, and waist circumference, whereas CRP was related to time to exhaustion and body fat percentage among firefighters. Furthermore, firefighters with higher levels of cardiorespiratory fitness expressed lower concentrations of AOPP and CRP than their less fit counterparts.[18] High-stress occupational conditions trigger the activation of the sympathoadrenal medullary and hypothalamic pituitary adrenal axes (primary components of the fight or flight response),[25–28] which can contribute to increased oxidative stress and inflammation. Biomarkers, such as salivary α-amylase (sAA), cortisol (CORT), and testosterone (T),

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Data availability: Data may be shared upon reasonable request by contacting corresponding author. Note, consent was not obtained by the participants to make data publicly available.

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reflect the activation of the sympathoadrenal medullary and hypothalamic pituitary adrenal axes and have been postulated to be predictive of CMD risk.[29,30] However, there is a paucity of data regarding these biomarkers among LEOs.

Recent analyses among firefighters have demonstrated that blood markers of oxidative stress and inflammation are inversely associated with blood TAG, cardiorespiratory fitness, waist circumference, and body fat percentage.[17] However, no study has examined the associations between fitness metrics (eg, cardiorespiratory fitness, markers of body composition) and conventional CMD risk biomarkers (eg, blood glucose, lipids) in relation to markers of stress, oxidative stress, inflammation, and insulin resistance among LEOs. This study sought to bridge this research gap by examining the associations between multiple fitness and health metrics and biomarkers of stress, oxidative stress, inflammation, and insulin resistance in a sample of LEOs.

METHODS

Participants and Study Design

Our data consisted of a convenience sample of 66 male police officers from the Bryan and College Station Police Departments in central Texas. Participants provided written, informed consent before completing a general health and lifestyle history questionnaire, wherein potential risk factors for heart disease, skeletal muscle injury, orthopedic risk, and any contraindications to exercise were identified. The University's Institutional Review Board approved all study procedures. Descriptive statistics are presented in Table 1. Data collection occurred in Spring 2023 as part of an annual health and fitness evaluation program and produced 26 variables of interest across five broad domains, including (1) fitness (time-to-exhaustion, push-ups, sit-ups, sit-and-reach), (2) body composition (android/gynoid fat, total fat/lean mass, waist circumference, waist-to-hip ratio, total weight), (3) markers of cardiometabolic health (glucose, HOMA-IR, insulin, HDL-/LDL-/total cholesterol, triglycerides), (4) stress markers (sAA, blood and salivary CORT, salivary T, T:CORT ratio), and (5) markers of inflammation/oxidative stress (AOPP, CRP). Descriptive statistics are presented in Table 1.

TABLE 1. Sample Descriptives

	n	Mean	SD	Range
Demographics				
Age (years)	66	42	9	23, 61
Body composition				
Waist circumference (inches)	55	37.5	4.0	30.0, 46.0
Waist-hip ratio	55	0.91	0.08	0.79, 1.24
Weight (lbs)	61	206	36	108, 295
Fat mass (%)	61	24.0	4.7	14.0, 33.6
Fat mass (lbs)	61	52	17	25, 90
Lean mass (lbs)	61	160	21	116, 215
Android fat (%)	61	29	7	16, 44
Gynoid fat (%)	61	25.3	6.0	2.2, 36.6
Physical fitness				
Time to exhaustion	54	10.70	1.35	8.27, 13.50
Sit-ups	54	41	9	25, 63
Push-ups	54	49	17	20, 92
Sit and reach	55	14.20	3.07	7.00, 22.50
Cardiometabolic health				
HDL cholesterol	66	49	11	29, 82
LDL cholesterol	65	118	29	58, 189
Total cholesterol	66	191	30	133, 264
Triglycerides (blood)	66	121	68	38, 310
Glucose (blood)	66	92	9	70, 121
Insulin	55	9.6	4.7	3.0, 20.6
HOMA-IR	55	2.17	1.16	0.66, 5.62
Stress markers				
α-amylase	63	51	33	2, 125
Cortisol (blood)	57	12.8	5.5	3.0, 25.9
Cortisol (saliva)	60	0.36	0.22	0.07, 0.84
Testosterone (saliva)	52	164	76	49, 403
Testosterone-cortisol ratio	50	669	568	172, 2,847
Inflammation & oxidative stress markers				
AOPP	57	111	66	57, 346
CRP	53	1,356	1,298	125, 4,856

AOPP, advanced oxidation protein products; CRP, C-reactive protein; HDL, high-density lipoprotein; HOMA-IR, homeostatic model assessment for insulin resistance; LDL, low-density lipoprotein.

Testing Procedures

During an annual clinical testing program, demographic data (age), anthropometrics (height, total body mass), body composition parameters (percent body fat, fat-free mass, and waist and hip circumference measurements), fitness metrics (muscular endurance and maximal oxygen uptake), and blood and saliva samples were collected from all participants. The general fitness testing and sample collection procedures were previously described and conducted in a firefighter population.[17,18] The participants were instructed to arrive 12 hours fasted before all testing sessions. Upon arrival at the testing, participants assessed their height and body mass via a medical-grade scale (Seca Model 700, Hamburg, Germany). Then, the participants underwent a dual-energy x-ray absorptiometry scan (DEXA; Hologic Horizon A, Marlborough, MA), wherein total body mass, body fat percentage, fat mass, fat-free mass, body fat distribution (ie, android and gynoid), and visceral adipose tissue metrics were collected. Participants then had their waist and hip circumference using the World Health Organization waist circumference and waist-to-hip ratio standards. Regarding the fitness metric assessments, the participants completed the sit-and-reach following the American College of Sports Medicine criteria and protocols.[31] Afterward, the participants were instructed to perform as many repetitions without stopping for the push-up and sit-up assessments within 1 minute.[31] Lastly, the participants underwent a graded exercise test using the Bruce protocol on a standard treadmill (Quinton Q Stress System [Cardiac Science Corporation, Bothell, WA] with TM65 treadmill), where their time to exhaustion was used to predict VO_{2max} via the Foster equation.[32]

Blood Collection and Analysis Procedures

Participants were fasted ≥12 hours prior to sample collection. Venous blood samples of ≈8.5 mL were collected into serum separation tubes (BD Vacutainer; Becton, Dickinson and Company, Franklin Lakes, NJ) via venipuncture from an antecubital vein. Blood samples were left at room temperature to clot for 30 minutes before being centrifuged at 2500 revolutions/min for 15 minutes at 4°C. One aliquot of serum was immediately transported on ice to a clinical laboratory to analyze total cholesterol, TAG, HDL, LDL, and glucose. A second aliquot of serum was frozen at −80°C and later analyzed for insulin, AOPP, and CRP concentrations. Analyses of concentrations of insulin, AOPP, and CRP were conducted in duplicate and performed using commercial assay kits: insulin (ALPCO, Salem, NH), CRP (R&D systems, Inc. Minneapolis, MN), blood CORT (EagleBio Labs, Amherst, NH), and AOPP (Cell Biolabs, San Diego, CA). All procedures were adhered to as instructed by the kit manufacturer, and absorbance was detected using a BioTek colorimetric plate reader (Winooski, VT). Homeostatic model assessment for insulin resistance (HOMA-IR) was calculated by fasting GLU (mg/dL) × fasting insulin (μU/mL)/405.

Saliva Collection and Analysis Procedures

Salivary samples (~800 mL) were collected and then analyzed for the following physiological stress biomarkers: sAA, CORT, T,

and T:CORT ratio. A passive drool saliva collection procedure (Salimetrics, PA) was used. Before providing the saliva sample (~10 minutes), participants were asked to perform a mouth rinse with water. The participants were instructed to tilt their heads forward to allow for a passive drool sample to collect into the polypropylene cryovial until ≈800 μL were collected. The saliva samples were immediately transferred onto ice and stored at −80°C for later analysis. Samples were later thawed and centrifuged at 4°C for 15 minutes at 1500 rpm. Saliva samples were analyzed in duplicate for concentrations of sAA, CORT, and T using commercially available kits (Salimetrics, PA). Absorbance was determined via a BioTek plate reader (Winooski, VT). An automated washer was used for assays that required washing (BioTek, Winooski, VT). The intra-assay and interassay coefficients of variation were <10% for all assays.

Statistical Analyses

The primary goal of our analysis was to investigate associations with eight key biomarkers measured in our sample of LEOs: AOPP, CRP, HOMA-IR, sAA, CORT (blood and saliva), salivary T, and T:CORT ratio. These biomarkers served as dependent variables in multivariate models, with the remaining body composition, fitness, and cardiometabolic measures used as predictors. Initial models indicated the presence of multicollinearity among the groups of predictors. To address this, we conducted dimension reduction using principal components analysis (PCA) to summarize variables along dimensions that maximally explained variance in the underlying data (ie, using varimax rotations) within each variable group. Prior to PCA, all variables were log-transformed if they had a skew >1.0 or square root transformed if they had a skew <−1.0 and then z-standardized (mean = 0, SD = 1). Following PCA, we extracted the top principal components (PCs) for each variable group and used them to predict concentrations of our eight key biomarkers using multiple regression. We estimated all regression models twice, with and without statistically adjusting for participant age. Multiple comparisons were corrected for using the false-discovery rate method[33] with the family-wise error rate defined according to the eight key dependent variables and age-adjustment status (eg, all age-adjusted models with a common dependent variable were included in the same false-discovery rate adjustment). All analyses were conducted using the *R* statistical software (v4.3.3; R Core Team, 2024).[34]

RESULTS

Descriptive Results

Our analytic sample included 66 male police officers with an average age of 42 (SD = 9). All analyte data were winsorized at the second/98th percentiles. Winsorization avoids dropping cases with extreme values by recoding them according to a specified threshold, thereby also reducing the influence of outliers while conserving data. Despite this, some analytes had concentrations that were beyond the detection limits of specific assays, resulting in differing amounts of missingness (see Table 1). We reported the sample size along with the results of each model.

Dimension Reduction

Fitness

The fitness variables of time to exhaustion, sit-ups, push-ups, and sit-and-reach were included in a PCA (Table 2). A single PC with an eigenvalue >1 was extracted, explaining 53.6% of the variance in the data. We interpreted this PC as representing a "general fitness" dimension in the data, as the factor loadings were of similar magnitude

TABLE 2. Principal Components Analysis and Zero-Order Correlations of Fitness, Body Composition, and Cardiometabolic Health Measures

		Principal Components		Pearson's *r*						
		PC1	PC2	1	2	3	4	5	6	7
Fitness										
1	Time to exhaustion	0.52	–	–						
2	Push-ups	0.55	–	0.45	–					
3	Sit-ups	0.54	–	0.41	0.61	–				
4	Sit and reach	0.37	–	0.34	0.24	0.24	–			
% variance explained		53.6	–							
Body composition										
1	Android fat (%)	0.38	−0.31	–						
2	Gynoid fat (%)*	0.27	−0.51	0.52	–					
3	Fat mass (lbs)	0.44	−0.06	0.82	0.51	–				
4	Fat mass (%)	0.40	−0.34	0.90	0.60	0.91	–			
5	Lean mass (lbs)	0.29	0.56	0.28	0.07	0.64	0.28	–		
6	Waist cir. (inches)	0.42	0.19	0.70	0.35	0.84	0.72	0.69	–	
7	Waist-hip ratio††	0.23	0.18	0.31	0.17	0.34	0.32	0.29	0.67	–
8	Weight (lbs)	0.34	0.38	0.46	0.21	0.74	0.50	0.82	0.68	0.26
% variance explained		60.5	18.0							
Cardiometabolic health										
1	HDL cholesterol	−0.46	0.32	–						
2	LDL cholesterol	0.35	0.60	−0.18	–					
3	Total cholesterol	0.30	0.64	0.11	0.90	–				
4	Triglycerides (blood)††	0.53	−0.16	−0.56	0.15	0.18	–			
5	Glucose (blood)	0.40	−0.17	−0.41	0.07	0.03	0.44	–		
6	Insulin	0.37	−0.27	−0.45	0.02	−0.03	0.44	0.13	–	
% variance explained		38.6	31.6							

Note: PC1 for body composition and PC1 & 2 for cardiometabolic health were reverse coded to ease interpretation.

*Square root.

†Natural log.

HDL, high-density lipoprotein; LDL, low-density lipoprotein; PC, principal component.

for all variables (ranging from 0.52 to 0.55), except for sit-and-reach (loading = 0.37), indicating a smaller contribution of flexibility.

Body Composition

Eight variables related to body composition were included in a second PCA. Two PCs with eigenvalues >1.0 were extracted. The first PC (60% variance explained) was interpreted as capturing a "general adiposity" dimension in the data, with consistent small to moderate loadings across all variables (ranging from 0.29 to 0.44), except for waist-to-hip ratio that had a very small loading of 0.23. (Note: to ease interpretability, PC1 was reverse coded—original loadings were all negative—so more positive loadings were associated with greater adiposity). The second PC (18% variance explained) provided more specificity in the pattern of loadings that we interpreted as targeting a dimension related to "lean mass/fat distribution." The two strongest loadings were for lean mass (0.56) and gynoid fat percent (−0.51), with all remaining loadings falling below 0.38 in absolute value.

Cardiometabolic Health

A final PCA included six variables related to cardiometabolic health. Two PCs with eigenvalues >1 were extracted. The first PC (explaining 38.6% of the variance) was interpreted as capturing associations along a "dyslipidemia and insulin resistance" dimension in the underlying data, with small-moderate positive loadings for all variables (ranging from 0.3 to 0.53), except for HDL cholesterol, which was negative (−0.46). The second PC (31.6% variance explained) was interpreted as capturing the dimension of "cholesterol levels," with high factor loadings for LDL and total cholesterol (0.6 and 0.64, respectively). (Note: as above, PCs 1 and 2 were reverse coded to ease interpretability so that positive values were associated with higher risk levels).

Multivariate Analysis

Using the PCs for each group of variables identified above, we regressed each of the key dependent variables on the group-specific PCs in individual models. All models were estimated without covariates initially, and then age was included in a second model to rule out age-related confounding. Because PCs have no natural unit, all estimates are reported as standardized regression coefficients. We report findings according to each group of predictors.

Fitness

General fitness (PC1) was negatively associated with HOMA-IR levels ($\beta = -0.53$, $P < 0.001$) and was not greatly impacted by the inclusion of participant age in the model ($\beta = -0.47$, $P = 0.004$) (Table 3). Across models, general fitness explained a small degree of variance in each key biomarker (between 0.3% and 10%), except for HOMA-IR, for which it explained a moderate amount (28%).

Body Composition

General adiposity (PC1) demonstrated statistically significant positive associations with both HOMA-IR ($\beta = 0.59$, $P < 0.001$) and CRP ($\beta = 0.49$, $P < 0.001$) (Table 4). Neither association was substantially impacted by the inclusion of age in the model. Lean mass/fat distribution (PC2) was not associated with the eight key biomarkers. The body composition PCs explained a small to moderate amount of variance in HOMA-IR and CRP concentrations (37% and 25%, respectively, for the unadjusted models), though only a small degree of variance was explained in the other models (between 2% and 6%).

Cardiometabolic Health

Dyslipidemia/insulin resistance (PC1) was positively associated with AOPP concentrations ($\beta = 0.69$, $P < 0.001$) and HOMA-IR levels ($\beta = 0.71$, $P < 0.001$) (Table 5). These large associations were not substantively impacted by the inclusion of age in the model.

TABLE 3. Multiple Linear Regression of Cardiometabolic Risk Factors on a Principal Component for General Fitness

	AOPP			HOMA-IR			α-Amylase			CRP			Cortisol (Blood)			Cortisol (Saliva)			Testosterone			Test-Cort Ratio		
	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*
Unadjusted																								
General fitness (PC1)	−0.05	0.154	0.7	−0.53***	0.133	<0.001	0.02	0.143	0.9	−0.31	0.154	0.052	0.12	0.153	0.4	0.23	0.142	0.11	0.06	0.156	0.7	−0.06	0.158	0.7
R^2	0.003			0.278			0.000			0.095			0.014			0.052			0.003			0.003		
Age adjusted																								
General fitness (PC1)	0.00	0.180	>0.9	−0.47**	0.154	0.004	0.11	0.161	0.5	−0.25	0.175	0.2	0.17	0.179	0.3	0.14	0.156	0.4	0.10	0.181	0.6	0.07	0.175	0.7
R^2	0.010			0.287			0.031			0.107			0.022			0.090			0.009			0.060		
No. Obs.	44			43			51			40			44			49			43			42		

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
AOPP, advanced oxidation protein products; CRP, C-reactive protein; HOMA-IR, homeostatic model assessment for insulin resistance; PC, principal component; SE, standard error; Test-Cort, testosterone-cortisol.

Cholesterol levels (PC2) demonstrated a positive association with HOMA-IR ($\beta = 0.38$, $P < 0.001$) and were also not impacted by age adjustment. Cholesterol concentrations were also associated with sAA concentrations ($\beta = -0.28$, $P = 0.049$). Although this association increased with age adjustment ($\beta = -0.34$, $P = 0.018$), neither association was statistically significant following adjustment for multiple comparisons. The PCs for cardiometabolic health explained a moderate-large amount of variance in the models for AOPP and HOMA-IR (48% and 66%, respectively), with less explained variance for sAA (15%). All other models explained between 2% and 10%.

DISCUSSION

The main findings from this study suggest that higher cardiorespiratory and muscular fitness levels are associated with reduced markers of insulin resistance. Moreover, adverse body composition profiles (higher fat mass, higher body fat percentages) are associated with increased markers of inflammation and insulin resistance. While sAA demonstrated a statistically significant association with the cholesterol level PC, this relationship did not survive the multiple comparisons adjustment suggesting that the association either arose from random chance or was too weak to reliably identify given the size of our sample. Thus, stress biomarkers were not associated with markers of fitness or cardiometabolic health in the current sample. These findings suggest that LEOs should aim to maintain higher amounts of cardiorespiratory and muscular fitness and improved body composition profiles to reduce the risk of developing CMD.

It has been widely documented that LEOs have elevated CMD prevalence associated with elevated rates of obesity, metabolic syndrome, and dyslipidemia compared to the general population.[35–37] LEOs are chronically exposed to a variety of stressors,[38] which can increase the production of inflammatory cytokines, causing vascular dysfunction and increasing the risk of developing CMD.[39] However, the present data suggest no strong relationship between markers of *stress* and fitness metrics and CMD risk. Similar studies have included psychological stress-based surveys concerning markers of inflammation among LEOs.[40,41] Franke et al[41] reported increased CMD risk as related to elevated inflammation among LEOs, but this risk was not related to occupational stress, whereas Ramey et al[40] found significant relationships between occupational demand and cytokines such as IL-1β and IL-6 among a sample of LEOs ($n = 71$). The present findings complement these[40] as we included a panel of stress biomarkers instead of perceived stress scales and other surveys. However, it should be noted that much of the current evidence in this area is based on research using cross-sectional designs; longitudinal studies are needed to better reflect the relationship between these variables. The lack of significant relationship between biomarkers of stress and CMD risk may be related to high variability in concentrations of stress biomarkers among LEOs.[42] It should also be noted that the stress biomarkers included in the present study are sensitive to changes in acute stressors and this can impact potential for relationships with CMD risk factors. As such, it is likely that multiple time points of biosample collection are required to gauge physiological stress insight.

Concerning body composition, the present findings demonstrate that increased adiposity is associated with higher concentrations of CRP and HOMA-IR. These findings are unsurprising because adipose tissues (especially visceral adipose) have been identified as a highly active endocrine organ that secretes numerous cytokines that facilitate inflammation and oxidative stress and accelerate the risk of developing CMD and insulin resistance.[43] While CRP is secreted by the liver (as opposed to adipose tissue), it is secreted in increased amounts in response to other inflammatory cytokines, especially related to atherosclerosis.[44–47] It is important to note that while CRP is typically identified as a nonspecific marker of inflammation, recent work suggests that CRP can impair vascular function and may play a direct role in the progression of atherosclerosis.[24,48,49] Given the sedentary nature

TABLE 4. Multiple Linear Regression of Cardiometabolic Risk Factors on Principal Components of Body Composition

	AOPP			HOMA-IR			α-Amylase			CRP			Cortisol (Blood)			Cortisol (Saliva)			Testosterone			Test-Cort Ratio		
	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*	β′	SE	*P*
Unadjusted																								
General adiposity (PC1)	0.20	0.148	0.2	0.59***	0.123	<0.001	−0.14	0.137	0.3	0.49**	0.139	0.001	−0.04	0.152	0.8	−0.21	0.141	0.14	−0.14	0.155	0.4	0.13	0.154	0.4
Lean mass/fat dist. (PC2)	−0.14	0.148	0.4	−0.15	0.123	0.2	0.20	0.137	0.15	−0.13	0.139	0.4	0.06	0.152	0.7	0.08	0.141	0.6	0.02	0.155	>0.9	0.18	0.154	0.3
R^2	0.056			0.367			0.058			0.247			0.005			0.050			0.020			0.053		
Age adjusted																								
General adiposity (PC1)	0.15	0.166	0.4	0.54***	0.137	<0.001	−0.19	0.142	0.2	0.47**	0.154	0.004	−0.14	0.168	0.4	−0.19	0.146	0.2	−0.15	0.158	0.3	0.11	0.154	0.5
Lean mass/fat dist. (PC2)	−0.13	0.150	0.4	−0.14	0.124	0.3	0.21	0.136	0.12	−0.13	0.141	0.4	0.08	0.151	0.6	0.08	0.142	0.6	0.03	0.158	0.9	0.20	0.154	0.2
R^2	0.063			0.377			0.096			0.247			0.043			0.057			0.027			0.087		
No. Obs.	46			45			53			42			46			51			44			43		

[1]*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

AOPP, advanced oxidation protein products; CRP, C-reactive protein; HOMA-IR, homeostatic model assessment for insulin resistance; PC, principal component; SE, standard error; Test-Cort, testosterone-cortisol.

TABLE 5. Multiple Linear Regression of Cardiometabolic Risk Factors on Principal Components of Classic Cardiometabolic Measures

	AOPP			HOMA-IR			α-Amylase			CRP			Cortisol (Blood)			Cortisol (Saliva)			Testosterone			Test-Cort Ratio		
	β^1	SE	*P*	β^1	SE	*P*	β^1	SE	*P*	β^1	SE	*P*	β^1	SE	*P*	β^1	SE	*P*	β^1	SE	*P*	β^1	SE	*P*
Unadjusted																								
Dyslipid./IR (PC1)	0.69***	0.100	<0.001	0.71***	0.082	<0.001	0.06	0.137	0.6	0.24	0.138	0.095	0.06	0.135	0.7	−0.11	0.146	0.5	0.13	0.158	0.4	0.23	0.160	0.2
Cholesterol levels (PC2)	0.02	0.100	0.8	0.38***	0.082	<0.001	−0.28*	0.137	0.049†	−0.08	0.138	0.6	0.21	0.135	0.13	0.05	0.146	0.7	0.08	0.158	0.6	−0.02	0.160	>0.9
R^2	0.478			0.648			0.081			0.061			0.047			0.014			0.021			0.052		
Age adjusted																								
Dyslipid./IR (PC1)	0.70***	0.104	<0.001	0.69***	0.084	<0.001	0.00	0.137	>0.9	0.20	0.139	0.2	0.05	0.140	0.7	−0.08	0.150	0.6	0.12	0.165	0.5	0.18	0.164	0.3
Cholesterol levels (PC2)	0.03	0.103	0.8	0.36***	0.084	<0.001	−0.34*	0.137	0.018†	−0.11	0.138	0.4	0.20	0.139	0.2	0.08	0.150	0.6	0.07	0.164	0.7	−0.06	0.162	0.7
R^2	0.481			0.656			0.146			0.102			0.049			0.033			0.022			0.091		
No. Obs.	55			55			52			52			55			49			42			40		

^{1}*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

†$P > 0.05$ after false-discovery rate correction.

AOPP, advanced oxidation protein products; CRP, C-reactive protein; Dyslipid./IR, dyslipidemia and insulin resistance; HOMA-IR, homeostatic model assessment for insulin resistance; PC, principal component; SE, standard error; Test-Cort, testosterone-cortisol.

of law enforcement work[2] and the elevated risk of obesity,[37] these findings emphasize the importance of fitness and wellness standards among LEOs to ensure physical preparation for the job[50] and improve cardiometabolic health. The present findings also demonstrate that general fitness (cardiorespiratory and muscular) is inversely related to insulin resistance (HOMA-IR), further supporting the importance of maintaining regular fitness standards.

Regarding traditional markers of cardiometabolic health, such as a lipid and glucose panel, the present findings demonstrate that these factors are associated with elevated oxidative stress and insulin resistance as indicated by AOPP and HOMA-IR. Routine clinical practice typically incorporates a standard lipid and glucose panel when assessing CMD risk; however, it is important to consider an analysis of oxidative stress and inflammatory biomarkers.[51] While there is not sufficient data available to single out a particular oxidative stress biomarker to accurately gauge CMD risk, recent work has shown that AOPP has been shown to be associated with atherosclerosis[52] and may play a direct role in the progression of atherosclerosis.[23] As such, practitioners should consider including oxidative stress or inflammatory markers in assessing CMD risk, given the role oxidative stress plays in this progressive disease.[53,54] In short, endothelial dysfunction and atherosclerosis are indirectly driven largely by lifestyle factors such as smoking and a sedentary lifestyle; however, they are directly driven by oxidative stress and inflammation.[54] The literature increasingly demonstrates that a traditional lipid panel is insufficient in gauging CMD risk, given the role that oxidative stress and inflammatory cytokines play in atherosclerosis.[55] Regardless, those in the law enforcement community should implement regular assessments of traditional (lipids, glucose panels) and nontraditional (oxidative stress, inflammatory biomarkers) in assessing CMD risk.

The current study has limitations that need to be addressed. First, this study used a convenience sample; thus, it is nonprobabilistic, and strict interpretations of inferential tests are not applicable. Additionally, omitted variable bias is a limitation of the current study. While we did account for the influence of age across models (and all models held sex constant because of the lack of females in the analytic sample), other dimensions (eg, race/ethnicity, socioeconomic status) were not accounted for because of the lack of data. Additionally, our data were cross-sectional, which prevented us from establishing any temporal order between predictors and outcomes. Finally, because of the nonprobabilistic nature of the present sample and the lack of information on certain sociodemographic variables, the degree of representativeness of the current sample to any larger group is unknown. Given these limitations, we advise readers that all associations reported herein should be assumed to be exploratory and peculiar to the present sample until replication in independent samples can be achieved.

CONCLUSIONS

These data demonstrate the importance of maintaining a high level of general fitness, as demonstrated by increased cardiorespiratory and muscular fitness, improved body composition, and improved cardiometabolic blood panels, to reduce the risk of CMD among LEOs. Given the high-stress nature of this occupation, improving these metrics would likely benefit not only physical health but mental health as well.[56] This study provided descriptive evidence that associations between classic and emerging risk factors for CMD are observable among law enforcement samples. In terms of practical applications, law enforcement agencies should consider the implementation of regular fitness/wellness assessments and interventions aimed at improving these metrics. It should be noted that many basic fitness assessments could be done at minimal cost to law enforcement agencies. In terms of future research, we believe that future work should build on our findings in two ways. First, relative levels of risk among LEOs should be established by making direct comparisons between LEOs and the general population and/or other high-stress occupations (eg,

firefighters). Second, longitudinal assessments of LEOs should be undertaken to establish the etiology and progression of CMD risk across the career.

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