Work And Chronic Disease: Comparison Of Cardiometabolic Risk Markers Between Truck Drivers And The General U.S. Population

By: Yorghos Apostolopoulos, PhD, Michael K. Lemke, PhD, **Adam Hege, PhD**, Sevil Sonmez, PhD, Huiyan Sang, PhD, Douglas J. Oberlin, MS, and Laurie Wideman, PhD

Abstract

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Cardiometabolic disease (CMD) risk refers to the presence of a diverse set of indicators that are linked to cardiovascular and metabolic disease outcomes. Multiple markers may be utilized to assess CMD risk, but metabolic syndrome represents a cluster of clearly defined, specific risk factors: while each of these risk factors has an independent effect on CMD risk, they also function synergistically to elevate such risk.[1,2] Metabolic syndrome is diagnosed if subjects meet three or more of the following five criteria: abdominal obesity (waist circumference $\geq$102 cm for men and $\geq$89 cm for women); high triglycerides ($\geq$150 mg/dL for men and women); low high-density lipoprotein (HDL) cholesterol ($<$40 mg/dL for men and $<$50 mg/dL for women); high blood pressure ($\geq$130/85 for men and women); and high glucose ($\geq$100 mg/dL for men and women).[3]

Obesity has been well established as a risk marker for CMD.[4] Novel measures of body composition that assess abdominal deposits of adiposity are associated with hypertension, diabetes, and cardiovascular disease.[2,4] Abdominal obesity is commonly measured non-invasively by waist circumference (WC) or sagittal abdominal diameter (SAD).[5,6] Blood pressure and blood lipids constitute traditional CMD risk markers.[1,7,8] Blood glucose levels may indicate type 2 diabetes mellitus, itself associated with cardiovascular disease risk.[9] Finally, CMD risk markers may indicate systemic low-grade inflammation associated with obesity. Due to its impact on the inflammatory system, obesity generates a systematic inflammatory response.[2] At the cellular level, obesity results in adipocyte hypertrophy, which can induce hypoxia and cellular apoptosis and shift the macrophage phenotype of adipose tissue from anti-inflammatory to pro-inflammatory.[10] This transition in macrophage phenotype induces the production of cytokines such as Interleukin-6 (IL-6).[5] Chronic elevations in IL-6 that occur with inflammation are associated with elevated CRP levels.[5,11] Systemic low-grade inflammation has been hypothesized to be the linkage between obesity and CMD outcomes.[5,10–12]

In the US, cardiometabolic health is generally poor. Heart disease, one CMD outcome, is the leading cause of death.[13] Type 2 diabetes mellitus, another CMD outcome, has steadily increased in prevalence over the past several decades.[9] Because type 2 diabetes mellitus is a major cardiovascular disease risk factor, and because mortality rates from cardiovascular disease are two to four times higher among adults with type 2 diabetes mellitus,[8,9] cardiovascular disease and type 2 diabetes mellitus may function with other CMD risk factors to synergistically increase disease burden among affected populations. Numerous factors influence the CMD risk of the general population. Non-modifiable risk factors include age, race/ethnicity, sex, and genetics.[1,9] Modifiable factors include sleep patterns, healthcare access, smoking, dietary choices, and physical activity patterns.[9,14,15] The workplace provides additional modifiable risk factors, such as work hours and scheduling, job strain and stress, and physical exertion.[16]

Commercial drivers—and in particular, long-haul truck drivers—face numerous and interrelated CMD risks, and thus exhibit heightened levels of key CMD risk markers. For example, elevated levels of hypertension, dyslipidemia, and obesity (as measured by both body mass index [BMI] and abdominal obesity) have been found among long-haul truck drivers.[17–19] Unique work-related experiences of long-haul truck drivers exacerbate their CMD risk, such as work organization and workplace characteristics, including work hours, shift work, fatigue, job strain, stress, and availability of health resources.[19,20] This unique constellation of CMD risk factors enhances long-haul truck drivers' likelihood of developing multiple chronic health conditions, including type 2 diabetes mellitus, cardiovascular disease, and other cardiometabolic comorbidities.[21,22] These outcomes generate related comorbidities that can increase accident risk and reduce commercial drivers' life expectancies.[23]

Elucidating CMD risk among US long-haul truck drivers is needed; however, because no existing epidemiological studies of long-haul truck drivers have simultaneously collected anthropometric and biometric data, a comprehensive clinical picture of CMD risk among long-haul truck drivers in the US is not available. Thus, our paper has three objectives: (1) to generate for the first time a CMD risk marker profile for long-haul truck drivers based on primary data collected; (2) to compare the CMD risk marker profile for long-haul truck drivers to that of the general US population using

From the Complexity & Computational Population Health Group and Department of Health & Kinesiology (Dr Apostolopoulos, Dr Lemke); Department of Health & Exercise Science, Appalachian State University, Boone (Dr Hege); Rosen College of Hospitality Management, University of Central Florida, Orlando, Florida (Dr Sönmez); Department of Statistics (Dr Sang), Texas A&M University, College Station, Texas; Department of Kinesiology, University of North Carolina Greensboro, Greensboro (Mr Oberlin, Dr Wideman), North Carolina.

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Address correspondence to: Michael K. Lemke, PhD, 4243 TAMU, College Station, TX 77843-4243 (Michael.Lemke@hlkn.tamu.edu).

a national dataset; and (3) to examine relationships between CMD risk markers and CMD outcomes. To accomplish these three objectives, we use two datasets. The first dataset consists of a sample of long-haul truck drivers and is used in pursuit of all three objectives. The second dataset, which is used in pursuit of objectives two and three, is the National Health and Nutrition Examination Survey (NHANES), which consists of a large representative sample and combines both interviews and physical examinations.[24] The NHANES was selected because of its quality of data, sample size, and degree of overlap with the long-haul truck driver dataset on key variables related to CMD risk and outcomes.[24] We hypothesized that: (1) long-haul truck drivers have heightened CMD risk markers compared with that of the general population; and (2) traditional, body composition, and inflammatory CMD risk markers of both long-haul truck drivers and the general US population will be significantly associated with CMD outcomes.

METHODS

Study Design and Procedures

The study was approved by the Institutional Review Board (IRB) of the University of North Carolina at Greensboro. A non-experimental, descriptive, cross-sectional design was employed to collect survey and biometric data from 262 long-haul truck drivers over a period of 6 months at a large-size TravelCenters of America (TA) truckstop located in North Carolina. This location constituted a representative national truckstop: because of the transient nature of long-haul trucking, and because of the consistent and high level of trucking activity at this location, this site was representative of typical US truckstops. Permission to conduct the study at the truckstop was requested and granted by the TA Corporate Office.

Field researchers trained in survey and biometric data collection and phlebotomy spent approximately 3 or 4 days each week at the truckstop in two teams. One team of two to four researchers remained at the TA truckstop from approximately 6 to 10 pm to collect survey and biometric data. Signs regarding the study were posted at strategic locations around the truckstop. Using intercept techniques, researchers approached drivers and asked screening questions to assure they were long-haul truck drivers and that they had an overnight layover at the truckstop. During this conversation, study details, including the voluntary nature of participation, cash incentives, and the necessary fasting for blood draw the next morning, were explained. Those drivers able and willing to return to the same location between 4 and 8 am the next morning were enrolled and appointments were made for the following morning. Enrolled drivers were then asked to sign an informed consent form and were allowed to use aliases for greater confidentiality and in some cases anonymity. In this manner, drivers' biometric measures were collected and drivers were paid a $10 cash incentive. They were given appointment cards and told they would receive another $10 the following morning after the blood draw (along with a small snack).

Of the 262 long-haul truck drivers that completed questionnaires and anthropometric measures, 115 long-haul truck drivers returned for blood draws the following morning. The second team of one to two certified phlebotomists arrived early at the truckstop, set up their equipment, and, using a medical privacy screen and fluorescent lamp, proceeded to collect blood samples from drivers. Following the blood draws, appointment cards were collected and incentives and small snacks were given to drivers. Blood samples were then stored in a portable centrifuge for delivery to the university laboratory later that morning. With Type I error set at 0.05 and power at 90%, our sample size was anticipated to enable us to conduct appropriate statistical analyses, including examining significant differences among independent and outcome variables.

Survey and Sample Characteristics

Data for demographic, behavioral, and health status variables that could potentially be related to CMD risk among long-haul truck drivers were collected. We developed the Trucker Sleep Disorders Survey from insights gleaned from other key instruments, relevant literature, and our previous work with long-haul truck drivers.[25–28] Key variables for this study included diabetic status, cardiovascular problems, prescribed medication use, age, race/ethnicity, and tenure in the profession. Diabetes diagnosis and cardiovascular health problem information was provided via self-report.

Anthropometric Measures

Given the high prevalence of overweight and obesity among long-haul truck drivers, we were interested in identifying simple anthropometric measures that could be utilized in this group to screen drivers with the highest risk for long-term health complications. Using a privacy screen in a low-traffic area of the truckstop, the weight of each driver was recorded in kilograms to the nearest tenth using an Elite XXL scale. Height was measured to the nearest centimeter using a portable stadiometer (Seca, Chino, CA). BMI (kg/m^2) was calculated and rounded to the nearest tenth. Waist circumference was assessed using a Gulick II tape measure with tension indicator and SAD measures were taken at the level of the umbilicus [approximating the L4–L5 level of the spine] using a Rosscraft Campbell caliper #20 (Vancouver, BC) and values recorded to the nearest tenth of a centimeter. Each measure was taken two times and averaged.

Blood Pressure

Participants rested quietly for 5 minutes with their arm supported at heart level and their feet on the floor, as outlined by the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure.[29] Manual cuff blood pressure measurements were repeated two times with 5 minutes between measures, and values for systolic and diastolic blood pressure were averaged from the two measures.

Blood Draws and Specimens

Following occupational safety and health administration procedures,[30] blood was taken from the antecubital space in either arm using aseptic technique by a certified phlebotomist. Blood was collected in red top tubes and allowed to clot at room temperature for 15 to 20 minutes. Using a portable centrifuge (LW Scientific E8 Portafuge, Atlanta, GA), blood samples were spun at 3000 rpm for 15 minutes and then transported on ice to the laboratory. To limit freeze/thaw cycling, serum was divided into aliquots and stored at $-80\,^{\circ}C$ for future analysis.

We requested that participants fast for 8 hours prior to the blood draw. Because of the scheduling of long-haul truck drivers, which are demanding and structured around 10 hours breaks in between driving shifts,[31] we realize that it was not possible for all participants to fast for the requested 8 hours. Based on the available literature, which suggests ambiguity in terms of standardized required fasting periods for our various blood analyes,[32] and given the impracticality of requiring longer fasting periods of the drivers in our sample, we felt that this fasting time was appropriate. In comparison, the NHANES sample used for comparisons in this study only fasted for approximately 6.49 hours.

Blood Analysis

All samples are analyzed in duplicate with appropriate quality controls in the University's Exercise Physiology Laboratory using commercially available ELISA systems and the EPOCH plate reader (BioTek, Winooski, VT). Specifically, lipid profiles (total cholesterol, triglycerides, low-density lipoproteins, and high-density lipoproteins), were assayed using colorimetric reagents using protocols specified by the manufacturer (Wako USA, Richmond, VA). Glucose was assayed using a colorimetric assay (Kit no.

10009582; Caymen Chemical, Ann Arbor, MI). The range of this assay is 2.5 to 25 mg/dL and all serum samples were diluted 1:5 prior to analysis. Samples above the detection limit of 25 mg/dL were further diluted and reanalyzed. Tolerance for duplicate sample variance was set at 15% and samples were re-analyzed if the coefficient of variance (CV) for the duplicate was greater than 15%.

The National Health and Nutrition Examination Survey

The NHANES provided an excellent comparison sample to elucidate the CMD risk of long-haul truck drivers versus the general US population. The NHANES is collected annually through household screenings to assess for meeting predetermined criteria for inclusion and involves both an interview and physical examination.[33] Beginning in 2011, there was no age limit for inclusion, and the NHANES initiated purposive oversampling of minority populations, including, Hispanics, African Americans, Asians, Whites at or below 130% of the federal poverty level, and Whites 80 years of age or older.[34] The interview portion includes demographic, health, and nutrition information, with physical measurements and blood collections including blood and urine specimens for laboratory testing.[33] The final sample for the 2011 to 2012 sample, which was the reference sample for the bulk of our comparisons included 9338 people.[33] Since our long-haul truck driver sample featured only men 18 and older, we filtered the NHANES dataset to match these demographic characteristics. For all comparisons except for high-sensitivity C-reactive protein (hs-CRP), the NHANES 2011 to 2012 cohort was used, which included 2820 subjects. Because this cohort did not include hs-CRP measure, we utilized the data from the 2009 to 2010 cohort, which included 2561 subjects.

Statistical Analysis

We first performed descriptive analyses to create a profile of the long-haul truck driver sample in comparison to the NHANES data. Descriptive statistics included age, job tenure (as years in profession), race/ethnicity (white vs. non-white), and the use of prescription medications. Next, we conducted descriptive analyses of CMD risk for each sample to include traditional (blood pressure; HDL, low-density lipoprotein (LDL), non-HDL, and total cholesterol; triglycerides; and blood glucose), body composition (BMI, WC, and SAD), and inflammatory (hs-CRP) risk markers. We then recorded the means and standard deviations, along with the sample size information, to utilize for summary independent-sample t-tests. These t tests analyzed statistical significance in mean differences between the two samples. The outcome variables used for further CMD risk analyses included metabolic syndrome, diabetes, and cardiovascular health problems (for long-haul truck drivers) or coronary heart disease (for the NHANES cohort) diagnoses. Metabolic syndrome was diagnosed if subjects met three or more of the five diagnostic criteria discussed in the introduction (or were prescribed medication for lipids, BP, or glucose). We then tested for group differences between the long-haul truck driver and NHANES samples using chi-squared (χ^2) tests. Using the CMD risk and outcome variables, we performed partial correlation analyses for both samples to compare associations; with these analyses we controlled for prescription medication use and weighted the data for race/ethnicity due to the discrepancies in racial make-up of the two samples (51.0% white in the long-haul truck driver sample vs. 37.1% white in the NHANES sample). This was most likely to due to the aforementioned purposive oversampling of minority populations within NHANES. All statistical analyses were performed using SPSS 23.0.[35]

RESULTS

While many long-haul truck drivers agreed to participate in the questionnaire and anthropometric portion of the study, slightly fewer than half these drivers ($N = 115$, 43.9%) returned the following morning for a fasted blood draw. We first performed χ^2 tests to assess for non-response bias among the long-haul truck drivers who did not return for the morning blood draw versus who did return for the morning blood draw. Three subjects from the non-blood draw group had missing anthropometric variables and were excluded from the analysis. We found that there were no statistically significant differences between the two groups. When comparing anthropometrics or resting blood pressure, the group that returned for a blood draw was not significantly different on any variable compared with the individuals who did not return for a blood draw the following morning. The drivers who returned for a blood draw in the morning were slightly older (47.8 vs. 45.7 years old), had slightly larger WC (115 cm vs. 114.6 cm) and SAD (32.4 cm vs. 32.2 cm), and had slightly higher resting systolic (129.3 mm Hg vs. 128.5 mm Hg) and diastolic blood pressure (82.8 mm Hg vs. 80.6 mm Hg), but none of these differences were significant. The drivers who returned for blood draws had identical BMI (33.4) as those who did not. These comparisons were similarly reported in a previous study which used the same dataset.[36]

TABLE 1. Comparison of Demographics and Prescribed Medication Use of Long-Haul Truck Driver Sample and NHANES (Filtered) 2011 to 2012 Data

	Truck Drivers	NHANES	*P*
Age: mean (SD)	47.8 (9.7)	47.9 (18.4)	NS
Years in profession: mean (SD)	14.4 (11.3)	15.1 (12.9)	NS
Race/Ethnicity			
White (%)	51.0	37.1	[a]
Non-White (%)	49.0	62.9	
Prescribed medication use (%)	67.0	69.1	NS
Blood pressure (%)	24.1	—	
Cardiovascular health (%)	13.4	11.8	
Cholesterol (%)	7.1	—	
Diabetes (%)	5.3	3.5	
Metabolic (%)	—	6.7	

NHANES, National Health and Nutrition Examination Survey; NS, not significant; SD, standard deviation.
[a] $P < 0.01$.

The long-haul truck driver and NHANES samples were very similar across several measures (see Table 1). There were no statistically significant differences between the two samples based on age, years in profession, or the use of prescription medications. The mean age of the long-haul truck driver sample was 47.8 (standard deviation [SD] = 9.7) and the mean age of the NHANES cohort was 47.9 (SD = 18.4). Long-haul truck drivers reported working in the profession for an average of 14.4 years (SD = 11.3), while those in the NHANES cohort reported working in their respective professions for an average of 15.1 years (SD = 12.9). Sixty-seven percent of the long-haul truck driver sample reported using prescription medications, compared with 69.1% of the NHANES sample. There were statistically significant differences between the two samples based on race/ethnicity: of the truck driver sample, 51% were whites, compared with 37.1% of the NHANES sample.

The long-haul truck driver sample was significantly higher than the NHANES sample across most CMD risk markers (Table 2). Mean differences of 5.79 for BMI ($t = 7.42$, $P < 0.01$), 23.19 cm for WC ($t = 11.38$, $P < 0.01$), and 10.28 cm for SAD ($t = 21.57$, $P < 0.01$) were found across the body composition measures, with the long-haul truck driver sample measuring higher for all three. With regards to blood pressure, the means of both the systolic and diastolic readings were significantly greater among the long-haul truck driver sample, with a mean difference of 8.22 mm Hg for

TABLE 2. Comparisons of Cardiometabolic Risk Markers of Long-Haul Truck Driver Sample and NHANES (Filtered) 2011 to 2012 Data

CMD Marker	Mean (SD)	Mean Difference	*P*
BMI			
Truck drivers	33.38 (6.70)	5.79	[a]
NHANES	27.59 (8.26)		
Waist circumference (cm)			
Truck drivers	115.00 (16.15)	23.19	[a]
NHANES	91.81 (21.60)		
Sagittal diameter (cm)			
Truck drivers	32.41 (5.68)	10.28	[a]
NHANES	22.13 (4.98)		
Systolic BP (mm Hg)			
Truck drivers	129.32 (19.29)	8.22	[a]
NHANES	121.10 (19.66)		
Diastolic BP (mm Hg)			
Truck drivers	82.82 (11.43)	14.73	[a]
NHANES	68.09 (13.49)		
HDL cholesterol (mg/dL)			
Truck drivers	35.08 (10.69)	17.07	[a]
NHANES	52.15 (13.44)		
LDL cholesterol (mg/dL)			
Truck drivers	113.66 (27.64)	4.98	NS
NHANES	108.68 (35.46)		
Non-HDL-cholesterol (mg/dL)			
Truck drivers	133.39 (30.49)	2.74	NS
NHANES	130.65 (40.55)		
Total cholesterol (mg/dL)			
Truck drivers	168.16 (30.21)	14.64	[a]
NHANES	182.80 (41.08)		
Blood glucose (mg/dL)			
Truck drivers	86.32 (26.79)	18.94	[a]
NHANES	105.26 (32.03)		
Triglycerides (mg/dL)			
Truck drivers	164.12 (91.80)	44.70	[a]
NHANES	119.42 (96.40)		
hs-CRP (mg/L)[*]			
Truck drivers	8.83 (9.96)	8.47	[a]
NHANES (2009–2010)	0.35 (0.78)		
Diabetes diagnosis[†]			
Truck drivers	18.3	11.3	[a]
NHANES	7.0		
Metabolic syndrome[†]			
Truck drivers	73.7	39.9	[a]
NHANES	33.8		
Cardiovascular health problems/coronary heart disease[†]			
Truck drivers	4.3	0.7	NS
NHANES	3.6		

BP, blood pressure; BMI, body mass index; CMD, cardiometabolic disease; NHANES, National Health and Nutrition Examination Survey; NS, not significant; SD, standard deviation.

[*]Used NHANES 2009 to 2010 data for hs-CRP.

[†]Comparisons are expressed in percentages and percentage differences.

[a]$P < 0.01$.

systolic ($t = 4.40$, $P < 0.01$) and 14.73 mm Hg for diastolic ($t = 11.54$, $P < 0.01$). The NHANES sample was significantly higher for HDL cholesterol ($M = 17.07$ mg/dL, $t = 13.45$, $P < 0.01$), total cholesterol ($M = 14.64$ mg/dL, $t = 3.78$, $P < 0.01$), and blood glucose ($M = 18.94$ mg/dL, $t = 6.25$, $P < 0.01$). The long-haul truck driver sample had significantly greater means for triglycerides ($M = 44.70$ mg/dL, $t = 4.88$, $P < 0.01$) and, as reported in a previous study using the same dataset,[36] for hs-CRP ($M = 8.47$ mg/L, $t = 40.52$, $P < 0.01$).

For the three CMD outcome variables (diabetes diagnosis, metabolic syndrome, and cardiovascular problems) (see Table 2), 18.3% of the long-haul truck driver sample had been diagnosed with diabetes, compared with only 7% of the NHANES sample. Nearly 74% (73.7%) of the long-haul truck driver sample met the criteria for metabolic syndrome, versus only 33.8% of the NHANES sample. There were significant differences between the two samples for both diabetes diagnosis and meeting the criteria for metabolic syndrome ($P < 0.01$ for both). Finally, 4.3% of the long-haul truck driver sample reported being diagnosed with cardiovascular health problems, while only 3.6% of the NHANES sample had been diagnosed with coronary heart disease; however, this was not a statistically significant difference.

When examining the partial correlations between the three CMD outcome variables and the CMD risk markers (Table 3), there were interesting similarities and differences between the two samples. For diabetes diagnosis, there was little association with the risk markers within the NHANES sample; however, with the long-haul truck driver sample there were significant correlations with measures of WC ($r = 0.26$, $P < 0.05$), SAD ($r = 0.24$, $P < 0.05$), non-HDL cholesterol ($r = -0.34$, $P < 0.05$), total cholesterol ($r = -0.32$, $P < 0.05$), and diastolic BP ($r = -0.41$, $P < 0.01$). For metabolic syndrome, there were several modest to relatively strong associations with the CMD risk markers. Statistically, significant associations for long-haul truck drivers included: BMI ($r = 0.32$, $P < 0.01$), WC ($r = 0.28$, $P < 0.05$), SAD ($r = 0.35$, $P < 0.011$), HDL ($r = -0.30$, $P < 0.01$), triglycerides ($r = 0.22$, $P < 0.05$), systolic blood pressure ($r = 0.31$, $P < 0.01$), and diastolic blood pressure ($r = 0.45$, $P < 0.01$). For the NHANES cohort, statistically significant associations included BMI ($r = 0.34$, $P < 0.05$), WC ($r = 0.35$, $P < 0.05$), SAD ($r = 0.36$, $P < 0.05$), LDL ($r = 0.37$, $P < 0.05$), glucose ($r = 0.47$, $P < 0.01$), and triglycerides ($r = 0.52$, $P < 0.01$). Finally, for the long-haul truck driver sample, only non-HDL cholesterol ($r = 0.23$, $P < 0.05$) and total cholesterol ($r = 0.23$, $P < 0.05$) held significant correlations with cardiovascular health problems; similarly, for the NHANES sample, the only two significant correlations with coronary heart disease were non-HDL cholesterol ($r = -0.14$, $P < 0.05$) and total cholesterol ($r = -0.15$, $P < 0.05$).

DISCUSSION

Heightened CMD risk among long-haul truck drivers has far-reaching consequences. Among long-haul truck drivers, heightened CMD risk is associated with excessive daytime sleepiness, disordered sleep, and workplace fatal and nonfatal injuries.[37–40] Cumulatively, heightened CMD risk contributes to life expectancies approximately 16 years shorter than the general US population.[23] The trucking industry is burdened by excessive healthcare costs and reduced labor productivity associated with CMD risk and associated outcomes.[20] Given the importance of the trucking industry to the US economy, poor long-haul truck driver health has negative impacts for multiple stakeholders, such as insurance companies, healthcare systems, manufacturing and warehousing firms, and truckstop companies.[20] Further, CMD risk has implications for public safety, as factors such as hypertension, obesity, diabetes, and cardiovascular disease impair key safe driving abilities required of long-haul truck drivers.[20]

These findings present a comprehensive clinical picture of CMD risk among long-haul truck drivers in the US for the first time. The long-haul truck driver sample presented elevated CMD risk compared with established normal ranges for CMD risk markers. On average, the long-haul truck driver sample was pre-hypertensive (120 to 139 mm Hg systolic; 80 to 89 mm Hg diastolic) and exhibited undesirable LDL cholesterol (>100 mg/dL), HDL cholesterol (<60 mg/dL), and triglyceride (>150 mg/dL) levels.[41,42] The long-haul truck driver sample was also, on average, obese (BMI ≥30) and had risk-indicative adipose tissue distribution (WC >102 cm; SAD >30 cm).[43,44] Finally, and as indicated in a previous study using the same dataset,[36] the mean hs-CRP level in the long-haul truck driver

TABLE 3. Partial Correlations for both Long-Haul Truck Drivers Sample and NHANES 2011 to 2012 Data (Controlling for Prescribed Medication Use and Weighed for Race/Ethnicity)

Analyses	Correlation	Analyses	Correlation
Truck drivers		NHANES	
Diabetes diagnosis		Diabetes diagnosis	
BMI	0.21	BMI	−0.05
Waist circumference	0.26[a]	Waist circumference	−0.08
Sagittal diameter	0.24[a]	Sagittal diameter	−0.09
HDL	0.06	HDL	−0.11
LDL	−0.23	LDL	−0.03
Non-HDL cholesterol	−0.34[a]	Non-HDL cholesterol	−0.06
Total cholesterol	−0.32[a]	Total cholesterol	−0.10
Glucose	0.00	Glucose	−0.02
Triglycerides	−0.08	Triglycerides	−0.06
Systolic BP	−0.05	Systolic BP	−0.03
Diastolic BP	−0.41[b]	Diastolic BP	−0.07
Metabolic syndrome		Metabolic syndrome	
BMI	0.32[b]	BMI	0.34[a]
Waist circumference	0.28[a]	Waist Circumference	0.35[a]
Sagittal diameter	0.35[b]	Sagittal diameter	0.36[a]
HDL	−0.30[b]	HDL	0.17
LDL	0.08	LDL	0.37[a]
Non-HDL cholesterol	0.15	Non-HDL cholesterol	−0.09
Total cholesterol	0.06	Total cholesterol	−0.05
Glucose	0.12	Glucose	0.47[b]
Triglycerides	0.22[a]	Triglycerides	0.52[b]
Systolic BP	0.31[b]	Systolic BP	−0.02
Diastolic BP	0.45[b]	Diastolic BP	0.10
Diagnosed with cardiovascular problems		Diagnosed with coronary heart disease	
BMI	0.03	BMI	0.04
Waist circumference	0.02	Waist circumference	−0.03
Sagittal diameter	0.04	Sagittal diameter	−0.03
HDL	0.02	HDL	−0.01
LDL	0.05	LDL	0.00
Non-HDL cholesterol	0.23[a]	Non-HDL cholesterol	−0.14[a]
Total cholesterol	0.23[a]	Total cholesterol	−0.15[a]
Glucose	0.07	Glucose	−0.10
Triglycerides	0.01	Triglycerides	−0.05
Systolic BP	−0.02	Systolic BP	0.01
Diastolic BP	0.01	Diastolic BP	0.08

BP, blood pressure; BMI, body mass index; NHANES, National Health and Nutrition Examination Survey.
[a]$P < 0.05$.
[b]$P < 0.01$.

sample was far above the normal range ($\leq$3.0 mg/L), indicating significant inflammation.[45] Long-haul truck drivers from other countries exhibit similarly elevated CMD risk profiles. For example, among Brazilian long-haul truck drivers, elevated levels of hypertension, dyslipidemia, blood glucose, obesity, abdominal obesity, and metabolic syndrome have been observed compared with established ranges of CMD risk.[21,46] Studies have found elevated BMIs of long-haul truck drivers in Canada, as compared with a national dataset from the Canadian Community Health Survey, and in Italy, compared with bus drivers,[47,48] as well as elevated cardiovascular disease outcomes among long-haul truck drivers in Sweden, matching similar patterns of other transportation workers.[49] Other studies have also shown US long-haul truck drivers to have elevated levels of metabolic syndrome and diabetes compared with the US adult working population.[17,18]

In comparison to the general US population from NHANES, the long-haul truck driver sample presented elevated CMD risk markers and had higher diagnosis rates for metabolic syndrome and diabetes, confirming our first hypothesis. However, there were some exceptions; namely, total cholesterol and blood glucose levels. Because of data incompatibilities, it was not possible to detect whether cholesterol differences are attributable to medication usage alone. While the long-haul truck driver sample had lower total cholesterol, measures of LDL and non-HDL cholesterol were higher, and HDL was lower; thus, their overall cholesterol profile indicates elevated atherosclerotic,[50] and thus elevated cardiometabolic, risk compared with the NHANES sample. Regarding the lower levels of blood glucose among the long-haul truck driver sample, drivers who are diagnosed with type 2 diabetes and are insulin dependent are subject to stringent federal regulations which require them to apply for a diabetes exemption and mandate that they exhibit control of their disease[51,52]; thus, drivers' livelihoods are dependent on controlling their glucose levels, and those who are unable to do so are medically disqualified from the profession. This highlights the possibility of federal policy to impact CMD risk and outcomes among long-haul truck drivers. The long-haul truck driver sample had a slightly greater percentage on diabetes medications, which may also explain the comparatively lower levels of blood glucose. The higher diabetes medication use is likely attributable to the higher diabetes diagnosis rate among the long-haul truck driver sample, which suggests that screening for diabetes catalyzes efforts among these individuals to manage their blood glucose levels. Also, the NHANES fasting times were nearly an hour and a half shorter than those of the long-haul truck drivers; hence, it is possible that equivalent fasting times would have negated these differences.

The overall degree of CMD risk of the long-haul truck drivers compared with the NHANES sample suggest the powerful influence of unique occupational characteristics endured by long-haul truck drivers. Other studies have implicated the role of long work hours, unpredictable schedules, shift work, job strain, and lack of health-supportive resources (eg, healthful foods; truck stop gyms) in the workplace[53–56] as factors which induce CMD risk among long-haul truck drivers. Extant long-haul truck driver health and wellness programs address these factors rarely, if at all.[57] For example, many long-haul trucking companies provide programs which target one area of concern, such as Schneider National, Inc. and Gordon Trucking, Inc., which had programs targeting sleep apnea through screening and treatment.[58,59] Others, such as those provided by JB Hunt, Inc. and Con-Way Freight, Inc., are more comprehensive; however, even these focus on individual behavior and fail to address critical elements of work organization, such as scheduling.[58,60] Interventions to curb excess CMD risk and outcomes among drivers should target these vital elements of workplace and work organization.

The distinct relationships between CMD risk markers and CMD outcomes for long-haul truck drivers provide potentially useful predictive information for clinicians, as unique aspects of the long-haul trucking profession may differentially induce CMD risk compared with the general US population. However, while several significant associations were found, particularly with regard to metabolic syndrome and cardiovascular disease outcomes, the unevenness of some of the associations was relatively surprising with respect to our second hypothesis. One such association is between glucose and diabetes, which was a nonsignificant but positive correlation among the long-haul truck drivers. These are likely partially explained by medication usage, which was relatively higher among the long-haul truck driver sample compared with the NHANES sample. Also, as discussed previously, long-haul truck drivers' livelihoods are dependent on controlling their glucose levels, and those who are unable to do so are medically disqualified from the profession. This may mean that, not only are drivers especially vigilant in controlling this measure of CMD risk after being diagnosed with diabetes, but that those that are unsuccessful in doing so are forced out of the profession through the revocation of their medical certification.

Other takeaways among the long-haul truck drivers' sample are the significant associations between CMD risk markers and diabetes diagnosis, many of which are components of metabolic syndrome. It appears that metabolic syndrome and diabetes are indeed associated with similar factors, suggesting the syndemic nature of both diseases. The pattern of nonsignificance of associations between glucose and metabolic syndrome further suggests, within the context of the regulatory environment, the vigilance of drivers in controlling their glucose levels. In contrast, in the NHANES sample, none of the CMD risk markers were significantly associated with diabetes diagnosis, and in fact these risk factors were negatively correlated. This may also be a function of medication usage, which was nearly 70%. Finally, there were relatively few significant associations between CMD risk markers and cardiovascular outcomes. Among the long-haul truck drivers and NHANES samples, the significance of non-HDL cholesterol and total cholesterol highlights the importance of these cholesterol types in arteriosclerosis[50] and suggests that these types of cholesterol may be the most relevant in predicting later cardiovascular disease outcomes in both populations.[7,61]

Many of the unexpected patterns of associations between CMD risk markers and CMD outcomes among our long-haul truck driver sample are likely influenced by our research design, which is cross-sectional and represents a ''snapshot'' in time. To elucidate the relationship between CMD risk and long-haul truck driver outcomes, a longitudinal design is required to allow CMD risk and outcome dynamics to develop over time within a cohort of drivers. Such a study would also facilitate understanding of the unique interplay of CMD risk and outcomes within the context of long-haul trucking. For example, it is possible that CMD outcomes may be masked in our data by medical examination requirements imposed on long-haul truck drivers. Federal policy currently dictates that long-haul truck drivers must undergo a screening process at least once every 2 years.[17] As the accumulation of CMD risk factors manifests as disease states, long-haul truck drivers are medically disqualified from the profession and thus leave long-haul truck driving. Should this be the case, our sample—consisting of medically qualified long-haul truck drivers—may not have captured the bulk of drivers who are in disease states as a result of a career in a CMD-inducing occupation. A longitudinal study would also answer additional, and potentially confounding, questions, such as whether there is a selection bias among those who choose to enter the long-haul trucking profession in the first place. It is possible that there is a subset of the population who finds the default health behaviors—namely, the consumption of high-fat and high-calorie foods and the sedentary lifestyle[55]—of the long-haul truck driving profession appealing. Such default behaviors are propagated by the lack of healthful food options and opportunities for exercise at long-haul truck driver worksites.[56] While the medical certification process likely screens out many of these individuals from entering the profession, particularly those who exhibit CMD disease states,[62] individuals with a propensity toward such behaviors may find these tendencies exacerbated upon entering the profession, with the array of CMD risk and outcomes highlighted in the current study being the result.

There are three primary limitations of the current study. First, the overall sample size is relatively small, with 262 long-haul truck drivers, 115 of whom participated in blood draws. While a larger sample size may have increased our likelihood of finding additional relationships, the congruency of our findings with other studies involving long-haul truck drivers indicates that our sample was highly representative of the population. Second, the potential for selection bias is an important limitation to consider when interpreting our results. Drivers may have refused to participate for myriad reasons. For example, giving the increasingly-stringent medical requirements that drivers must meet to operate a commercial motor vehicle in the US, drivers may have been concerned that results from the current study could have potentially resulted in medical disqualification or termination. Drivers may also have been leery of releasing any personal information to a government entity, including the University conducting this study. Our own extensive experience with collecting data from this population has indicated the presence of a certain level of mistrust among many drivers, and similar feedback was received from non-participating drivers informally in the current study as well. These potential selection biases were discussed in a previous study using the same dataset.[36] Third, we employed a sampling technique that involved blood draws in an actual long-haul truck driver workplace (at a truckstop). While this minimized the barriers to participation and likely increased the willingness of individuals to be involved in the study, it limited the amount of time drivers were able to fast prior to the blood draw. Although these shorter fasting times may slightly have altered our blood values, they are representative of the normal schedules maintained by these individuals. Further, because the NHANES sample which was used for comparison had similar or shorter fasting windows, and because shorter fasting windows generally result in artificially high readings of many of the CMD risk indicators used in this study,[32] our analyses may in fact underestimate the disparities in CMD risk between long-haul truck drivers and the general US population.

In conclusion, this sample of US long-haul truck drivers presented elevated CMD risk markers, providing a comprehensive CMD risk marker profile for the first time. Heightened CMD risk compared with the general US population indicates

occupationally-linked CMD pathogenesis. As the trucking industry continues to be highly competitive, as the labor pool of commercial drivers continues to shrink, and as regulatory pressure continues to increase, measures to reduce the CMD risk of long-haul truck drivers and its adverse consequences are imperative. These measures should address unique occupational characteristics experienced by long-haul truck drivers.

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