Driving towards obesity: A systematized literature review on the association between motor vehicle travel time and distance and weight status in adults

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Competing interests

The authors have no competing interests to declare.

Author's contributions

GRM conceived the study. GRM and JSV contributed to the methodology, conducted the study, interpreted the findings, and drafted the manuscript. All authors approved the final draft.

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ABSTRACT

Background: Higher levels of sedentary behavior are associated with adverse health outcomes. Over-reliance on private motor vehicles for transportation is a potential contributor to the obesity epidemic. The objective of this study was to review evidence on the relationship between motor vehicle travel distance and time and weight status among adults.

Methods: Keywords associated with driving and weight status were entered into four databases (PubMed, Medline, Transportation Research Information Database, and Web of Science) and retrieved article titles and abstracts screened for relevance. Relevant articles were assess their eligibility for inclusion in the review (English-language articles, a sample ≥16 years of age, included a measure of time or distance travelling in motor vehicle and weight status, and estimated the association between driving and weight status).

Results: The database search yielded 2781 articles, from which 88 were deemed relevant and 10 studies met the inclusion criteria. Of the 10 studies included in the review, 8 found a statistically significant positive association between time or distance travelled in a motor vehicle and weight status.

Conclusions: Multilevel interventions that make alternatives to driving private motor vehicles more convenient, such as walking and cycling, are needed to promote healthy weight in the adult population.

Keywords: physical activity; driving; obesity; weight; transportation; motor vehicle

BACKGROUND

The prevalence of overweight and obesity continues to increase globally (Organisation for Economic Co-Operation and Development, 2012, Flegal, et al., 2010, Malik, et al., 2013). The treatment and management of overweight and obesity as well as resulting chronic diseases (i.e., cardiovascular disease, hypertension, diabetes, cancers, depression) incurs a significant health and financial burden on individuals and societies (Anis, et al., 2010, Tsai, et al., 2011). Reductions in workplace, leisure-time, and transportation-related physical activity combined with the consumption of high caloric nutrient poor diets have been implicated as determinants of the obesity epidemic (French, et al., 2001, Hill and Peters, 1998). Recently however, research has focussed on sedentary behavior, independent of physical activity, as a determinant of weight status and poor health (Owen, et al., 2010). Higher levels of sedentary behavior (e.g., television, computer use and video gaming, driving motor vehicles) are associated with an increased risk of cardiovascular disease (Aadahl, et al., 2007), hypertension (Jakes, et al., 2003), type II diabetes (French, et al., 2001), and obesity (Jakes, et al., 2003). The adverse effect of sedentary behavior on the cardio-metabolic system may also increase the risk of premature mortality (Owen, et al., 2010, Florez Pregonero, et al., 2012). Therefore, population-level interventions that decrease sedentary behavior while increasing physical activity are needed to reduce the risk of chronic diseases and overweight and obesity (Owen, et al., 2010).

Owen et al. (2010) suggest that sedentary behavior may have its own individual-level and environmental determinants, other than those that have been associated with physical activity. "Sedentary" behavior however, captures different types of low-intensity activities that are often undertaken within different contexts (i.e., at home, workplaces, inside motor vehicles). Similar to the built environment-physical activity literature where associations between neighborhood walkability and transportation versus walkability and recreational walking are more consistent (Saelens and Handy, 2008), it is likely that there is specificity in the types of contexts that directly influence participation in certain sedentary behaviors (Giles-Corti, et al., 2005). Focussing on context-specific sedentary behavior may provide insight about specific policies and interventions necessary to discourage such activities – for example driving private motor vehicles. In particular, driving behavior is a sedentary behavior that is undertaken outside the home and might be influenced by urban and transportation planning and policy as well as

economic and regulatory factors (i.e., commodity prices, competing transportation mode costs, and utility) to a greater extent than other sedentary behaviors. The saturation of car ownership and driving behavior within countries such as the US, Canada, and Australia where rates of obesity are also higher compared with less auto-dependent European countries (Bassett, et al., 2011) suggests that driving is an opportunistic target for population health interventions, whereby small reductions in unhealthy behavior over a large proportion of the population could offer significant positive health benefits (Kindig and Stoddart, 2003, Hawe and Potvin, 2009).

Findings from studies on work-related health suggest that occupations where the primary duties include operating a motor vehicle (e.g., bus, train, taxi drivers) are associated with a higher risk of adverse health outcomes including overweight and obesity compared with occupations that involve no or limited operation of a motor vehicle (Caban, et al., 2005, Rosengren, et al., 1991). Some evidence from ecological studies suggest a negative relationship between obesity prevalence and reliance on active transportation (Bassett, et al., 2011) as well as gasoline prices (Rabin, et al., 2007) might exist, while counter-intuitive associations such that lower prevalence of obesity has been found in European countries with higher counts of auto-oriented infrastructure (i.e., density of motorways and proportion of pave roads) and total passenger cars (Rabin, et al., 2007). Moreover, other research has focussed on examining whether transportation mode choice is associated with health and weight-related outcomes with mixed results (Lindstrom, 2008, Wanner, et al., 2012). Linstrom (2008) for example, found that men and women commuting to work by car were more likely to be overweight compared with those commuting by walking/bicycling. Equivocal findings for an association between motor vehicle ownership and risk of overweight and obesity (Parra, et al., 2009, Giles-Corti, et al., 2003) have been found, although in some cases motor vehicle ownership may reflect socioeconomic status and not only sedentary behavior. Evidence to date suggest that associations between driving behavior and weight status exist, however; the extent to which driving time and distance are consistently associated with adult weight status has not been investigated. The objective of this study was to undertake a systematized literature review of quantitative studies estimating the relationship between motor vehicle driving distance and time and weight status among adults.

METHOD

Database search and study inclusion

Four databases including PubMed, Medline, Transportation Research Information Database (TRID), and Web of Science were searched for all years up to March 2014. Keyword search terms associated with driving behavior (i.e., motor vehicle, automobile, and driving) and weight status (i.e., obese, obesity, waist circumference, weight, body mass index, and body composition) were entered into the databases. The majority of initial articles were found via the Web of Science and TRID databases (Figure 1). Excluding duplicates, the search yielded n=2781 articles. The researchers independently screened titles and abstracts to identify relevant peer-reviewed articles based on their content and type (i.e., literature reviews, commentaries, and editorials were excluded). The initial screen of abstracts yielded n=88 articles to undergo a full-text review (Figure 1).

The researchers independently assessed the n=88 articles for eligibility. Retained articles included those that were written in English, included a sample ≥16 years of age, quantitative studies, included a self-reported or objectively-assessed measure of driving time or distance (either as primary driver or passenger of a private motor vehicle), included a self-reported or objectively-assessed measure of weight status, and estimated the association between driving behavior and weight status. Studies that measured frequency of transportation mode or driving behavior only were excluded. Based on consensus, n=10 studies met the eligibility criteria and underwent data extraction and analysis (Figure 1). The reference lists of these articles were also screened for additional relevant studies not identified in the search however, none were found.

Data extraction and analysis

Data from each article were extracted, summarized, and tabulated. Extracted data included study design, sample size, participant characteristics, description of weight status measures, description of driving behavior measures, statistical analysis, adjustment for confounding variables, and findings. The summary table facilitated the comparison and contrast of the study methods, findings, and validity across studies. Given the heterogeneity in study and sample designs, measures of driving and weight status, and statistical estimates used, a meta-analysis was not conducted.

RESULTS

Study background characteristics

Among the ten studies reviewed, six were undertaken in United States (US) and the remainder undertaken in the United Kingdom (UK), Spain, Columbia, and Canada (Table 1). The study designs consisted of seven cross-sectional (Florez Pregonero, et al., 2012, Frank, et al., 2010, Frank, et al., 2004, Goodman, et al., 2012, Swanson and McCormack, 2012, Jilcott, et al., 2011, Yang and French, 2013), two longitudinal/ecological (Behzad, et al., 2012, Jacobson and King, 2009), and one prospective cohort study (Nunez-Cordoba, et al., 2013). All but two studies reported recruitment of participants using probability sampling – Nunez Cordoba et al. (2013) recruited a purposive sample of university students while Jilcott (2011) recruited women from a Department of Social Services waiting room area. Response rates among studies reporting estimates ranged from 16% (Goodman, et al., 2012) to 85.5% (Nunez-Cordoba, et al., 2013). The age of participants sampled in most studies was ≥18 years of age and included adults across the lifespan, with one study including those 16 years of age and older (Frank, et al., 2004). One study however, focused on the relationship between driving behavior and weight status among older adults only (≥50 years of age) (Frank, et al., 2010). All but one study samples included both men and women (Jilcott, et al., 2011).

Measurement of driving behavior

Most studies included a measure of self-reported driving behavior. Driving distance and time were commonly captured over a period of a day (Frank, et al., 2010, Frank, et al., 2004, Jilcott, et al., 2011, Yang and French, 2013), week (Florez Pregonero, et al., 2012, Goodman, et al., 2012, Swanson and McCormack, 2012), or year (Behzad, et al., 2012, Jacobson and King, 2009, Nunez-Cordoba, et al., 2013). While not specifying how data were originally captured, Jacobson et al. (2009) and Behzad et al. (2012) used existing US transportation data on vehicle miles travelled (VMT) per licensed driver (LD). Total driving behavior was usually examined – combining time or distance of driving undertaken for discretionary and non-discretionary purposes. Frank et al. (2004), although relying on self-report travel diary data, used geographical information systems to estimate the expected car travel time between reported origins and destinations using the spatial network data. Their estimates of car travel time took into account time of day and travel direction. Yang and French (2013) included self-reported minutes of

driving time as well as the proportion of total traveling and commuting time spent in a motor vehicle. One study only (Nunez-Cordoba, et al., 2013) provided evidence of reliability or validity for their measures of driving time or distance.

Measurement of weight status

Similar to driving behavior, most studies captured self-reported anthropometric measures, in particular height and weight. However, two studies did include objective-assessment of respondent weight status (e.g., weight, height, waist circumference, and abdominal obesity) measured by trained personnel (Florez Pregonero, et al., 2012, Jilcott, et al., 2011). All studies included a continuous (Jilcott, et al., 2011, Yang and French, 2013, Behzad, et al., 2012, Jacobson and King, 2009) or categorical (Florez Pregonero, et al., 2012, Frank, et al., 2010, Frank, et al., 2004, Goodman, et al., 2012, Swanson and McCormack, 2012, Yang and French, 2013, Nunez-Cordoba, et al., 2013) measure of body mass index (BMI; weight/height^2).

Associations between driving behavior and weight status

To estimate the association between driving behavior and weight status and to adjust for measured covariates, all studies used regression techniques. Four studies used binary or polytomous logistic (Florez Pregonero, et al., 2012, Frank, et al., 2010, Frank, et al., 2004, Swanson and McCormack, 2012), four used linear (Goodman, et al., 2012, Jilcott, et al., 2011, Yang and French, 2013, Jacobson and King, 2009), one used ridge and partial least squares (Behzad, et al., 2012), and one used cox regression (Nunez-Cordoba, et al., 2013). The measured covariates included in the regression models estimating associations between driving behavior and weight status varied across studies. Two studies adjusted for diet (Behzad, et al., 2012, Nunez-Cordoba, et al., 2013), six adjusted for physical activity or physical fitness (Florez Pregonero, et al., 2012, Frank, et al., 2010, Frank, et al., 2004, Goodman, et al., 2012, Swanson and McCormack, 2012, Nunez-Cordoba, et al., 2013), one adjusted for other sedentary behavior (Nunez-Cordoba, et al., 2013), three adjusted for built environment or neighborhood characteristics (Frank, et al., 2010, Frank, et al., 2004, Yang and French, 2013), and all but one study (Behzad, et al., 2012) adjusted for sociodemographic characteristics.

Of the ten studies reviewed, eight (Florez Pregonero, et al., 2012, Frank, et al., 2004, Goodman, et al., 2012, Swanson and McCormack, 2012, Yang and French, 2013, Behzad, et al., 2012, Jacobson and King, 2009, Nunez-Cordoba, et al., 2013) reported evidence for a statistically significant positive association between driving behavior and weight status. In contrast, Frank et al. (2010) found no association between daily car travel time and the likelihood of being overweight versus not overweight among older adults (≥65 years of age), while Jilcott et al. (2011) found no association between average motor vehicle travel time or distance and objectively-determined BMI in a sample of women. Several studies also found some unexpected associations. Nunez-Cordoba et al. (2013) found an increase in the overweight or obesity among students whose travel distance by car remained stable. Florez Pregonero et al. (2012), despite excluding car owners from their sample, found a positive association between weekly time spent travelling in a motor vehicle among men, but not among women. Furthermore, Swanson and McCormack (2012) found a positive association between weekly driving time and the likelihood of being overweight versus not overweight however, they also found that those who drove ≥1680 minutes per week were less likely to be obese than those driving <210 minutes/week. Despite some unexpected findings, there appears to be consistent published scientific evidence showing that higher levels of driving, measured either as time or distance spent travelling in a motor vehicle, is adversely associated with weight status among adults.

DISCUSSION

This review identified ten studies that have quantified the relationship between driving time and distance and weights status in an adult population. Eighty percent of these studies present some evidence suggesting that higher levels of driving behavior, regardless of operational definition (time or distance spent travelling in a motor vehicle) is associated with a higher risk of adverse weight status. This finding supports related research showing that higher levels of motor vehicle ownership (Parra, et al., 2009, Bell, et al., 2002) and frequency of car use (Sugiyama, et al., 2013, Hess and Russell, 2012) are associated with an increased risk of overweight and obesity as well as some studies that report higher levels of overweight and obesity in auto-oriented neighborhoods versus pedestrian-oriented neighborhoods, where driving behavior is more convenient (Frank, et al., 2007, Coogan, et al., 2011).

Despite the apparent negative contribution that driving motor vehicles has on weight status, the extent to which "car culture" is ingrained into the mindset of modern society could pose challenges to encouraging adults to reduce their reliance on private motor vehicles. Moreover, encouraging adults to replace motor vehicle trips with active transportation modes (i.e., walking and cycling) may be even more challenging when trying to promote active travel behavior among residents of auto-oriented neighborhoods. Community-wide interventions targeting individual-level travel attitudes, beliefs, and behaviors (e.g., personalised travel feedback programs and marketing campaigns (Fujii, et al., 2009, Maibach, et al., 2009)) combined with changes to policy that result in the creation of more supportive pedestrian and cycling environments at regional and local scales, may be necessary to obtain significant and long-term changes in active travel behavior. This multilevel approach could also include health professionals in clinical settings educating patients or clients about the health risks associated with excessive motor vehicle driving (as well as other sedentary behavior), in the same way health professional discuss with their clients the benefits of healthy diets, physical activity, smoking cessation, and stress reduction. A recent review of intervention case-studies found that implementation of comprehensive (multilevel) interventions was successful in increasing cycling trips and cycling mode share (Bassett, et al., 2011). Furthermore, higher levels of active transportation in general are associated with higher levels of physical activity and lower body weight (Wanner, et al., 2012).

Consistent support for the association between higher amounts of driving (time and distance) and adverse weight status was found among studies included in our review, however, it should be noted that the majority of these studies were cross-sectional. Longitudinal evidence was mixed – one study found a positive association between annual national estimates of motor vehicle miles per licensed driver travelled and BMI (Behzad, et al., 2012) while another reported an increase in overweight/obesity among individuals whose self-reported distance traveling in a motor vehicle (>20,000km/year) did not change over time (Nunez-Cordoba, et al., 2013). The lack of longitudinal evidence limits our understanding with regard to the causal relationship between driving behavior and weight status. Furthermore, the longitudinal findings that do exist for the most part have relied on ecological or aggregated data – meaning that results cannot be generalized to individuals.

It is plausible that weight status informs the decision to drive. For instance, Goodman et al.'s (2012) path model posited weight status along with other characteristics as determinants of active travel, motorized travel, car engine size, and transport-related CO_2 emissions. The relationship between driving and weight status might also be influenced or mediated by other factors (e.g., diet, physical activity, socioeconomic status). Additional analysis undertaken by Yang and French (2013), although not specifically focussing on motor vehicles, did show significant negative associations between time spent traveling for commuting and non-commuting trips and time spent cooking, eating, exercising, participating in leisure and sleeping. Among women receiving Supplemental Nutrition Assistance, Jilcott et al. (2011) found that minutes travelling by motor vehicle was positively associated with frequency of fast-food consumption, controlling for age and employment status, while Frank et al. (2010) found that taking a recent trip to a fast food destination increased the odds of obesity among older adults. Prospective research evidence suggests that higher fast-food consumption is associated with increased caloric intake and higher BMI (Rosenheck, 2008). Mixed associations between driving behavior and physical activity have also been found (Swanson and McCormack, 2012, Jilcott, et al., 2011). Thus, the findings of our review together with previous evidence suggest that that relationship between driving behavior and weight status is complex and that driving behaviour may have direct and indirect influence on weight status (Yang and French, 2013). An example of this complexity is explicitly shown in one study in our review (Florez Pregonero, et al., 2012) where time spent driving in motor vehicles was adversely associated with weight status among those who did not own a car. Intervention and longitudinal studies are needed to better understand this relationship; in particular those which examine contribution of time or distance spent travel my different modes of motorized travel (e.g., car versus public transport).

Despite significant associations between driving behavior and weight status these findings are for the most part estimated using self-reported data, and more importantly lacked any assessment for reliability and validity. Self-reported measures of weight status are known to be inaccurate and biased (Villanueva, 2001). Inaccurate reporting of driving behavior is also likely (Stopher, et al., 2007). More reliability and validity testing of items capturing self-reported time and distance spent travelling in motor vehicles is needed, especially as this is a common approach for

measuring driving behavior in larger surveys. Alternatively, objective-measurement of driving behavior (as well as weight status) could be used; for example, reporting the distance and time spent traveling during a defined period that is recorded by the motor vehicle's instruments (during the last week, month, year etc.). It is also possible to use global position satellite units connected to the motor vehicle to track travel (time, speed, and geographical location). Travel diaries that capture origins and destination, trip purpose, mode of travel, and time of day information for use in the generation of expected travel times might be more useful when travel behavior by different modes is of interest to the researcher (Frank, et al., 2004). More research is needed on the development of reliable and valid measures of driving behavior.

This review has several limitations. Despite taking a systematic approach, it is possible that some relevant and eligible studies were not included in this review (e.g., unpublished or non-peer reviewed evidence). Systematized reviews include some, but not all, characteristics of systematic reviews and are particularly useful when there is diversity in study methodologies and designs within a given topic. Thus in our review, we did not include a formal validity/quality assessment of the included studies, but rather, narratively described the strengths and limitations of studies. Moreover, our focus on studies including adult samples only means that we cannot draw conclusion regarding the relationship between time or distance travelled in motor vehicles and weight status in other populations (e.g., children). Speculatively, levels of motor vehicle use might have a great impact on the weight status of specific subpopulations (e.g., low income, age groups); these relationships are yet to be explored. Our review focussed on studies that examined time or distance travelled in a motor vehicle, however; other characteristics of this behavior such as frequency of trips and travel mode share, might also be important predictors of weight status (Sugiyama, et al., 2013, Hess and Russell, 2012). Publication bias cannot be ruled out and therefore it is possible the studies included in this review over-represent the negative impact driving has on weight status in adults.

The fact that consistent associations between driving behavior and weight status have been found across multiple studies with diverse methodological approaches is encouraging. Similar to other types of sedentary activity (Thorp, et al., 2011), time and distance spent travelling in motor vehicles appears to be positively associated with risk of overweight and obesity in adults.

However, intervention and longitudinal research that include individual-level analysis is needed to draw stronger causal inferences regarding this relationship. Moreover, a better understanding of the direct and indirect pathways by which driving behavior affects weight status could inform intervention efforts to reduce driving and promote healthy weight. Multilevel comprehensive interventions that make driving a less convenient travel choice while making active transportation, in particular walking and cycling, an attractive and convenient travel option are needed to promote healthy weight in adults.

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Table 1. Associations between motor vehicle driving time and distance and weight status from the studies reviewed (n=10)

Author(s)	Study Design	Sample Recruitment and Response Rate (RR) Where Available	Sample Characteristics including Gender, Age, and Car Ownership	Driving Behavior Variables	Weight Status Variables	Analysis and Confounding Variables	Findings
Behzad et al. (2012)	Longitudinal/ecological US, 1970-2010	Sample design and recruitment not reported. Included a secondary analysis from multiple data sources	≥18 yrs of age	Self-reported data collected from US Federal Highway Administration, annual mean number of non-commercial motor vehicle and motorcycle miles travelled per year per licensed drivers (from 1970-2009)	Self-reported data from Behavioral Risk Factor Surveillance System (BRFSS); national average BMI (1984-2010)	Ridge and partial least squares regression Confounders: Diet	National average BMI was significantly associated (+) with motor vehicle miles per licensed driver travelled per year. β=0.58 (p<.05)
Pregonero et al.	Cross-Sectional, Columbia, 2005,	Recruited: n=7900, Analytic sample n=7622. Secondary analysis of data from the National Nutrition Survey of Columbia (response rate not reported)	18-64 yrs of age (mean: 32.9±13.1), 62.2% female. Non-owners of motor vehicles only.	Self-reported time spent travelling in motor vehicles per week (TSTMV) categorized as: <10 min, 10-149 min, and ≥150 min/wk.	Objective data collected using trained personnel; a) waist circumference (WC) (Abdominal obesity (AO)) b) BMI categories ((normal or underweight), overweight, obesity)	Polytomous logistic and binary logistic regression Confounders: Socio-demographics, PA behavior	For men only, TSTMV 10-149min and ≥150 min/wk was significantly associated (+) with being overweight (OR 158 and 155, respectively) and obese (OR 2.39 and 1.93, respectively) and abdominal obesity (OR 1.81 and 1.73, respectively) compared with those TSTMV <10min/wk.
Frank et al. (2010)	Cross-Sectional, Atlanta, Georgia, US, 2001-2002 (SMARTRAQ Study)	Random sample. Recruited: n=1970 (response rate not reported).	≥65 yrs of age. 56.3% female. 61.4% owned ≥2cars	Self-reported time travelling in a car (<1hr/day vs. ≥ 1hr/day)	Self-reported BMI (categorized as healthy weight, overweight, obese)	Binary logistic regression Confounders: Socio-demographics, PA behavior, built environment, physical fitness and health	Driving for more than 1 hr/ day was not associated with being overweight or obese.
Frank et al. (2004)	Cross-Sectional, 13 counties, Atlanta, Georgia, US, 2000 and 2002	Random sample. Households selected based on net residential density of neighborhood. Recruited: n=10,878 (RR=30.4%)	16-99 yrs of age. 46% male	Expected time spent travelling by car (minutes per day) estimated (GIS) from the shortest distance between origin and destinations captured from a travel diary	Self-reported BMI (categorized as obese or not obese)	Logistic regression Confounders: Socio-demographics, PA behavior, built environment, physical fitness and health	Expected estimated car time minutes per day was significantly associated (+) with obesity (OR=1.001).
Goodman et	Cross-sectional,	Random sample	18-69 yrs of age	Self-reported motorized travel	Self-reported in BMI	Linear regression	Motorized travel distance per

al. (2012)	Cardiff, Kenilworth and Southampton, UK, 2010 (iConnect study)	Recruited: n=3516 (RR=16%) Analytic sample: n=3463	45% male	distance and time per week for different purposes (for work, education, business, personal, social, leisure activities)	(categorized: healthy weight, overweight, obese)	Confounders Socio-demographics, PA behavior	week was significantly higher among those categorized as overweight (β=0.15) and obesity (β=0.16) compared with those healthy weight.
Jacobson et al.(2009)	Longitudinal/ Ecological, US, 1985-2007	Sample design and recruitment not reported. Included a secondary analysis from multiple data sources.	≥18 yrs of age	Statistical data from annual National Transportation Statistics (1990-2007) and Highway Statistics (1985-1989); annual noncommercial vehicle miles traveled (VMT) per licensed driver (LD)	Self-reported BMI from Behavioral Risk Factor Surveillance System (BRFSS) (1995-2007); annual national prevalence (%) of obese adults	Linear regression Confounders: Socio-demographics	VMT per LD was significantly associated (+) with obesity rates. From lag yrs 0-10 each 1000 miles VMT per LD per year was associated with an increase in annual % obese (β ranged from 8.433-4.076).
Núñez-Córdoba et al. (2013)	Prospective Cohort, Spain, 1999-2011 Seguimiento Universidad de Navarra (SUN) Project	Non-random sample. Drawn from Spanish University graduates. Recruited: n=9361 (RR=85.5%)Analytic sample: n=9160	Mean age 36.9 yrs 57.6% women	Self-reported annual distance traveled in km (≤10,000, >10,000 to ≤20,000, and >20,000) by motor vehicles.	Self-reported BMI from a postal questionnaire (categorized: overweight or obese or not)	Cox regression (with overweight/obese cases at baseline excluded from analysis) Confounders: Socio-demographics, diet, PA behavior, sedentary behavior, physical fitness and health, other health behavior	An increase in annual motor vehicle travel distance was not associated with overweight/ obesity, but those consistently reporting high levels of driving over time (i.e., >20,000km/yr) was associated (+) with overweight/obesity (HR 1.34) compared with those consistently driving <10000 km/yr)).
Swanson & McCormack (2012)	Cross-sectional, Calgary, Alberta, Canada, Aug-Oct 2007	Random sample. Recruited: n=2199 (RR=33.6%). Analytic sample: n=1026	18-93 yrs of age (mean 50.9±15.5) 63.2% female 85.5% that always have car access	Self-reported total time per week spent driving in a motor vehicle from a postal questionnaire	Self-reported BMI from a postal questionnaire (categorized: healthy weight, overweight or obese)	Binary logistic regression Confounders: Socio-demographics, PA behavior	Weekly driving time was significantly associated (+) with being overweight/obese and obese. Overweight/obesity more likely among those driving 840-1679 (OR 2.08) and ≥1680min/wk (OR 1.30) versus driving <209.Obesity more likely among those driving 840-1679 (OR 2.35) and less likely among those driving ≥1680min/wk (OR 0.42) versus driving <209

							min/wk.
Jilcott et al.(2011)	Cross-sectional, Pitt County, North Carolina, US, October 2009-April 2010	Non-random sample. Volunteers from Department of Social Services waiting area. Recruited: n=215	20-64 yrs of age 100% female	Self-reported time and distance spent in vehicular travel on average weekday and weekend day from face-to-face interviews.	Objective data collected by the interviewer (BMI)	Pearson correlations Confounders: Sociodemographics	Estimates were not provided but authors noted: "Neither travel time nor travel distance was significantly associated with BMI."
Yang & French (2013)	Cross-Sectional Us, 2003-2008	Random sample: n=73 810, Analytic sample n=16 604. Secondary analysis of data from the American Time Use Survey (ATUS) (response rate not reported)	No sample characteristics listed for the overall sample. For a subsample of overweight/obese participants: 35.1% ≥50 yrs 55.8% female	Self-reported total time travelled in a motor vehicle in past 24-hours captured from the ATUS (2003-2008).	Self-reported BMI from Eating and Health Modules in the ATUS (2006-2007).	Pearson correlations and multivariate linear regression Confounders: Sociodemographics	Motor vehicle time travelled and BMI were significantly correlated (+). Among overweight and obese individuals only reporting a high percentage of travel time in a motor vehicle was significantly (+) associated with BMI (β=0.74). The percentage of commuting time spent in a vehicle was also (+) associated with BMI (β=1.35)

POR=prevalence odds ratio; OR=odds ratio; BMI=body mass index; HR=hazard ratio; SD=standard deviation; PA=physical activity; β=regression coefficient; (+) positive association; (-) negative association. Significant associations included those estimates where p<.05 and or where confidence intervals for estimates did not include 1.

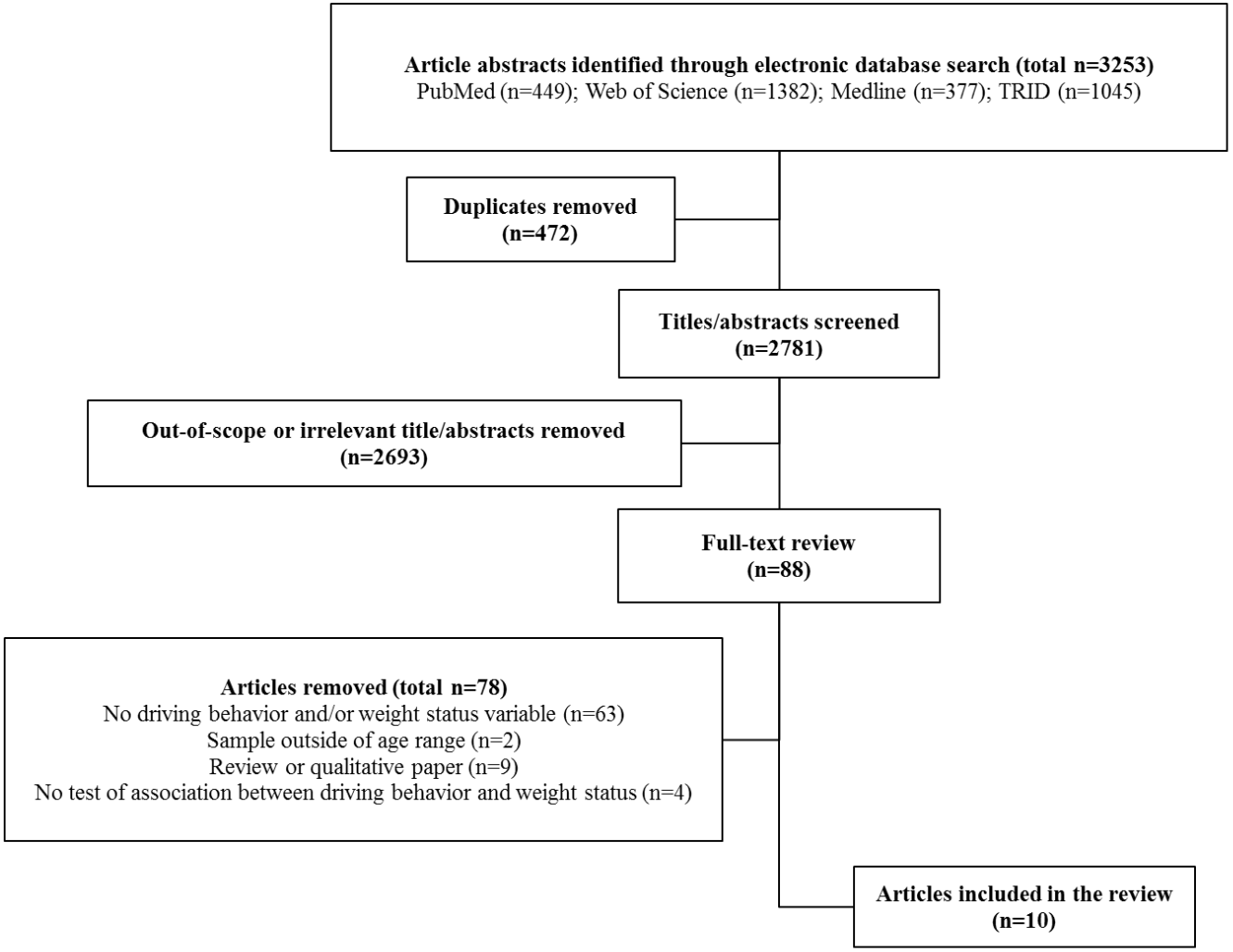

Figure 1. Flow chart showing the article selection process