



Longitudinal associations of family functioning with body mass index in Mexican-origin adolescents living in the U.S.



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ABSTRACT

Mexican-origin adolescents have a high prevalence of obesity. Research is needed to understand how family context may shape adolescent BMI. This study examined longitudinal associations of family functioning variables with the Centers for Disease Control and Prevention's modified BMI z-score (BMI_z) in 1175 Mexican-origin adolescents, and explored interactions with acculturation. Adolescents (50% female, aged 11–13 y in 2005–06) were identified from an ongoing cohort study of Mexican-origin adults in Houston, TX, and were assessed three times from 2005–06 to 2010–11. In multivariate linear mixed models stratified by gender, we assessed longitudinal associations of family cohesion and family conflict with adolescent BMI_z and explored interactions with language acculturation. We disaggregated the between- (mean) and within-person (individual deviation) components of family cohesion and family conflict to assess the effects on BMI_z. Approximately one-third of adolescents were obese at baseline, and BMI_z declined during the study. In girls, higher mean family cohesion and conflict were associated with steeper declines in BMI_z. Parental linguistic acculturation modified the relationship between within-person deviation in family cohesion and BMI_z in girls, such that high parental U.S. acculturation was associated with a stronger inverse association. There were no significant associations in boys. These findings highlight the potential importance of the family context to female adolescent BMI and the promise of addressing family context in obesity-related interventions.

1. Introduction

Adolescent obesity in the U.S. remains a persistent public health concern, with 20% and 21% of boys and girls obese, respectively (Ogden et al., 2016). The prevalence of obesity is even higher among Hispanics, with 23% of boys and girls obese (Ogden et al., 2016). Obesity in adolescence tends to persist into adulthood (Herman et al., 2009), and increases the risk of type 2 diabetes, cardiovascular disease, and certain cancers (Biro and Wien, 2010; Freedman et al., 2007; World Cancer Research Fund/American Institute for Cancer Research, 2007). As such, understanding the factors that affect weight during the vulnerable period of pubertal development is critical to the design of health promotion efforts.

Previous research places growing emphasis on the importance of the family context for adolescent obesity and related behaviors (Crossman et al., 2006; Gruber and Haldeman, 2009). Family systems theory suggests that family members both influence and are influenced by the actions of others in the family (Broderick, 1993). In this way, the family context helps to shape the formation and maintenance of health behaviors. Indeed, prior research has identified aspects of the family context associated with adolescents' weight and weight-related behaviors. Parental factors include practices such as modeling health behaviors and providing encouragement and support for health behaviors (Rhee, 2008; Pearson et al., 2009; Trost et al., 2003), along with general parenting style (i.e., authoritative, authoritarian, permissive, neglectful) (Berge, 2009; Olvera and Power, 2010; Sleddens et al., 2011;

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Berge et al., 2010). Family-level factors such as family functioning, however, are less understood. Family functioning refers to the interactions among family members and how they manage daily routines, communicate, and respond emotionally to each other (Halliday et al., 2014). Family environments characterized by conflict, a lack of support, and neglect are believed to create conditions ill-suited to support a healthy lifestyle (Broderick, 1993). Although some studies suggest that higher levels of cohesion and lower levels of conflict are associated with healthy weight-related behaviors and outcomes in children and adolescents, particularly girls (Halliday et al., 2014; Franko et al., 2008; Mendelson and White, 1995; Zeller et al., 2007; Bigman et al., 2015; Hooper et al., 2014; Hooper et al., 2009; Berge et al., 2013; Haines et al., 2016), null findings have also been found (Hooper et al., 2009; Hasenboehler et al., 2009; Stradmeijer et al., 2000; Gibson et al., 2007). However, the vast majority of research is based on cross-sectional studies involving predominantly non-Hispanic White participants. There is a need to further study family functioning and adolescent obesity in racial/ethnic minorities using longitudinal data (Halliday et al., 2014; Hooper et al., 2014). This research is especially needed in Hispanics, the fastest growing ethnic minority group in the U.S. (Ennis et al., 2011).

Acculturation, which refers to the process of cultural change whereby an individual adopts aspects of a new culture (Lara et al., 2005), may be critical to consider in investigations of family functioning and health outcomes in Hispanic adolescents. Cultural practices of parenting and socialization within the family may modify the relation of family context variables with adolescent obesity (Halliday et al., 2014; Parke and Buriel, 1998; Kitzman-Ulrich et al., 2010; Rollins et al., 2010; Sen, 2006; Olvera and Power, 2010) and previous studies have shown that obesity-related behavior in Hispanic adolescents differ by acculturation level (Gordon-Larsen et al., 2003; Liu et al., 2009). Family cohesion and conflict, two important family functioning variables, may vary by acculturation (Baer and Schmitz, 2007; Miranda et al., 2000). Further, Hispanic families are often comprised of individuals with differing levels of acculturation, which can be a source of familial stress and tension (Romero and Roberts, 2003; Martinez, 2006), particularly as adolescents seek increasing independence (Wagner et al., 2008). There is a need to investigate whether acculturation in Hispanic families may modify the relationship between family functioning and adolescent weight outcomes (Niemeier et al., 2012; McLean et al., 2003; Branscum and Sharma, 2011; Golan and Crow, 2004). The purpose of this study was twofold: 1) to examine longitudinal associations of two critical dimensions of family functioning (family cohesion and family conflict) with a modified BMI z-score in Mexican-origin adolescents, and 2) to explore the potential moderating effects of adolescent and parent acculturation on these relationships.

2. Methods

2.1. Study sample

Participants were members of a prospective cohort study, the Mexican American Tobacco Use in Children (MATCh) study, that examined factors associated with smoking initiation in Mexican-origin adolescents (Wilkinson et al., 2008). Participants enrolled when they were 11–13 years of age and were followed until 2011, with in-person assessments conducted in 2005–06 (baseline), 2008–09 (follow-up 1 [F1]) and 2010–11 (follow-up 2 [F2]). MATCh participants were identified from an ongoing adult cohort study, the Mano a Mano Mexican American Cohort Study (MACS) (Chow et al., 2017). Recruitment and other details on the MACS cohort can be found elsewhere (Chow et al., 2017; Wilkinson et al., 2005). Households with age-eligible participants for MATCh were identified from the MACS database and invited to participate. A total of 1328 of 1425 households contacted (93%) agreed, and one child from each household enrolled in the study. Bilingual interviewers obtained informed consent from participants'

parents and informed assent from participants. Additional details on MATCh recruitment are described elsewhere (Wilkinson et al., 2008). F1 was completed by 1153 adolescents (87%), and F2 was completed by 1001 adolescents (75%).

At each assessment, participants completed a survey in English or Spanish, depending on their preference, on a hand-held personal digital assistant. Trained interviewers measured adolescents' height (to the nearest centimeter) and weight (to the nearest 0.5 lb) with shoes removed and in light clothing using a portable stadiometer and digital scale, respectively. While only a single measurement of height and weight was taken at baseline, duplicate measures were taken at F1 and F2 and averaged together at each time point. BMI (kg/m^2) was then converted to modified BMI z-scores (BMI_z) using age- and gender-specific criteria from the Centers for Disease Control and Prevention (Centers for Disease Control and Prevention, 2017). Modified z-scores were developed to address the limitations of traditional BMI z-scores (BMI_z), particularly for use with obese and severely obese children, in which the maximum BMI_z attainable at a given sex and age is constrained. This can result in poor quantification of z-scores at very high BMI levels, as a wide range of BMIs may correspond with similar BMI_z, depending on the age and sex of the child (Centers for Disease Control and Prevention, 2017; Freedman et al., 2017a; Freedman et al., 2017b; Freedman et al., 2017c; Berkey and Colditz, 2007; Cole et al., 2005). In comparison, BMI_z does not have an upper limit, and the values are not compressed into a fixed range. The modified z-scores correlate more strongly with measures of adiposity in obese and severely obese children and have been recommended for use with these populations in place of BMI_z (Freedman and Berenson, 2017; Chambers et al., 2017). Demographic (i.e., parents' education and marital status) and measured height and weight data from the parent enrolled in the MACS were obtained from the MACS database. The Institutional Review Board approved all aspects of this study.

2.2. Measures

For this study, we used data from baseline, F1 and F2. BMI_z across the three time points was the dependent variable. Independent variables of interest included family cohesion and family conflict (Foxcroft and Lowe, 1995) assessed at the same three time points using the Family Life Questionnaire, which was validated in MATCh participants using Confirmatory Factor Analysis (Rajesh et al., 2015; Rajesh, 2011). The family cohesion subscale included four items (e.g., “In my family, we really help and support one another”; “We really get along well with each other”), and the family conflict subscale included four items (e.g., “We don't often fight in my family”; “In my family, we hardly ever lose our tempers”). Response options were on a four-point Likert scale ranging from “strongly disagree” to “strongly agree.” The family conflict subscale was reverse coded so that higher scores indicated higher family conflict. Responses for both subscales were averaged to create a summary score (range 1–4). The family cohesion scale demonstrated very good internal reliability (Cronbach's alpha = 0.83), and the family conflict scale demonstrated lower reliability (Cronbach's alpha = 0.61). The scales were significantly inversely correlated ($r = -0.38, -0.45, -0.43, P < 0.001$ at baseline, F1, and F2, respectively).

Indicators of acculturation included adolescent and parent linguistic acculturation, country of birth, and time in the U.S. Adolescent linguistic acculturation was assessed at baseline, F1, and F2 with the Brief Acculturation Scale for Hispanics (Norris et al., 1996), a four-item scale that ascertains language used when reading, speaking at home, speaking with friends, and thinking. Responses were averaged to create a summary score. In parents, linguistic acculturation was assessed for the MACS study (at a single time point) with eight items from the Bidimensional Acculturation Scale for Hispanics (Marín and Gamba, 1996) that inquired about language use, language proficiency, and electronic media preference in English and Spanish, allowing for assessment in two cultural domains (i.e., U.S., Hispanic). Responses were

Table 1
Participant demographics of 1175 Mexican-origin adolescents in Houston, TX.

Adolescent measures		Total sample N = 1175	Girls N = 586	Boys N = 589
Adolescent age Mean (SD)	Baseline	12.4 (0.89)	12.3 (0.87)	12.4 (0.90)
	Follow-up 1	14.9 (1.00)	14.8 (1.00)	14.9 (0.99)
	Follow-up 2	17.3 (1.08)	17.3 (1.08)	17.3 (1.08)
Adolescent modified BMI z-score Mean (SD)	Baseline	0.86 (1.35)	0.75 (1.22)	0.98 (1.45)
	Follow-up 1	0.90 (1.36)	0.74 (1.12)	1.05 (1.55)
	Follow-up 2	0.64 (1.44)	0.48 (1.19)	0.81 (1.64)
Adolescent BMI Mean (SD)	Baseline	23.0 (5.75)	22.8 (5.58)	23.3 (5.90)
	Follow-up 1	25.1 (6.36)	24.7 (5.84)	25.5 (6.82)
	Follow-up 2	25.7 (6.58)	25.2 (6.29)	26.2 (6.84)
Adolescent Obese N (%)	Baseline	373 (32.4)	160 (27.9)	213 (36.9)
	Follow-up 1	318 (31.6)	132 (26.2)	186 (37.0)
	Follow-up 2	228 (26.8)	91 (20.9)	137 (32.9)
Adolescent linguistic acculturation Mean (SD)	Baseline	3.5 (0.89)	3.5 (0.88)	3.5 (0.90)
	Follow-up 1	3.5 (0.72)	3.5 (0.68)	3.5 (0.75)
	Follow-up 2	3.4 (0.71)	3.4 (0.68)	3.4 (0.75)
Adolescent time in the U.S. (baseline) N (%)	< 5 years	87 (7.4)	44 (7.5)	43 (7.3)
	≥ 5 years	216 (18.4)	112 (19.1)	104 (17.7)
	Born U.S.	872 (74.2)	430 (73.4)	442 (75.0)
Family cohesion Mean (SD)	Baseline	3.2 (0.48)	3.2 (0.51)	3.1 (0.45)
	Follow-up 1	3.1 (0.49)	3.1 (0.52)	3.1 (0.45)
	Follow-up 2	3.2 (0.51)	3.2 (0.53)	3.2 (0.49)
Family conflict Mean (SD)	Baseline	2.4 (0.55)	2.4 (0.57)	2.4 (0.54)
	Follow-up 1	2.4 (0.55)	2.4 (0.56)	2.3 (0.54)
	Follow-up 2	2.3 (0.55)	2.3 (0.54)	2.2 (0.55)

Parent measures		Total sample	Girls	Boys
Parent BMI Mean (SD)	–	30.1 (6.24)	30.2 (6.39)	30.1 (6.09)
Parent education N (%)	Less than high school	759 (64.6)	376 (64.2)	383 (65.0)
	High school or equivalent	201 (17.1)	103 (17.6)	98 (16.6)
	Greater than high school	215 (18.3)	107 (18.3)	108 (18.3)
Married N (%)	–	1034 (88.0)	511 (87.2)	523 (88.8)
Parent time in the U.S. N (%)	< 5 years	118 (10.0)	57 (9.7)	61 (10.4)
	5–15 years	471 (40.1)	244 (41.6)	227 (38.5)
	> 15 years	387 (32.9)	188 (32.1)	199 (33.8)
	Born U.S.	199 (16.9)	97 (16.6)	102 (17.3)
Parent linguistic acculturation N (%)	Low U.S. acculturation	804 (68.4)	401 (68.4)	403 (68.4)
	High U.S. acculturation	77 (6.6)	39 (6.7)	38 (6.5)
	Bicultural	294 (25.0)	146 (24.9)	148 (25.1)

averaged within cultural domain and then dichotomized according to established cut-points (Marín and Gamba, 1996). Both domains were combined and categorized to represent a single acculturation variable: high U.S. acculturation (high U.S. score, low Hispanic score); low U.S. acculturation (low U.S. score, high Hispanic score); and bicultural (high U.S. score, high Hispanic score). For both adolescents and parents, country of birth and years in the U.S. were combined into a single variable to reduce collinearity and ease interpretation (see Table 1).

2.3. Analysis

Analyses assessed longitudinal associations of family functioning variables with adolescent BMI_z. For time-varying predictors of interest (i.e., family cohesion, family conflict), we created two variables to disaggregate the between- (mean) and within-person (or individual deviation) components, an approach used previously in studies of adolescent obesity (Laska et al., 2012; Stevens et al., 2007). The first variable represented the mean value of each time-varying predictor over the three time points for each participant (i.e., between-person differences). The second variable represented the deviation from that mean of each participant (i.e., within-person differences) for each time point (Howard, 2015). To facilitate interpretation, all continuous variables, except for the within-person family cohesion and family conflict, were centered by subtracting the grand mean of the observed values. Baseline mean-centered age, henceforth referred to as age,

served as the index for time.

Linear mixed models were used for all analyses, as they account for clustering of observations within individuals, allow for the inclusion of time-invariant and time-varying predictors, model individual-specific associations through the inclusion of random slopes and intercepts, and flexibly accommodate missing data (Gibbons et al., 2010). We used linear mixed models with individual-specific random intercepts and random slopes that were allowed to be correlated. The first set of models regressed BMI_z on the mean and deviation variables for family cohesion and family conflict, age, and interaction terms for family cohesion and conflict by age. Interactions enabled examination of whether the change in BMI_z over time (i.e., as adolescents aged) varied according to family functioning variables. Models were stratified by gender and controlled for adolescents' and parents' acculturation, adolescents' and parents' time in the U.S., and parents' marital status, BMI, and education, as well as household size. We did not include income due to considerable missingness (approximately 40%) in the MACS database. Nonsignificant interactions ($P \geq 0.05$) were removed, and the models were reassessed. We then ran exploratory models to examine whether associations of family cohesion and family conflict with BMI_z differed by acculturation variables, with interaction terms for each acculturation variable examined in separate models. Only interaction terms that were statistically significant ($P < 0.05$) in these individual models were retained. Analyses were performed using the “lme4” package in the R statistical computing environment (R Version 3.3.2) (R

Core Team, 2015).

3. Results

The sample included 1175 adolescents. Of the original 1328 participants at baseline, 135 had missing parent data, 17 had invalid or missing anthropometric data, and 1 had missing demographic data. Girls who were excluded were more likely to have parents who were low U.S. acculturated than girls who were not excluded (83.3% vs. 68.4%, $P = 0.04$). Boys who were excluded were slightly older at F1 and F2 than boys who were not excluded (14.9 years vs. 14.6 years, $P = 0.02$ at F1; 17.3 years vs 16.8 years, $P = 0.01$ at F2), and were less likely to have married parents (76.4% vs. 88.8%, $P = 0.02$). There were no statistically significant differences in those included and excluded for baseline, F1 and F2 BMIaz, and no significant differences in baseline BMIaz in participants who had missing data at F1 or F2 versus those who had complete follow-up data.

Characteristics of the sample are shown in Table 1. Participants were evenly distributed by gender with a baseline mean age of 12.4 years. The majority of adolescents were born in the U.S. (74.2%), whereas 16.9% of parents were born in the U.S. Among parents, 6.6% were categorized as high U.S. acculturated, 68.4% were low U.S. acculturated, and 25% were bicultural. Adolescent BMIaz fluctuated over the study period, with mean values of 0.86, 0.90 and 0.64 at baseline, F1, and F2, respectively.

3.1. Main analyses: association of family cohesion and conflict with adolescent BMI

Table 2 presents the results of the primary analyses in girls that tested the main effects of family cohesion and conflict on adolescent BMIaz along with their interactions with age. The deviation of family cohesion was inversely associated with BMIaz such that an adolescent girl whose family cohesion increased by one unit during the study period had an average decrease in BMIaz of 0.09 ($P < 0.05$). The interactions between mean family cohesion and mean family conflict with age were statistically significant, whereas the interactions involving the deviations of these variables with age were not (non-significant interactions were not retained). Results indicate that girls' BMIaz declined with age, and that higher levels of mean cohesion and mean conflict

were associated with steeper declines (Fig. 1a and b).

In boys, BMIaz also declined with age, yet no significant relationships were observed between any measure of family functioning and adolescent BMIaz (Table 3).

3.2. Exploratory analyses: moderating effect of acculturation

In girls, parental linguistic acculturation modified the relationship between within-person deviation in family cohesion and BMIaz such that high parental U.S. acculturation was associated with a stronger inverse association (Fig. 2). A one-unit increase in family cohesion during the study period was associated with a decrease of 0.40 in BMIaz in a girl whose parents were highly U.S. acculturated and a decrease of 0.052 and 0.095 in BMIaz in a girl whose parents were low U.S. acculturated and bicultural, respectively. Adolescent acculturation variables and adolescent and parent time in the U.S were not significant effect modifiers.

There were no significant interactions between any family functioning and acculturation variables in boys.

4. Discussion

In this study, we observed significant longitudinal associations between family functioning variables and adolescent girls' BMIaz. Specifically, higher levels of mean family cohesion and mean family conflict over the study were each associated with steeper declines in BMIaz. Additionally, associations of within-person increases in family cohesion with BMIaz varied in magnitude, according to parental linguistic acculturation. These longitudinal findings highlight the potential importance of the family's social and cultural contexts to adolescent girls' BMI.

Our finding that both mean and within-person deviations in family cohesion were inversely associated with BMIaz in girls is consistent with the literature. Previous studies have generally found that higher levels of family cohesion are associated with better dietary habits (Franko et al., 2008; Welsh et al., 2011; Cromley et al., 2010; Mellin et al., 2002), higher physical activity (Ornelas et al., 2007; Bigman et al., 2015), and lower BMI in adolescents (Beck and Terry, 1985; Banis et al., 1988). The longitudinal design of our study and the focus on a Mexican-origin population bolster the evidence that family cohesion

Table 2
Girls' Longitudinal Model Predicting Adolescent modified BMI z-score (BMIaz).

Variables	Model 1 ^a			Model 2 ^b		
	β	(SE)	95% CI	β	(SE)	95% CI
Adolescent age	-0.05***	0.01	-0.06, -0.03	-0.05***	0.01	-0.06, -0.03
Family cohesion						
Deviation	-0.09*	0.04	-0.16, -0.01	-0.05	0.05	-0.14, 0.04
Mean	-0.10	0.13	-0.35, 0.16	-0.10	0.13	-0.36, 0.15
Mean \times age	-0.04*	0.02	-0.09, -0.01	-0.04*	0.02	-0.08, -0.01
Family conflict						
Deviation	0.03	0.03	-0.04, 0.09	0.02	0.03	-0.04, 0.09
Mean	0.08	0.13	-0.16, 0.32	0.08	0.13	-0.16, 0.33
Mean \times age	-0.04*	0.02	-0.08, -0.01	-0.04*	0.02	-0.08, -0.01
Interactions between family cohesion \times acculturation						
Deviation \times parent low U.S. acculturation (ref)	-	-	-	-	-	-
Deviation \times parent high U.S. acculturation	-	-	-	-0.35*	0.14	-0.63, -0.07
Deviation \times parent bicultural	-	-	-	-0.04	0.08	-0.20, 0.12

This study was conducted in Houston, TX from 2005-06 to 2010-11.

Bold refers to statistically significant estimates ($p < 0.05$).

^a Model controlled for household size, parent marital status, parent BMI, parent education, parent acculturation, adolescent age (shown in the table) and adolescent acculturation.

^b Model controlled for household size, parent marital status, parent BMI, parent education and adolescent age (shown in the table).

* $P < 0.05$.

*** $P < 0.001$.

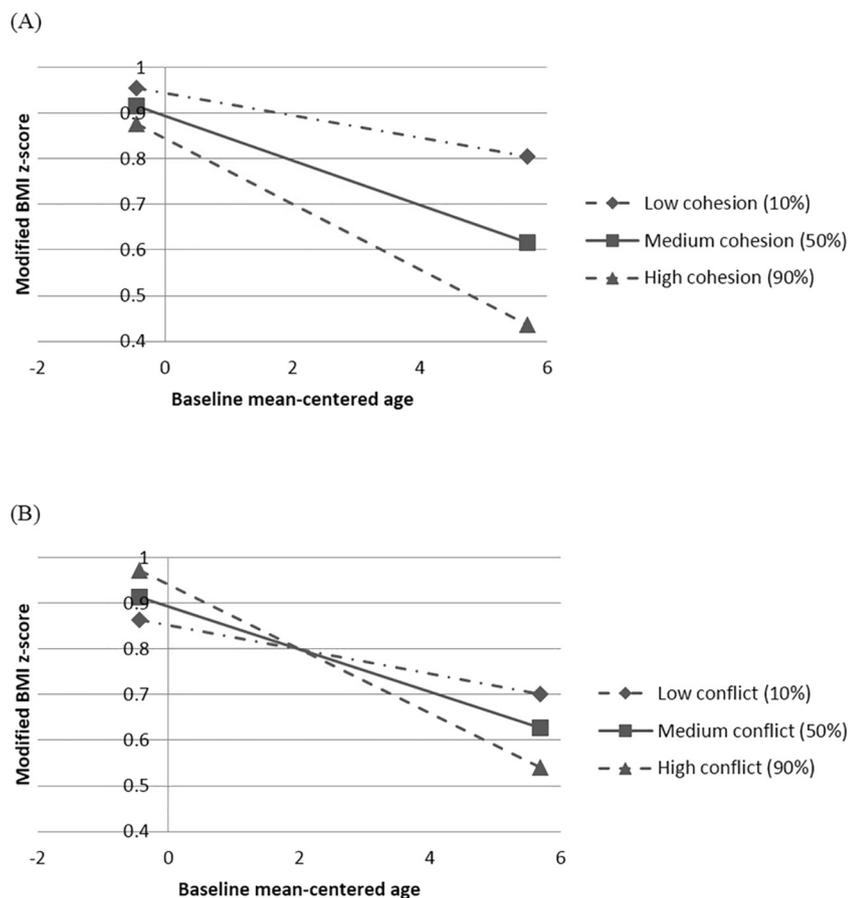


Fig. 1. Interactions of age and family functioning variables on girls' modified BMI z-score (BMIaz). (A) BMIaz trajectories for girls with low, medium, and high levels of mean family cohesion*. (B) BMIaz trajectories for girls with low, medium, and high levels of mean family conflict*. *We used the 10th, 50th and 90th percentiles mean conflict to represent the low, medium and high levels of family conflict, respectively; this study was conducted in Houston, TX from 2005–06 to 2010–11.

Table 3
Boys' Longitudinal Model Predicting Adolescent modified BMI z-score (BMIaz).

Variables	Model 1		
	β	(SE)	95% CI
Age	-0.03**	0.01	-0.05, -0.01
Family cohesion			
Deviation	-0.03	0.05	-0.13, 0.07
Mean	-0.10	0.17	-0.42, 0.23
Family conflict			
Deviation	0.01	0.04	-0.07, 0.09
Mean	-0.17	0.15	-0.47, 0.13

Notes: model controlled for household size, parent marital status, parent BMI, parent education, parent acculturation, adolescent age and adolescent acculturation; this study was conducted in Houston, TX from 2005–06 to 2010–11.

Bold refers to statistically significant estimates ($p < 0.05$).

** $P < 0.01$

can affect adolescent BMI, at least among girls. Surprisingly, mean family conflict was also inversely associated with BMIaz in girls. This differs from previous studies (Halliday et al., 2014; Hooper et al., 2009; Hanson et al., 1990; Hernandez and Pressler, 2015) and underscores the need for further research in this population. While the reasons for this association are unclear, the effects of family interactions including teasing and pressure to lose weight on girls' emotional health, body image, and weight-related behaviors warrant further investigation (Toro et al., 2006; Ata et al., 2007).

In contrast to girls, Mexican-origin adolescent boys' BMI may not be strongly affected by family cohesion and family conflict. Although some studies have observed significant associations with family functioning (Halliday et al., 2014), our findings are consistent with other studies

(Mendelson and White, 1995; Berge et al., 2013; Haines et al., 2016) and may indicate that other aspects of the family context, such as parent BMI (Butte et al., 2007; Elder et al., 2010; Lin et al., 2004), parenting style (Berge et al., 2010), or consistent family meals together (Taveras et al., 2005), have more influence on adolescent boys' BMI. Similarly, family conflict in boys may be more strongly related to other risk factors such as smoking and alcohol use (Rajesh et al., 2015; Baer et al., 1987; Bray et al., 2001).

This study was unique in its assessment of possible interactions between family functioning and acculturation variables. Parental U.S. acculturation was an effect modifier with significant interactions in girls involving the within-person deviations in family cohesion. The inverse association between the within-person deviation in family cohesion and BMIaz was much stronger in girls whose parents were highly U.S. acculturated relative to those who were less U.S. acculturated or bicultural. Although this study did not allow for the examination of mechanisms underlying these relationships, the literature may offer some insight. First, poverty is strongly associated with increased risk of obesity in children and adolescents (Rogers et al., 2015) and is more concentrated among less acculturated Hispanics. For Hispanic girls with less acculturated parents, this may offset positive influences of family cohesion on adolescent weight outcomes. Second, acculturation may be associated with parents' body image perception of their children, which could have implications for children's actual weight status (Olvera et al., 2005). Research has found that low-income Hispanic mothers and mothers in Mexico prefer their children to have a heavier body shape (Contento et al., 2003). If such traditional beliefs are more prevalent among bicultural and low U.S. acculturated parents, this may contribute to the differential associations of family cohesion with adolescent weight outcomes observed. Although speculative, this offers potential pathways for further investigation.

Notably, BMIaz declined between F1 and F2 in both boys and girls,

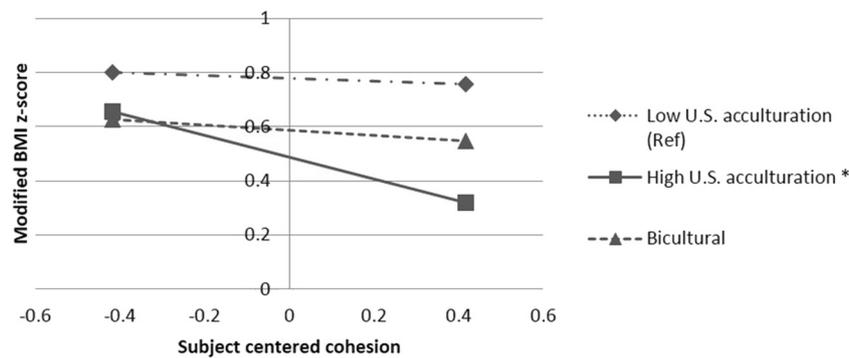


Fig. 2. Interaction of deviations in within-person family cohesion and parent's linguistic acculturation on girl's modified BMI z-score (BMI_z). *Interaction effect is significant at $P < 0.05$; this study was conducted in Houston, TX from 2005–06 to 2010–11.

although BMI continued to increase. While this contrasts with national trends (Ogden et al., 2016; Kimm et al., 2002; Gordon-Larsen et al., 2004), other studies have documented declines in BMI_z and obesity during the latter teenage years (Araujo et al., 2014; Popkin and Udry, 1998). The reasons for the decline are not clear but may pertain to growth patterns, pubertal maturation (Loomba-Albrecht and Styne, 2009), body dissatisfaction, social pressures to lose weight (Calzo et al., 2012), and possibly regression to the mean over time (Cockrell Skinner et al., 2016). Importantly, the high baseline prevalence of obesity indicates that gains in adiposity took place prior to adolescence.

4.1. Future research and practice

Results from this study have implications for the design of culturally appropriate family-based interventions in Mexican-origin adolescent girls. Few interventions targeting obese Hispanic adolescents have intervened upon family system components (Kitzman-Ulrich et al., 2009), yet family cohesion may be important to focus on through activities and counseling that promote support and bonding among family members. Although family cohesion may be less relevant for adolescent Mexican-origin boys, other actionable variables within the family environment can be considered, such as instrumental support from parents or the family's food culture (Heredia et al., 2016). Interventions should also consider levels of acculturation within the family (Miranda et al., 2006). Further research is needed to better explicate the longitudinal relationships between family functioning, acculturation, and adolescent weight outcomes in understudied populations such as Mexican-origin adolescents.

4.2. Strengths and limitations

This study had several limitations. First, the purpose of the MATCH study was to examine smoking initiation in Mexican-origin adolescents, and thus it was not designed or powered to test associations of family functioning with BMI_z. Nonetheless, the study presented an opportunity to expand the research of an understudied population to include investigation in this new area, recognizing the limitations of this approach. Further research is needed to better elucidate the pathways linking family cohesion and conflict with adolescent weight-related outcomes to inform obesity prevention efforts in this population. Second, the lower internal reliability ($\alpha = 0.61$) of the family conflict subscale may indicate a need for further refinement of this measure in this population. Third, we tested multiple interaction terms, making it possible that the significant interaction between family functioning and parental linguistic acculturation was due to chance alone. Because of the exploratory nature of these analyses, we did not adjust for multiple comparisons (Schochet, 2008). Fourth, the findings observed here may not generalize to other Hispanic subgroups or to adolescents of a different race/ethnicity. Fifth, in this study we used the modified BMI z-

score developed by the CDC to overcome recognized limitations of BMI_z that hinder valid correlations with adiposity in severely obese children (Centers for Disease Control and Prevention, 2017; Chambers et al., 2017). However, the most appropriate measure for tracking BMI over time remains unclear and may depend on the population studied and degree of obesity (Kelly and Daniels, 2017). Finally, our results showed small to moderate effect sizes on BMI_z. Thus, other factors likely exert a stronger effect, such as attitudes towards and support for weight-related health behaviors, access to healthy foods, and opportunities for physical activity. Despite these limitations, this study has several important strengths. This study capitalized on two large, linked, and unique datasets of an understudied population of Mexican-origin adolescents and their parents. We were able to examine repeated measures of key predictor and outcome variables over a six-year period, with high participation rates across all time points. We disaggregated the effects of family cohesion and family conflict into between- and within-person components. This facilitated understanding of the longitudinal, independent contributions of the mean values and deviations of family functioning.

4.3. Conclusion

This study lends evidence to the body of work aimed at understanding the potential effects of family functioning on adolescent weight outcomes, particularly in Mexican-origin youth. Our results suggest that family cohesion, family conflict, and parental language acculturation are important variables to consider in examinations of family influences on adolescent girls' weight outcomes.

Abbreviations

BMI	body mass index
MATCH	Mexican American Tobacco Use in Children
MACS	Mano a Mano Mexican American Cohort Study

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Conflict of interest statement

The authors declare that there are no conflicts of interest.

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