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By: Michael K. Lemke, Yorghos Apostolopoulos, Adam Hege, Laurie Wideman, and Sevile Sönmez

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**Keywords:** Sleep | Occupational epidemiology | Cardiovascular disorders | Work hours | Shift work

## Article:

***Note: Full text of article below

# Work, sleep, and cholesterol levels of U.S. long-haul truck drivers

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Abstract: Long-haul truck drivers in the United States experience elevated cardiovascular health risks, possibly due to hypercholesterolemia. The current study has two objectives: 1) to generate a cholesterol profile for U.S. long-haul truck drivers; and 2) to determine the influence of work organization characteristics and sleep quality and duration on cholesterol levels of long-haul truck drivers. Survey and biometric data were collected from 262 long-haul truck drivers. Descriptive analyses were performed for demographic, work organization, sleep, and cholesterol measures. Linear regression and ordinal logistic regression analyses were conducted to examine for possible predictive relationships between demographic, work organization, and sleep variables, and cholesterol outcomes. The majority (66.4%) of drivers had a low HDL (<40 mg/dL), and nearly 42% of drivers had a high-risk total cholesterol to HDL cholesterol ratio. Sleep quality was associated with HDL, LDL, and total cholesterol, and daily work hours were associated with LDL cholesterol. Workday sleep duration was associated with non-HDL cholesterol, and driving experience and sleep quality were associated with cholesterol ratio. Long-haul truck drivers have a high risk cholesterol profile, and sleep quality and work organization factors may induce these cholesterol outcomes. Targeted worksite health promotion programs are needed to curb these atherosclerotic risks.

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## Introduction

There are nearly 2 million heavy and tractor-trailer truck drivers in the United States[1]. Most of these drivers are considered long-haul truck drivers, who remain on the road for prolonged periods of time[1, 2]. Long-haul truck drivers endure numerous hazards[2] endemic to their occupation, many of which are related to the physical and psychologi-cal strains associated with the profession; in particular, the work organization of long-haul truck driving contributes to considerable disease burden[2]. Unsurprisingly, work organization characteristics induce poor quality of life, and likely shorter lifespans[3], among long-haul truck drivers[4]. Further, such disease burden has far-reaching consequences, impacting other entities including transportation and warehousing companies, health insurance companies, and the general motoring public[2].

Long-haul truck drivers' work organization is replete with long work hours, shift work, irregular schedules, job strain, wage declines, and lack of worksite resources[5−9].

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The excessive competition among trucking companies in the wake of deregulation has led to increases in pace-of-work and declining wages for drivers, with piece work, mile-based compensation structures now the norm[8]. Since long-haul truck drivers are not protected by federal laws pertaining to overtime pay[8, 10], when combined with declining wages and increased pressures from employers for productivity, drivers end up working excessively long hours. While work hours are regulated by the federal government, these protections: a) still allow for long shifts by providing a maximum of 11 hours of driving per day, and only prohibit further driving after 14 hours since a driver's last 10-hour break; b) do not curb long weekly workhours; c) have enforcement gaps which allow drivers to circumvent restrictions, such as by allowing them to log non-driving working time as off-duty; and d) fail to account for circadian rhythms, cumulative fatigue, and other valid considerations in evaluating driver sleep duration, sleep quality, and well-being[11].

The work organization characteristics discussed above have been shown to degrade sleep quality and duration among white collar workers, such as individuals in administrative and managerial positions, as well as blue collar workers, such as long-haul truck drivers[12−21]. Accordingly, the transportation sector as a whole has a higher prevalence of insufficient sleep compared to other occupational categories[22]. Unfortunately, sleep quality and duration affect numerous aspects of health, with insufficient sleep associated with hypertension, diabetes, obesity, cardiovascular disease, and mortality[22−24]. In particular, sleep quality and duration have been associated with hypercholesterolemia[25−29], which directly influences atherosclerosis and eventual cardiovascular disease manifestation[30, 31]. Thus, sleep quality and duration likely contribute to the excessive cardiovascular disease burden endured by long-haul truck drivers[32, 33].

Sleep quality and duration influence cholesterol levels through several mechanisms. Endocrine functioning is impacted by sleep, which influences various metabolic processes, including lipid metabolism, by altering levels of hormones such as thyrotropin and cortisol[34−36]. Sleep may also impact genes responsible for cholesterol transportation[37]. Other mechanisms are more indirect. For example, sleep restriction results in prolonged nocturnal elevations of growth hormone and higher levels of noradrenalin, which have been associated with increases in non-esterified fatty acids during nocturnal and early morning hours[28]. Conditions which increase concentrations of non-esterified fatty acids also support cholesterol redistribution from non-atherogenic HDL cholesterol to atherogenic LDL cholesterol[38]. Further, sleep deprivation has been associated with decreases in leptin levels, which lead to increased hunger and appetite and generating dietary patterns which may contribute to hypercholesterolemia[39]. Sleep also influences health behaviors, including physical activity and diet, which impact cholesterol levels[31, 40]. The influence of sleep on cholesterol appears to be curvilinear, as long sleep duration has been association with hypercholesterolemia as well[28], although the specific mechanisms which induce cholesterol changes are likely different for short sleep duration compared to long sleep duration.

Because hypercholesterolemia is the leading cause of atherosclerosis[31], identifying salient factors which induce elevated cholesterol levels is crucial for preventing subsequent cardiovascular disease. Such diseases not only contribute to substantially reduced life expectancies among commercial drivers[3, 4], but also detrimentally impact roadway safety and thus impact the general motoring public[41, 42]. Therefore, our current study has two objectives: 1) to generate a cholesterol profile for long-haul truck drivers; and 2) to determine the influence of work organization characteristics and sleep quality and sleep duration on cholesterol levels of long-haul truck drivers. These objectives were predicated on the following hypotheses: 1) long-haul truck drivers will have cholesterol profiles generally indicative of atherosclerotic risk; and 2) because of strong and direct influence between sleep and hypercholesterolemia, and based on the assumption that work organization variables impact cholesterol levels indirectly by influencing sleep, workday sleep duration and workday sleep quality will be the strongest predictors of cholesterol levels among long-haul truck drivers.

## Subjects and Methods

*Study design and participants*

A detailed description of the study procedures and cohort characteristics has been described previously[5, 17, 43, 44]. This study was approved by the Institutional Review Board (IRB) of a university in North Carolina. Briefly, a non-experimental, descriptive, cross-sectional design was employed to collect survey and biometric data from 262 U.S. LHTD over six months at a large truckstop located in North Carolina. Because of volume of trucking activity at this site, coupled with the transient nature of the long-haul trucking profession, this location is representative of typical truckstops in the U.S. Permission to conduct the study at the truckstop was requested and granted by the

truckstop's corporate office. Using intercept techniques, researchers approached drivers and asked screening questions to assure they were long-haul truck drivers who had an overnight layover at the truckstop. Study details, including the voluntary nature of participation, cash incentives, and blood draw procedures, were explained to drivers who met the inclusion criteria and were interested in participating the study. Participating drivers were then asked to sign an informed consent form and were allowed to use aliases for greater confidentiality. Of the 262 truck drivers that completed questionnaires and anthropometric measures (2 were excluded in final analyses due to missing data), 115 truck drivers returned for blood draws the following morning.

*Survey data*

Data for demographic, behavioral, workplace, and work organization variables that could potentially be related to blood cholesterol among long-haul truck drivers were collected. We developed the Trucker Sleep Disorders Survey (TSLDS) from insights gleaned from other key instruments, relevant sleep literature, and our previous work with truck drivers[45, 46]. Characteristics of this survey, including questions pertaining to demographic, work organization, and sleep quality and duration which were used in this manuscript, have been described in previous manuscripts which used this same dataset[5, 17, 43, 44].

*Work organization*

To measure drivers experience with driving a truck, drivers were asked, "How many years of experience do you have driving a truck?" To measure weekly mileage, we asked, "How many miles do you average driving per week?" Daily work hours and compensation type were asked in a categorical fashion. To measure daily work hours, drivers were asked, "On average, how many hours do you work in a day?" The response selections for daily work hours included: "6 or less hours"; "7–8 hours"; "8–9 hours"; "9–10 hours"; "10–11 hours"; "11–12 hours"; "12–13 hours"; "13–14 hours"; and "more than 14 hours". To measure compensation type, we asked drivers, "How do you usually get paid as a long-haul driver?" For compensation type, the response selections included: "by the mile"; "by the load"; "% of revenue"; and "other", and drivers were allowed to select more than one option.

*Sleep duration and quality*

To measure workday sleep duration, drivers were asked, "On average, how many hours of sleep do you get on your

workdays?" To measure non-workday sleep duration, drivers were asked, "On average, how many hours of sleep do you get on your non-workdays?" To measure workday sleep quality, drivers were asked, "How often do you get a good night's sleep on your workdays?" To measure non-workday sleep quality, drivers were asked, "How often do you get a good night's sleep on your non-workdays?" Response selections included: "never", "rarely", "almost every night", and "every night".

*Blood draws and blood analysis*

Blood was taken from the antecubital space in either arm using aseptic technique by a certified phlebotomist. 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, low-density lipoproteins and high-density lipoproteins), were assayed using colorimetric reagents using protocols specified by the manufacturer (Wako USA, Richmond, VA). 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%.

*Statistical analysis*

We first performed descriptive analyses to assess for differences between participants within our sample pertaining to demographic (age and race/ethnicity), work organization (driving experience, compensation type, driving miles per week, daily work hours, and prescribed medications), and sleep (workday and non-workday sleep quality and sleep duration) variables that did not have a blood draw taken versus those that did have a blood draw taken. For continuous variables (age and driving experience) we assessed for differences in means, and for categorical variables we examined frequencies and percentages within each category and then performed chi-square tests for group differences. Next, we examined correlations between the predictor variables (sleep duration and sleep quality) and found statistically significant but not strong relationships between the variables. We did this to assess for the concern of multicollinearity; further, we also used assessed multicollinearity while conducting linear regression analyses[47]. We then performed descriptive analyses of the blood cholesterol measures of HDL (mg/dL), LDL (mg/dL), non-HDL (mg/dL), and total cholesterol (mg/dL) while controlling for the use of prescription medications.

While controlling for the use of prescription medica-

tions, we next conducted a series of linear regression analyses to examine for potential predictive relationships between demographic, work organization, and sleep variables and blood cholesterol (HDL, LDL, and total cholesterol) outcomes. We then re-coded the predictor variables for the purposes of logistic regression. First, age was categorized: "45 and younger"=lower age risk; and "46 and older"=increased age risk. We coded driving experience as follows: "10 or less years"=0; "11–20 years"=1; and "more than 20 years"=2. Driving mileage was coded as follows: "less than 2,500 miles"=0; "2,500–3,000 miles"=1; and "more than 3,000 miles" =2. Based on Department of Transportation hours-of-service regulations pertaining to driving limits (the "11-Hour Driving Limit")[11], we then coded work hours as follows: "11 or less hours"=1, and "more than 11 hours"=0. Based on the specific implications of being paid "by the mile" compared to other compensation types[7, 48], we coded compensation type as follows: "by the mile"=0, and all other forms of compensation ("by the load", "% of revenue", and "other")=1. Based on National Sleep Foundation recommendations for adults[49], we created a categorical variable for sleep duration (both workdays and non-workdays), where "less than 7 hours daily" was "short", "7 to 9 hours daily" was "optimal", and "over 9 hours daily" was "long". We then re-coded sleep duration as follows: "optimal"=0; and "short or long"=1. We created a categorical variable for sleep quality, where "never" or "rarely" were considered "poor" and "almost every night" or "every night" were considered "good". We then coded sleep quality as follows: "poor"=0, and "good"=1. Lastly, we performed ordinal logistic regression analyses with non-HDL and cholesterol ratio (total cholesterol-to-HDL) as outcome variables. For the logistic regression analyses we re-coded and categorized the outcome variables based on scientific literature and guidelines related to cholesterol as well as the variability of our sample. For non-HDL cholesterol, we categorized in this manner: <100 mg/dL="low/healthy"; 100–129.99 mg/dL="moderate risk"; and ≥130 mg/dL="increased risk"[50]. For cholesterol ratio, we categorized in the following fashion: 2.5–4="low risk"; 4.01–5.5="moderate risk"; and 5.51 and greater="increased risk"[51, 52]. All statistical analyses were conducted using SPSS 23.0[53].

## Results

The mean age of the drivers was 47.8 for those providing a blood sample, with a non-significant difference in the means between those receiving a blood draw and

not receiving a blood draw. The majority of the sample (65.2%) identified as White/Caucasian, with 24.4% identifying as Black/African-American, 7.8% identifying as Hispanic, and 2.9% identifying as other. There were statistically significant differences in group proportions between those receiving a blood draw and not receiving a blood draw, with a higher proportion of drivers identifying as White/Caucasian and other and a lower proportion of drivers identifying as Black/African-American and Hispanic in the blood draw sample compared to the non-blood draw sample ($p$ <0.05). Specifically, 65% were white in the portion of the sample providing blood for analysis. Drivers reported having an average of nearly 15 years of experience ($M$=14.97) in the long-haul truck driving profession, and there was a 1-year difference in means between those receiving a blood draw and not receiving a blood draw ($M$=14.4 and $M$=15.4, respectively; $p$=0.49). The most common form of compensation was "by the mile", and drivers averaged 2,812.6 miles of driving per week. In the drivers providing blood, the average weekly mileage was 2,740.8 miles. Most of the drivers (70.4%) reported working more than 11 hours daily. There were no significant differences between those who provided a blood draw compared to those who did not for compensation, driving miles per week, or daily work hours. Nearly 60% (compared to 67% of those giving blood) of drivers reported taking prescribed medications, and there were statistically significant differences in medication usage between those who participated in the blood draw compared to those who did not, with a greater proportion of the blood draw sample reporting prescribed medication usage than the non-blood draw sample ($p$<0.05). Overall, these findings suggest that the sample receiving a blood draw was not meaningfully different from those who did not receive a blood draw. Complete demographic and work organization characteristics can be found in Table 1.

The sample of long-haul truck drivers reported getting an average of 6 hours and 55 minutes (6.92 hours) of sleep on their workdays (6.86 among those providing blood) as opposed to 8 hours and 16 minutes (8.27 hours) on their non-workdays. There was not a significant difference in workday sleep duration between those receiving a blood draw and those not receiving a blood draw; however, there was a significant difference in non-workday sleep duration between those receiving a blood draw and those not receiving a blood draw, with non-workday sleep duration being lower among the former ($M$=7.95 and $M$=8.52, respectively; $p$=0.03). Regarding sleep duration, 53.9% reported short or long sleep duration on workdays, and 50.5% did

**Table 1.** Demographics, work organization, use of prescribed medications, and sleep characteristics of drivers providing a blood sample (N=115)

| | Mean±SD | n (%) | | Mean±SD | n (%) |
|---|---|---|---|---|---|
| Age | 47.8±9.7 | | Prescribed Medication | | |
| Race | | | *Yes* | | 77(67.0) |
| *White/Caucasian* | | 75 (65.2) | *Blood Pressure* | | 27 (23.7) |
| *Black/AA* | | 28 (24.4) | *Cardiovascular* | | 15 (13.2) |
| *Hispanic* | | 9 ( 7.8) | *Cholesterol* | | 8 ( 7.0) |
| *Other* | | 3 ( 2.6) | *Diabetes* | | 6 ( 5.3) |
| Driving Experience | 14.4±11.3 | | *No* | | 38 (33.0) |
| Compensation | | | Sleep Duration (Workdays) | | |
| *By the mile* | | 80 (69.6) | *Less than 7 hrs* | | 55 (47.8) |
| *By the load* | | 15 (13.0) | *7 to 9 hrs* | | 53 (46.1) |
| *% of revenue* | | 18 (15.7) | *More than 9 hrs* | | 7 ( 6.1) |
| *Other* | | 2 ( 1.7) | Sleep Duration (Non-Workdays) | 6.86±1.48 | |
| Driving Miles per Week | 2,740.8±792.1 | | *Less than 7 hrs* | | 27 (23.5) |
| *Less than 2,500* | | 35 (30.4) | *7 to 9 hrs* | | 57 (49.6) |
| *2,500–3,000* | | 58 (50.5) | *More than 9 hrs* | | 31 (27.0 |
| *More than 3,000* | | 22 (19.1) | Sleep Quality (Workdays) | 7.95±1.99 | |
| Daily Work Hours | | | *Poor* | | 41 (35.7) |
| *11 or less* | | 34 (29.6) | *Good* | | 74 (64.3) |
| *More than 11* | | 81 (70.4) | Sleep Quality (Non-Workdays) | | |
| | | | *Poor* | | 15 (14.9) |
| | | | *Good* | | 86 (85.1) |

so on non-workdays. Regarding sleep quality, 35.7% reported never or rarely getting a good quality of sleep on workdays, while 14.9% did so on non-workdays. There were no significant differences between those receiving a blood draw and those not receiving a blood draw across the sleep quality measures. Complete sleep characteristics can also be found in Table 1.

Only those drivers who provided a blood draw (N=115) were included in subsequent cholesterol analyses (Tables 2–4). Portions of these analyses are available in a previous manuscript[32]. Overall, cholesterol measures for the long-haul truck drivers averaged 35.08 mg/dL for HDL, 113.66 mg/dL for LDL, 133.399 mg/dL for non-HDL, 5.25 for cholesterol ratio, and 168.16 mg/dL for total cholesterol. Using NHLBI categories to determine general cardiometabolic risk associated with these cholesterol measures[50], we found that 66.4% of drivers had an undesirably low HDL (<40 mg/dL), 23.4% of drivers had either a borderline high (130–159 mg/dL) or high (160–189 mg/dL) LDL, 52.2% of drivers had elevated (≥130 mg/dL) non-HDL, and 11.4% of drivers had undesirable (≥ 200 mg/dL) total cholesterol. Over 40% of drivers had total cholesterol to HDL cholesterol ratios which signified at least double the average risk for heart disease[51, 52]. Complete cholesterol characteristics can be found in Table 2.

We first performed a linear regression analysis, with

**Table 2.** Cholesterol measures of sample

| | Mean±SD | n (%) |
|---|---|---|
| HDL (mg/dl) | 35.08±10.67 | |
| *Good/High (≥60 mg/dl)* | | 3 ( 2.7) |
| *Average (40–59 mg/dl)* | | 35 ( 30.9) |
| *Low (<40 mg/dl)* | | 75 ( 66.4) |
| LDL (mg/dl) | 113.66±27.64 | |
| *Optimal (<100 mg/dl)* | | 41 ( 35.7) |
| *Near Optimal (100–129 mg/dl)* | | 47 ( 40.9) |
| *Borderline High (130–159 mg/dl)* | | 20 ( 17.4) |
| *High (160–189 mg/dl)* | | 7 ( 6.0) |
| Non-HDL Cholesterol | 133.39±30.49 | |
| *<100 mg/dl* | | 17 ( 15.3) |
| *100–129 mg/dl* | | 36 (312.4) |
| *130–159 mg/dl* | | 41 ( 36.9) |
| *160–189 mg/dl* | | 11 ( 9.9) |
| *190–219 mg/dl* | | 4 ( 3.6) |
| *≥220 mg/dl* | | 2 ( 1.8) |
| Cholesterol ratio (Total: HDL) | 5.25±1.84 | |
| *2.5–4.0* | | 28 ( 25.9) |
| *4.01–5.5* | | 35 ( 32.4) |
| *9.6+-double the average risk* | | 45 ( 41.7) |
| Total Cholesterol (mg/dl) | 168.16±30.21 | |
| *Desirable (<200 mg/dl)* | | 101 ( 88.6) |
| *Borderline High (200–239 mg/dl)* | | 9 ( 7.9) |
| *High (≥240 mg/dl)* | | 4 ( 3.5) |

**Table 3.   Linear regression models for HDL, LDL, and total cholesterol**

| | *b* (95% CI) | SE B | β | *p* |
|---|---|---|---|---|
| ***HDL*** | | | | |
| *Constant* | 41.32 (32.48, 50.16) | 4.45 | | 0.00 |
| Years of Driving | −0.18 (−0.37, 0.02) | −0.10 | −0.18 | 0.07 |
| Compensation Type | 0.83 (−1.78, 3.45) | 1.32 | 0.06 | 0.53 |
| Driving Miles per wk | 0.00 (−0.01, 0.00) | 0.00 | −0.13 | 0.20 |
| Workday Sleep Quality | 3.78 (−1.62, 9.19) | 2.72 | 0.16 | 0.17 |
| Non-Workday Sleep Quality | −9.23 (−16.23, −2.23) | 3.53 | −0.30 | <0.01 |
| *F(5, 94) = 2.55, p = 0.03, R$^2$ = 0.12* | | | | |
| ***LDL*** | | | | |
| *Constant* | 132.15 (86.66, 177.64) | 22.84 | | 0.00 |
| Age | −0.22 (−0.78, 0.34) | 0.28 | −0.09 | 0.44 |
| Years of Driving | 0.20 (−0.32, 0.72) | 0.26 | 0.09 | 0.45 |
| Race | 1.75 (−5.29, 8.80) | 3.54 | 0.05 | 0.62 |
| Compensation Type | 3.58 (−2.82, 9.98) | 3.21 | 0.11 | 0.27 |
| Driving Miles per wk | 0.00 (−0.01, 001) | 0.00 | −0.05 | 0.64 |
| Daily Work h | 14.24 (3.17, 25.30) | 5.56 | 0.25 | 0.01 |
| Workday Sleep Duration | −3.45 (−7.12, 0.21) | 1.84 | −0.20 | 0.06 |
| Non-Workday Sleep Duration | 0.42 (−2.34, 3.19) | 1.39 | 0.03 | 0.76 |
| Workday Sleep Quality | 16.71 (3.32, 30.08) | 6.72 | 0.30 | 0.02 |
| Non-Workday Sleep Quality | −38.95 (−57.58, −20.31) | 9.36 | −0.51 | 0.00 |
| *F(10, 77) = 3.02, p < 0.01, R$^2$ = 0.28* | | | | |
| ***Total Cholesterol*** | | | | |
| *Constant* | 211.30 (172.77, 249.83) | 19.36 | | 0.00 |
| Years of Driving | 0.32 (−0.20, 0.84) | 0.26 | 0.13 | 0.23 |
| Compensation Type | 5.54 (−7.50, 18.57) | 6.55 | 0.09 | 0.40 |
| Driving miles per wk | −0.01 (−0.01, 000) | 0.00 | −0.17 | 0.11 |
| Workday Sleep Duration | −4.27 (−8.68, 0.14) | 2.21 | −0.22 | 0.06 |
| Non-Workday Sleep Duration | −0.81 (−3.98, 2.36) | 1.59 | −0.06 | 0.61 |
| Workday Sleep Quality | 17.09 (1.12, 33.05) | 8.02 | 0.27 | 0.04 |
| Non-Workday Sleep Quality | −29.64 (−51.90, −7.39) | 11.18 | −0.34 | <0.01 |
| *F(7, 79) = 2.64, p = 0.02, R$^2$ = 0.19* | | | | |

HDL as the dependent variable. In the first model we inputted all of the potential predictor variables (from Table 1). The results of this model were: F (10, 76) = 1.12 ($p$ = 0.36, R$^2$ = 0.13). Based on these results, we sought to eliminate variables that had very little statistical significance ($p$ > 0.50) to the model to fit a statistically significant model. This resulted in using driving experience, compensation type, driving miles per week, workday sleep quality, and non-workday sleep quality, being retained as predictor variables. The results of this model were: F (5, 94) = 2.55 ($p$ = 0.03, R$^2$ = 0.12), with non-workday sleep quality (b = −9.23, $p$ = 0.01) being the only statistically significant predictor to the model. This meant that, when non-workday sleep quality was poor as opposed to good, the HDL measure decreased by 9.23 mg/dL.

With LDL as the dependent variable, and all potential predictor variables included, the results of this model were:

F (10, 77) = 3.02 ($p$ < 0.01, R$^2$ = 0.28). Significant predictors were daily work hours (b = 14.24, $p$ < 0.01), workday sleep quality (b = 16.71, $p$ = 0.02), and non-workday sleep quality (b = −38.95, $p$ < 0.01). This meant the following: When drivers worked more than 11 hours daily as opposed to 11 hours or less, the LDL measure increased by 14.24 mg/dL; when workday sleep quality was poor rather than good, the LDL measure increased by 16.71 mg/dL; and when non-workday sleep quality was poor rather than good, the LDL measure decreased by 38.95 mg/dL.

With total cholesterol as the dependent variable, and all predictor variables included, the results of this model were: F (10, 76) = 1.81 ($p$ = 0.07, R$^2$ = 0.19). Significant predictors to the model included workday sleep duration (b = −4.59, $p$ = 0.04), workday sleep quality (b = 16.78, $p$ = 0.05), and non-workday sleep quality (b = −31.45, $p$ = 0.01). With no statistical significance to the overall model, we again

**Table 4.  Associations between work organization, sleep, non-HDL Cholesterol, and Cholesterol Ratio (adjusted for age and race/ethnicity)**

|  | OR | 95% CI | p |
|---|---|---|---|
| **Model[1] (non-HDL Cholesterol as outcome variable)** |  |  | 0.05 |
| Years of Driving (21 or more yrs reference) | 1.00 | — | — |
| 10 or less yrs | 0.39 | 0.14, 1.08 | 0.08 |
| Between 11 and 20 yrs | 0.82 | 0.26, 2.57 | 0.95 |
| Daily Work h (11 h or less, vs. more than 11 h reference) | 0.54 | 0.21, 1.39 | 0.20 |
| Driving Miles per wk (3,000 or more miles reference) | 1.00 | — | — |
| Less than 2,500 miles per wk | 1.43 | 0.39, 5.23 | 0.59 |
| Between 2,500 and 2,999 miles per wk | 3.16 | 0.90, 11.04 | 0.07 |
| Workday Sleep Duration (optimal, vs. too short or too long reference) | 0.33 | 0.13, 0.83 | 0.02 |
| Non-Workday Sleep Duration (optimal, vs. too short or too long reference) | 2.02 | 0.81, 5.03 | 0.13 |
| Workday Sleep Quality (good, vs. poor reference) | 0.50 | 0.16, 1.55 | 0.23 |
| Non-Workday Sleep Quality (good, vs. poor reference) | 2.06 | 0.48, 8.86 | 0.33 |
| **Model[2] (Cholesterol Ratio as outcome variable)** |  |  | 0.04 |
| Years of Driving (21 or more yrs reference) | 1.00 | — | — |
| 10 or less yrs | 0.29 | 0.11, 0.78 | 0.01 |
| Between 11 and 20 yrs | 0.30 | 0.10, 0.88 | 0.03 |
| Compensation Type (by the mile, vs. other form of compensation reference) | 0.57 | 0.24, 1.34 | 0.20 |
| Workday Sleep Quality (good, vs. poor reference) | 2.22 | 0.82, 6.00 | 0.12 |
| Non-Workday Sleep Quality (good, vs. poor reference) | 0.25 | 0.06, 0.95 | 0.04 |

[1] $\chi^2 = 17.16$; $R^2 = .17$ (Cox & Snell), .20 (Nagelkerke)
[2] $\chi^2 = 11.59$; $R^2 = .12$ (Cox & Snell), .13 (Nagelkerke)

eliminated variables based on their statistical significance ($p < 0.50$) in a backward stepwise fashion in order to attempt to strengthen and fit a statistically significant model. The remaining predictor variables included years of driving, compensation type, driving miles per week, workday sleep duration, non-workday sleep duration, workday sleep quality, and non-workday sleep quality. The results of this model were: F (7, 79) = 2.64 ($p = 0.02$, $R^2 = 0.19$). The only two statistically significant predictors were workday sleep quality (b = 17.09, $p = 0.04$) and non-workday sleep quality (b = −29.64, $p < 0.01$). This meant that, when drivers reported a poor sleep quality the total cholesterol value increased by 17.09 mg/dL and when non-workday sleep quality was poor, the total cholesterol value decreased by 29.64 mg/dL. Complete results of the linear regression analyses for all significant models can be found in Table 3.

Next we explored possible relationships between non-HDL cholesterol and cholesterol ratio in relation to the predictor variables using ordinal logistic regression. With non-HDL cholesterol as the dependent variable and all of the predictor variables included, the model was statistically insignificant ($\chi^2 = 13.47$, $p = 0.33$, Cox and Snell $R^2 = 0.14$, Nagelkerke $R^2 = 0.15$). Based on these findings we eliminated variables with a $p > 0.50$ in order to fit a statistically significant model. The remaining predictors included: years of driving experience, daily work hours, driving miles per week, and all of the sleep variables. The only significant predictor to the model ($\chi^2 = 17.16$, $p = 0.05$, Cox and Snell $R^2 = 0.17$, Nagelkerke $R^2 = 0.20$) was workday sleep duration (OR = 0.33, $p = 0.02$), meaning a 67% reduced odds across the non-HDL categories when drivers reported an optimal sleep duration for their workdays. With cholesterol ratio as the dependent variable and all of the predictor variables included, the model was statistically insignificant ($\chi^2 = 15.56$, $p = 0.21$, Cox and Snell $R^2 = 0.16$, Nagelkerke $R^2 = 0.19$). Like with non-HDL, we next eliminated variables with a $p > 0.50$ in order to fit a statistically significant model. The remaining predictors included: years of driving experience, compensation type, and sleep quality (both workday and non-workday). The statistically significant predictors to this model ($\chi^2 = 11.59$, $p = 0.04$, Cox and Snell $R^2 = 0.12$, Nagelkerke $R^2 = 0.13$) included: 10 or less years of driving experience (OR = 0.29, $p = 0.01$) and 11 to 20 years of driving experience (OR = 0.30, $p = 0.03$) when compared to those driving for 21 or more years; and a good workday sleep quality on non-workdays (OR = 0.25, $p = 0.04$). This meant a 71% and 70% decreased odds for those driving for 10 or less years and 11 to 20 years, respectfully, and a 75% reduced odds for those with a good sleep quality across the cholesterol ratio categories.

## Discussion

The long-haul truck driver sample in this study appears to be approximately representative of U.S. long-haul truck drivers as a whole across age, race, and driving experience, although the proportion of Black/African-American drivers was somewhat higher and White/Caucasian drivers was somewhat lower in our sample[54]. Most drivers are paid by the mile, which reflects overall trends within the trucking industry since deregulation[8]. Given these pay structures, which are associated with lower wages, wage evasion (e.g., disparities between "paid miles" and actual miles driven), and are strictly performance-based[8], it is unsurprising that drivers reported both a large number of driving miles per week and long daily work hours[48]. Across both measures of sleep – duration and quality – the long-haul truck driver sample has far superior characteristics on non-workdays as compared to workdays. Sleep duration findings generally corroborate other studies of long-haul truck drivers, which have found short workday sleep durations; however, none of these studies have directly compared workday durations with those of non-workdays[54, 55]. Also, few studies have investigated sleep quality, as the emphasis has generally been on duration; however, one such study showed contrasting findings to ours, with over 70% of drivers reporting "good" or "excellent" workday sleep quality[56]. As is the case with sleep duration, no studies have directly compared workday and non-workday sleep quality among long-haul truck drivers[55].

The overall cholesterol profile for the long-haul truck drivers was poor and generally supports our first hypothesis. Optimal levels are higher or equal to 60 mg/dL for HDL, below 100 mg/dL for LDL, and below 200 mg/dL for total cholesterol[50, 57]. Unfortunately, only 3% of the sample had optimal HDL cholesterol, and only 35.7% had optimal LDL cholesterol. The vast majority of the sample (88.6%) had optimal total cholesterol; however, this is misleading, as it is diminished by the extremely low levels of "good" HDL cholesterol. Non-HDL cholesterol – which appears to be an important indicator of cardiovascular disease risk and offers several advantages over more traditional measures of cholesterol[58, 59] – provides useful information into the atherosclerotic risk of this sample of long-haul truck drivers. Non-HDL cholesterol should be below 130 mg/dL[50]. In this sample, less than half (49.6%) presented optimal non-HDL cholesterol profiles, suggesting that, in sum, long-haul truck drivers have elevated atherosclerotic risk. Finally, the ratio of total cholesterol to HDL cholesterol in this sample was problematic, with over

40% of these drivers having ratios which indicate double than average risk for heart disease[51, 52]. These findings are particularly stark when considering the high levels of medication usage in the sample, which may mask the influence of employment in the long-haul trucking profession on atherosclerotic risk. To our knowledge, this represents for the first time a complete cholesterol profile for long-haul truck drivers in the United States or internationally.

Our second hypothesis was generally supported by our regression analyses. Sleep variables – especially those related to sleep quality – were indeed powerful predictors of HDL, LDL, and total cholesterol. Further, workday sleep duration was a significant predictor of non-HDL cholesterol, and non-workday sleep quality was a significant predictor of the ratio of total cholesterol to HDL cholesterol. However, the direction of some of these relationships were unexpected, with LDL and total cholesterol levels increasing with better non-workday sleep quality. Our findings regarding the influence of sleep quality on cholesterol levels is somewhat in concordance with other studies, which have found that poor sleep quality is associated with low HDL cholesterol[60], that sleep disturbances increase cholesterol levels[61], and that poor sleep quality increases risk of cardiovascular disease[62], although some studies have failed to find relationships between sleep quality and cholesterol levels[26]. Similarly, multiple studies have found relationships between short sleep duration and cholesterol levels[36], including decreased HDL cholesterol[37, 63], increased LDL cholesterol[25, 37], and increased total cholesterol[27, 29]. Other studies, none of which investigate long-haul truck drivers, have reported a curvilinear relationship between sleep duration and cholesterol levels[26, 28]. Regarding the influence of sleep duration on non-HDL cholesterol levels, a curvilinear relationship may exist between sleep duration and cholesterol levels, but is difficult to detect given the sleep characteristics of the population, which are generally defined by sleep deprivation[22]. It is important to note that there are relatively few studies investigating the influence of sleep quality and duration on cholesterol levels among long-haul truck drivers, whose occupational milieu is largely unique, especially with regard to the constellation of work organization and workplace forces[2]. For example, it may be that the unique array of work organization characteristics of long-haul truck driving, which compromises sleep[17], contributes to the excessively low HDL cholesterol levels found in our sample.

A number of our findings regarding the influence of sleep on cholesterol levels were unexpected. For one, non-workday sleep quality was a significant predictor for

increased HDL, increased LDL, and increased total cholesterol. This was unexpected because long-haul truck drivers are on the road for extended periods of time, often only experiencing non-workdays a few weekends per month. These findings implicate the surprising importance of non-workday sleep quality, which includes not only sleep during home time but also while on the road, during 34-hour breaks ("34-hour restarts")[11]. Alternately, it may be that these findings are not a function of the actual impact of non-workday sleep quality, but instead is an artifact of the study methodology: Workday and non-workday sleep quality measures were self-reported, and thus subject to biases. For example, rating non-workday sleep quality as "good" may be influenced by extremely poor sleep quality on workdays, and thus the relationship between non-workday sleep quality and cholesterol levels may instead be a reflection of the truly poor quality of sleep drivers are obtaining on workdays. Regardless of drivers' perceptions about sleep quality, because their work schedules usually only allow them a few weekends per month at home[54], and with some drivers actually remaining away from home for months at a time[2], it is unlikely that sleep quality during such a relatively small percentage of non-workdays would exert such influence on cholesterol levels. Also to our surprise, daily work hours were a significant predictor of LDL cholesterol levels. This suggests that work organization likely has a significant and direct influence on cholesterol levels, perhaps by inducing allostatic load through job strain and chronic stress[64-66]. Work organization variables endemic to the long-haul truck driving profession are known to impact cardiometabolic disease risks among this population[67-69].

Efforts to reduce atherosclerosis and subsequent cardiovascular disease among long-haul truck drivers are vital to the long-term health of the trucking industry and broader economy in the United States. The trucking industry is experiencing a driver shortage, which is expected to exacerbate as the need for long-haul truck drivers is expected to grow by 5% over the next decade[1, 70]. Further, with the high turnover rates endemic to the profession, it is unclear whether the trucking industry will be able to meet future needs[4, 71]. Fueling this driver shortage are increasingly stringent medical fitness demands on long-haul truck drivers[11, 72]. To be legally allowed to drive a commercial motor vehicle in the U.S., long-haul truck drivers must undergo a medical examination by a licensed medical examiner listed in a national registry[72]. This certification is generally valid for 2 years, although specific medical conditions such as hypertension shorten this time period[72]. As addi-

tional research findings suggest that an array of medical conditions may compromise the ability of long-haul truck drivers to safely operate a commercial motor vehicle (e.g., diabetes; hypertension), the medical certification process has become more rigorous. These more stringent medical requirements, combined with the poor overall health of the workforce[2], underscore an urgent need to improve population-level health outcomes.

Existing efforts to improve long-haul truck driver cardiovascular health have primarily taken the form of worksite health promotion programs, which have been ineffective in reversing negative health trends at the population level[73, 74]. However, proliferation of individual-based worksite health promotion programs, such as those that target physical activity and nutrition behaviors, have been shown to provide cardiovascular health benefits to long-haul truck drivers and are generally well-received[74]. In contrast to the bulk of extant worksite health promotion programs in the long-haul trucking industry, which are narrow in scope and siloed[73], such programs should aim to deliver comprehensive program elements to increase their impact on cardiovascular health outcomes. Further, although such programs are beneficial, efforts that address work organization and sleep quality will likely be needed to curb atherosclerosis at the population level among long-haul truck drivers. This will likely require both more comprehensive worksite health promotion programs, which address sleep and work organization factors, as well as policy changes on the part of the trucking industry and federal regulatory bodies. Further, given the influence of physical activity and food intake on cholesterol levels[31, 75], and the lack of opportunities for physical activity and poor availability of healthful food choices in long-haul truck drivers' worksites[9], foci of programmatic and policy efforts should include physical activity- and nutrition-related environmental changes to encourage health-supportive behaviors.

There are four primary limitations of the current study. First, the overall sample size is relatively small. However, the similarity of our findings with other studies involving long-haul truck drivers suggests that our sample was highly representative of the population. Second, the potential for selection bias is an important limitation, as drivers may have refused to participate for a number of reasons. For example, 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 skittish of releasing any personal information. Third, we employed a sampling technique that involved blood draws in the actual workplace. Although this mini-

mized the barriers to participation and likely increased the willingness of individuals to be involved in the study, it also 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. These first three limitations have been discussed in previous studies using this dataset[32, 43]. Finally, our sample did not include any female drivers. Other studies have found differentiating patterns of results between males and females[27]. However, given the small percentage of female drivers in the trucking industry as a whole[76], the relevance of this limitation is mitigated.

The work organization characteristics of U.S. long-haul truck drivers induce poor quality of life and shorter lifespans, which negatively impact transportation and warehousing companies, health insurance companies, and the general motoring public. Given the economic outlook of the U.S. trucking industry, reducing atherosclerosis and subsequent cardiovascular disease among long-haul truck drivers is more important than ever. Long-haul truck drivers have a cholesterol profile which indicates elevated atherosclerotic risk, and sleep quality and work organization factors appear to be particularly influential in hypercholesterolemia in this population. To ensure that the U.S. trucking industry is able to meet future demands, key stakeholders must urgently take action by initiating comprehensive worksite health promotion programs and creating policy change to address these key factors.

## Acknowledgements

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