Mother-reported sleep, accelerometer-estimated sleep and weight status in Mexican American children: sleep duration is associated with increased adiposity and risk for overweight/ obese status

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SUMMARY

We know of no studies comparing parent-reported sleep with accelerometer-estimated sleep in their relation to paediatric adiposity. We examined: (i) the reliability of mother-reported sleep compared with accelerometer-estimated sleep; and (ii) the relationship between both sleep measures and child adiposity. The current cross-sectional study included 303 Mexican American mother–child pairs recruited from Kaiser Permanente Northern California. We measured sleep duration using maternal report and accelerometry and child anthropometrics. Concordance between sleep measures was evaluated using the Bland–Altman method. We conducted zero-ordered correlations between mother-reported sleep, accelerometer-estimated sleep and child BMI *z*-scores (BMIz). Using linear regression, we examined three models to assess child BMIz with mother-reported sleep (model 1), accelerometer-estimated sleep (model 2) and both sleep measures (model 3). Children had an average age of 8.86 years (SD = 0.82). Mothers reported that their child slept 9.81 $\pm$ 0.74 h [95% confidence interval (CI): 9.72, 9.89], compared to 9.58 $\pm$ 0.71 h (95% CI: 9.50, 9.66) based on accelerometry. Mother-reported sleep and accelerometer-estimated sleep were correlated ($r = 0.33$, $P < 0.001$). BMIz outcomes were associated negatively with mother-reported sleep duration (model 1: $\beta = -0.13$; $P = 0.02$) and accelerometer-estimated sleep duration (model 2: $\beta = -0.17$; $P < 0.01$). Accounting for both sleep measures, only accelerometer-measured sleep was related to BMIz (model 3: $\beta = -0.14$, $P = 0.02$). Each sleep measure was related significantly to adiposity, independent of covariates. Accelerometry appeared to be a more reliable measure of children's sleep than maternal report, yet maternal report may be sufficient to examine the sleep–adiposity relationship when resources are limited.

INTRODUCTION

Given the global rise in paediatric obesity, as well as the increase in short sleep duration among children and adolescents, recent investigations have examined the association between sleep and adiposity in this population. Identifying the underlying factors that may contribute to the development of overweight and obesity during childhood years is imperative, given that obesity is an independent risk factor for lifelong obesity and metabolic dysfunction, including insulin resistance, type 2 diabetes and inflammation, which are disproportionate among Latino children (de Ferranti *et al*., 2006; Skinner *et al*., 2010). Moreover, research has found that Latino children are more likely to have an irregular bedtime and/or have a bedtime after 21:00 hours in comparison to non-Latino white children (Owens and Jones, 2011). Further research is needed to identify points of prevention and intervention, particularly among Latino youth, who are affected disproportionately by obesity and metabolic disturbances (Ogden *et al*., 2010).

Recently, short sleep duration has been described as a risk factor for childhood overweight and obesity. Two separate meta-analyses of cross-sectional studies reported that short sleep duration was related consistently to increased adiposity in children (Cappuccio *et al*., 2008; Chen *et al*., 2008). Of these studies, most investigations utilized parent and/or child reports of sleep. Few studies have used accelerometer-estimated sleep to examine the relationship between sleep duration and child adiposity (Chaput *et al*., 2011; Colley *et al*., 2012; Gupta *et al*., 2002; Nixon *et al*., 2008). Of these studies, Gupta *et al.* (2002) found that for every hour of sleep loss, the odds of obesity increased by 80% in US adolescents ($n = 383$). Chaput *et al.* (2011) found a U-shaped relationship between sleep duration and adiposity in Canadian 8–10-year-olds ($n = 550$), and Colley *et al.* (2012) did not find any association. Nixon *et al.* (2008) found that sleeping fewer than 9 h was related independently to obesity in a cross-sectional study of Australian children at age 7 years. Furthermore, several longitudinal studies have been conducted, but have yielded inconsistent findings (Agras *et al*., 2004; Araujo *et al*., 2012; Eisenmann *et al*., 2006; Lumeng *et al*., 2007; Tatone-Tokuda *et al*., 2012; Touchette *et al*., 2008). Of these studies, three studies supported the findings of cross-sectional studies (Agras *et al*., 2004; Lumeng *et al*., 2007; Touchette *et al*., 2008); two studies reported that sleep mattered more in the development of overweight or obesity in boys than girls (Eisenmann *et al*., 2006; Tatone-Tokuda *et al*., 2012); and one study reported that sleep did not predict adiposity significantly in boys or girls (Araujo *et al*., 2012). These studies were based on parent- or self-reported sleep, which may explain some of the differences in findings given that reports may have been representative of the time to bed as opposed to sleep onset. Because sleep onset is variable, subjective reports of sleep, whether by parent or child, may be less reliable and result in an over-estimation of sleep duration (Holley *et al*., 2009). However, whether or not parent-reported sleep is sufficiently reliable to examine the relationship between sleep and child adiposity has yet to be established. In contrast, accelerometry is becoming recognized as a useful method of sleep assessment for epidemiological purposes (Hjorth *et al*., 2012). One study used accelerometry to estimate sleep duration and found a consistent relationship between sleep and obesity in both adolescent males and females (Lytle *et al*., 2011). A comparison study of parent-reported sleep duration and accelerometer-estimated sleep duration and their relation to paediatric adiposity could be beneficial, given the state of the budget and limited funds to assess sleep using more costly objective methods compared with cost-effective parent report.

To our knowledge, three studies have compared parent-reported sleep with objectively measured sleep in 6–11-year-olds (Colley *et al*., 2012; Holley *et al*., 2009; Nixon *et al*., 2008). In one study (United Kingdom; $n = 91$), investigators did not examine the relationship between sleep and adiposity (Holley *et al*., 2009). In the second study (Canada, $n = 878$), researchers did not compare the reliability of parent-reported sleep with accelerometer-estimated sleep, nor did they detect a relationship between sleep and adiposity, using both sleep measures (Colley *et al*., 2012). In the third study, sleep duration estimates were compared between parent report and accelerometry, but they did not examine the relationship between parent-reported sleep and adiposity. To address these gaps in the literature, the purpose of this study was threefold. First, we examined the reliability of retrospective parent-reported sleep duration, compared with an objective measure of sleep duration in a sample of Mexican American children. Secondly, we assessed the cross-sectional relationship between both retrospective parent-reported and objectively measured sleep and children's weight status, while controlling for potential covariates [i.e. maternal body mass index (BMI), occupation, acculturation, child pubertal status]. Lastly, we explored whether or not there was a sleep–gender interaction in the relationship with BMI status.

METHODS

Participants and data collection

We recruited 326 families who were members of Kaiser Permanente Northern California, an integrated health-care delivery organization. Parents were sent letters introducing the research, were telephoned, screened for eligibility and invited to participate in the study. Parent–child pairs were eligible if: (i) the mother was of Mexican origin (born in the United States or Mexico), (ii) the child was 8–10 years of age and (iii) the child had no major illnesses. Bilingual interviewers obtained parent-informed consent and child assent to participate in the research. They interviewed parent–child pairs in their homes in the participants' preferred language. Twenty-three mother–child pairs who were missing data on children's sleep, height or weight were excluded from the study, resulting in a final sample of 303 mother–child pairs. The study was approved by the University of California San Francisco and Kaiser Permanente Northern California Research Foundation Institutional Review Boards.

Measure development

All study measures were translated into Spanish and reviewed side-by-side by a bilingual committee. Translations were compared for equivalent meaning, and items were revised or decentred as needed (Marin and Vanoss Marin, 1991). Decentring is a process in which both languages are considered equally important, and either language may be altered to obtain linguistically equivalent items.

Study measures

Mother-reported sleep duration (retrospective)

We assessed children's sleep duration with two items used in previous research (Blair *et al.*, 2012). Mothers were asked: 'What time does (child) usually go to sleep at night?' and 'What time does (child) usually wake up in the morning?'. From these responses, the child's usual sleeping time was calculated. No distinction was made between weekday and weekend night-time sleep duration.

Accelerometer-estimated sleep duration

Sleep duration was assessed consecutively for 2 week-nights and 1 weekend night. Three days was chosen to reduce participant burden and maximize study participation. Children's free-living activity was recorded for 3 consecutive days (2 week-days, 1 weekend day) using the Actical accelerometer (Philips Respironics, Bend, OR, USA). Actical contains an omnidirectional accelerometer built from a cantilevered rectangular piezo-electric bimorph plate and seismic mass, which is sensitive to movement in all directions. The piezo-electric sensor is orientated in the Actical such that maximum sensitivity is obtained when the centre of body mass is moved against gravity. When positioned on the hip, the device is most sensitive to vertical movements of the torso. Actical is sensitive to movements in the 0.5–3 Hz range, allowing for detection of sedentary movements as well as high-energy movements. Actical's frequency range minimizes the effect of undesirable noise impulses, which tend to skew results.

Each accelerometer was programmed to collect data at 1-min intervals at a specified start time. The monitor was attached to an elastic belt with an adjustable buckle, and positioned on the child above the iliac crest of the right hip. Research assistants provided verbal and written instructions for care and placement of the monitor and belt at the time of the home visit. The child was instructed to wear the monitor at all times for 3 consecutive days, except during bathing. Accelerometers were collected after the third day.

Night-time sleep duration was determined as the mean of the three 24-h accelerometer measurements. To minimize interinterpreter variation, a single trained research assistant conducted visual inspections. A plot of activity counts per minute for each 24-h period was used to identify the time of sleep onset and termination. The night-time sleep period lasts about 10 h, during which the activity counts are usually zero. Sleep periods were cross-checked with the participants' wear log for 'off' times. Stretches of 20 min of zeroes without being explained as sleep were considered 'off'. Any minutes scored as awake were removed from the sleep duration. Sleep duration measured by hip-worn accelerometry has been found to be highly correlated ($r = 0.93$) with sleep duration measured with a wrist-worn accelerometer in children aged 10–11 years (Kinder *et al.*, 2012).

Meeting the 10-h sleep recommendation

Using mother-reported and accelerometer-estimated sleep duration variables, we created two categorical sleep variables according to the National Sleep Foundation's (NSF) 10-h sleep recommendation for 5–12-year-olds (National Sleep Foundation). Children were categorized as meeting the 10-h sleep recommendation (≥10 h = 1; reference group) and not meeting the 10-h recommendation (<10 h = 2).

Body mass index (BMI)

Trained research assistants measured child height and weight using standard procedures (Stallings and Fung, 1999). Height and weight were measured in duplicate while the participant was wearing light indoor clothing and no shoes. BMI was calculated [BMI = weight (kg) height (m)^2] converted to age- and gender-specific percentiles, and converted to *z*-scores using Centers for Disease Control (CDC) growth charts. Based on BMI percentiles, children were also classified as underweight (<5th percentile), normal weight (≥5th–<85th percentile), overweight (≥85th–<95th percentile) or obese (≥95th percentile). For the linear regressions, we used children's BMI *z*-scores (BMIz). For logistic regressions, we classified children as normal (<85th percentile = 1) versus overweight/obese (≥85th percentile = 2).

Pubertal status

We used the five-item Pubertal Development Scale to assess pubertal status (Petersen *et al.*, 1988), which was completed by mothers. This measure, with versions for males and females, asks about physical development on characteristics associated with physical maturation (growth spurt, body hair, skin change, breast development, menarche, voice changes), with responses ranging from no (1) to yes, a lot (3). A single score representing the mean of the scale items was obtained.

Covariates

Demographic variables included child age and gender and maternal characteristics, including BMI, years of education, occupational status and acculturation. Mothers' height and weight was measured and BMI was calculated: BMI <25 (normal weight); BMI: 25–29.9 (overweight); BMI ≥30 (obese). Occupational status ranged from lowest (1 = unskilled) to highest (9 = professional) (Hollingshead, 1975). Mother's acculturation was assessed using the Spanish and English Language Use subscales of the Bidimensional Acculturation Scale for Hispanics (Marin and Gamba, 1996). For example, Spanish subscale items included: 'how often do you speak Spanish; how often do you think in Spanish; how often do you speak Spanish at home with your family?'. Items are scored from never (=1) to always (=5), and subscales had good reliabilities in this sample (α = 0.88–0.94).

Statistical analyses

The results of the two sleep measurements (mother-reported and accelerometer-estimated sleep) were analysed by means of descriptive statistics [median, mean and standard deviation (SD)]. Pearson's correlation coefficient was used to estimate between mother-reported and accelerometer-estimated sleep. In addition, we estimated Pearson's correlations between the sleep variables and child BMIz. A Bland–Altman plot with 95% limits of agreement was calculated as a measure of agreement between (and within) the instruments (Bland and Altman, 1986). This approach allowed individual comparisons between mother-reported sleep and accelerometer-estimated sleep by examining a plot of the differences in sleep duration by maternal report and accelerometry versus mean sleep duration by both measurements. To evaluate the presence of a systematic bias, we performed a regression analysis of the difference in sleep duration by maternal report and accelerometry on mean sleep duration. Paired *t*-tests were performed to determine differences between the mean values obtained with maternal report and accelerometry and to compare night-time sleep duration during the week (mean of two nights) versus the weekend (one night).

We also conducted correlations to assess which demographic variables and covariates were related to child BMI, and should therefore be included in multivariate analyses. Next, we conducted three multiple regressions, examining child BMIz with (1) mother-reported sleep, (2) accelerometer-estimated sleep or (3) both mother-reported and accelerometer-estimated sleep. Each regression equation included the demographics and covariates that had been related significantly to child BMI in the correlations. Finally, we conducted secondary analyses to test whether not meeting the NSF's 10-h sleep recommendation was a risk factor for being overweight or obese. We conducted three multiple regressions, examining overweight/obese status with (1) mother-reported sleep, (2) accelerometer-estimated sleep or (3) both mother-reported and accelerometer-estimated sleep. We used SPSS version 20 (SPSS Inc., Chicago, IL, USA) to perform all analyses at $P < 0.05$.

RESULTS

Sample characteristics

Descriptive statistics for mother–child pairs are included in Table 1. Participating children were aged 8–10 (mean = 8.86 years, SD = 0.82), 53% female and 95% US-born. Nearly half the children were overweight (20%) or obese (28%). Mothers had about 11 years of education, 75% were employed and the average occupation was being a skilled worker (mean = 3.23; SD = 2.03). Most mothers chose to be interviewed in Spanish (71%).

Forty-eight per cent of mothers reported that their child slept at least 10 h compared with accelerometer data, showing that 26% of children slept at least 10 h (Table 1). As shown in Table 2, mother-reported sleep duration was an average of 9.81 h night^{-1} [SD = 0.74; median = 10.0; 95% confidence interval (CI): 9.72, 9.89] compared with accelerometer-estimated sleep duration, which was an average of 9.58 h night^{-1} (SD = 0.71; median = 9.55; 95% CI: 9.50, 9.66); $t_{(302)} = 4.43$). The difference in mean values was statistically significant ($P < 0.001$). On average, mothers reported that their child slept 0.22 h [SD = 0.87 (CI: 0.12, 0.32)] more (equivalent to 13 min) compared with the accelerometer-estimated sleep duration. In addition, the paired *t*-test showed that children slept slightly more at

Table 1 Descriptive characteristics of Mexican American Mother–child pairs (n = 303)

Variable (range)	*% or mean (SD)*
Child	
Female	54
Age (8–10 years)	8.86 (0.82)
Pubertal status (1–5)	1.32 (0.26)
BMI *z*-score	0.97 (1.02)
Overweight	20
Obese	30
Meets the NSF sleep recommendation*	
≥10-h sleep duration (accelerometer)	26
≥10-h sleep duration (maternal report)	52
Mother	
Education (0–19 years)	10.79 (3.67)
Occupational status (1–9)	3.27 (2.10)
Acculturation (1–5)	
English language	2.64 (1.28)
Spanish language	4.21 (1.12)
BMI	30.38 (6.86)
Overweight	33
Obese	48

BMI, body mass index; NSF, National Sleep Foundation; SD, standard deviation.
*National Sleep Foundation recommendation for 5–12-year-olds.

the weekend [9.84, SD = 1.25 (CI: 9.70, 9.98)] than during the week [9.45 SD = 0.90 (CI: 9.36, 9.53)].

As shown in Table 2, we found a significant correlation between mother-reported sleep and accelerometer-estimated sleep ($r = 0.33$, $P < -0.001$). A Bland–Altman plot for night-time sleep duration is shown in Fig. 1. This plot shows comparisons between mother-reported and accelerometer-estimated sleep duration by plotting differences between sleep duration maternal report and accelerometry. There was no significant bias detected in the regression analysis of the difference in sleep duration by maternal report and accelerometry on mean sleep duration. The mean difference between maternal report and accelerometer measures was not a function of the mean sleep duration.

We estimated bivariate correlations between sleep measures and child BMIz. Both mother-reported sleep and accelerometer-estimated sleep were correlated significantly with child BMIz ($r = -0.18$, $P = 0.001$; $r = -0.20$, $P = 0.001$, respectively). In addition, child pubertal status and maternal characteristics were also related to child BMIz, including mothers' occupation ($r = -0.16$, $P < 0.01$), Spanish-language acculturation ($r = 0.14$, $P = 0.02$) and BMI ($r = 0.32$, $P < 0.001$). Accordingly, these variables were used as covariates in subsequent multiple regression analyses. Child age and gender, mother's education and English-language acculturation were not correlated with child BMIz and were therefore excluded from further analyses.

As shown in Table 3, we examined three multivariate linear regression models using one or both child sleep measures as explanatory measures in a model of child BMIz, with each model controlling for covariates. In the first model, longer sleep duration by maternal report was related to lower child BMIz ($\beta = -0.13$, 95% CI: -0.34, -0.04; $P = 0.02$). In the second model, longer sleep duration based on accelerometry was related to lower child BMIz ($\beta = -0.17$; 95% CI: -0.39, -0.08; $P < 0.01$). In the third model, we included both mother-reported and accelerometer-estimated sleep durations. Only accelerometer-estimated sleep duration remained significantly related to lower child BMIz ($\beta = -0.14$; 95% CI: -0.36, -0.03; $P = 0.02$).

In all three models, only two covariates were related significantly to child BMIz. More advanced pubertal stage was related to higher BMIz ($\beta = 0.17$; 95% CI: 0.24–0.25, 1.10–1.11; $P < 0.01$). In addition, higher maternal BMI was related to higher child BMIz ($\beta = 0.29$–0.31; 95% CI: 0.03, 0.06; $P < 0.001$).

Table 4 shows three multivariate logistic regression models using one or both variables for meeting the 10-h sleep recommendation (based on maternal report and accelerometry) in a model of child overweight/obese status, with each model controlling for covariates. In the first model, children who did not meet the 10-h sleep recommendation, based on maternal report, were at greater risk for being overweight/obese (OR: 2.1; 95% CI: 1.08, 4.24; $P = 0.03$) than those children who met the 10-h recommendation. In the second model, we found no association between children who did not meet the 10-h sleep recommendation, based on accelerometry and risk for being overweight/obese. In the third model, we included both variables for meeting the 10-h sleep recommendation and found no statistically significant association with being overweight/obese. The only significant covariate in all three models was maternal BMI, which was related to higher risk for being overweight/obese (OR = 1.1; 95% CI: 1.03–1.04, 1.18–1.19; $P = 0.002$–0.003).

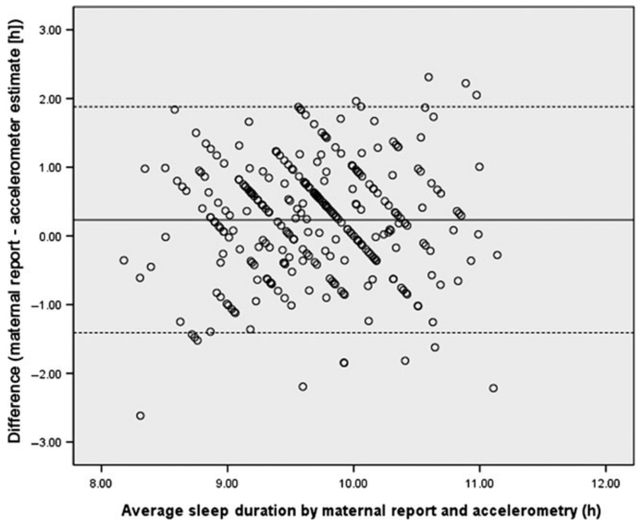

Figure 1. Bland–Altman plot between maternal reported and accelerometer-estimated sleep duration ($n = 303$).

Table 2 Night-time sleep duration and correlation between sleep measures in Mexican American 8–10-year-olds

Sleep measure	*Mean (SD)*	*Median*	*Pearson's correlation*	*Mean difference (95% CI)*
Maternal report (h)*	9.81 (0.74)	10.00	0.33 ($P < 0.001$)	0.23 ± 0.84 (0.14, 0.33)
Accelerometry (h)	9.58 (0.71)	9.55		
Week-night†	9.45 (0.90)	9.42		
Weekend night	9.84 (1.25)	9.85		

CI, confidence interval; SD, standard deviation.
*Mother-reported and accelerometer-estimated sleep were statistically different ($P < 0.001$).
†Week-night and weekday sleep duration were statistically different ($P < 0.001$).

Table 3 Multivariate linear regressions with child sleep measures and child BMI *z*-score, showing standardized β coefficients (95% CI)

	Child BMI z-score		
Independent variables	*Model 1*	*Model 2*	*Model 3*
Mother-reported sleep	−0.13 (−0.35, −0.04)*	–	−0.09 (−0.29, 0.03)
Accelerometer-estimated sleep	–	−0.17 (−0.39, −0.08)*	−0.14 (−0.36, −0.03)*
Covariates			
Child pubertal status	0.17 (0.24, 10.10)**	0.17 (0.25, 10.11)**	0.17 (0.24, 10.0)**
Mother BMI	0.31 (0.03, 0.06)**	0.30 (0.03, 0.06)**	0.29 (0.03, 0.06)**
Occupational status	−0.08 (−0.10, 0.03)	−0.09 (−0.11, 0.02)	−0.09 (−0.11, 0.02)
Mother Spanish acculturation	0.11 (−0.02, 0.21)	0.11 (−0.02, 0.21)	0.11 (−0.02, 0.21)
R^2	0.18	0.20	0.20

BMI, body mass index.
*$P < 0.05$; **$P \leq 0.001$.

Table 4 Multivariate logistic regressions examining the 10-h NSF sleep recommendation and child overweight/obesity, showing odds ratios (95% CI)

	Child overweight/obese weight status		
Independent variables	*Model 1*	*Model 2*	*Model 3*
<10-h sleep duration (maternal report)	2.1 (1.08, 4.24)*	–	1.9 (0.94, 4.00)
<10-h sleep duration (accelerometer)	–	1.8 (0.83, 5.1)	1.4 (0.61, 3.52)
Covariates			
Child pubertal status	3.6 (0.86, 15.04)	3.1 (0.76, 3.6)	3.5 (0.84, 14.8)
Mother BMI	1.1 (1.04, 1.19)*	1.1 (1.03, 1.18)*	1.1 (1.03, 1.18)*
Occupational status	1.1 (0.89, 1.34)	1.1 (0.87, 1.29)	1.1 (0.88, 1.33)
Mother Spanish acculturation	1.1 (0.79, 1.53)	1.1 (0.81, 1.54)	1.1 (0.79, 1.52)
R^2	0.17	0.15	0.18

BMI, body mass index; CI, confidence interval; NSF, National Sleep Foundation.
*$P < 0.05$; reference group (1): ≥10-h sleep duration.

DISCUSSION

This study addresses a gap in the literature regarding the use of parent-reported sleep and objectively measured sleep to assess the sleep–obesity relationship in children. The first aim of the study was to examine the reliability of mother-reported with accelerometer-estimated sleep duration in Mexican American children. We found a correlation between mother-reported sleep and accelerometer-estimated sleep, and that mothers overestimated sleep compared to accelerometer-estimated sleep duration. Secondly, we examined the relationships between mother-reported sleep duration, accelerometer-estimated sleep duration and obesity. We found that both measures were related significantly to child BMIz, independent of modelled covariates; however, only accelerometer-estimated sleep remained significant when both sleep measures were included in the same model. Lastly, we found that children who did not meet the 10-h sleep recommendation were more likely to be overweight or obese than children who met the 10-h sleep recommendation.

Our study examined the reliability of parent-reported sleep with accelerometer-estimated sleep. In this sample of mother–child pairs, mothers over-reported sleep by an average of 13 min. This small difference between sleep duration by maternal report and accelerometry and the moderate correlation between the two may lie in the inability of parents to account for sleep onset latency. Using accelerometry to assess sleep duration may be more reliable, as accelerometers are able to detect small movements, such as restlessness or fidgeting, that may occur immediately before a child falls asleep. Nevertheless, our findings suggest reasonable concordance and close agreement between the two sleep methods on the basis of the Bland–Altman plot, with no measurement bias detected (indicating that the measures agree equally).

Our findings show a negative association between sleep duration and child BMIz. Mexican American youth who slept fewer hours had higher BMIz, and this finding was consistent for both maternal report and accelerometer-estimated sleep when they were considered separately. In these separate equations, each sleep measure remained related significantly to child weight status, even after accounting for multiple covariates. However, when both sleep measures were included in the same equation, only accelerometer-estimated sleep remained related significantly to BMIz. These findings suggest that maternal report of sleep alone may be sufficient for examining the cross-sectional relationship between children's usual sleep duration and adiposity. Similarly, we found that children who did not meet the 10-h sleep recommendation had greater risk for being overweight or obese than children who obtained at least 10 h of sleep. This association was consistently significant when examining each 10-h sleep variable (based on maternal report and accelerometry) separately. Given these findings, accelerometer-estimated sleep may be a better measure of sleep duration for longitudinal purposes, as it may provide a more reliable estimate of actual sleep time. Because mothers tended to over-report sleep duration, nearly half the children met the sleep recommendation according to mothers' reports, compared with about a quarter of children who met the recommendation based on accelerometer data. Future research should consider the use of accelerometers to assess sleep when resources are available.

In our sample of Mexican American children, the average sleep duration was less than the 10–11-h recommendation by the National Sleep Foundation to achieve adequate rest (National Sleep Foundation). Our findings echo others' reports that Latino children are at risk for inadequate sleep duration, perhaps because they may have irregular and/or later bedtimes compared to other ethnic groups (Owens and Jones, 2011). Nevertheless, we found that children may attempt to obtain sufficient sleep on the weekend, in contrast to another study reporting that Hispanic youth were more likely to sleep less at the weekend (Adam *et al.*, 2007). Lastly, our findings support previous research findings that Mexican American children who reported sleeping more than 9 h per night had lower BMIz compared with those who slept fewer than 9 h per night (Silva *et al.*, 2011). Future studies should investigate how to promote adequate sleep as a protective factor against childhood obesity. Also, efforts should be made to prevent the decreasing trend in sleep duration that occurs throughout childhood (Snell *et al.*, 2007). Perhaps advocating for later school start times could help in this effort.

Child pubertal status and maternal BMI were related significantly to a higher child BMIz, as would be expected. Studies have noted that increased adiposity is associated with pubertal onset (Biro *et al.*, 2006) and maternal BMI (Butte *et al.*, 2007). Blair *et al.* (2012) reported gender differences in sleep and paediatric obesity. However, like Seo *et al.* (2010), we did not find any gender differences. Lastly, in the model examining mother-reported sleep, acculturation based on orientation towards Spanish language use was related marginally to a higher BMIz. Similarly, Wojcicki *et al.* (2012) found that speaking Spanish in the home was associated independently with risk for childhood obesity among Central and South Americans in the San Francisco Bay Area. Others have reported that Spanish-speaking Latino mothers may be more likely to push children to eat more and use positive incentives to encourage children to eat (Seth *et al.*, 2007). This type of feeding behaviour has been reported in several studies of Mexican mothers who, culturally, prefer a child that is *llenito* (diminutive of chubby) and do not recognize childhood overweight (Guendelman *et al.*, 2010; Martinez *et al.*, in press).

The strengths of our study include the relatively large sample size. In addition, we measured sleep using two types of measurement—maternal report and accelerometry. Accelerometer-estimated sleep included three consecutive nights, including 2 week-nights and 1 weekend night. Another strength was the use of both measures to assess their respective utility in relation to children's weight. Future investigators aiming to assess sleep duration longitudinally should consider using accelerometers when sufficient resources are available. Another strength of the current study was the focus on Mexican American children, a group with some of the highest obesity rates but about whom little is known regarding sleep as a risk factor for obesity. Although our findings may not be generalizable to other Latino subgroups or other ethnic groups, we were able to provide support for the relationship between insufficient sleep duration and obesity in Mexican American children. These findings can begin to inform paediatric obesity prevention in this at-risk population. Future studies could also examine these relationships in younger children as well as other Latino subgroups and other ethnic groups.

A limitation of the current study includes the narrow age range of child participants, who were aged 8–10 years. Our findings should not be generalized beyond this age range. This study was cross-sectional; therefore, causality could not be determined. Lastly, this study used 3 days of accelerometer-estimated sleep duration compared to at least 5 days of monitoring. Despite this limitation, 3 days of sleep monitoring was a more reliable estimate compared with mother-reported.

While mothers over-reported children's sleep in this sample, mother-reported sleep was in agreement with accelerometer-estimated sleep. Both measures of sleep duration were related negatively to BMI status, suggesting that children who slept less had a higher risk for greater adiposity. Our results contribute to the growing body of evidence suggesting that insufficient sleep exacerbates the growing epidemic of childhood obesity. Lastly, our findings suggest that parent-reported sleep may provide a reasonable estimate to examine sleep and adiposity in cross-sectional studies.

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AUTHOR CONTRIBUTIONS

SMM conceptualized and designed the study, conducted the data analysis, contributed substantially to the interpretation of the data, drafted the initial manuscript and approved the final manuscript as submitted. LCG contributed to the conceptualization and design of the study, contributed substantially to the acquisition of data and contributed to the methods of the manuscript. She has read and approved the final version. NFB contributed substantially to the acquisition of data, provided feedback on the data analysis and critically reviewed the manuscript. She has approved the final version. SG contributed substantially to the design of the project and acquisition of the data and provided feedback on the data analysis and data interpretation. He has read and approved the final version. CLdeG contributed substantially to the acquisition of data and data collection instruments and assisted with the data analysis. She has read and approved the final version. JD contributed substantially to the acquisition of data and data collection instruments and assisted with data interpretation. She has read and approved the final version. CP contributed substantially to the acquisition of data and revised the article critically for important intellectual content. He has read and approved the final version. LAP contributed substantially to the conception and design of the project. She has read and approved the final version. EF contributed substantially to the conception and design of the project and provided feedback on several drafts. She has read and approved the final version. JMT contributed substantially to the conception and design of the project, acquisition of data, assisted with data analysis and interpretation and revised the article critically for important intellectual content on several occasions. She has read and approved of the final version.

CONFLICT OF INTEREST

No conflicts of interest declared.

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