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RESEARCH ARTICLE

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Metabolic syndrome among commercial truck drivers: The relationship between condition prevalence and crashes

Michael K. Lemke PhD[1] | Matthew S. Thiese PhD, MSPH[2] | Adam Hege PhD[3] | Uchenna C. Ogbonnaya PhD-c, MS[2] | Kurt T. Hegmann MD, MPH[2]

[1]Department of Social Sciences, University of Houston-Downtown, Houston, Texas, USA

[2]Rocky Mountain Center for Occupational and Environmental Health, School of Medicine, University of Utah and Weber State University, Salt Lake City, Utah, USA

[3]Department of Public Health & Exercise Science, Appalachian State University, Boone, North Carolina, USA

Correspondence

Michael K. Lemke, PhD, Department of Social Sciences, University of Houston-Downtown, One Main St, Suite N1025, Houston, TX 77002, USA.
Email: lemkem@uhd.edu

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Abstract

Background: Metabolic syndrome (MetS) is especially prevalent among US truck drivers. However, there has been limited research exploring associations between MetS conditions with roadway crashes among truck drivers. The objective of this paper is to assess relationships between specific combinations of individual MetS components and crashes and near-misses.

Methods: Survey, biometric, and anthropometric data were collected from 817 truck drivers across 6 diverse US states. Survey data focused on demographics and roadway safety outcomes, and anthropometric/biometric data corresponded to five MetS conditions (waist circumference blood pressure, hemoglobin A1c, triglycerides, and high-density lipoprotein [HDL] cholesterol). Logistic regression was used to calculate odds ratios of lifetime crashes and near-miss 1-month period prevalence associated with: 1) specific MetS conditions regardless of presence or absence of other MetS conditions, and 2) specific MetS conditions and counts of other accompanying MetS conditions.

Results: Hypertension was the MetS characteristic most strongly associated with lifetime crash and 1-month near-miss outcomes, while high triglycerides, low HDL cholesterol, and large waist circumference were most commonly present among groups of conditions associated with crashes and near-misses. Overall, an increasing number of specific co-occurring MetS conditions were associated with higher reporting of roadway crashes.

Conclusions: Specific combinations and higher prevalence of MetS conditions were associated with increased frequency of reported crashes. Moreover, when the co-occurrence of MetS conditions is aggregated, a dose–response relationship with crashes appears. These results suggest that policy changes and interventions addressing MetS may increase driver health and reduce crash risk.

KEYWORDS

commercial truck drivers, crashes, medical certification, metabolic syndrome, near-misses

1 | INTRODUCTION

The US trucking industry is a vital component of the economy, totaling nearly $800 billion in gross freight revenues in 2019 and accounting for over 80% of the nation's total freight bill.[1] Central to the US trucking industry are the approximately 2 million heavy and tractor-trailer truck drivers, who altogether traversed over 300 billion miles in 2018.[1,2] These drivers, who are commercial driver's license holders, move the bulk of the nation's freight by operating 3.91 million Class 8 trucks, which includes both straight trucks and tractors.[1]

The commercial driving industry has a broad range of work environments and organizational characteristics that make it unique compared to other occupations.[3] The duties of truck drivers extend beyond simply driving, as suggested by the job title, and often include equipment inspections, completing paperwork, securing loads, chaining tires, and loading/unloading freight, the latter of which may include detention time at shippers or consignees.[2] Drivers may be compensated "by the mile," which may or may not include direct compensation for nondriving activities.[4,5] Further, many drivers have irregular hours[6] and are exposed to multiple physical and psychosocial stressors.[7]

These occupational demands on truck drivers are associated with cardiovascular and metabolic disease risk factors, poor sleep health, inadequate physical activity, poor nutrition, and tobacco use.[6,8–12] Besides involving work commonly performed away from a terminal, trucking industry worksites have been noted for an absence of key resources to support healthful diets, adequate physical activity, and access to healthcare[13–15] and as such, the industry's common worksites have been characterized as both "healthy food deserts" and "active-living deserts."[16,17] The demands on truck drivers and drivers' health-related behaviors have been associated with negative physical and mental health outcomes.[3,6,18] Notably, truck drivers reportedly experience disproportionately high rates of cardiovascular, metabolic, and respiratory afflictions compared to workers in other occupations and the general US population.[19–25] Further, truck drivers have a high prevalence of workplace injuries and roadway crashes.[7,18,26,27]

A particularly relevant set of cardiovascular and metabolic outcomes are those that constitute metabolic syndrome (MetS), which is defined as the presence of three or more of the following risk factors, or "conditions": Abdominal obesity, high triglycerides, low high-density lipoprotein (HDL) cholesterol, high blood pressure, and high blood glucose.[28] The prevalence of MetS has been estimated at over 50% of truck drivers, which is nearly three times higher than that of the general working population.[23,24] While the co-occurrence of health disorders including MetS among truck drivers is common,[3,18,23,29] their potential association(s) with crashes or near-misses are poorly understood. However, the existing literature has identified relationships between specific MetS conditions—obesity in particular—with roadway crash risks.[8,30]

A nuanced understanding of the influence of MetS on safety outcomes can inform safety policymaking and prevention planning. For example, while current policies address individual MetS conditions such as hypertension or diabetes, other MetS conditions that may be relevant to roadway safety performance (triglycerides, waist circumference, and HDL cholesterol) are not addressed by these policies. Further, current medical examiner guidelines do not account for the psynergistic nature of MetS conditions[31–33] that may disproportionately shape roadway safety outcomes, particularly when a driver has three or more co-occurring MetS conditions. Thus, this paper aims to explore two hypotheses: (1) combinations of individual MetS conditions are associated with roadway crashes and near-misses; and (2) combinations of 3/5, 4/5, or 5/5 MetS conditions are more strongly associated with roadway crashes and near-misses than single or pairs of MetS conditions.

2 | MATERIALS AND METHODS

2.1 | Study population and design

This cross-sectional study was approved by the Institutional Review Boards at the University of Utah (IRB #: 22252) and the University of Wisconsin-Milwaukee (IRB #: 07.02.297). Informed consent was obtained from all participating commercial truck drivers. Participants were enrolled at truck shows and truck stops in Iowa, Kentucky, Nevada, Texas, Utah, and Wisconsin. Potential participants were approached by study personnel and invited to participate. We did not track how many drivers were approached or how many declined to participate. Participants had been driving for at least a year in any capacity (local, dedicated, or over-the-road) requiring a commercial driver's license. After providing informed consent, participants were asked to complete a questionnaire via computer, had blood-pressure measured after resting for at least 5 min, had height, weight, anthropometry measured, and provided a blood sample for lipid, nonfasting glucose, and hemoglobin A1c measurements. Participants were provided the results from their blood pressure and blood sample at the end of the enrollment. The entire enrollment process took an average of 1 h, and all participants were provided a $20 gift-card. There was no follow-up of drivers. The methodology employed in the current study has been described in greater detail elsewhere.[12,23,34,35]

2.2 | Study measures

Truck drivers completed a computerized questionnaire, which included conditional question sets to simplify administration, and included a possible total of 864 items. The questionnaire included: (1) demographics, including age reported to the nearest 0.1 year, gender, race, and type of driving (e.g., local; over-the-road); (2) occupational lifetime crash history; (3) 1-month period prevalence of near-misses; and (4) past medical history, including diagnoses by a medical professional of diabetes mellitus, hypertension, and hyperlipidemia. Additional data were collected but are not presented in this manuscript.

2.2.1 | MetS measures

Height and weight were measured after participants removed shoes and items in their pocket using a stadiometer and digital scale recorded to the nearest tenth of a centimeter and tenth of a kilogram, respectively. Hip, waist, chest, and neck circumferences were measured to the nearest tenth of a centimeter using a tailor's measuring tape.[36] Blood pressure and heart rate were obtained using an Omron HEM-780 after the truck driver was seated a minimum of 5 min, often at the end of the questionnaire after the participant had been seated for 20 min or more. Only one measure was taken, unless the participant asked for a second measure. If a second measure was taken, those data were entered and used. Nonfasting blood measurements were obtained via finger-stick. Total cholesterol, HDL cholesterol, triglycerides, low-density lipoprotein cholesterol, and nonfasting blood glucose were measured using a Cholestech® LDX machine. Hemoglobin A1c was measured using a Cholestech® GDX machine.

2.2.2 | MetS definition

MetS was defined according to current recommendations,[37] with the substitution of hemoglobin A1c for fasting glucose due to the inability to obtain fasting glucose measurements. Participants met MetS criteria if they had three or more of the following five criteria: Waist circumference ≥102 cm for men or ≥88 cm for women; triglycerides ≥150 mg/dL or currently on medication for dyslipidemia; HDL cholesterol ≤40 mg/dL for men or ≤50 mg/dL for women or currently on medication for dyslipidemia; systolic pressure ≥130 mmHg or diastolic pressure ≥85 mmHg or currently taking medication for hypertension; and hemoglobin A1c ≥ 7.0% or prior diagnosis of diabetes mellitus by a medical professional. The waist circumference limits are those recommended for a White population in the United States.[37] The finger-stick blood testing for triglycerides, HDL cholesterol and hemoglobin A1c were performed as per the testing equipment manufacturer. All equipment was calibrated according to the manufacturer's schedule. Each participant had a selected finger cleaned using an alcohol wipe on the side of their finger, typically ring or long finger. A single use lancet was used after the alcohol was dry, and a drop of blood was expressed for the Cholestech LDX (triglycerides and HDL cholesterol) and Cholestech GDX (hemoglobin A1c) machines. This was collected in a manufacturer supplied pipette and deposited into the testing cartridge or reagent. This was then placed into the machine and the test was performed. Test results were printed and recorded, then explained to the participant. In occasions where there was an error in the reading, the entire process was restarted if the participant was willing to provide an additional blood sample.

2.2.3 | Assessment of crash and near-miss outcomes

A Department of Transportation (DOT)-reportable crash is one that involved a fatality, an injury requiring immediate treatment away from the scene, and/or any vehicle involved having to be towed due to disabling damage.[38] One question in the questionnaire assessed lifetime history of truck crashes: "Have you ever had any reportable motor vehicle crashes?" Personal injury related to the crash was not assessed as part of the questionnaire. If the driver indicated that they had at least one DOT-reportable crash in their lifetime, then additional information about the crash, including reported causes, were collected. A separate question asked about the number of near misses in the past month while driving a truck: "In the past month, how many near miss truck accidents did you experience?," where near-miss was defined as requiring "some evasive action to avoid a crash (brake hard, swerve steering, etc.,)." This number was classified into a "yes" or "no" based on responses.

2.3 | Data analysis

SAS 9.4 software was used for data analyses (SAS Institute). Descriptive statistics included means, medians, standard deviations, and frequencies. One participant did not answer the question about near-misses and was excluded from the near-miss analyses. All other data elements were answered by all participants. Statistical analyses included test for normality for continuous variables, χ^2, Wilcoxon rank sum and logistic regression. Separate comparisons were made between drivers with individual and specific combinations of MetS conditions and for: (1) lifetime crash cumulative incidence; and (2) 1-month near-miss period-prevalence.

We wanted to explore relationships between specific MetS conditions regardless of presence or absence of other MetS conditions, as well as relationships between specific MetS conditions and counts of other MetS conditions. Crude and adjusted logistic regression were used to calculate the odds ratio (OR) and 95% confidence interval (95% CI) for the relationships between MetS conditions and both lifetime crashes and near-miss 1-month period prevalence. The crude logistic models include only the MetS condition(s) and the outcome of interest. Adjusted models included the MetS condition(s) and a third variable, the potential confounders, as they relate to the outcome. The model including the third variable provides an adjusted odds ratio for the relationship between the MetS condition(s) and the outcome of interest, thereby statistically adjusting for confounding by the third variable. Stratification was not considered as a method for adjustment for confounding for this manuscript because of the decrease in statistical power. Potential confounders considered in these analyses include age, gender, race, body mass index (BMI), years as a truck driver, physical activity, and estimated percent of calories from fat. These were selected because of biological plausibility, prior research demonstrating a relationship with the exposures or outcomes, or anecdotal evidence from clinical observations by the coauthors. Variables were included in the final logistic model if there was at least a 10% change between crude OR and adjusted OR, an accepted method for adjusting for confounders using statistical modeling.[39–42] Adjustments for BMI and other MetS conditions were not included because they are either a MetS condition or they are believed to lie in the causal pathway between MetS and roadway crashes. A $p < 0.05$ was considered statistically significant. We also assessed for interaction between the main effect variables of the five individual MetS conditions.

3 | RESULTS

3.1 | Descriptive summary of demographic, MetS, and roadway safety data

Most drivers were male (705; 86.3%), the mean age was 47.3 years old, and 687 participants (86.2%) were White. Most drivers self-identified as long-haul or over-the road drivers. Drivers had a mean body mass index of 32.9 kg/m^2, and measurements classified 507 (62.1%) as obese (BMI ≥ 30.0 kg/m^2) (see Table 1). The most common MetS condition was large waist circumference (77.6%). Lifetime DOT-reportable crashes were common, with 326 (39.9%) reporting at least one DOT-reportable crash. The average number of near misses in the past month was 2.7, and nearly half of the drivers reported at least one near-miss crash in the past month.

3.2 | Main and interaction effects between MetS conditions and lifetime crashes or 1-month near-misses

The adjusted analyses of main and interaction effects between MetS conditions, 1-month period prevalence of near-misses, and lifetime cumulative incidence of crashes are presented in Table 2. Nearly all associations indicated increased odds of having either a lifetime reportable crash or 1-month prevalence of near-miss; however, relatively few were statistically significant. Hypertension was related to both crashes and near misses among six of the statistically significant groups of MetS conditions. High triglycerides was present among four of the statistically significant groups of MetS conditions, and large waist circumference and low HDL cholesterol was present among three of the statistically significant groups of MetS conditions, while diabetes was not present in any.

The final models were adjusted for age and gender only. Additional analyses were performed to statistically adjust for potential confounders. Adjusting for race in addition to age and gender did not provide different results. Physical activity and estimated percent calories from fat were not confounders for the relationships between MetS conditions and either crashes or near-misses. Years spent as a driver was considered as a confounder but was found to be co-linear with age and could not be included in the same logistic model. Age was a stronger control for confounding than years as a driver and was selected for inclusion in the final model.

TABLE 1 Descriptive summary of metabolic syndrome conditions, near-misses, crashes, and demographic characteristics (n = 817)

Variable	*N* (%)
Gender	
Female	112 (13.7%)
Male	705 (86.3%)
Body mass index (kg/m^2)	
Underweight (<18.5)	2 (0.2%)
Normal (18.5–24.9)	83 (10.2%)
Overweight (25–29.9)	225 (27.5%)
Obese (30–30.9)	393 (48.1%)
Morbidly obese (>40)	114 (14.0%)
Metabolic syndrome conditions	
High triglycerides[a]	552 (67.6%)
Low high density lipoprotein[b]	580 (71.0%)
High blood pressure[c]	175 (21.4%)
Diabetes[d]	97 (11.9%)
Large waist circumference[e]	634 (77.6%)
Near-misses in the past month (categorical)	430
0	52.6%
1	115 (14.1%)
2	100 (12.2%)
3	38 (4.7%)
4	22 (2.7%)
≥5	112 (13.7%)
Lifetime DOT-reportable crashes	326 (39.9%)
≥1	

Abbreviations: DOT, Department of Transportation; HDL, high-density lipoprotein.
[a]≥150 mg/dL or currently on medication for dyslipidemia.
[b]HDL cholesterol ≤40 mg/dL for men or ≤50 mg/dL for women or currently on medication for dyslipidemia.
[c]Systolic pressure ≥130 mm Hg or diastolic pressure ≥85 mm Hg or currently taking medication for hypertension; and hemoglobin.
[d]A1c ≥ 7.0% or prior diagnosis of diabetes mellitus.
[e]≥102 cm for men or ≥88 cm for women.

3.3 | Associations between individual and multiple MetS conditions, near-misses, and crashes

The adjusted analyses between specific MetS conditions, their co-occurrence with other MetS conditions, and the two roadway safety outcomes are provided in Table 3. A few patterns can be seen in these analyses. First, there are a few single MetS conditions that were statistically significantly related to either lifetime crashes or

TABLE 2 Associations of metabolic syndrome conditions, with or without other conditions, and outcomes of 1-month prevalence of near-misses and crashes

MetS conditions	Conditions *N* (%)	Adjusted[a] near misses in the past month (≥1) OR (95% CI)	Adjusted[a] lifetime reportable crashes OR (95% CI)
Single MetS conditions regardless of presence or absence of other MetS conditions			
High triglycerides	552 (67.6%)	1.33 (0.98, 1.8)	0.91 (0.66, 1.24)
Low HDL cholesterol	580 (70.99%)	1.25 (0.92, 1.7)	1.10 (0.8, 1.51)
Hypertension	175 (21.42%)	1.32 (0.94, 1.87)	1.20 (0.84, 1.7)
Diabetes	97 (11.87%)	1.24 (0.81, 1.90)	1.17 (0.76, 1.81)
Large waist circumference	634 (77.6%)	0.97 (0.69, 1.37)	0.92 (0.65, 1.31)
Pairs of MetS conditions, regardless of presence or absence of other MetS conditions			
High triglycerides, low HDL cholesterol	442 (54.1%)	1.26 (0.95, 1.67)	1.01 (0.76, 1.36)
High triglycerides, hypertension	140 (17.14%)	1.48* (1.02, 2.16)	1.28 (0.88, 1.87)
High triglycerides, diabetes	83 (10.16%)	1.30 (0.82, 2.05)	1.14 (0.72, 1.81)
High triglycerides, large waist circumference	461 (56.43%)	1.27 (0.96, 1.70)	1.00 (0.75, 1.34)
Low HDL cholesterol, hypertension	140 (17.14%)	1.39 (0.95, 2.03)	1.30 (0.89, 1.90)
Low HDL cholesterol, diabetes	76 (9.3%)	1.07 (0.66, 1.73)	1.01 (0.62, 1.63)
Low HDL cholesterol, large waist circumference	463 (56.67%)	1.09 (0.82, 1.44)	1.07 (0.80, 1.43)
Hypertension, diabetes	49 (8 (6%)	1.39 (0.77, 2.49)	1.06 (0.59, 1.92)
Hypertension, large waist circumference	159 (19.46%)	1.48* (1.03, 2.12)	1.12 (0.78, 1.61)
Diabetes, large waist circumference	89 (10.89%)	1.31 (0.84, 2.05)	1.15 (0.74, 1.81)
Three-way groups of MetS conditions, regardless of presence or absence of other MetS conditions			
High triglycerides, low HDL cholesterol, hypertension	123 (15.06%)	1.54* (1.04, 2.3)	1.44 (0.97, 2.14)
High triglycerides, low HDL cholesterol, diabetes	70 (8.57%)	1.20 (0.73, 1.96)	1.06 (0.64, 1.75)
High triglycerides, low HDL cholesterol, large waist circumference	373 (45.65%)	1.17 (0.88, 1.55)	1.07 (0.80, 1.43)
High triglycerides, hypertension, diabetes	43 (5.26%)	1.27 (0.68, 2.35)	0.93 (0.49, 1.74)
High triglycerides, hypertension, large waist circumference	130 (15.91%)	1.70* (1.15, 2.51)	1.25 (0.85, 1.85)
High triglycerides, diabetes, large waist circumference	76 (9.3%)	1.43 (0.89, 2.31)	1.08 (0.67, 1.75)
Low HDL cholesterol, hypertension, diabetes	40 (4.9%)	1.36 (0.72, 2.59)	0.84 (0.43, 1.61)
Low HDL cholesterol, hypertension, large waist circumference	129 (15.79%)	1.49* (1.01, 2.20)	1.25 (0.85, 1.85)
Low HDL cholesterol, diabetes, large waist circumference	70 (8.57%)	1.13 (0.69, 1.86)	0.92 (0.55, 1.52)
Hypertension, diabetes, large waist circumference	46 (5.63%)	1.61 (0.88, 2.96)	1.00 (0.54, 1.84)
Four-way groups of mets conditions, regardless of presence or absence of other MetS conditions			
High triglycerides, low HDL cholesterol, hypertension, diabetes	38 (4.65%)	1.36 (0.70, 2.62)	0.93 (0.48, 1.82)
High triglycerides, low HDL cholesterol, hypertension, large waist circumference	116 (14.2%)	1.68* (1.11, 2.52)	1.39 (0.92, 2.09)
High triglycerides, low HDL cholesterol, diabetes, large waist circumference	64 (7.83%)	1.29 (0.77, 2.15)	0.96 (0.57, 1.62)
High triglycerides, hypertension, diabetes, large waist circumference	40 (4.9%)	1.49 (0.78, 2.85)	0.85 (0.44, 1.64)
Low HDL cholesterol, hypertension, diabetes, large waist circumference	38 (4.65%)	1.53 (0.79, 2.96)	0.73 (0.37, 1.44)

Abbreviations: CI, confidence interval; HDL, high-density lipoprotein; MetS, Metabolic syndrome.

[a]Adjusted for age and gender.

*$p < 0.05$.

TABLE 3 Associations between individual and discrete multiple metabolic syndrome conditions, near-misses, and crashes

MetS conditions or groups of conditions	Conditions (yes) *N* (%)	Adjusted[a] near misses in the past month (≥1) OR (95% CI)	Adjusted[a] lifetime reportable crashes (yes) OR (95% CI)
High triglycerides			
High triglycerides alone	19 (2.33%)	0.72 (0.28, 1.82)	0.74 (0.27, 1.99)
High triglycerides and any one other condition	126 (15.42%)	1.16 (0.79, 1.70)	0.76 (0.51, 1.14)
high triglycerides and any two other conditions	257 (31.46%)	0.96 (0.71, 1.30)	0.86 (0.63, 1.17)
High triglycerides and any three other conditions	114 (13.95%)	1.39 (0.93, 2.10)	1.67* (1.11, 2.52)
Low HDL cholesterol			
Low HDL cholesterol alone	44 (5.39%)	1.14 (0.62, 2.11)	1.35 (0.72, 2.51)
Low HDL cholesterol and any one other condition	135 (16.52%)	1.20 (0.83, 1.75)	0.92 (0.62, 1.36)
Low HDL cholesterol and any two other conditions	253 (30.97%)	0.82 (0.61, 1.10)	0.87 (0.64, 1.18)
Low HDL cholesterol and any three other conditions	112 (13.71%)	1.40 (0.93, 2.12)	1.59* (1.05, 2.41)
Hypertension			
Hypertension alone	2 (0.24%)	1.23 (0.08, 19.74)	NA
Hypertension and any one other condition	18 (2.2%)	0.60 (0.22, 1.63)	0.53 (0.18, 1.52)
Hypertension and any two other conditions	31 (3.79%)	0.94 (0.46, 1.94)	0.87 (0.40, 1.85)
Hypertension and any three other conditions	88 (10.77%)	1.53 (0.97, 2.41)	1.69* (1.07, 2.67)
Diabetes			
Diabetes alone	1 (0.12%)	NA	
Diabetes and any one other condition	3 (0.37%)	0.64 (0.06, 7.20)	0.71 (0.06, 8.24)
Diabetes and any two other conditions	21 (2.57%)	1.25 (0.53, 2.99)	2.32 (0.95, 5.70)
Diabetes and any three other conditions	36 (4.41%)	0.94 (0.48, 1.85)	1.19 (0.61, 2.35)
Large waist circumference			
Large waist circumference alone	64 (7.83%)	0.55* (0.32, 0.95)	0.87 (0.50, 1.5)
Large waist circumference and any one other condition	154 (18.85%)	0.95 (0.67, 1.36)	0.87 (0.60, 1.25)
Large waist circumference and any two other conditions	266 (32.56%)	0.93 (0.69, 1.24)	0.9 (0.66, 1.22)
Large waist circumference and any three other conditions	114 (13.95%)	1.46 (0.97, 2.20)	1.53* (1.01, 2.30)

Abbreviations: CI, confidence interval; HDL, high-density lipoprotein; MetS, Metabolic syndrome.

[a]Adjusted for age and gender.

*$p < 0.05$.

1-month prevalence of near-misses in these data, and most of the single occurring conditions tended to be associated with both lower lifetime crashes and 1-month prevalence of near misses. Odds ratios tended to increase as additional numbers of conditions are evaluated, as four of the five statistically significantly increased odds ratios involved the co-occurrence of a MetS condition with three other conditions. Second, waist circumference represented a unique pattern in these analyses. This condition alone was associated with significantly lower odds ratios for near-misses, and nonsignificant reduced odds of crashes, and this apparent relationship persists when co-occurring with one or two other MetS conditions (although not reaching statistical significance). However, these associations gradually shift with increasing numbers of co-occurring conditions, and rapidly shifts and reaches statistical significance for increased odds of crashes when waist circumference co-occurs with three other conditions.

Regarding analyses for two of the MetS conditions that are not the focus of current policies (high triglycerides and low HDL cholesterol), high triglycerides alone tended to be associated with both lower lifetime crashes and near-misses, although not significant. These odds ratios increase as additional MetS conditions are added to the group. Low HDL cholesterol did not follow the same pattern, with low HDL being slightly increased odds when alone but does not tend to increase or reach statistical significance until any three other conditions are added to the group.

4 | DISCUSSION

The results from this study suggest that the number of co-occurring MetS conditions are associated with of outcomes of both 1-month prevalence of near-misses and lifetime crashes. Additionally, each of the five conditions are not weighted equally, and specific combinations of conditions may have stronger associations with near-misses and crashes than others. This suggests that further empirical study of the unique and potentially nonlinear association between MetS-specific patterns and crashes may be relevant to the creation or modification of guidance and programs related to commercial truck driver safety.

More broadly, we found that the specific combinations of MetS conditions among truck drivers may differentially relate to the odds of having lifetime reportable crashes or 1-month prevalence of near-misses. This suggests that, instead of the usual assumption of linear or monotonic relationships between discrete variables (i.e., factors) and crashes or near-misses, it is possible that the impacts of combinations of MetS conditions may interact to be more strongly associated with near misses and crashes. Previous studies that have found relationships between co-occurring MetS components and outcomes such as insulin resistance,[33] as well as co-occurring MetS syndrome with obstructive sleep apnea (OSA) and subsequent cardiovascular disease risk.[31] Alternately, it has been argued that MetS is not a distinct syndrome and is not effective for predicting health and disease outcomes—in other words, MetS is not "greater than the sum of its parts."[32]

The representation of specific MetS conditions among the statistically significant interaction effects and combinations of conditions on crash/near-miss suggest a need for a more comprehensive understanding of the prevalence of these conditions among truck drivers, the consequences for roadway safety when these conditions are present, and the seemingly complex and nonlinear relationship they have with crash/near-miss outcomes. However, there are disparities in the literature regarding the prevalence of specific MetS conditions and their connections with crash outcomes. Overall, specific MetS conditions—and especially those that correspond with federal policies, such as hypertension[18,22,43–45]—have received more attention in the empirical literature compared to combinations of those conditions and therefore are better-understood. For example, high triglycerides and low HDL cholesterol levels are less understood compared to conditions such as diabetes, which is comparatively well-elucidated.[8,18,30,43,46,47] Also, while there are a handful of studies that have focused on waist circumference specifically,[22,29] much of the existing literature reports on related measures, such as obesity (e.g., BMI measures).[8,18,30,43,46,47] Similarly, although studies that focus on blood glucose measures do exist,[22,29] many studies focus instead on the presence of diabetes mellitus.[18,48]

The associations between truck driver health and subsequent roadway crashes have been readily demonstrated in previous studies.[47,49–51] These connections are less clear for the constellation of conditions which comprise MetS and are the rationale for this manuscript. However, individual MetS conditions have been associated with crashes among truck drivers, including sleepiness[52] and sleep disorders, such as OSA.[53,54] The latter is of particular significance, as OSA is especially prevalent among truck drivers.[53–55] Thus, as the motivation for the current study, explicating the relationships between groups of MetS conditions and numbers of conditions in each group with crashes/near-misses may contribute to increasing safety of both truck drivers and the driving public.

There are several interesting insights that may correspond to the differing patterns in these results. First, although large waist circumference alone was associated with lower risks for crashes and near-misses, this pattern shifted when large waist circumference was in clusters that included high triglycerides and low HDLs. It is unclear what may explain this pattern of findings, but the answer may lie in the interplay between abnormalities in blood lipids and other co-occurring MetS conditions, especially abdominal obesity, which was measured in the current study using waist circumference. Interestingly, there does not appear to be any obvious policy connections in this study that would explain this effect, as there are fewer guidelines for medical certification around triglycerides, HDLs and waist circumference as compared to hypertension and diabetes. For example, in revisiting the results from the specific co-occurring groups, waist circumference did not seem to appear within significant additive effects that corresponded to MetS conditions not currently under the purview of medical examiner certification policies any more than it appeared among those that did not. This may suggest that waist circumference plays a different role in crash/near-miss odds than other MetS conditions, and thus requires subsequent investigation. This may be important given the role that abdominal obesity plays in MetS.[56] However, it should be noted that the value of measuring abdominal obesity (e.g., waist circumference) compared to more general measurements of obesity (e.g., BMI) has been contentious, especially for assessing cardiometabolic risk.[57,58] Thus, existing studies that utilize BMI and other metrics of obesity in the context of truck driver crash risk may shed insights into this domain as well.

Hypertension was the most common MetS condition within the significant specific MetS condition groups, opening the possibility that existing medical certification guidance may be inadequate for controlling crash risks. Currently, to be considered for medical certification, truck drivers with hypertension must have ongoing hypertension management and not exhibit any side effects of their condition that impairs their ability to operate a vehicle safely.[59] Hypertensive drivers must be recertified on a more frequent basis based on FMCSA guidance, depending on the degree of BP elevation, with cutoffs at 140–159/90–99 (annual recertification), 160–179/100–109 (recertification every 3 months), and >180/110 (disqualified from certification altogether). Because hypertension is quite common among truck drivers,[43] the findings from this study may indicate a need for additional studies to verify the current guidelines, particularly when hypertension is diagnosed in conjunction with other MetS conditions.

It is unclear if guidance for medical certification for diabetes are effective for reducing the number of crashes in these data, as there were very few drivers in the sample had diabetes. It appears that drivers who have diabetes are screened and not frequently medically certified, as compared to the general population.[20,60] However, a recent change to federal regulations may impact this: Whereas drivers with diabetes mellitus who are insulin-dependent were formerly disqualified from receiving medical certification,[59,61] it is now possible for insulin-dependent drivers receive medical certification for up to 12 months if their treating clinician completes a form stating that they have proper control over their disease and a stable insulin regimen.[62] Ultimately, policy and guidance for medical certification to reduce crashes must balance limiting the number of potential drivers and exacerbating driver recruitment and retention—therefore impacting supply chains—with the potential risk to roadway safety posed by more liberal regulations.[63,64]

4.1 | Practical implications

There are two implications of the current study for practice at the nexus of MetS prevalence and roadway safety risk among truck drivers. First, the findings of the current study indicate that MetS conditions that are not directly addressed in current DOT/FMCSA medical certification guidelines—high waist circumference, high triglycerides, and low HDL cholesterol—more commonly manifested with statistically significant associations with near misses and crashes. Therefore, future research is needed to determine whether medical examiner certification guidelines should be expanded to accommodate the full array of MetS conditions that may affect roadway safety performance among truck drivers. For example, because several MetS conditions require blood testing to be detected, blood testing mat warrant consideration for inclusion as part of the medical certification process. The FMCSA's Medical Review Board and some of the Medical Expert Panels have recommended the inclusion of blood testing in the commercial driver medical examinations for over 10 years.[65] However, to date, FMCSA has not taken action to include blood testing. Alternately, since this study has suggested that hypertension is involved in much of the apparent crash risk, this suggests that absent blood testing, additional research on the effectiveness of current hypertension guidance may be warranted, particularly for identification of those with MetS to guide requisite interventions.

Second, given the known cardiometabolic and MetS disparities among truck drivers,[8,18,20] comprehensive workplace health promotion programs could be implemented to reduce the overall prevalence of these conditions within the population and be proliferated to better meet the need within the population. Such programs could holistically address the large number of health and safety risks endemic to the truck driving occupation, including strenuous work organization characteristics, poor healthcare access, and unhealthful worksite environments.[3,18,43,66] Extant research suggests that, if grounded in evidence-based approaches, preventive interventions can be effective in improving health and safety among truck drivers.[67,68] These returns hold true for interventions that specifically target MetS and its constituent conditions.[61,67–69]

5 | LIMITATIONS

Given the noted difficulties in studying truck driver populations, especially due to the transient nature of the occupation, the current study had several strengths. Chief among these were the large sample size involving drivers from many US states and the measurement of the full array of MetS conditions. Additional strengths include the ability to estimate prevalence of MetS conditions and combinations of conditions, as well as control for potential confounders. However, despite these strengths, this study has four primary limitations. First, as a cross-sectional study, it is not possible to ascertain temporality between MetS conditions and roadway crash risk; longitudinal studies are needed for that purpose. Second, although MetS criteria specify fasting blood glucose, the current study instead used hemoglobin A1c; however, other studies have demonstrated that this is a reasonably accurate proxy for fasting blood glucose.[70,71] Third, there is the possibility of the presence of two biases: (1) recall bias, as roadway crash risk data are derived from self-report measures; and (2) selection bias, as truck drivers who participated in the study may be systematically different than those who refused to do so. Regarding the former, the possibility of recall bias for recall of crashes cannot be excluded, although the similarities between the lifetime and 1-month recall suggest this may not have been a major source of error. Regarding the latter, as noted elsewhere, this study's demographics mirror those of the general truck driving population and other studies,[8,18,20] suggesting there is minimal selection bias. Also, the similarities between the current findings and known prevalence of MetS conditions as described above suggest that these biases may not be a significant concern. Finally, there also data and statistical limitations. While we addressed confounding from many potential confounders, there may be additional residual confounding. For example, we were unable to adjust for the presence of OSA as a confounder, and yet this may play an important role in explaining the associations between MetS conditions and roadway safety outcomes observed in this study. Similarly, there may be other variables which are confounders in these relationships which are not accounted for because we did not collect data on them. Additionally, there are many comparisons for individual and combinations of factors for MetS and the crash or near-miss outcomes. Our overall hypothesis is that individual MetS conditions are related to crashes or near-misses, however we also wanted to investigate specific combinations of conditions. As this is the first study investigating specific individual combinations of MetS conditions related to crashes among truck drivers, some analyses can be considered exploratory in nature. Therefore, some of the statistically significant findings may be due to chance alone and not represent a true relationship. Further investigation regarding the proximal and remote causes for these reported crashes may illuminate additional relationships, such as investigating whether drivers who attributed their crash to drowsiness or inattention more likely to have significant relationships with MetS conditions. This study is underpowered to address these types of questions, and a separate study would therefore be needed.

6 | CONCLUSION

MetS conditions are prevalent among truck drivers in this study. A nuanced understanding of how nonadditive patterns of MetS conditions may be related to crashes is needed for effective policymaking and prevention programming. This study demonstrates that the specific combinations of MetS conditions among truck drivers may have a stronger association with lifetime prevalence of crashes and 1-month prevalence of near-misses as compared to other combinations of MetS conditions. There is also some evidence that there may be a dose-response relationship between the number of co-occurring MetS conditions and crashes or near-misses. Lastly, additional research on waist circumference, high triglycerides, and low HDLs may improve crash outcomes and help improve medical certification guidance. Altogether, the current study suggests that a further exploration of the unique and potentially nonlinear relationship between MetS-specific conditions and both near-misses and crashes may be warranted. These relationships may be relevant to the complex constellation of MetS conditions and crash risk, and current medical certification and guidance related may change based on additional research.

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CONFLICTS OF INTEREST

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DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

AUTHOR CONTRIBUTIONS

Michael K. Lemke generated the research questions and hypotheses, contributed to the analytical plan, interpreted the analyzed data, led the drafting of the manuscript, revised the manuscript critically for important intellectual content, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work. Matthew S. Thiese contributed to generating the research questions and hypotheses, led the analytical plan, interpreted the analyzed data, contributed to the drafting of the manuscript, revised the manuscript critically for important intellectual content, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work. Adam Hege contributed to generating the research questions and hypotheses, contributed to interpreting the analyzed data, revised the manuscript critically for important intellectual content, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work. Uchenna C. Ogbonnaya led the data analysis, revised the manuscript critically for important intellectual content, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work. Kurt T. Hegmann revised the manuscript critically for important intellectual content, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work.

ETHICS APPROVAL AND INFORMED CONSENT

This work was performed at the University of Utah and the University of Wisconsin—Milwaukee. It was approved by the Institutional Review Boards at the University of Utah (IRB #: 22252) and the University of Wisconsin—Milwaukee (IRB #: 07.02.297). Informed consent was obtained from all participating commercial truck drivers.

ORCID

Michael K. Lemke http://orcid.org/0000-0002-5921-1473
Matthew S. Thiese http://orcid.org/0000-0003-4505-2907
Uchenna C. Ogbonnaya http://orcid.org/0000-0002-2189-3544

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