

# Association of Exposure to Communities With Higher Ratios of Obesity With Increased Body Mass Index and Risk of Overweight and Obesity Among Parents and Children

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**IMPORTANCE** Little is known about whether the substantial clustering of obesity and overweight within social and geographic networks results from causal pathways, such as social contagion and shared environments, or from self-selection.

**OBJECTIVES** This study aimed to determine whether exposure to communities with higher rates of obesity increases the body mass index (BMI) of individuals, calculated as weight in kilograms divided by height in meters squared, and their risk of being overweight or obese, and whether social contagion, shared environments, or self-selection can account for identified differences.

**DESIGN, SETTING, AND PARTICIPANTS** This natural experiment study used the routine assignment of military service members to installations as a source of exogenous variation in exposure to communities with higher vs lower rates of obesity. The study, which used data collected by the Military Teenagers' Environments, Exercise, and Nutrition Study, examined families from 38 military installations around the United States to determine if individuals had higher BMI and greater odds of overweight and obesity when assigned to installations in counties with higher rates of obesity. The study also examined if the relationship persisted after controlling for shared built environments. The participants included 1 parent and 1 child aged 12 or 13 years from 1519 families of Army-enlisted personnel. Data analysis was completed from November 2016 to October 2017.

**EXPOSURES** Adult obesity rate in the county where the assigned installation of the service member was located. Time at installation and location of residence (on-installation vs off-installation) were used to measure the degree of exposure.

**MAIN OUTCOMES AND MEASURES** For parents, outcomes were BMI, overweight/obesity (BMI,  $\geq 25$ ) and obesity (BMI,  $\geq 30$ ). For children, outcomes were BMI z score, overweight/obesity (BMI percentile for age and sex,  $\geq 85$ ), and obesity (BMI percentile for age and sex,  $\geq 95$ ). These outcomes were based on self-reports for parents, self-reports and parent reports for all children, and anthropometric measurements for a subsample of children.

**RESULTS** Members of 1519 families participated, including 1314 adults (of whom 740, or 56%, were fathers) and 1111 children (of whom 576, or 52%, were boys); anthropometric measurements were performed on 458 children. The sample was 40% white, 22% black, 24% Hispanic, and 14% other races/ethnicities. A 1 percentage point higher county obesity rate was associated with a higher BMI (a difference of 0.08; 95% CI, 0.02-0.13) and greater odds of obesity (adjusted odds ratio [aOR], 1.05; 95% CI, 1.02-1.08) in parents, and a higher BMI z score (0.01; 95% CI, 0.003-0.02) and greater odds of overweight/obesity (aOR, 1.04; 95% CI, 1.01-1.06) in children. The evidence supported stronger associations among families with more time at installation and off-installation residence. Associations persisted even after controlling for shared built environments.

**CONCLUSIONS AND RELEVANCE** Exposure to counties with higher rates of obesity was associated with higher BMI and higher odds of overweight and/or obesity in parents and children. There was no evidence to support self-selection or shared built environments as possible explanations, which suggests the presence of social contagion in obesity.

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The idea that the health of individuals is interconnected has gained considerable attention over the last 10 years after a series of influential articles by Nicholas A. Christakis, MD, PhD, MPH, and James H. Fowler, PhD,<sup>1-3</sup> showed substantial clustering in obesity and other health-related attributes, behaviors, and conditions within social networks. This clustering pattern has been replicated in numerous studies.<sup>4,5</sup> Christakis and Fowler<sup>1</sup> have argued that this pattern is likely arising via social contagion. Specifically, in the case of obesity, social contagion would mean that if individuals in a social network became obese, it would increase the likelihood of any other individual in that network also becoming obese owing to social influences such as changing norms or mirroring. However, this claim has been challenged by other researchers<sup>6-8</sup> on 2 main grounds. The first and perhaps most important critique is that clustering of obesity within networks could simply be due to latent (unmeasured) homophily (the tendency for people to associate with people who have similar attributes). Second, the clustering of obesity may capture the influence of a shared environment (eg, network members may have similar proximity to green space and food opportunities that would influence their body weight similarly). Observational data on networks are largely unable to disentangle these alternative explanations because individuals self-select into social networks (homophily) and locations (residential selection) based on unobservable preferences that also influence their health outcomes directly.

Disentangling the extent to which the clustering of obesity within networks is due to social contagion vs the competing explanations of self-selection (ie, homophily and residential selection) and shared environment is crucial because of their different implications for public health policy making. A contagion effect would favor policies that target social networks, such as directing interventions toward well-connected individuals within networks to leverage their potential multiplier effect<sup>9</sup> or interventions that seek to change norms and attitudes.<sup>10</sup> A shared environment effect would favor interventions that target aspects of the built or policy environment. However, self-selection would suggest a more limited role for interventions focusing on social networks or built environments.

This study uses a unique natural experiment to examine the potential role of social contagion in obesity. We study military families because service members are routinely assigned to installations based on the needs of the military, thereby providing plausibly exogenous variation in their exposure to communities with varying rates of obesity. The reason and duration of exposure is outside of the control of individuals (with rare exceptions), offering a unique opportunity to study whether living in communities with higher rates of obesity can make individuals more likely to become obese themselves. Specifically, we examine whether parents and children in military families assigned to installations in counties with higher obesity rates are more likely to be overweight or obese than parents and children in families assigned to installations in counties with lower rates of obesity. We also examine whether time at installation and on-installation residence (vs off-installation residence), which proxy the degree of ex-

## Key Points

**Question** Does exposure to communities with higher rates of obesity increase the body mass index (BMI) and risk of overweight/obesity of individual residents?

**Findings** Using data from military service members assigned to installations around the country, this study found that exposure to counties with higher rates of obesity (relative to counties with lower obesity rates) was associated with higher mean BMI and greater odds of obesity in parents and higher BMI z scores and greater odds of overweight/obesity in children. Associations were stronger among families who had resided longer in a given location and with off-installation residence; no evidence supported self-selection or shared built environment as explanations for these results.

**Meaning** Exposure to communities with higher rates of obesity is associated with higher BMI and greater risk of overweight and/or obesity in parents and children, and this may suggest the presence of social contagion.

posure to the obesity rate in the county, were associated. Finally, we examine whether shared built environment explains the observed association.

## Methods

### Context

We used data from the Military Teenagers Environments, Exercise, and Nutrition (M-TEEN) Study. The M-TEEN Study recruited families of US Army enlisted personnel located primarily at 12 military installations in the continental United States: Joint Base Lewis-McChord (Washington), Fort Carson (Colorado), Fort Drum (New York), Fort Bragg (North Carolina), Fort Benning (Georgia), Fort Bliss (Texas), Fort Campbell (Kentucky-Tennessee), Fort Hood (Texas), Fort Polk (Louisiana), Fort Stewart (Georgia), Fort Sill (Oklahoma) and Fort Riley (Kansas). These installations were chosen because they accounted for most of the active-duty US Army-enlisted population in the continental United States.

### Consent Procedures

The study was approved by the institutional review boards at RAND, University of Southern California, and the US Army Human Research Protection Office. Parent consent and child assent were obtained online prior to participation.

### Participants

Using US Army personnel records, enlisted service members located at these 12 installations who had a dependent child aged 12 or 13 years (as of March 31, 2013) were contacted from March 2013 through December 2014 via emails and postal mail with invitations to complete an eligibility screening.

There were 3 inclusion criteria: the service member did not intend to leave the military within the coming year; the eligible child resided with the service member at least half of the time; and the eligible child was enrolled in a public school or a Department of Defense Education Activity school. One parent and 1 child per family were invited to complete the sur-

veys, regardless of family size. Participants were spread across 38 installations, 26 more than the original 12 installations selected, because of outdated information in the personnel dataset and because some personnel relocations occurred after personnel data were extracted.

## Measures

### County Obesity Rate

Exposure was measured using the adult obesity rate in the service member's assigned county (installation county). The county obesity rate (COR) is a useful summary measure (or realized measure) of potential obesogenic influences in the county. County obesity rates for each of the 35 counties to which personnel were assigned were obtained from the Robert Wood Johnson Foundation County Health Rankings data<sup>11</sup> and were linked to the M-TEEN Study sample by assigned installation and year of survey completion. (The installation counties are listed in eTable 1 in the [Supplement](#).) The county obesity rates are from the 2013 and 2014 releases of the County Health Rankings data,<sup>12</sup> which are based on estimates computed by the US Centers for Disease Control and Prevention by pooling the 2008-2010 and the 2009-2011 Behavioral Risk Factor Surveillance System dataset<sup>13</sup> (eTable 1 in the [Supplement](#)). The lagged county obesity data were preferred because of the typical length of time at installation for our sample (**Table 1**).

A subset of families lived in neighboring counties around the installation county (18%). Installation county, instead of residential county, was used to assess exposure to county obesity rate (akin to an intent-to-treat analysis) because residential choice at a given installation may be less exogenous. Moreover, military families regularly access the installation for health care, shopping, recreation, and education, and so are exposed to the installation county regardless of where they live.

### Body Mass Index, Overweight, and Obesity

The height and weight of each child was collected via self-report and parent report for all children. In addition, height and weight measurements were collected during visits to the original 12 installations for a subsample of children who attended the visits on specified days (n = 458). There were no meaningful differences between the measured and unmeasured children in terms of their sex, self-reported or parent-reported body mass index (BMI), overweight/obese status, and family socioeconomic characteristics (eTable 2 in the [Supplement](#)).

Using child self-reports, parent reports, and measurements, we computed 3 sets of child outcomes using the 2000 US Centers for Disease Control and Prevention Growth Charts: BMI z score, overweight or obese indicator (BMI  $\geq$ 85th percentile), and obesity indicator (BMI  $\geq$ 95th percentile). Results using measures based on child self-reports and measurements are presented in **Table 2**. Results based only on child self-reports are presented in **Tables 3, 4, and 5**. Body mass index, overweight/obese status, and obese status of adult participants were computed from self-reported height and weight data collected in the survey and are presented in **Tables 2, 3, 4, and 5**.

**Table 1. Descriptive and Outcome Statistics for Parents and Children**

Characteristic	No. (%)
<b>Descriptive Statistic</b>	
Child covariates (n = 1111)	
Male	576 (52)
Age, mean (SD), mo	162 (9.4)
Covariates of participating parent (n = 1314)	
Father	740 (56.3)
Age, y, mean (SD)	36.5 (4.7)
Military service member	967 (73.6)
Married	1176 (89.5)
Race/ethnicity	
Non-Hispanic white	529 (40.3)
Non-Hispanic black	287 (21.8)
Hispanic	316 (24.0)
Other race/ethnicity	182 (13.9)
Rank of military rank	
E4 or less (corporal or specialist)	150 (11.4)
E5 (sergeant)	237 (18.0)
E6 (staff sergeant)	410 (31.2)
E7 (sergeant first class)	363 (27.6)
E8 or higher	154 (11.7)
Highest education level of parents	
High school or less	81 (6.2)
Trade, technical, or some college	472 (35.9)
Associate degree or equivalent	373 (28.4)
4-y college degree or higher	388 (29.5)
Family covariates (n = 1314) <sup>a</sup>	
Annual household income, \$	
<40 000	274 (20.9)
40 001-50 000	262 (19.9)
50 001-85 000	632 (48.1)
$\geq$ 85 001	146 (11.1)
Time at installation, mo	
$\leq$ 12	140 (10.7)
13-24	356 (27.1)
25-48	534 (40.6)
$\geq$ 49	284 (21.6)
Children in the household	
1	170 (12.9)
2	443 (33.7)
$\geq$ 3	701 (53.3)
Family lives off installation	732 (55.7)
<b>Outcome Measure</b>	
Self-reported data on children (n = 1111)	
BMI z score, mean (SD)	0.27 (1.14)
Overweight/obese	284 (25.6)
Obese	98 (8.8)
Parent-reported data on children (n = 1288)	

(continued)

**Table 1. Descriptive and Outcome Statistics for Parents and Children (continued)**

Characteristic	No. (%)
BMI z score, mean (SD)	0.23 (1.18)
Overweight/obese	324 (25.1)
Obese	123 (9.5)
Anthropometric measurements of children (n = 458)	
BMI z score, mean (SD)	0.40 (1.01)
Overweight/obese	126 (27.5)
Obese	47 (10.3)
Self-reported data on parents (n = 1314)	
BMI, mean (SD)	27.83 (4.52)
Overweight/obese	987 (75.1)
Obese	356 (27.1)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

<sup>a</sup> Family covariates were only available when a parent participated in the survey (n = 1314) and were therefore not available for 205 of the 1519 families in the study.

**Covariates**

All regressions controlled for a rich set of covariates including the age, sex, and race/ethnicity of the participant (non-Hispanic white, non-Hispanic black, Hispanic/Latino, or other); the marital status and highest education level among the child’s parents (high school or less; trade, technical or some college; associate degree or equivalent; 4-year college degree or higher), the rank of the military parent (corporal/specialist or lower, sergeant, staff sergeant, sergeant first class, master sergeant/first sergeant or higher); household income ( $\leq$ \$40 000; \$40 001-\$50 000; \$50 001-\$75 000;  $\geq$ \$75 001), number of children in the household (1, 2, and 3 or more), on-installation residence, and time at installation ( $\leq$ 12 months, 13-24 months, 25-48 months, and  $\geq$ 49 months).

**Statistical Analyses**

We estimated the association between the installation COR and body weight outcomes of children and parents using linear and logistic regression models, adjusting for the covariates described. Next, we tested for evidence of self-selection in 3 ways. First, we estimated unadjusted models, which should yield estimates similar to adjusted models if families did not self-select into counties based on our observed covariates. Second, we compared the observed characteristics of families in counties with high vs low COR (eTable 3 in the Supplement). Finally, we conducted a falsification test by estimating the association between COR and both child and parent height, which should be unrelated to the COR (eTable 4 in the Supplement).

To assess the importance of degree of exposure to the county, we estimated the adjusted association between COR and parent and child body weight outcomes separately for families with time at installation up to 24 months vs longer than 24 months, and families living on-installation vs off-installation. A longer time at installation implies greater exposure to the county, so we expected a stronger correlation between body weight outcomes and COR for these families.

**Table 2. Associations Between County Obesity Rate and Parent and Child Body Mass Index, Overweight, and Obesity<sup>a,b</sup>**

Outcome	Estimate (95% CI)	
	Adjusted	Unadjusted
Self-reported data on parents		
No.	1314	1314
BMI <sup>c</sup>	0.08 (0.02 to 0.13)	0.07 (0.02 to 0.13)
Overweight/obese <sup>d</sup>	1.00 (0.98 to 1.03)	1.00 (0.98 to 1.02)
Obese <sup>d</sup>	1.05 (1.02 to 1.08)	1.04 (1.02 to 1.07)
Self-reported data on children		
No.	1111	1111
BMI z score <sup>c</sup>	0.01 (0.003 to 0.02)	0.01 (0.003 to 0.02)
Overweight/obese <sup>d</sup>	1.04 (1.01 to 1.06)	1.03 (1.00 to 1.05)
Obese <sup>d</sup>	1.01 (0.99 to 1.04)	1.02 (0.99 to 1.06)
Anthropometric measurements of children		
No.	458	458
BMI z score <sup>c</sup>	0.02 (-0.01 to 0.04)	0.02 (0.00 to 0.04)
Overweight/obese <sup>d</sup>	1.06 (1.01 to 1.12)	1.06 (1.01 to 1.11)
Obese <sup>d</sup>	1.05 (0.96 to 1.15)	1.07 (0.99 to 1.15)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

<sup>a</sup> Contrasts are for a 1 percentage point higher county obesity rate. All data are self-reported.

<sup>b</sup> All regressions also controlled for age, sex, race/ethnicity, marital status of parents, highest education level of parents, rank of military parent, household income, number of children in household, residence status (on-installation or off-installation), and time at installation. Reference categories are male, non-Hispanic white, families living off-installation, nonmilitary parents, unmarried people, personnel holding the rank of corporal/specialist or lower, adults with a high school diploma or less, a household income of \$40 000 or less, 1 child in household, and a time at installation of 12 months or less.

<sup>c</sup> Estimates are reported as linear regression coefficients ( $\beta$ ).

<sup>d</sup> Estimates are reported as adjusted odds ratios.

Because time at installation is determined by the military, this analysis offers a strong test of whether the degree of exposure matters. Likewise, we expected COR to be more strongly associated with body weight outcomes among families living off-installation owing to greater exposure to the county.

However, a potential concern was that families can self-select into living on-installation vs off-installation. Data in eTable 5 in the Supplement detail that, while off-installation families were more likely to have higher rank and education (often considered protective factors against obesity), they did not differ from on-installation families in terms of the race/ethnicity and sex of the children, nor in the parent and child body weight outcomes.

To examine whether shared environments could explain the observed association between COR and the body weight outcomes of parents and children, we estimated our main models adding 3 distinct sets of controls for the obesogenic built environment (eAppendix in the Supplement). The first set includes objective measures of the built environment in the county obtained from the Robert Wood Johnson County Health Rankings data: the percentage of the county population that lived close to a park or recreational facility, the percentage of

Table 3. Association Between County Obesity Rate and Parent and Child BMI, Overweight, and Obesity, Stratified by Time at Installation<sup>a,b</sup>

Outcome	Estimate (95% CI)		P Value <sup>c</sup>
	≤24 mo	>24 mo	
Self-reported data on parents			
No.	496	818	
BMI <sup>d</sup>	0.06 (-0.02 to 0.13)	0.08 (-0.00 to 0.16)	.67
Overweight/obese <sup>e</sup>	0.99 (0.97 to 1.01)	1.00 (0.97 to 1.04)	.61
Obese <sup>e</sup>	1.06 (0.99 to 1.14)	1.04 (1.00 to 1.07)	.53
Self-reported data on children			
No.	429	682	
BMI z score <sup>d</sup>	-0.01 (-0.03 to 0.01)	0.03 (0.01 to 0.04)	.001
Overweight/obese <sup>e</sup>	1.00 (0.93 to 1.09)	1.06 (1.04 to 1.09)	.002
Obese <sup>e</sup>	0.97 (0.89 to 1.06)	1.07 (1.00 to 1.15)	.14

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

<sup>a</sup> Contrasts are for a 1 percentage point higher county obesity rate. All data are self-reported.

<sup>b</sup> All regressions also controlled for age, sex, race/ethnicity, marital status of parents, highest education level of parents, rank of military parent, household income, number of children in household, residence status (on-installation or off-installation), and time at installation. Reference categories are male, non-Hispanic white, families living off-installation, nonmilitary parents,

unmarried people, personnel holding the rank of corporal/specialist or lower, adults with a high school diploma or less, a household income of \$40 000 or less, 1 child in household, and a time at installation of 12 months or less.

<sup>c</sup> P value is from a cross-model hypothesis test of difference in estimates for length of residence less than or equal to 24 months vs more than 24 months.

<sup>d</sup> Estimates are reported as linear regression coefficients ( $\beta$ ).

<sup>e</sup> Estimates are reported as adjusted odds ratios.

county population that was low income, and the percentage that did not live close to a grocery store. The second set includes objective Geographic Information Systems-based measures of the neighborhood built environment: the number of grocery stores, sports and recreational facilities, and intersections (a measure that captures walkability) within a 2-mile buffer of residence. The third measure includes the subjective environment score based on the Neighborhood Environment Walkability Scale for Youth, which asked parents about perceived land use mix-diversity, recreation facility availability, pedestrian/automobile traffic safety, crime safety, aesthetics, walking/cycling facilities, street connectivity, land use mix-access, and residential density.<sup>14</sup>

Data analysis was completed from November 2016 to October 2017. All analyses were conducted using Stata version 14.1 (StataCorp). A robust variance estimator accommodated correlation related to the clustering of families within counties.<sup>15</sup>

## Results

### Descriptive Statistics

In all, 3140 families completed the eligibility screening; 2475 were considered eligible; and 1721 provided consent to participate. One child and 1 parent in each family were invited to complete online surveys, and 1519 families completed at least 1 parent or 1 child survey (sample flowchart in the eFigure in the Supplement; missing data details in eTable 6 in the Supplement). In total, 1314 parents and 1111 children were included. Descriptive statistics for the analysis sample are reported in Table 1.

The prevalence of overweight or obesity in the M-TEEN Study sample was 75% among parents (987/1314 parents) and ranged from 25% (324/1288) to 28% (126/458) in children, de-

pending on whether height and weight information came from parent reports or anthropometric measurements, respectively (Table 1). The responding parent was more likely to be the military parent (967/1314; 74%) and male (740/1314; 56%). The racial/ethnic composition of the sample included non-Hispanic white persons (529/1314; 40%), non-Hispanic black persons (287/1314; 22%), Hispanic/Latino persons of any race/ethnicity (316/1314; 24%), and all others (182/1314; 14%). Approximately 44% of the families (582/1519) lived on-installation, and 818 of 1314 families (63%) had been at their current installation for longer than 24 months.

County obesity rates ranged from 21% in El Paso County, Colorado, to 38% in Vernon County, Louisiana, with a mean and median of 30%. (Full distribution is presented in eTable 1 in the Supplement.)

### Regression Results

In adjusted models, military families in counties with higher obesity rates had higher BMI and higher odds of overweight and/or obesity (Table 2). Specifically, a 1 percentage point higher COR was associated with 0.08 higher BMI among the parents in the study cohort (95% CI, 0.02-0.13) and 5% higher odds of obesity (adjusted odds ratio [aOR], 1.05; 95% CI, 1.02-1.08).

The COR was also positively associated with children's BMI z-score and odds of overweight/obesity. For example, a 1 percentage point higher COR was associated with 4% higher odds of overweight/obesity (aOR, 1.04; 95% CI, 1.01-1.06). The COR was also associated with higher odds of overweight/obesity among children (aOR, 1.06; 95% CI, 1.01-1.12) even when constructed from anthropometric measurements instead of self-reports among the subsample with measurements (Table 2).

We found no evidence to suggest that self-selection was a concern. The associations between COR and the body weight outcomes of parents and children remained similar even in unadjusted models (Table 2). There were no systematic differ-

**Table 4. Association Between County Obesity Rate and Parent and Child BMI, Overweight, and Obesity, Stratified by On-Installation or Off-Installation Residence<sup>a,b</sup>**

Outcome	Estimate (95% CI)		P Value <sup>c</sup>
	Off-Installation	On-Installation	
Self-reported data on parents			
No.	732	582	
BMI <sup>d</sup>	0.11 (0.06 to 0.16)	0.04 (-0.06 to 0.14)	.20
Overweight/obese <sup>e</sup>	1.00 (0.97 to 1.03)	1.01 (0.97 to 1.05)	.51
Obese <sup>e</sup>	1.07 (1.04 to 1.11)	1.02 (0.98 to 1.06)	.05
Self-reported data on children			
No.	604	507	
BMI z score <sup>d</sup>	0.02 (0.01 to 0.03)	0.003 (-0.02 to 0.03)	.04
Overweight/obese <sup>e</sup>	1.06 (1.04 to 1.09)	1.00 (1.00 to 1.01)	.002
Obese <sup>e</sup>	1.07 (1.04 to 1.11)	1.00 (0.99 to 1.00)	.002

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

<sup>a</sup> Contrasts are for a 1 percentage point higher county obesity rate. All data are self-reported.

<sup>b</sup> All regressions also controlled for age, sex, race/ethnicity, marital status of parents, highest education level of parents, rank of military parent, household income, number of children in household, residence status (on-installation or off-installation), and time at installation. Reference categories are male, non-Hispanic white, families living off-installation, nonmilitary parents,

unmarried people, personnel holding the rank of corporal/specialist or lower, adults with a high school diploma or less, a household income of \$40 000 or less, 1 child in household, and a time at installation of 12 months or less.

<sup>c</sup> P value is from a cross-model hypothesis test of difference in estimates for on-installation vs off-installation residence.

<sup>d</sup> Estimates are reported as linear regression coefficients ( $\beta$ ).

<sup>e</sup> Estimates are reported as adjusted odds ratios.

ences in the observed characteristics of families by COR (eTable 3 in the [Supplement](#)). In addition, the falsification test showed no statistically significant association between child or parent height and the COR (eTable 4 in the [Supplement](#)).

The association between COR and the BMI z scores and odds of overweight/obesity in children was stronger among families with time at installation longer than 24 months vs those with time at installation shorter than that length (Table 3). The association between COR, the odds of obesity in parents, and all child outcomes was stronger among families who lived off-installation than those who lived on-installation (Table 4).

The positive association between COR and the body weight outcomes of parents and children remained similar even after controlling for the shared built environment in the county, Geographic Information Systems measures of built environment in the neighborhood of residence, and parent-reported Neighborhood Environment Walkability Scale for Youth scores (Table 5).

### Results of Alternative Models

We conducted several additional analyses to confirm that these findings were robust. First, eTable 7 in the [Supplement](#) demonstrates that similar results were obtained when using residential county to assess exposure to county obesity rather than installation county. Second, we reran analyses using parent-reported child outcomes and found that these yielded similar results (eTables 8-10 in the [Supplement](#)). In another alternate model, the occupation of the military parent (recorded as any of 22 occupation code indicators) and seniority were added as control variables, but again results remained similar (eTables 11 and 12 in the [Supplement](#)). Models using alternative cut-offs (12 months, 18 months, and 30 months) for the time at installation analyses yielded similar results to the 24-month cut-off (eTables 13-15 in the [Supplement](#)).

Finally, we conducted 3 additional sets of analyses to support our main results. First, we estimated models that used corrected child BMI, overweight, and obesity measures instead of parent-reported or child-reported measures to address concerns about measurement error in reports (eTable 16 in the [Supplement](#)). Briefly, we used the subsample that also had measured BMI to correct for measurement error in reports.<sup>16</sup> These results were similar to those shown in Table 2. Second, for the subsample of children with measurements, we also estimated models using alternate body composition measures based on waist-to-height ratio, waist circumference, and percentage of body fat (eTable 17 in the [Supplement](#)). These results also provided evidence of a relationship with COR. Third, we examined whether COR was associated with the diet-related and activity-related behaviors of families, as would be expected if it were associated with body weight. We found some relationships for parent and child physical activity and healthiness of the home food environment, but not for dietary intake (eTable 18 in the [Supplement](#)).

## Discussion

Our results suggest that military families assigned to installations in counties with higher obesity rates were more likely to be overweight and/or obese than their counterparts assigned to installations in counties with lower obesity rates. The natural experiment design of this study, whereby military families are exogenously assigned to different installations (and hence different counties) in the course of their service allowed us to address concerns about self-selection, which is one of the primary limitations of existing studies. We found no systematic pattern in the observed

**Table 5. Association Between County Obesity Rate and Parent and Child BMI, Overweight, and Obesity, Controlling for Shared Built Environment in the County and Neighborhood<sup>a,b</sup>**

Outcome	Estimate (95% CI)		
	After Controlling for County Shared Built Environment Measures <sup>c</sup>	After Controlling for GIS-Based Neighborhood Built Environment Measures <sup>d</sup>	After Controlling for Neighborhood Built Environment via NEWSY Scores <sup>e</sup>
Self-reported data on parents			
No.	1314	1311	1300
BMI <sup>f</sup>	0.08 (0.01-0.14)	0.08 (0.02-0.13)	0.08 (0.03-0.12)
Overweight/obese <sup>g</sup>	1.01 (0.98-1.04)	1.01 (0.98-1.04)	1.00 (0.98-1.02)
Obese <sup>g</sup>	1.04 (1.01-1.08)	1.05 (1.02-1.07)	1.05 (1.02-1.08)
Self-reported data on children			
No.	1111	1109	1107
BMI z score <sup>f</sup>	0.01 (0.00-0.02)	0.01 (0.00-0.02)	0.01 (0.00-0.02)
Overweight/obese <sup>g</sup>	1.03 (1.01-1.05)	1.03 (1.01-1.06)	1.03 (1.01-1.06)
Obese <sup>g</sup>	0.99 (0.97-1.02)	1.01 (0.99-1.04)	1.01 (0.99-1.04)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); GIS, Geographic Information Systems; NEWSY, Neighborhood Environment Walkability Scale for Youth.

<sup>a</sup> Contrasts are for a 1 percentage point higher county obesity rate. All data are self-reported.

<sup>b</sup> All regressions also controlled for age, sex, race/ethnicity, marital status of parents, highest education level of parents, rank of military parent, household income, number of children in household, residence status (on-installation or off-installation), and time at installation. Reference categories are male, non-Hispanic white, families living off-installation, nonmilitary parents, unmarried people, personnel holding the rank of corporal/specialist or lower, adults with a high school diploma or less, a household income of \$40 000 or

less, 1 child in household, and a time at installation of 12 months or less.

<sup>c</sup> County shared built environment measures were percentage of county population that lives close to a park or recreational facility and percentage of county population that is low income and does not live close to a grocery store.

<sup>d</sup> Neighborhood GIS built environment measures are intended to capture walkability and included the number of grocery stores, sports and recreational facilities, and intersections within a 2-mile buffer of residence.

<sup>e</sup> NEWSY scores are intended to capture walkability.<sup>14</sup>

<sup>f</sup> Estimates are reported as linear regression coefficients ( $\beta$ ).

<sup>g</sup> Estimates are reported as adjusted odds ratios.

characteristics of families at installations located in counties with higher vs lower obesity rates that could explain our findings.

Greater exposure to the county, proxied by longer time at installation and by off-installation residence, was associated with stronger observed correlation between COR and the body masses of military families. We also examined whether our findings could be explained by shared built environments. Controlling for the county built environment using objective measures and controlling for neighborhood built environment using objective or subjective measures did not explain the association between the COR and the BMI and rates of overweight/obesity in families. While this study cannot definitively rule out the role of shared environments with the available measures, these findings suggest that other mechanisms may be at work.

The absence of evidence supporting self-selection or shared environment opens the possibility that social contagion may explain our findings. The work of Christakis and Fowler<sup>1</sup> and others<sup>5</sup> have suggested that social contagion may operate via common behaviors or mirroring. However, according to a review by Cunningham et al,<sup>4</sup> the evidence on mirroring has not been consistent. Mirroring is more commonly observed in friends and family networks, peer networks, and cultural groups, where individuals may mirror the behavior of significant others or those they esteem; it is therefore less likely to be a primary mechanism in our geography-based network. Social contagion can also operate through changing societal norms and aspirations, personal aspirations to attain the body size of others, and changing behaviors in response to the body

sizes in a particular setting. In a randomized clinical trial, Kroes et al<sup>17</sup> found that being around people who were thinner than average increased body weight dissatisfaction among young women. In another study, children and adolescents whose social networks (parents and schoolmates) were composed of overweight individuals were more likely to underestimate their own weight and develop inaccurate perceptions of what constitutes appropriate weight status.<sup>18</sup> Unfortunately, our data did not allow us to explore these issues directly.

### Limitations

Our study also has other limitations. First, generalizability may be a concern. However, there was remarkable similarity in the overall prevalence of overweight or obesity between the M-TEEN Study sample (75% in parents; 27% in children) and the general population (69% in adults; 34.5% in children aged 12-19 years),<sup>19</sup> despite the common perception that military populations are healthier due to the fitness requirements of service members. Second, the focus on geography-based networks (ie, counties) is different from the friends, family, and peer networks that have dominated the literature. However, there are important advantages of our approach. The exogenous placement of military families into counties minimizes concerns that individuals self-select into locations despite the cross-sectional nature of the data. Moreover, our geography-based networks are less subject to homophily concerns that plague friendship and family networks, which are based on self-identification. Nevertheless, we acknowledge that our results might not be generalizable to other networks because the close social ties in networks of families, friends, and

peers are likely to create more complex relationships and behaviors, which would make behaviors more contagious but are also confounded by self-selection. While we did not find any evidence of self-selection, we cannot completely rule it out because we cannot control for all unobserved confounders. Likewise, given that measuring the built environment is complex, our objective and subjective measures may not capture all relevant features influencing obesogenic behaviors. Lastly, self-reported BMI for parents is a limitation.

## Conclusions

Exposure to counties with a higher prevalence of obesity was associated with associated with higher BMI, overweight, and/or obesity in parents and children. There was no evidence to support self-selection or shared environment as explanations for this association, which may suggest the presence of social contagion in obesity.

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*Study concept and design:* Datar.

*Acquisition, analysis, or interpretation of data:*

All authors.

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