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Obesity Indices Are Predictive of Elevated C-Reactive Protein in Long-Haul Truck Drivers

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Background *Obesity rates in long-haul truck drivers have been shown to be significantly higher than the general population. We hypothesized that commercial drivers with the highest levels of general obesity and abdominal adiposity would have higher concentrations of high sensitivity C-reactive protein (CRP), a marker of inflammation.*
Methods *Survey and anthropometric data were collected from 262 commercial drivers. Weight, circumference measures, and blood analysis for CRP (N = 115) were conducted and compared to National Health and Nutrition Examination Survey (NHANES) data. CRP values were non-normally distributed and logarithmically transformed for statistical analyses.*
Results *BMI, waist circumference, sagittal abdominal diameter, and CRP were significantly higher than in the general population. Anthropometric indices that included height (BMI, waist-to-height ratio, and sagittal diameter-to-height ratio), were most predictive of CRP values.*
Conclusions *Abdominal obesity is prevalent in commercial vehicle drivers and is an important indicator of the presence of inflammation in this population.* Am. J. Ind. Med. 59:665–675, 2016. © 2016 Wiley Periodicals, Inc.

KEY WORDS: commercial vehicle drivers; obesity; abdominal obesity; cardiovascular disease; inflammation; sagittal diameter; high sensitivity C-reactive protein

INTRODUCTION

In the past decade (2000–2010), the number of deaths attributed to cardiovascular disease (CVD) declined 16.7%, but CVD remained the leading cause of death and accounted for 31.9% of all deaths in the United States [Go et al., 2013]. Commercial vehicle drivers are exposed to a wide array of unique occupationally induced health hazards that have been shown to negatively impact health, quality of life and ultimately, longevity [Apostolopoulos et al., 2010]. Particularly for long-haul truck drivers, lifestyle and occupational factors such as imposed sedentariness, limited availability of healthy dietary options, sleep deprivation, irregular schedules, long work hours, and postural fatigue collectively increase job related strain and stress [Robinson and Burnett, 2005; Apostolopoulos et al., 2010]. Adverse work characteristics and job strain have been related to CVD [Kivimäki et al., 2012; Steptoe and Kivimäki, 2012], and while health-related behaviors are paramount in CVD risk for all individuals, chronic job strain in long-haul truck drivers may affect their physiological stress response [Schnorpfeil et al., 2003], altering the hormonal milieu and promoting a pro-inflammatory environment.

Low-grade systemic inflammation has been linked to several diseases and long-term adverse outcomes. Chronic

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low-grade inflammation has consistently been postulated as the link between obesity, type 2 diabetes and cardiovascular disease [Esser et al., 2014; McNelis and Olefsky, 2014; Zhou and Pan, 2015]. At a cellular level, the inflammatory process associated with obesity is considered "sterile," since it is produced in response to metabolic rather than infectious stimuli and remains at the subacute level, chronically sustained without an adequate resolution [McNelis and Olefsky, 2014]. Although the specific precipitating events are not yet fully elucidated, studies have shown that exposure to adipocyte hypertrophy, the resulting hypoxia, and cellular apoptosis initiate a shift in the adipose tissue macrophage phenotype from anti-inflammatory (M2) to proinflammatory (M1) [McNelis and Olefsky, 2014]. This shift favors the production of cytokines such as Interleukin (IL)-1 beta (IL-1β), IL-6, and Tumor necrosis factor—alpha (TNF-α) that are known to perpetuate systemic low-grade inflammation [Esser et al., 2014]. IL-6 is one of the most important factors involved in induction of synthesis of CRP, an acute phase reactant. Thus, chronic elevation of IL-6 results in elevated CRP levels, making it an excellent marker for inflammation [Camelo et al., 2014]. Normal concentrations of CRP in humans are considered to be <10 mg/L, with levels >10 mg/L indicative of a source of infection or inflammation [Aronson et al., 2004; Seyeda et al., 2014]. Elevated CRP has been observed in individuals with obesity and metabolic syndrome [Aronson et al., 2004] and several epidemiologic studies have shown that elevations in CRP are related to CVD [Ridker et al., 1997; Ridker and Haughie, 1998; Rost et al., 2001], even predicting future mortality from cardiovascular events in apparently healthy adults [Ridker et al., 2002; Pai et al., 2004]. The in vivo half-life of this peptide is 19 hr [Foglar and Lindsey, 1998], which suggests that even transient elevations will be observable for several days and may reflect altered risk for CVD.

Smoking is one of the main causes of preventable illnesses in the world [Rom et al., 2015a], and is generally thought to be pro-inflammatory, raising systemic levels of cytokines, and other inflammatory markers [Rom et al., 2013]. Smoking is also known to alter metabolism such that smokers have lower BMI and lower lean mass but higher central adiposity [Rom et al., 2015b]. Several studies have shown elevated CRP in smokers in the general population [Shiels et al., 2014; Loprinzi and Walker, 2015; Rom et al., 2015a], but the relationship appears to be strongest in long-term habitual smokers with high pack-year histories [Loprinzi and Walker, 2015; Rom et al., 2015b]. One study showed that CRP is elevated at a very low threshold (1–10 cigarettes per day), suggesting that even a low degree of exposure to cigarette smoke may alter the systemic levels of inflammatory markers [Shiels et al., 2014]. Since smoking prevalence is significantly higher in long-haul truck drivers compared to the general adult working population [Sieber et al., 2014; Birdsey et al., 2015], smoking may play an important role in CRP levels in this particular sub-group of the population.

Obesity rates in long-haul truck drivers or other categories of commercial drivers have consistently been shown to be significantly higher than the rates observed in the general population. In several recent studies, only 20.8% of truck drivers were found to have a healthy weight [Sangaleti et al., 2014], and greater than 60% were either overweight or obese [Saberi et al., 2011; Rosso et al., 2015] . Some of these studies additionally assessed waist circumference and found similar results, with 58–68% of drivers having a waist circumference greater than 102 cm [Saberi et al., 2011; Sangaleti et al., 2014]. While waist circumference is widely used for assessing abdominal obesity, some studies have shown that sagittal diameter is correlated more strongly with cardiovascular risk than either waist circumference or BMI [Ehrlich and Smith, 2011; Vidigal et al., 2013] and should be investigated as an alternative for waist circumference in assessing risk associated with centralized obesity.

Sleep is generally considered restorative and reduced sleep duration has been associated with increased cardiovascular morbidity [Hoevenaar-Blom et al., 2014], while sleep restriction has been shown to elevate CRP [Meier-Ewert et al., 2004]. In a study simulating accumulated sleep loss across 5 work days, CRP concentrations increased 145% over baseline and continued to rise to 231% over baseline after two nights of recovery sleep [van Leeuwen et al., 2009]. In studies documenting sleep duration in long-haul truck drivers, sleep duration averaged 3.8–5.2 hr per day [Apostolopoulos et al., 2010], similar to the 4 hr per night allowed in the sleep loss simulation. Given this consistent sleep deprivation in truck drivers, it is expected that CRP levels would be higher than the general population.

Commercial drivers have a high prevalence of risk factors for CVD, including sedentary lifestyle, poor eating habits, obesity, high blood pressure, smoking, poor sleep habits, and chronic stress [Robinson and Burnett, 2005; Apostolopoulos et al., 2010; Sangaleti et al., 2014] and trucking is classified as one of the highest-risk occupations in the United States [Apostolopoulos et al., 2010]. However, lack of empirical data investigating likely mechanisms for increased risk of cardiovascular disease in long-haul truck drivers may inhibit the ability of researchers, governments and businesses to design and implement optimal intervention strategies aimed at reducing CVD in this particular occupational segment. The purpose of the current study was to investigate acute phase inflammatory levels, as assessed by CRP concentrations, in long-haul truck drivers. We hypothesized that long-haul truck drivers with the highest levels of general obesity and abdominal adiposity would have higher concentrations of CRP.

MATERIALS AND METHODS

Study Procedures

Approval of all procedures was obtained from the Institutional Review Board of the University of North Carolina Greensboro. A non-experimental descriptive, cross-sectional design was employed in this pilot study to collect survey and anthropometric data from 262 long-haul truckers at a major truck stop located in central North Carolina over a 6-month time frame. Using intercept techniques, researchers approached drivers and asked several screening questions to determine whether they would be eligible for inclusion in this study. We estimate that approximately 50% of the drivers who were approached met the inclusion criteria and agreed to participate in the study. To be included drivers were required to be long-haul, meaning that they spend consecutive nights away from home, and they had to be spending the night at the truck stop where data collection took place, so that fasting blood samples could be taken the following morning before they got back on the road. With Type I error set at 0.05 and power at 90%, our likely sample size was anticipated to enable us to conduct appropriate statistical analyses, including examining significant differences among predictor and outcome variables. Using intercept techniques, researchers approached drivers between 1800 and 2200 hr and asked screening questions to determine eligibility for inclusion in to the study. Those drivers who were long-haul truckers, who were planning to spend the night at the truck stop and leaving between 0400 and 0800 hr the following morning were enrolled in the study. All aspects of study participation were explained and drivers interested in participating were asked to read and sign an informed consent. Drivers were allowed to use aliases to assure greater confidentiality and/or anonymity. Using a privacy screen in a low traffic area of the truck stop, the weight of each truck driver was recorded in kg to the nearest 0.1 kg with shoes off using an Elite XXL scale. Height was measured to the nearest cm using a portable stadiometer (Seca, Chino, CA). BMI (kg/m^2) was calculated and rounded to one decimal.

Circumference measures were assessed using a Gulick II tape measure with tension indicator and values recorded to a single decimal. Each measure was taken two times and averaged. Waist and hip circumference were assessed as outlined by the standardization reference manual [Callaway et al., 1988]. Briefly, waist circumference was assessed at the natural waist (smallest circumference), while hip circumference was assessed with clothes on at the level of the maximum extension of the buttocks. Sagittal diameter was measured to the nearest tenth of a centimeter at the level of the umbilicus [approximating the L4-L5 level of the spine] using a Rosscraft Campbell caliper #20 (Vancouver, BC). When the level of the umbilicus was altered by the presence of abdominal folds, the tops of the iliac crest were palpated and the sagittal measure was taken at this level. Subjects were asked to breathe normally for several breaths before a value was taken.

Sample Characteristics

Data for demographic and lifestyle variables that could potentially be related to CRP in long-haul truck drivers were collected. We developed the Trucker Sleep Disorders Survey from insights gleaned from other key instruments (i.e., Basic Nordic Sleep Questionnaire, Berlin Questionnaire), relevant sleep literature, and our previous work with truck drivers [Partinen and Gislason, 1995; Netzer et al., 1999; Philip and Åkerstedt, 2006; Ursin et al., 2009]. The Trucker Sleep Disorders Survey was organized into five sections, which assessed: (i) trucking work environment, including work hours, workplace characteristics, workload, job strain, and schedules; (ii) individual work- and health-related factors, including sociodemographics, psychosocial factors, dietary and physical activity patterns, substance use patterns, sleep patterns, and health history; (iii) self-reported sleep disturbances and sleep disorders; (iv) self-reported health consequences resulting from sleep disorders; and (v) self-reported comorbidities associated with chronic sleep disorders. Key variables included smoking status, average hours of nightly sleep (including both working and non-working nights), average daily work hours, diabetic status, anti-inflammatory medication use, and ethnic identification. Participants were asked if they smoked cigarettes, and if so, the number of packs per day. However, given the large proportion of non-smokers and the low variability in reported volume among users, smoking status was dichotomized into smoker/non-smoker and this was used in all analyses. Information on smoking history was not collected since current smoking is most influential for inflammatory status [Rom et al., 2015a] and over time, smoking cessation results in inflammatory markers reverting back to levels observed in never smokers [Shiels et al., 2014]. Ethnic identification was coded as White/other than White. Diabetes diagnosis information and anti-inflammatory usage information were provided via self-report, and dichotomized into diabetic/non-diabetic and user/non-user for anti-inflammatory medication (i.e., ibuprofen, aspirin, non-steroidal anti-inflammatory drugs, etc.).

Blood Draws

After completing all questionnaires and measurements, the drivers were given an appointment card for the following morning and instructed to fast for at least 8 hr or the remainder of the evening, whichever was longer. Of the 262 truck drivers that completed questionnaires and anthropometric measures,

only 115 truck drivers returned for blood draws the following morning and were provided with a snack immediately after the blood draw was completed. Following Occupational and Safety Health Administration (OSHA) procedures [United States Department of Labor, 2003] blood was taken from the antecubital space in either arm using aseptic technique by a trained research technician. Blood was collected in red top tubes and allowed to clot at room temperature for 15–20 min. Using a portable centrifuge (LW Scientific E8 Portafuge, Atlanta, GA), blood samples were spun at 3,000 rpm for 15 min and then transported on ice to the laboratory. Serum was divided into aliquots and stored at −80°C for future analysis.

Blood Analysis

High sensitivity C-reactive protein (CRP) values were assessed using ELISA (Calbiotech, Spring Valley, CA). The minimum detectable dose of the assay is 0.005 μg/ml and inter-assay variance was 9%.

Anthropometric Indices

Given the extremely high prevalence of overweight and obesity in truck drivers, we were interested in identifying simple anthropometric measures such as waist circumference or sagittal diameter that could be utilized in this group to screen drivers with the highest risk for long term health complications. The most widely used anthropometric index is BMI, but as part of the current study, we calculated three additional anthropometric indices. The waist-to-height ratio, was calculated as the waist circumference (cm) divided by the height (cm) and the sagittal diameter-to-height ratio, was calculated as the sagittal abdominal diameter (cm) divided by the height (m). The conicity index (COI) [Vidigal et al., 2013] was calculated as follows;

$$\mathrm{COI} = \frac{\mathrm{WC\ (m)}}{0.109\sqrt{\mathrm{Body\ weight\ (kg)} \div \mathrm{Height\ (m)}}}$$

NHANES Data

Since minimal data are available on the normative values for cardiometabolic risk factors in commercial drivers, we wanted to compare the values obtained in the drivers to the U.S. general population and we felt that the National Health and Nutrition Examination Survey (NHANES) provided the best comparison. Unfortunately, while the 2011–2012 NHANES data provided sagittal diameter values, these data did not include CRP. Therefore, we went to the most recent NHANES data that included CRP values (2009–2010). Thus, total datasets from two different NHANES groups (2009–2010 and 2011–2012), were filtered to include only males above 18 years of age. There were no changes to inclusion made for BMI, waist circumference, or sagittal diameter. Only NHANES participants who gave blood samples were included from the NHANES 2009 to 2010 group for comparison of CRP. The final number included in each sample was n = 3106 from NHANES 2009 to 2010 and n = 2594 from NHANES 2011 to 2012.

Statistical Analysis

Between-groups comparisons of long-haul truck drivers who did and did not complete blood draws were carried out using one-way analysis of variance (ANOVA), testing for differences in traditional (BMI, waist circumference, hip circumference, and sagittal diameter) and non-traditional anthropometrics (waist-to-height ratio, sagittal diameter-to-height ratio, and conicity index), resting HR, and resting BP. Single-sample *t*-tests were then used to test for differences in traditional anthropometrics between the entire sample of long-haul truck drivers and mean population values that were estimated using data from the NHANES 2011 to 2012 cohort. A second single-sample *t*-test was carried out to test whether the drivers who completed blood draws exhibited differences in CRP values from the mean population values estimated using the NHANES 2009–2010 cohort. NHANES sample weighting was taken into account when estimating all population values. Bonferroni corrections were applied to the threshold to achieve statistical significance within each set of comparisons.

The distribution of CRP values was expectedly non-normal; therefore, a logarithmic transformation was applied, and Q-Q plots examined to ensure the transformed distribution met normality assumptions [Ghasemi and Zahediasl, 2012]. All anthropometric variables were standardized, such that unit change reflected increases or decreases in standard deviations. Correlational analyses were used to test for bivariate relationships among individual anthropometric variables and log-adjusted CRP values, and between potential covariates and log-adjusted CRP. Pearson product moment correlations were calculated when both variables were continuous (i.e., sleep, work hours), and point biserial correlations calculated when one variable was dichotomous (i.e., smoking status, ethnic identification, anti-inflammatory medication use, and diabetic status). A series of 3-step hierarchical linear regression analyses was then conducted to determine the extent to which each anthropometric variable predicted log-adjusted CRP values: a separate hierarchical regression model was estimated for each anthropometric measure. Potential covariates were entered into the regression models at step 1. Only those covariates for which the bivariate correlation with log-adjusted CRP achieved at least marginal significance

($P \leq 0.10$) were included in the models; thus, the included covariates and results for step 1 were identical for each model. The anthropometric variable was entered at step 2. Finally, the square of the anthropometric value was entered at step 3 to test for quadratic associations with log-adjusted CRP.

RESULTS

While many long-haul truck drivers agreed to participate in the questionnaire and anthropometric portion of the study, slightly fewer than half the truckers (N = 115; 43.9%), returned the following morning for a fasted blood draw (Table I). Three subjects from the non-blood draw group had missing anthropometric variables and were excluded from the analysis. When comparing anthropometrics, resting heart rate, or resting blood pressure (BP), the group that returned for a blood draw was not significantly different on any variable compared to 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) and had slightly higher resting diastolic BP (82.8 vs. 80.6 mmHg), but neither of these differences was significant ($P = 0.113$ and $P = 0.119$, respectively). The drivers who returned for blood draws were slightly less likely to be smokers than the drivers who did not return for blood draws (35.7% vs. 43.8%, respectively), but this difference was not significant ($P = 0.204$). While the average BMI for both groups was 33.4, there were 17 drivers (11.8%) in the normal BMI range (18–25) in the group that did not have morning blood draws and only 10 drivers (8.7%) with a BMI were in the normal range among the drivers with blood draws. Thus, 88.2% of the drivers who did not return for morning blood draws were overweight or obese by BMI criteria, compared to 91.3% of the drivers who had blood draws; both values that are consistently higher than the general population. To further compare our long-haul truck driver population to the general population, we looked at NHANES (2011–2012) anthropometric data for individuals with similar demographics (see methods for specific details), and found that long-haul truck drivers had consistently higher BMI (33.4 ± 7.2 vs. 28.3 ± 5.8, $P < 0.001$), waist circumference (114.8 ± 16.6 vs. 100.5 ± 9.1, $P < 0.001$) and sagittal diameter (32.3 ± 5.8 vs. 23.1 ± 4.3, $P < 0.001$), compared to the individuals in this NHANES cohort.

When considering the long-haul truck driver CRP values, only 16 drivers or 13.9% had CRP values <1 mg/L, while 23 drivers (20%) had values in the 1–3 mg/L range. Interestingly, 43 long-haul truck drivers (37.4%) had CRP values between 3 and 10 mg/L and another 33 (28.7%) had values between 10 and 100 mg/L. Thus, 66.1 % of the drivers had elevated CRP concentrations (>3 mg/L). Figure 1 demonstrates mean CRP concentrations and mean sagittal diameter values based on standard BMI categories.

All bivariate correlations with log-adjusted CRP are listed in Table II. Pearson product-moment correlational analysis revealed that all anthropometric variables were positively associated with log-adjusted CRP (r values ranged from 0.184 to 0.316), and statistically significant (P values ranged from 0.001 to 0.048). Alternatively, correlations between other sample characteristics and log-adjusted CRP were non-significant, with only smoking status achieving marginal significance ($P = 0.055$). Therefore, smoking status was the only covariate meeting the threshold for inclusion and was entered into each regression at step 1. At step 1, the

TABLE I. Anthropometric Characteristics and Resting Heart Rate and Blood Pressure for Long-Haul Truck Drivers With and Without a Blood Draw

	No blood draw (N = 144)	Blood draw (N = 115)	*P*-value
Age	45.7 (11.1)	47.8 (9.7)	0.113
Height (cm)	180.1 (7.5)	179.1 (7.8)	0.305
Weight (kg)	108.7 (26.1)	107.3 (22.3)	0.658
Body mass index (kg/m^2)	33.4 (7.65)	33.4 (6.70)	0.972
Resting heart rate (bpm)	77.5 (13.1)	77.9 (12.2)	0.778
Systolic blood pressure (mm Hg)	128.5 (18.2)	129.3 (19.3)	0.725
Diastolic blood pressure (mm Hg)	80.6 (11.2)	82.8 (11.4)	0.119
Waist circumference (cm)	114.6 (17.0)	115.0 (16.1)	0.831
Sagittal abdominal diameter (cm)	32.20 (5.83)	32.41 (5.68)	0.771
Hip circumference (cm)	115.6 (13.9)	114.6 (13.8)	0.575
Waist-to-height ratio	0.637 (0.094)	0.643 (0.091)	0.599
Conicity index	1.358 (0.083)	1.366 (0.083)	0.469
Sagittal diameter-to-height ratio	17.89 (3.24)	18.11 (3.20)	0.589

Values are mean (SD).

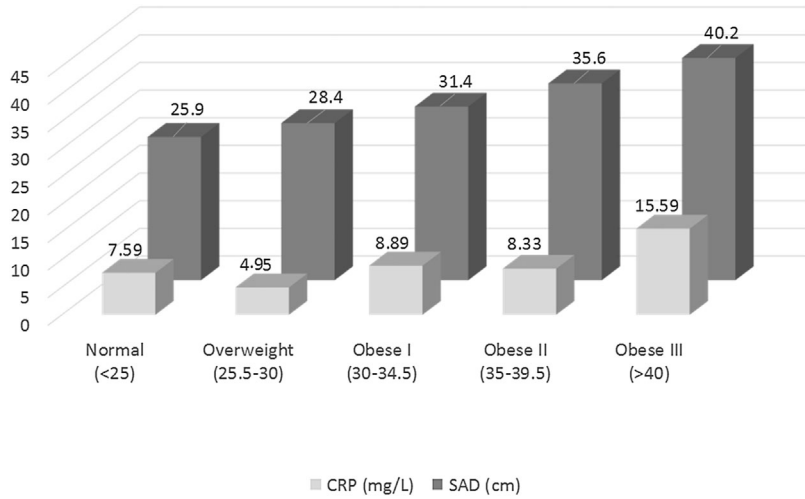

FIGURE 1. Mean fasting C-reactive protein (CRP) level assessed in serum (mg/L) and the sagittal abdominal diameter (SAD) (cm) in long-haul truck drivers stratified by BMI category.

model was marginally significant ($P = 0.055$), with smoking status accounting for approximately 2.4% of the variability in log-adjusted CRP. The addition of an anthropometric variable at step 2 yielded statistically significant models ($P \leq 0.015$), in which both smoking status ($P \leq 0.034$) and the anthropometric ($P \leq 0.03$) were significantly and positively predictive of log-adjusted CRP. Quadratic terms added at step 3 all failed to reach significance as individual predictors and resulted in either no change in, or decrements to, the overall models. A summary of regression results at step 2 are provided in Table III, and tests of quadratic associations failed to reach significance or improve any of the models at step 3.

TABLE II. Bivariate Correlations With Log-Adjusted C-Reactive Protein

	Corr.	*P*-value	N
Covariate			
Smoking*	0.180	0.055	115
Sleep	−0.047	0.620	115
White*	−0.018	0.845	115
Work hours	0.029	0.759	115
Diabetes*	−0.138	0.145	113
Anti-inflammatories*	−0.056	0.551	115
Obesity measure			
Body mass index	0.303	0.001	115
Sagittal diameter	0.283	0.002	115
Waist circumference (cm)	0.269	0.004	115
Hip circumference (cm)	0.235	0.011	115
Weight-to-height ratio	0.274	0.003	115
Waist-to-height ratio	0.310	0.001	115
Conicity index	0.184	0.048	115
Sagittal diameter-to-height ratio	0.316	0.001	115

*Point biserial correlation.

DISCUSSION

As a next step to understanding the possible pathways involved in the cardiovascular risk stratification of commercial drivers, the objective of the current study was to assess the inflammatory status of long-haul truck drivers as it relates to obesity. To our knowledge, this is the first study to assess inflammatory status in long-haul truck drivers and the primary findings from our study can be summarized as follows; (i) significant elevations (above 3 mg/L) in high sensitivity-CRP (mean 8.825 mg/L) were found in approximately two-thirds of all long-haul truck drivers; (ii) BMI, waist circumference and sagittal diameter were significantly higher than the values reported for the general population; (iii) among the anthropometric variables and indices investigated, variables that included height (BMI, waist-to-height ratio, and sagittal diameter-to-height ratio) were better predictors of adjusted CRP values than other anthropometric variables; and (iv) 10% of the variability in the CRP values was accounted for by the anthropometric indices (either BMI, waist-to-height ratio or sagittal diameter-to-height ratio).

Long-haul truck drivers represent a unique cohort, both within the occupational segment of commercial drivers and within the general population. First, these drivers are uniquely dependent on their worksites: Unlike other occupations, long-haul truck drivers may not return home for weeks at a time, spending not only their working hours but the majority of their non-working hours in worksite environments [Apostolopoulos et al., 2014]. These worksites offer very little health-supportive options, especially in

TABLE III. Predictive Capacity of Anthropometric Measures for Log-Adjusted C-Reactive Protein

Model	Anthropometric	β	$CI_{95\%}$	*P*-value	R^2adj.	R^2adj.Δ
1.	Body mass index	0.198	0.097–0.299	<0.001	0.131	0.107
	Smoking	0.284	0.073–0.494	0.009		
2.	Sagittal diameter	0.182	0.080–0.284	0.001	0.114	0.090
	Smoking	0.270	0.058–0.482	0.013		
3.	Waist circumference (cm)	0.179	0.076–0.281	0.001	0.110	0.086
	Smoking	0.281	0.067–0.494	0.010		
4.	Hip circumference (cm)	0.158	0.054–0.261	0.003	0.089	0.065
	Smoking	0.271	0.055–0.486	0.014		
5.	Weight-to-height ratio	0.185	0.083–0.288	0.001	0.116	0.092
	Smoking	0.289	0.076–0.503	0.008		
6.	Waist-to-height ratio	0.197	0.096–0.298	<0.001	0.131	0.107
	Smoking	0.272	0.063–0.482	0.011		
7.	Conicity index	0.116	0.011–0.220	0.030	0.056	0.032
	Smoking	0.235	0.019–0.452	0.034		
8.	Sagittal diameter-to-height ratio	0.196	0.096–0.297	<0.001	0.131	0.107
	Smoking	0.262	0.053–0.471	0.014		

*$CI_{95\%}$, 95% confidence interval; R^2adj., Adjusted R^2: which reflects the total variance (adjusted for sample size) in log-adjusted CRP accounted for by the model at step 2 of each regression analysis. R^2adj.Δ, Change in adjusted R^2: which reflects the variance in log-adjusted CRP accounted for by the anthropometric variable once the contribution of smoking status has been subtracted out.

dietary options and opportunities for physical activity [Apostolopoulos et al., 2011a, 2012]. Further, due to productivity pressures (especially mile-based compensation), drivers engage in health-compromising behavior such as excessively speeding, working when fatigued, and circumventing HOS rules [Centers for Disease Control and Prevention, 2007; Krueger et al., 2007; Apostolopoulos et al., 2010, 2011b; Shattell et al., 2010]. Despite regulatory limits on driving hours in the U.S., long-haul drivers typically work long and irregular hours [Puhkala et al., 2015], resulting in disrupted circadian rhythms, inadequate sleep, sleep disorders, and excessive daytime sleepiness, which can have significant negative impacts on long-haul truckers' mental and physical health [Krueger et al., 2007; Apostolopoulos et al., 2010].

When circadian misalignment occurs, energy metabolism is altered and shift-type work has been associated with chronic desynchronization between internal and external timing [Szosland, 2010]. This sets up a hormonal milieu that may alter appetite-related input to the hypothalamus, resulting in altered energy balance [Marqueze et al., 2012], and; ultimately, body weight and other cardiovascular risk factors will be affected. Making matters worse, many long-haul drivers lack basic health insurance coverage, and work hours make it difficult to seek medical care [Apostolopoulos et al., 2013]. Despite these dramatic health disparities, efforts to mitigate the multiple deleterious impacts on driver health endemic to the long-haul trucking profession, particularly those associated with working conditions of drivers, have been sporadic and piecemeal [Lemke and Apostolopoulos, 2015].

Obesity rates have become endemic to almost all parts of the world, but data from previous studies [Moreno et al., 2006; Martin et al., 2009; Saberi et al., 2011; Apostolopoulos et al., 2013; Sangaleti et al., 2014; Sieber et al., 2014; Rosso et al., 2015] and the current investigation suggest that long-haul truck drivers are significantly more obese than the general population. Abdominal obesity was highly prevalent in our group of drivers. Utilizing the standardized waist circumference cutoff for increased risk of heart disease of 102 cm [American College of Sports Medicine, 2014], 79.2% of our cohort met the criteria for increased risk. In a recent study of sagittal diameter as a screening tool for cardiometabolic risk, the authors suggested a cut-off of 22 cm for the highest risk quintile for men [Riserus et al., 2010]. In the current cohort of long-haul truck drivers, the mean value for sagittal diameter in every BMI group (including normal BMI), was above this 22 cm cut-off (Fig. 1). While individuals with sagittal diameters below 22 cm were present in our cohort, almost all of our truck drivers would have met the criteria for "metabolically obese" as outlined by Riserus and associates [Riserus et al., 2010]. Even when the more liberal sagittal diameter cutoff of 25 cm, suggested by Pouliot and associates [Pouliot et al., 1994] to be indicative of increased accumulation of visceral adipose tissue, was used as the cut point, 90% of our cohort met the criteria for increased risk.

When considering anthropometric measures, both waist circumference and sagittal diameter are relatively simple measures that require minimal equipment and training, a single measurement and no calculations, but sagittal diameter has consistently been shown to be more indicative of markers of glucose intolerance [Riserus et al., 2010] and CVD risk [Riserus et al., 2010; de Souza and de Oliveira, 2013], especially in men [Carlsson et al., 2013]. Given the work constraints placed on long-haul truck drivers, brevity of assessment may be a key factor for maximizing participation in research and using a single anthropometric measure that maximizes health risk assessment would be optimal. We would recommend the use of sagittal diameter in future studies that assess health risk in commercial vehicle drivers, especially when insulin sensitivity or glucose tolerance and the associated CVD risk are of primary interest.

In the current study of long-haul truck drivers, CRP values did not increase in a linear fashion across BMI categories. Individuals with Class I and II obesity had similar CRP values despite the fact that sagittal diameter values were steadily increasing. Both obesity (BMI) [Aronson et al., 2004] and sagittal diameter (abdominal obesity) [Vidigal et al., 2013] have been shown to be associated with elevated CRP, but our data suggest that substantially increasing both results in the most sizeable elevations in CRP. It is also notable that in our cohort, the CRP values were higher in the normal weight compared to the overweight category. The individuals in the normal weight category had a higher prevalence of smoking (50.0%), than the overweight individuals (35.7%), which likely explains this difference. BMI, waist-to-height ratio and sagittal diameter-to-height ratio each explained the same amount of variance ($\sim$10%) in the current study, but as in another study [Aronson et al., 2004] each still accounted for only a small amount of the overall variance in the CRP values. BMI, waist-to-height ratio and sagittal diameter-to-height ratio have the disadvantage that two measurements need be taken and ratios calculated, which is an additional source of potential error These anthropometric indices accounted for only slightly more of the variance in CRP than sagittal diameter by itself (9%).

The mean CRP concentration for our cohort of drivers (8.825 ± 9.962 mg/L), was considerably higher than the mean CRP concentrations reported for a similar cohort from the 2009 to 2010 NHANES (3.158 ± 6.990 mg/L, $P < 0.001$) and consistently higher than most studies that have assessed CRP in various populations [Aronson et al., 2004; Vidigal et al., 2013; Camelo et al., 2014; Tully et al., 2015]. Similar to Aronson et al., [2004], levels of CRP suggesting a source of infection or inflammation ($>$10 mg/L), were most common in individuals with the highest levels of obesity. Although some epidemiological studies have advocated the removal of data points $>$10 mg/L, since they reflect acute inflammatory conditions, the number of values above this range in the current study suggests that higher CRP values may be very common in this population. Whether or not these values are tied to specific active inflammatory conditions cannot be answered by our study and perhaps is somewhat irrelevant. When only 16 individuals out of 115 have a value $<$1 mg/L, the overarching conclusion should be that this cohort of individuals represents a unique and highly risky profile of metabolic factors known to be tied to CVD.

Since there are numerous factors that influence inflammatory status of individuals, we investigated the role of smoking status, sleep hours, ethnicity, work hours, diabetes status, and concomitant use of anti-inflammatory medication on CRP values. In our analysis, only smoking status trended toward a significant correlation with CRP. While other studies have found smoking status to influence CRP [Loprinzi, 2015; Loprinzi and Walker, 2015; Rom et al., 2015a] or other inflammatory markers [Shiels et al., 2014], we did not find this to be the case in our cohort. Many individuals provided incomplete information related to smoking and we did not collect information on past smoking history, both of which may have influenced our ability to observe this relationship. However, the strongest negative effects of smoking on CRP values appear to occur in current heavy smokers [Loprinzi and Walker, 2015; Rom et al., 2015a] and our population contained few current heavy smokers (only 7.3% of truckers smoked more than one pack per day).

Another important consideration for CRP values in long-haul truck drivers is related to second hand smoke exposure and environmental exposure to particulate matter. Compared to the general population, long-haul truck drivers have very high smoking rates ($\sim$50%) [Sieber et al., 2014; Birdsey et al., 2015] and even short term second hand smoke exposure has been shown to elevate CRP [Zhang et al., 2013], such that even non-smoking long-haul truck drivers may have elevated CRP.

Although the studies relating air pollution to CRP are very limited [Rückerl et al., 2014; Viehmann et al., 2015], preliminary evidence suggests that exposure to particulate matter may result in considerable elevations in CRP. Cumulatively, these studies may help explain the relatively high CRP levels that were very common in our cohort. Lastly, we assessed only CRP and while it is a very good measure of systemic inflammation, assessing other inflammatory biomarkers (either pro- or anti-inflammatory) may provide a more accurate picture of the inflammatory milieu in long-haul truck drivers.

One major limitation of the current study is that we employed a sampling technique that involved blood draws in the actual trucking environment (truck stop). While this minimized barriers to participation and likely increased the willingness of truck drivers to be involved in the study, it often did not allow the drivers to fast for at least 8 hr prior to a blood draw. Most truck drivers in our cohort fasted

approximately 6 hr (coinciding with their total sleep time for the night). While we recognize that this may slightly alter our blood values, this shorter fasting time is representative of the usual schedule maintained by these individuals.

Another limitation of the current study is the relatively small sample size of only 262 long-haul truck drivers and only 115 with fasted blood samples. While a larger sample size may have increased our likelihood of finding certain previously reported relationships, the congruency of our findings with other studies involving commercial vehicle drivers indicates that our sample was highly representative of the population. The potential for selection bias is an important consideration when interpreting our results. Drivers refusing to participate may have done so for myriad reasons. For example, given the increasingly-stringent medical requirements that drivers must meet to operate a commercial motor vehicle, drivers may have been concerned that results from the current study may have resulted in disqualification or termination. Drivers may have also 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.

In conclusion, the current study assessing the levels of CRP as a marker of inflammation in relation to obesity in long-haul truck drivers has clearly shown that abdominal obesity is not only highly prevalent in commercial vehicle drivers, but the CRP values are significantly elevated in this group. Future studies that include larger cohorts are necessary to further investigate the potential negative health impact of significant elevations of CRP in long-haul truck drivers.

AUTHORS' CONTRIBUTIONS

All of the above authors made substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data for the work; drafted the work or revised it critically for important intellectual content; gave final approval of the version to be published; and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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ETHICS REVIEW AND APPROVAL

Signed informed consent was obtained from each subject. Institutional Review Board (IRB) approval was granted by the University of North Carolina at Greensboro (IRB # 12-0248).

DISCLOSURE (AUTHORS)

All of the authors of this work confirm that they do not have any competing interests or conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Rodney Ehrlich declares that he has no competing or conflicts of interest in the review and publication decision regarding this article.

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