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A Difference-in-Difference Study Evaluating the Effect of Minimum Wage Policy on Body Mass Index and Related Health Behaviors

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Abstract

Minimum wage laws are a promising policy lever to promote health equity, but few rigorous evaluations have tested whether and how minimum wage policy affects health outcomes. This paper describes an ongoing difference-in-difference study evaluating the health effects of the 2017 Minneapolis Minimum Wage Ordinance, which incrementally increases the minimum wage to $15/hr. We present: (1) the conceptual model guiding the study including mediating mechanisms, (2) the study design, (3) baseline findings from the study, and (4) the analytic plan for the remainder of the study. This prospective study follows a cohort of 974 low-wage workers over four years to compare outcomes among low-wage workers in Minneapolis, Minnesota, and those in a comparison city (Raleigh, North Carolina). Measures include height/weight, employment paystubs, two weeks of food purchase receipts, and a survey capturing data on participant demographics, health behaviors, and household

finances. Baseline findings offer a profile of individuals likely to be affected by minimum wage laws. While the study is ongoing, the movement to increase local and state minimum wage is currently high on the policy agenda; evidence is needed to determine what role, if any, such policies play in improving the health of those affected.

Keywords: Minimum wage, difference-in-difference, obesity

1. Introduction

Income is recognized as a fundamental determinant of health (Berkman et al., 2014; Marmot, 2002). While minimum wage policy has long been discussed as a mechanism for raising income and alleviating poverty (Leigh, 2018), it is increasingly cited as a potential policy lever to promote population health and improve health equity (Berenson et al., 2017; Leigh, 2016, 2018; Rigby and Hatch, 2016; Robert Wood Johnson Foundation, 2017). Studies have reported that higher wages are associated with a range of positive health measures, including decreased smoking (Horn et al., 2017), improved birth outcomes (Bhatia and Katz, 2001; Komro et al., 2016; Wehby et al., 2016), and fewer premature deaths (Bhatia and Katz, 2001; Tsao et al., 2016). A surge of recent analyses demonstrate emerging multidisciplinary interest in evaluating the health effects of minimum wage (Leigh et al., 2019).

Minimum wage policies have the potential to improve health equity because they especially benefit groups who carry a disproportionate burden of health risks (Centers for Disease Control and Prevention, 2013), including low-income households and racial/ethnic minorities. Obesity is a health outcome that affects 36.5% of U.S. adults, and is especially prevalent among non-Hispanic black and Hispanic populations (Centers for Disease Control and Prevention, 2013; Krueger and Reither, 2015). As an upstream determinant of health, the minimum wage could affect a number of plausible obesity-related mechanisms even though it is not specifically designed to address obesity. For example, increases in minimum wage could improve food security, remove barriers to purchasing healthier foods, and reduce the reliance on inexpensive foods that are energy-dense but nutrient-poor (Drewnowski and Eichelsdoerfer, 2010).

Currently, there is no consensus on the relationship between wages and obesity or body mass index (BMI), including the causal direction and the dynamics (positive or negative) of a putative effect. Regarding directionality, a "wage penalty" for excess weight may affect those who are obese; alternately, higher wages might offer living conditions and promote behavioral patterns that result in a healthier weight. Regarding dynamics, most studies (Clark et al., 2020; Kim and Leigh, 2010; Meltzer and Chen, 2009), but not all (Andreyeva and Ukert, 2018), have reported that an increase in minimum wage is associated with a decrease in BMI. However, existing studies linking wages and weight have design weaknesses that limit causal inference and the ability to identify causal mechanisms. Major limitations among these studies are that they rely on self-reported weight outcomes, use proxy measures like education status to approximate the likelihood of being affected by minimum wage increases, and/or use annual income as a proxy for wages without regard to hours or weeks worked (Leigh et al., 2019).

Meanwhile, since 2012, dozens of ordinances in local jurisdictions have increased minimum wage above state levels (UC Berkeley Labor Center, 2020). Half of U.S. states will raise their minimum wage in 2020 (National Employment Law Project, 2019). In the midst

of a groundswell of new minimum wage policies, continued increases in U.S. adult obesity rates, and known disparities in obesity by socioeconomic status, a prospectively designed difference-in-difference (DID) study offers the potential to examine whether and how a minimum wage increase results in healthier weight-related outcomes among low-wage workers.

The purpose of this paper is to describe an ongoing study evaluating minimum wage policy as a determinant of body mass index (BMI) and obesity-related health behaviors. This prospective study tests whether and how an increase in minimum wage results in improved obesity-related outcomes among low-wage workers, by comparing low-wage workers in two different cities, one of which experienced an increase in the minimum wage and the other of which did not. This paper will also present: (1) the conceptual model guiding the study, including potential mechanisms linking minimum wage policy and obesity, (2) the prospective study design evaluating the Minneapolis Minimum Wage Policy on low-wage worker health; (3) descriptive findings (wages, demographics, mediators, and obesity-related outcomes) of low-wage workers in this study; and (4) the analysis plan for the assessment of the study endpoints. We conclude with a discussion of what this study adds over existing studies to the literature on minimum wage health effects.

2. Methods

2.1 Study Design

The WAGE$ study is funded by the National Institutes of Health and follows a cohort of low-wage workers to evaluate the health effects of the Minneapolis Minimum Wage Ordinance, which incrementally increases minimum wage to $15 using a phased implementation. Workers likely to be affected by the ordinance in Minneapolis, Minnesota (MN), and those in a comparison city (Raleigh, North Carolina (NC)), were enrolled in the study in 2018 and are being followed over four years, in which minimum wage will increase from $10 to $15 for large business and from $7.75 to $13.50 among small businesses in Minneapolis. Unlike the quasi-experimental research design in a number of recent minimum wage studies based on publicly available data (Andreyeva and Ukert, 2018; Wehby et al., 2016) this study was designed around the implementation of the minimum wage legislation in one of the two matched samples. This study is among the first to collect rigorous individual-level measures of wages, obesity, and potential confounding, moderating, and mediating variables.

The specific aims of the study are to test the effect of the minimum wage ordinance on: (1) change in BMI over the study period (the primary study endpoint); (2) change in the other nutrition-related outcomes, including purchasing healthier foods, food insecurity, and participation in government-supported food assistance programs (secondary study endpoints); and (3) change in other possible mechanisms through which wages might affect obesity (mediators). An exploratory aim is to analyze changes in household health-related expenses over time including (but not limited to) food, healthcare, housing, transportation and recreation.

Specific hypotheses that the study will test are: (H1) BMI changes among low-wage workers in Minneapolis will be more favorable (e.g., increase less) than BMI changes in low-wage workers in the control city; (H2a-2c) purchasing of healthier foods will increase to a greater extent than purchasing of less healthy foods, while food assistance program participation and food insecurity will decrease among the cohort of low-wage workers in

Date	**Large business ($>$ 100 employees)**	**Small business ($\leq$ 100 employees)**
Before Jan. 1, 2018	$9.50	$7.75
Jan. 1, 2018	$10	No increase
July 1, 2018	$11.25	$10.25
July 1, 2019	$12.25	$11
July 1, 2020	$13.25	$11.75
July 1, 2021	$14.25	$12.50
July 1, 2022	$15	$13.50
2023	Jan. 1: $15 indexed to inflation	July 1: $14.50
July 1, 2024	$15 indexed to inflation	$15 indexed to inflation

Table 1: Scheduled implementation of hourly wage increases in the City of Minneapolis.

Minneapolis compared to the control city; and (H3) the wage-obesity relationship will be mediated by one or more measured psychosocial or behavioral mediator, including stress, sleep, physical activity, and use of healthcare.

Participants recruited from the community in Minneapolis and Raleigh make annual visits to community locations, where research staff obtain height and weight, administer a survey, and record participants' paystub information. Data collection occurred at baseline in 2018 (T1) and will occur again after each Minneapolis wage increase, yearly from 2019 to 2022. After the in-person visit, participants collect, and submit to the research team, two weeks of receipts for their food expenditures at T1 and T5. Upon completion of data collection, DID analyses will compare changes in outcome measures in Minneapolis and Raleigh from T1 to T5.

2.2 The Minneapolis Minimum Wage Ordinance

On June 30 2017, the Minneapolis City Council passed the Minimum Wage Ordinance, following a succession of local ordinances in U.S. cities and counties (UC Berkeley Labor Center, 2020). The ordinance, which specifically states that its purpose was to "maintain worker's health, efficacy, and general well-being," incrementally increases the minimum wage (see Table 1). Employees are covered by the ordinance for all time worked within the geographic boundaries of the city of Minneapolis if at least 2 hours a week are worked. Affected employees do not include independent contractors, but do include part-time, joint, and temporary workers. The ordinance does not apply to federal or state employees. Employers cannot apply tips to the minimum wage. According to the ordinance, employer violations will result in backpay and reimbursement of other costs to the employee, as well as a civil penalty for the employer.

2.3 Conceptual Model

The study is guided by a conceptual model that outlines specific pathways potentially linking minimum wage policy and obesity-related health outcomes (Figure 1). Study instruments assess variables related to all concepts in the model. In most instances, the relationship

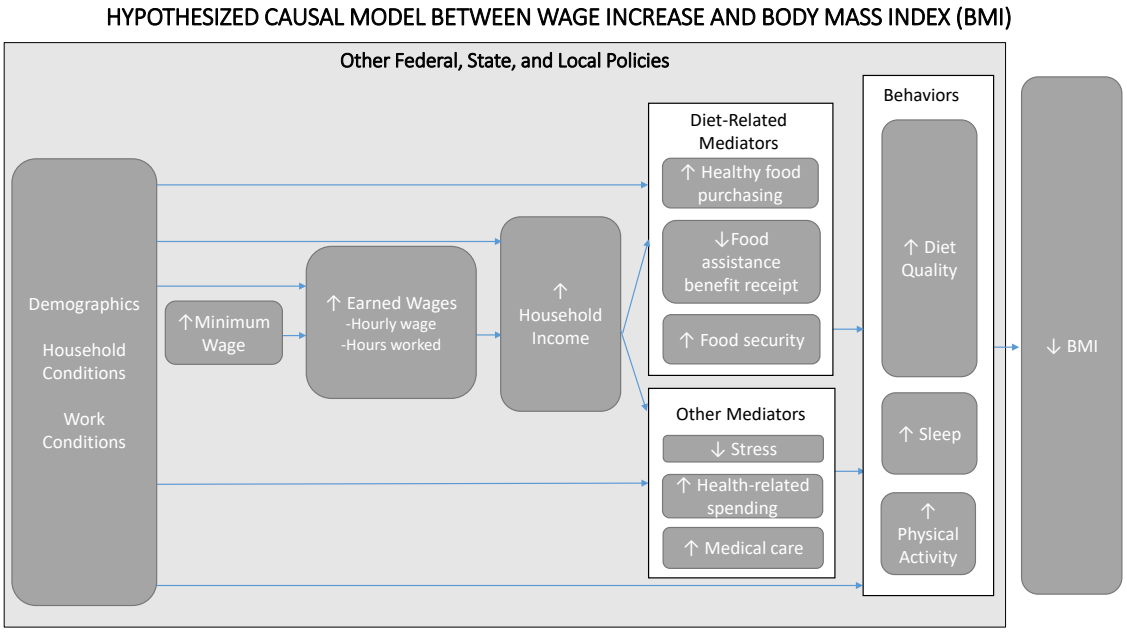

Figure 1: Hypothesized Causal Model Between Wages and Weight.

between these variables can be hypothesized from the available research, and suggests that minimum wage increases will result in health-promoting mediators and obesity-relevant health behaviors, ultimately resulting in a lower BMI. The proposed mediating pathways are plausible, but without strong evidence. For example, some research suggests that higher minimum wage reduces food insecurity (Rodgers, 2016), and other research suggests that food insecurity is associated with obesity, mostly among women (Dinour et al., 2007; Franklin et al., 2012). Though these factors have rarely been studied together, we hypothesize that a minimum wage increase will improve food security, which will result in healthier behaviors and a positive effect on weight. Other psychosocial and behavioral mechanisms, such as sleep, stress, physical activity, and poor preventive care could also plausibly be activated by an increase in wages among low-wage workers (Krueger and Reither, 2015; Levine, 2011; McGrail et al., 2009; Richardson et al., 2015; Swinburn et al., 2004).

Some mechanisms linking wages and obesity are likely to be complex, such as food assistance benefits. For every $1 increase in income, is has been estimated that food assistance benefits are reduced by $0.30 (West and Reich, 2014). In general, food assistance benefit use would be expected to result in healthier purchases by removing cost constraints, and yet the evidence to support this notion is mixed (Leung et al., 2012; Mabli et al., 2010; Popkin, 2017). Alternately, food assistance programs like the Supplemental Nutrition Assistance Program (SNAP) that are administered monthly could contribute to a cyclical "feast or famine" dietary pattern that increases obesity risk (Dinour et al., 2007). Changes in expenditures are also likely to be complex. Increasing food expenditures in low-income populations may result in improvements in diet quality (Mabli et al., 2010; Meltzer and Chen, 2009), but may also be allocated across competing necessities, such as housing,

transportation, and healthcare. Finally, the relationship between these variables is likely to be moderated by a number of demographic, household, and workforce factors unrelated to minimum wage, including baseline household composition (which could, for example, affect eligibility for social services) and job sector (which could affect behaviors like physical activity). The broader policy context could also modify the effect of the minimum wage policy positively or negatively. For example, local minimum wage ordinances could be enhanced by new sick leave policies; alternately, state-level minimum wage preemption laws could override local polices.

2.4 Selection of a Comparison Site

In identifying a control condition, the first step was to limit the possibilities to cities of similar size (within 50% of the total Minneapolis population), located in states with a minimum wage preemption law, to minimize the risk of a "crossover" to the intervention condition. We then identified the city that was the best match (within 25% of Minneapolis) on relevant demographics (median household income, four racial/ethnic categories, poverty, percent foreign born, percent with greater than a high-school degree, employment rate, total businesses, and median rent). Raleigh, NC emerged as the best candidate, matching on all criteria except the percent poverty and percent Black, and matching within 10% of Minneapolis on a number of key measures. Several other checks assessed whether Raleigh was an appropriate control site, including: (1) checking the parallel trends assumption for BMI over the previous 10-year period using Behavioral Risk Factor Surveillance System SMART data; (2) comparing the obesity rate, other cost of living measures, and common industries across cities; and (3) checking that the metropolitan areas demonstrated reasonably similar economic trends in relevant industries. Additional details about selection of the comparison site, including a comparison of site demographic indicators guiding the site selection, can be found elsewhere (Shanafelt et al., 2021).

The research team considered using a geographically contiguous control, as Minneapolis lies adjacent to its "Twin City," St. Paul. However, during study planning, St. Paul was considering adopting a similar ordinance, but the policy rules and implementation schedule were unknown; the ordinance has since passed and has begun implementation. Also problematic was the potential for spillover effects that could occur in a city neighboring Minneapolis, for example, if businesses with locations in both cities transferred a greater share of their operations to St. Paul or raised wages in St. Paul.

2.5 Participant eligibility and recruitment

For the purposes of the study, low-wage workers were defined as those likely to be affected by the minimum wage in Minneapolis and comparable workers in Raleigh. Participants were eligible if they: (1) were 18 years old or older, (2) worked at least 10 hours a week at a wage of less than or equal to $11.50/hour in Minneapolis/Raleigh OR were employed at that wage within the last six months and were currently seeking work in Minneapolis/Raleigh, (3) planned to serve in the workforce for at least five years, (4) could be contacted for follow-up, and (5) spoke English or Spanish. Participants were excluded if they were federal/state workers, full-time students, or planned to retire or move more than 100 miles away. Participants received a $70 incentive for completing all baseline study measures. Wage eligibility

was set at $11.50 an hour or less to capture workers earning up to 15% above the minimum wage at baseline, given that a rise in minimum wage can introduce a re-scaling of wages just above it (Dube, 2017). Including those who were unemployed at baseline but had been recently employed at low-wage jobs acknowledges that, within the labor market, low-wage workers form a sector characterized by low wages, high turnover, and job insecurity. These workers were considered likely to be affected by the minimum wage over its years-long implementation (Arai, 1997; Doeringer and Piore, 1975). Additional details about recruitment processes for participants can be found elsewhere (Shanafelt et al., 2021).

2.6 Measures

BMI. BMI is calculated as weight in kilograms/(height in meters)^2 with height and weight collected anthropometrically at baseline and each follow-up. Trained and certified research staff take measures in duplicate on a portable digital scale (Seca model) and portable Schorr stadiometer (Schorr Production, Olney, MD).

Wages and employment data. Paystubs or other employer documentation are requested at each visit for all current jobs. Employer name, address, employment start date, job titles, weekly hours worked during the past two weeks, and hourly salary are recorded by research staff. Job sector is subsequently coded according to the Bureau of Labor Statistics' guide to Standard Occupational Codes for job descriptions, and the North American Industry Classification System for employer sector. Codes are assigned at the four-digit (sub-sector) level if sufficient detail was provided, and coded at the two-digit (general sector) level otherwise. For participants who do not provide wage verification, employment information is self-reported, and the participant is asked to send paystub information.

Food Expenditures. At T1 and T5 participants are instructed to save and submit all household food purchase receipts (groceries, restaurants, carry out, and other food vendors) for two weeks. Participants use standardized protocols to collect and annotate food purchase receipts (Harnack et al., 2016). Forms for missing receipts are provided to help participants capture purchases without a receipt. The proportion of total spending on fruits and vegetables and the proportion of total spending on foods high in added sugars (specifically, sugar sweetened beverages, sweet baked goods, and candy) was calculated for each participant.

Survey measures. The survey assesses demographics (e.g., age, gender, race/ethnicity, education, household size). It also assesses diet-related mediators including Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) participation, monthly benefits from SNAP, food insecurity measured by the 6-item Household Food Security Survey Module, (United States Department of Agriculture, 2019), and an abbreviated 22-item Dietary Screener Questionnaire (National Cancer Institute, 2018). A 4-item physical activity measure (Paffenbarger et al., 1978), 2-item sleep measure (Gluck et al., 2001), and 4-item stress measure (Cohen et al., 1983) are also included. The survey includes 7 questions on healthcare utilization from the HHS Medical Expenditure Panel Survey (Agency for Healthcare Research and Quality, 2013). Questions about expenditures across 25 spending categories include mortgage or rent, public transit, exercise, healthcare, and medications (Hurd and Rohwedder, 2012).

2.7 Baseline Analysis Completed

Baseline characteristics were summarized using means and standard deviations, medians (25th percentile (Q1), 75th percentile (Q3)), and counts and percentages as appropriate. All analyses were performed using SAS software 9.4 (SAS institute Inc., Cary, NC).

2.8 Planned DID Analysis to Test Study Hypotheses

The planned analysis will use a DID design to detect whether there is a statistically significant difference in change in each outcome in the Minneapolis sample compared with the Raleigh sample from baseline (T1) to post-assessment (T5). We will use an intent-to-treat approach where each individual will be included in the analysis regardless of their ultimate employment status or their actual wage increase. An alpha level of 0.05 will be used to determine statistical significance in all tests. In preliminary analyses, we will conduct 2-sample t-tests to determine the balance of demographics and other covariates across the two cities. Models will be adjusted for appropriate individual and area-level confounders. For the primary endpoint, change in BMI units, we will test H1 using linear regression models to test the DID effect across the two cities, controlling for relevant covariates. We will use a model of the form

$$BMI_{(i,c,t)} = \lambda_c + \lambda_t + \delta D_{(c,t)} + \beta X_i + \epsilon_{(i,c,t)}$$

where λ_c is the city effect (Minneapolis vs. Raleigh), λ_t is the time effect in years, $D_{(c,t)}$ is the city-by-treatment interaction, δ is the treatment effect, βX_i captures the effects of adjustment covariates, and $\epsilon_{(i,c,t)}$. For the secondary endpoints (food expenditures, food insecurity, and participation in food assistance programs) we will test H2a-2c using a similar approach of linear and logistic regression modeling controlling for relevant covariates. For food expenditures, we will look at changes in the proportion of food expenditures used for healthy (e.g., fruits and vegetables) vs. less healthy (e.g., sugar-sweetened beverages) foods. For food insecurity, we will look at change in the proportion of households in our cohort that report having low or very low food security (i.e., they respond in the affirmative to more than 1 question on the 6-item module). We will also look at changes in participation rates of SNAP and WIC status (i.e., the proportion of our sample who participate in each, yes/no), as well as changes in SNAP benefit amounts (a categorical variable), which can vary depending on income and household size. Potential confounders likely to be included are age, sex, race/ethnicity, country of origin, employment sector, educational attainment, household size, pregnancy status, smoking status, health insurance status, the timing (in weeks) of the participant's data collection appointment relative to the minimum wage increase, and number of jobs worked. Likely area-level potential confounders to be included in our models are annual state Temporary Assistance for Needy Families (TANF) enrollment (percent of total recipients), state SNAP enrollment (percent of total recipients), annual state unemployment rate (annual average), and each city's annual Cost of Living Index, compiled by the Council for Community and Economic Research. We will use appropriate methods for time-varying confounders (such as employment sector or health insurance status) and time-invariant cofounders (such as race/ethnicity or country of origin) in order to minimize bias on our estimate of the effects of a wage increase in Minneapolis (Zeldow and Hatfield, 2019).

Mediation analysis will be used to test other indirect pathways in the wage-obesity relationship (H3). Key hypothesized mediators include sleep, stress, physical activity, and healthcare use. Because mediators are measured by self-report, we will use a mediation analysis process that accounts for measurement error in the mediators (Valeri et al., 2014). Though this regression-based method allows estimation of both controlled and natural effects, we will focus on the latter in order to explore the various mechanisms by which wage policy influences obesity. For our exploratory expenditure analysis we will base our analyses on Deaton and Muellbauer's Almost Ideal Demand System (Deaton and Muellbauer, 1980), from which we will capture price elasticities of demand and substitution effects between spending categories, as well as the proportion of total spending allocated to health-promoting resources.

In our larger analysis, we will manage missing data through the following steps: a) testing for differences in characteristics of the respondents vs non-respondents; b) testing for differences in characteristics of respondents with missing items versus those without missing items (by item); c) testing for selection bias associated with missing observations versus missing items; and d) identifying the first stage regressions in a Heckman model to correct for any selection bias.

2.9 Power analysis

The power analysis for this study is based on the primary aim comparing the change in BMI in Minneapolis to the change in BMI in Raleigh from T1 to T5. We use a target detectable effect size of 0.44 based on estimates from Meltzer and Chen (2009), who calculated BMI change associated with a $1 change in minimum wage for those <60 years old with income <$30,000. We assume an alpha of 0.05 and a standard deviation (SD) of change in BMI of 1.9 units (Albrecht et al., 2013; Watson et al., 2016), and 80% power to detect at least a difference in BMI change of 0.44 BMI units between the two groups. Under this scenario, a retention rate of at least 60% at T5 is necessary to have adequate power for our primary endpoint. Assuming a simple mediation model with pairwise correlations between the exposure, mediator, and outcome of 0.2 yields 95% power for the indirect effect.

3. Results

The total analytic sample for the baseline analysis was 974 (495 in Minneapolis, 479 in Raleigh); the analytic sample excludes 6 participants who were determined to be double enrollees post-enrollment. Baseline demographic and wage data on participants are presented in Table 2. Participants were, on average, slightly older in Minneapolis (45.0 years versus 37.8 in Raleigh), with an average household size of 2.6 people across cities (2.4 in Minneapolis and 2.8 in Raleigh). Just over half (55.5%) completed high school, which was similar across cities. Black/African American participants comprised 72% of the study sample (64.2% in Minneapolis and 80.8% in Raleigh), white participants comprised 14.1% of the sample (16.9% in Minneapolis, 11.3% in Raleigh), with a smaller percentage identifying as Asian, American Indian/Alaska Native, two or more races, or other race in both sites. In both cities, 5.5% were Hispanic. The Minneapolis sample was comprised of a smaller proportion of females (48.1% in Minneapolis versus 63.5% in Raleigh). A large proportion of the sample reported an annual household income $\leq$ $20,000 (83.3% in Minneapolis, 71%

	Minneapolis			Raleigh			Combined		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Age	494	45.0	13.7	479	37.8	12.8	973	41.4	13.7
Household size	488	2.4	1.7	470	2.8	1.6	958	2.6	1.7
Hourly wage (verified or self-report)	484	10.4	1.5	471	9.3	1.7	955	9.9	1.7
Weekly hours worked	476	26.4	10.4	471	32.7	9.4	947	29.5	10.4
	N	%		N	%		N	%	
Education									
Less than high school	103	21.0		62	13.1		165	17.1	
High school completed	164	33.4		206	43.6		370	38.4	
Some college	117	23.8		122	25.8		239	24.8	
Associate/Technical degree	62	12.6		40	8.5		102	10.6	
Bachelor's degree or higher	45	9.2		43	9.1		88	9.1	
Race									
American Indian/Alaska Native	25	5.1		4	0.8		29	3.0	
Asian	2	0.4		2	0.4		4	0.4	
Black/African American	312	64.2		387	80.8		699	72.4	
White	82	16.9		54	11.3		136	14.1	
Two or more	36	7.4		18	3.8		54	5.6	
Other	29	5.6		14	2.9		43	4.5	
Ethnicity									
Hispanic	26	5.5		26	5.5		52	5.5	
Non-Hispanic	450	94.5		450	94.5		900	94.5	
Gender									
Male	250	51.3		173	36.1		423	43.8	
Female	234	48.1		304	63.5		538	55.7	
Non-binary	3	0.6		2	0.42		5	0.52	
Household income									
Less than $5,000	146	30.0		96	20.3		242	25.3	
$5,001 to $10,000	132	27.2		100	21.2		232	24.2	
$10,001 to $20,000	127	26.1		139	29.5		266	27.8	
$20,001 to $30,000	49	10.1		86	18.2		135	14.1	
$30,001 to $40,000	12	2.5		31	6.6		43	4.5	
$40,001 to $50,000	14	2.9		10	2.1		24	2.5	
More than $50,000	6	1.2		10	2.1		16	1.67	
Currently unemployed	112	22.6		32	6.7		144	14.8	
Working more than one job	58	11.7		54	11.3		112	11.5	
Job sector									
Food Preparation & Serving Related	75	15.5		97	20.7		172	18.1	
Office and Administrative Support	33	6.82		104	22.2		137	14.4	
Transportation and Material Moving	78	16.1		59	12.6		137	14.4	
Building and Grounds Cleaning & Maintenance	72	14.9		26	5.54		98	10.3	
Sales & Related Occupations	38	7.85		40	8.53		78	8.18	
Healthcare Support	29	5.99		39	8.32		68	7.14	
Protective Service	9	1.86		16	3.41		25	2.62	
Other	150	43.8		88	18.8		238	25.0	

Table 2: Baseline (T1) demographics and wages (US Dollars) in the WAGE$ study sample. [1] = N for non-missing responses.

in Raleigh). The average hourly wage among workers enrolled in the study was $10.40 in Minneapolis and $9.30 in Raleigh. In Minneapolis, 22.6% of the recruited sample was unemployed, versus 6.7% in Raleigh. The number of participants working more than one job was similar across cities (11.7% in Minneapolis and 11.3% in Raleigh). Across the sites, the most common job types were Food Preparation and Serving (18.1%), Office and Administrative Support Occupations (14.4%), Transportation and Material Moving (14.4%).

Weight-related outcomes and potential mediators are presented in Table 3, with several key similarities between the two cities. Overweight or obesity was similar across the cities (74.7% in Minneapolis and 75.6% in Raleigh). Mean BMI across the sample was 30.5 (29.8 in Minneapolis, 31.2 in Raleigh). Food insecurity was similarly high in both cities, with 74.8% in Minneapolis and 75.1% in Raleigh reporting low or very low food security. Food purchase patterns across the two cities were similar, with 6% of grocery spending on fruits and vegetables in Minneapolis and 7% in Raleigh. The proportion spent on foods high in added sugar was 12% in Minneapolis and 13% in Raleigh. Total hours of sleep reported was 8.0 in Minneapolis and 7.8 in Raleigh. Stress scores were also similar (6.8 out of 16

	Minneapolis			Raleigh			Combined		
	N[1]	Mean	SD	N	Mean	SD	N	Mean	SD
Body Mass Index (BMI)	495	29.8	7.6	479	31.2	8.6	974	30.5	8.1
Sleep (average hrs/day)	495	8.0	2.2	477	7.8	2.0	972	7.9	2.1
Diet quality									
Fruits and vegetables (times/day)	495	3.2	2.6	479	3.3	2.6	974	3.2	2.6
Whole grain-rich foods (times/day)	495	1.00	1.1	479	0.8	1.16	974	0.9	1.1
Foods high in added sugar (times/day)	495	3.2	3.4	479	3.3	3.1	974	3.3	3.2
Stress scale (0-16 points)	493	6.8	2.9	473	7.2	3.1	966	7.0	3.0
Food purchases									
Proportion of grocery spending on fruits and vegetables	284	0.06	0.12	226	0.07	0.13	510	0.07	0.12
Proportion of grocery spending on foods high in added sugar	284	0.12	0.19	226	0.13	0.19	510	0.12	0.19
	N	Median (Q1, Q3)		N	Median (Q1, Q3)		N	Median (Q1, Q3)	
Spending in the last 30 days (US Dollars)									
Mortgage or rent	484	450 (125, 750)		468	600 (310, 849.5)		952	517.5 (200, 800)	
Public transit	458	30 (0, 75)		376	0 (0, 20)		834	5 (0, 45)	
Exercise	461	0 (0, 0)		413	0 (0, 0)		874	0 (0, 0)	
Healthcare & medications	472	0 (0, 20)		433	6 (0, 88)		905	0 (0, 50)	
Physical activity (times/week)									
Moderate	475	2 (0, 5)		467	2 (0, 4)		942	2 (0, 4)	
Vigorous	475	1 (0, 3)		468	0 (0, 3)		943	1 (0, 3)	
	N	%		N	%		N	%	
Weight status									
Underweight (<18.5 BMI)	6	1.2		8	1.7		14	1.4	
Normal (18.5 - <25 BMI)	119	24.0		109	22.8		228	23.4	
Overweight (25.0 - <30 BMI)	151	30.5		113	23.6		264	27.1	
Obese (30 or greater BMI)	219	44.2		249	52.0		468	48.1	
SNAP[2] participation									
Yes	299	61.8		202	42.9		501	52.5	
No	178	36.8		266	56.5		444	46.5	
Not sure	7	1.5		3	0.6		10	1.1	
SNAP benefit amount									
None	187	38.6		276	58.7		463	48.5	
$1-25	33	6.82		24	5.11		57	5.97	
$26-100	42	8.68		28	5.96		70	7.34	
$101-150	44	9.09		20	4.26		64	6.71	
$151-250	121	25.0		55	11.7		176	18.5	
$>250	57	11.8		67	14.3		124	13.00	
WIC[3] participation									
Yes	48	10.4		65	14.1		113	12.2	
No	411	88.8		392	84.9		803	86.8	
Not sure	4	0.9		5	1.1		9	1.0	
Food insecurity									
Food security	124	25.2		118	24.9		242	25.1	
Low food security	177	36.0		154	32.5		331	34.3	
Very low food security	191	38.8		202	42.6		393	40.7	
Health insurance									
Any insurance	443	90.6		259	54.9		702	73.1	
Uninsured	46	9.4		213	45.1		259	27.0	
Visited doctor within 12 months (not counting hospitalizations)									
Yes	415	84.7		319	67.6		734	76.3	
No	75	15.3		153	32.4		228	23.7	

Table 3: Baseline (T1) weight-related outcomes and mediators in the WAGE$ study sample. [1] = N for non-missing responses, [2] = Supplemental Nutrition Assistance Program, [3] = Special Supplemental Nutrition Program for Women, Infants, and Children.

in Minneapolis, 7.2 out of 16 in Raleigh). Dietary intake patterns indicated that fruit and vegetable consumption was reported 3.2 times per day in Minneapolis (3.3 times per day in Raleigh), whole grain-rich food consumption was reported 1.0 times per day in Minneapolis (0.8 times per day in Raleigh), and foods high in added sugars was consumed 3.2 times per day in Minneapolis (3.3 times per day in Raleigh). Weekly physical activity was similar, with a median of two episodes of moderate physical activity in both cities, and median of one episode of vigorous physical activity Minneapolis, compared with zero in Raleigh.

There were also several key differences between the two cities in potential weight-related mediators. SNAP participation was 61.8% in Minneapolis, compared with 42.9% in Raleigh;

WIC participation was more similar, with 10.4% in Minneapolis, compared with 14.1% in Raleigh participating. In Minneapolis, the percent uninsured was 9.4%, compared with 27% in Raleigh, and the proportion not having visited a doctor within 12 months was 15.3% in Minneapolis compared with 32.4% in Raleigh.

4. Discussion

Minimum wage laws are a promising policy lever to improve population health and health equity, but existing evidence surrounding their effectiveness is limited (Leigh et al., 2019). The WAGE$ study will contribute to the field in several ways. First, there are measurement-related advantages of our design, in which we will collect data on individual wages and thereby calculate the precise "wage dose" received. While each participant may follow a nonlinear trajectory of wage changes over the course of the follow-up period, the study is designed to test whether a minimum wage policy results in an increase in wages and subsequent changes in health status among those it is designed to affect. The study also measures the primary health outcome objectively to eliminate self-report bias, and captures a range of plausible mediators to further test causal mechanisms. Our inclusion of the full spectrum of low-wage sectors through a community-recruited sample is designed to offer greater generalizability than in single-sector studies. Finally, a prospective, longitudinal study design is the best way to test the direction and dynamics of the association between wages and weight.

The descriptive findings of the study sample at baseline highlight several features about the segment of the population likely to be affected by minimum wage ordinances. In this community-based sample, participants represented a broad range of employment sectors. The data also reveal a pattern of financial vulnerability for low-wage workers. For example, a large majority reported <$20,000 annual household income, and approximately 40% had very low food security. The large majority of participants were also overweight or obese. The research team is currently developing an interactive dashboard that will allow partners to explore and visualize study summary data and request data extracts from the team.

While differences in the racial/ethnic composition of the sample were expected, the magnitude of gender and age differences between the two cities was unexpected. Community engagement processes and political sentiments were naturally unique at each site, and may have led to different patterns of enrollment (Shanafelt et al., 2021). Although these differences exist, they can be addressed in the study's statistical analyses; the research team collected individual-level data on these variables and will be able to adjust for these potential confounders more precisely than if group-level attributes were assigned to each individual.

Other differences in the sample between cities might be attributed to local policies. For example, different rates of insurance coverage could potentially be explained by MN's voluntary expansion of Medicaid following the Affordable Care Act, in contrast with NC. While differences in local policy cannot easily be controlled for in quantitative analyses, they are being tracked by the study team and will be discussed in the results interpretation. An ongoing supplemental qualitative study is being conducted in a study subsample that will offer narrative accounts of the lived experience of low-wage workers in both cities and the policies that affect them. Minneapolis has a variety of local policies that could augment

the health effects of an increase in minimum wage by strengthening worker protections and increasing access to basic necessities. This included a local staple foods ordinance to address disparities in food access, a paid sick and safe time (time off to receive assistance because of sexual assault, domestic abuse or stalking) ordinance, and a wage theft ordinance. A citywide affordable housing plan with inclusionary zoning for low-income renters is underway. By contrast, in NC, a Governor's executive order established sick and safe time only for those who work for the state. Also in NC, the elimination of waivers on SNAP work requirements for able-bodied adults without dependents (ABAWDs) could affect SNAP participation for participants who are unemployed. In sum, the broader state and local policy context is particularly important to consider because such policies could enhance or diminish the effects of a local minimum wage policy.

4.1 Limitations of the study

In this two-site study, there are local and state-level differences between the intervention and control conditions. While some of these differences can be observed (e.g., changes in cost of living), other differences are more difficult to measure and account for in analyses. Previous minimum wage studies have used synthetic matching estimators (Jardim et al., 2017; Neumark et al., 2013; Reich et al., 2017), interactive fixed effects (Totty, 2015), and propensity score matching (Basu et al., 2017) to bypass this limitation; however, such studies rely on strong assumptions about likely affected and unaffected groups that create other challenges in interpreting results. A related limitation is that there are differences in the sample characteristics in Minneapolis and Raleigh, suggesting that the samples recruited in the current study do not represent identical segments of the population in each city. While we will be able to control for many of the characteristics that differed by site, residual confounding by unmeasured factors that affect behaviors (e.g., local food environments, cultural norms) is possible. Additionally, the two-site DID study design is the dependent on the parallel trends holding in the post-period. While we tested the parallel trends assumption in the pre-period, there is no guarantee that the parallel trends in BMI between the two sites will hold during the study period. The parallel trends assumption also has implications when considering whether results are valid across populations. If the average treatment effect on the treated in the current study differs from the average treatment effect, results will not be generalizable beyond the study areas. However, this potential non-generalizability is not unique to DID study designs. The data collected in this study enables us to assess the overall similarly between our sample and the population of low-wage workers in other areas, providing a basis for predicting how well the effect observed in our sample might generalize to these other areas. Further, because wage policy generally applies to all workers in the area it is enacted, there is minimal risk of self-selection into the treated group, eliminating one important reason otherwise similar populations might differ in their response.

4.2 Conclusion

While decades of research point conclusively to the existence of socioeconomic gradients in health, research that tests minimum wage and other economic policy effects on health in the U.S. setting is comparatively nascent and sometimes mixed. Recent policy action

related to minimum wage at the local, state, and federal level make this study particularly relevant to the current U.S. policy discourse. The WAGE$ study is poised to test whether and how minimum wage policy affects obesity-related behaviors and BMI in a prospectively designed DID study with strong measures of exposure and outcomes.

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