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Multiple contexts and adolescent body mass index: Schools, neighborhoods, and social networks

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ABSTRACT

Adolescent health and behaviors are influenced by multiple contexts, including schools, neighborhoods, and social networks, yet these contexts are rarely considered simultaneously. In this study we combine social network community detection analysis and cross-classified multilevel modeling in order to compare the contributions of each of these three contexts to the total variation in adolescent body mass index (BMI). Wave 1 of the National Longitudinal Study of Adolescent to Adult Health is used, and for robustness we conduct the analysis in both the core sample (122 schools; $N = 14{,}144$) and a sub-set of the sample (16 schools; $N = 3335$), known as the saturated sample due to its completeness of neighborhood data. After adjusting for relevant covariates, we find that the school-level and neighborhood-level contributions to the variance are modest compared with the network community-level ($\sigma^2_{\text{school}} = 0.069$, $\sigma^2_{\text{neighborhood}} = 0.144$, $\sigma^2_{\text{network}} = 0.463$). These results are robust to two alternative algorithms for specifying network communities, and to analysis in the saturated sample. While this study does not determine whether network effects are attributable to social influence or selection, it does highlight the salience of adolescent social networks and indicates that they may be a promising context to address in the design of health promotion programs.

1. Introduction

Multiple contexts are relevant in shaping individual and population-level health and health behaviors. These include both *physically or spatially defined environments*, such as neighborhoods, schools, and workplaces, and *socially defined environments*, such as the social networks within which individuals are embedded. Historically these contexts have often been studied individually, likely due to the recentness of the availability of methods capable of addressing them simultaneously (Dunn et al., 2015b; Rasbash and Goldstein, 1994), such as cross-classified multilevel modeling (CCMM). Since the development of CCMM, researchers have used them most frequently to study the *simultaneous* and *relative* contributions of schools and neighborhoods (Aminzadeh et al., 2013; Dunn et al., 2015a, 2015b; Teitler and Weiss, 2000; West et al., 2004), and workplaces and neighborhoods (Moore et al., 2013; Muntaner et al., 2006, 2011; Virtanen et al., 2010) to variation in health behaviors and outcomes. However, studies have rarely bridged the domains of social networks and physical environments, and never within a CCMM framework. This gap in current knowledge is critical to address for two major reasons. First, there is tremendous value in ascertaining the *relative* contributions made by these contexts to the distribution of particular health behaviors and outcomes, as this would enable researchers and policy makers to more effectively target interventions and policies to address heath inequalities (Merlo et al., 2012). Second, omitting potentially relevant contexts from analyses—particularly those using CCMM—may result in *omitted context bias*, or the attribution of variance associated with the omitted level to the included level or levels (Dunn et al., 2015b; Meyers and Beretvas, 2006).

In this study we apply a novel combination of social network community detection analysis and cross-classified multilevel modeling to address this knowledge gap by directly and explicitly comparing the contributions of each of three contexts—schools, neighborhoods, and social networks—to the total variation in adolescent body mass index (BMI). The analysis is conducted using data from wave 1 of the National Longitudinal Study of Adolescent to Adult Health, herein referred to by the official shortened title

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"Add Health". Adolescent body mass index (BMI) is the focus of this study for two main reasons. First, all three contexts have been implicated in prior research as highly relevant to shaping individual-level and population-level distributions of adolescent BMI. Second, the obesity epidemic among children and adolescents in the United States represents a major public health challenge due both to its scope (Ogden et al., 2012) and numerous comorbidities (Ferraro and Kelley-Moore, 2003; National Institute of Health, (1998)). Disentangling the contributions of relevant contexts that shape this epidemic will be key to addressing it.

1.1. Schools

The clustering of child and adolescent weight status by school-level has been found in a variety of data sets and populations (Procter et al., 2008; Richmond and Subramanian, 2008; Townsend et al., 2012). In particular, school-level factors that have been linked to student BMI, physical activity levels, and healthiness of diets, include: socioeconomic status (Miyazaki and Stack, 2015; Richmond et al., 2006; Richmond and Subramanian, 2008), the prevalence of school food practices (*e.g.*, using food as rewards and incentives) (Kubik et al., 2005), aspects of the school built environment such as rural locality, school size and setting, and playground area (Gomes et al., 2014; Miyazaki and Stack, 2015), and aspects of the school curriculum, such as frequency and duration of physical education classes, the qualification of physical education teachers, and the presence of school-based nutrition programs (Gomes et al., 2014; Veugelers and Fitzgerald, 2005). These findings have situated schools in the policy limelight as both potential shapers of child and adolescent diet and physical activity, and as potential locales for the implementation of health promotion programs.

1.2. Neighborhoods

Neighborhoods have similarly been identified as salient to the clustering of child and adolescent BMI (Townsend et al., 2012). Aspects of neighborhood *built environments*, such as proximity and access to parks, physical activity establishments, grocery stores, and fast food providers (Carroll-Scott et al., 2013; Schwartz et al., 2011), aspects of neighborhood *socioeconomic environments*, particularly area deprivation (Carroll-Scott et al., 2013; Grow et al., 2010, Schwartz et al., 2011; Townsend et al., 2012), and aspects of neighborhood *social environments*, including neighborhood crime, safety, and social connectivity (Carroll-Scott et al., 2013; Molnar et al., 2004), have been linked to child and adolescent BMI, healthy and unhealthy eating behaviors, physical activity levels, and hours of sedentary screen time.

1.3. Social networks

The structuring of social networks by health status has become an intriguing new area of research. Among both adolescents (Trogdon et al., 2008; Valente et al., 2009) and adults (Christakis and Fowler, 2007), a tendency for individuals with overweight or obesity to cluster, or in other words, for friends to be similar to each other in terms of weight status, has been found. A recent review (Fletcher et al., 2011) of social network analyses evaluating the eating behaviors and bodyweight of young people found consistent evidence that school friends are clustered according to BMI, and that the frequency of fast food consumption clusters within groups of boys, whereas body image concerns, dieting, and eating disorders cluster among girls. Additionally, youth affected by overweight are less likely to be popular and more likely to be socially isolated.

It is not the purpose of this study to disentangle the roles of *selection* (the tendency for individuals to preferentially select friends who are similar to them in weight status, or other characteristics that are correlated with weight status) and *social influence* (the social contagion of behaviors with relevance to weight status, such as diet and exercise) in generating clustering of weight status in social networks. Instead we address another primary concern (Cohen-Cole and Fletcher 2008; Fowler and Christakis 2008)—the disentangling of the roles of shared environments such as schools and neighborhoods from network effects.

1.4. Simultaneous contexts

The substantive goal of this study is to determine the *relative* contributions of schools, neighborhoods of residence, and adolescent school-based peer networks to the variance of BMI observed. Studies addressing the simultaneous roles of schools and neighborhoods have consistently determined that both contexts contribute significantly to the variance in adolescent BMI and physical activity (Townsend et al., 2012), yet such studies are still rare, and none that we are aware of have included adolescent peer networks as well.

Studies that have addressed the roles of both social networks (broadly defined) and environments to health outcomes of any kind are uncommon. In a recent review we conducted, these studies fell into three categories. In Category 1, network analyses involved the use of friend (or "alter") attributes to predict attributes of individuals (or "egos") of interest, while school environments were controlled for as fixed effects (Ali et al., 2011a,b; Ali and Dwyer, 2011; Ali et al., 2011c; Ali and Dwyer, 2010; Cohen-Cole and Fletcher, 2008; Cohen-Cole and Fletcher, 2009; Trogdon et al., 2008). Variants on this theme include studies where the effect of alters on egos was evaluated based on geographic distance to determine whether the effect degraded as distance increased (Christakis and Fowler, 2007; 2008). The hallmark of studies belonging to this category is that environment is treated as a confounder to be adjusted for, rather than as a separate contributor to the variance that is of substantive interest.

Studies in Category 2 included both network covariates (such as rate of cholera in a social community) and environment covariates (such as rate of cholera in a spatial community) as fixed effect predictors in regression models (Emch et al., 2012; Giebultowicz et al., 2011a, 2011b). Variants of studies in this category would include covariates for constructs related to social networks, such as social capital (Richmond et al., 2014), though we did not specifically review that literature. While studies such as these enable comparisons of particular aspects of networks or environments that may be of interest, this approach does not enable an evaluation of the holistic contributions made by networks and environments.

Category 3 included only one study, which was recently published by Perez-Heydrich et al. (2013). In this study, networks were represented using fixed effects and neighborhood elements were included as spatial autoregression coefficients in order to correct for spatial dependence. This innovative approach to understanding both social and spatial processes is worthy of further exploration. However, for our current purposes this approach does not enable a direct comparison of the relative influence of networks and environment contexts.

This review highlights two points. First, BMI and obesity were addressed in a networks context but only in Category 1, where environment was not usually of substantive interest. Second, an innovative approach is required in order to directly compare and better understand the simultaneity of multiple contexts. In this study we present a novel analytic approach, combining social network analysis and multilevel modeling, to disentangle and compare school, neighborhood, and social network contexts.