Health Psychology

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BRIEF REPORT

Exercise Mitigates Cumulative Associations Between Stress and BMI in Girls Age 10 to 19

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Objective: Long-term psychological stress is associated with BMI increases in children as they transition to adulthood, whereas long-term maintenance of physical activity can slow excess weight gain. We hypothesized that in addition to these main effects, long-term physical activity mitigates the relationship between long-term stress and BMI increase. *Method:* The NHLBI Growth and Health Study enrolled 2,379 10-year-old Black and White girls, following them annually for 10 measurement points. Growth curve modeling captured the dynamics of BMI, measured yearly, and stress and physical activity, measured at varying years. *Results:* At average levels of activity and stress, with all covariates remaining fixed, average BMI at baseline was 19.74 ($SE = 0.38$) and increased 0.64 BMI ($SE = 0.01$, $p < .001$) units every year. However, this increase in BMI significantly varied as a function of cumulative stress and physical activity. Slower BMI gain occurred in those girls who were less stressed and more active (0.62 BMI units/year, $SE = .02$, $p < .001$), whereas the most rapid and largest growth occurred in girls who were more stressed and less active (0.92 BMI units/year, $SE = .02$, $p < .001$). Racial identification did not alter these effects. *Conclusions:* As hypothesized, in girls who maintained long-term activity, BMI growth was mitigated, even when reporting high long-term stress, compared with less physically active girls. This study adds to a converging literature in which physical activity, a modifiable prevention target, functions to potentially limit the damaging health effects of long-term psychological stress.

Keywords: body mass index, chronic psychological stress, NHLBI Growth and Health Study, physical activity, stress and health

Chronic psychological stress can promote weight gain in adults (Block, He, Zaslavsky, Ding, & Ayanian, 2009), in part through eating as well as chronic stimulation of the hypothalamic-pituitary-adrenal axis and chronically elevated circulating cortisol that leads to visceral fat deposition (Adam & Epel, 2007). The effect of chronic stress on weight gain likely extends to children. Tomiyama and colleagues (2013) demonstrated that greater stress between ages 10 through 19 was longitudinally associated with excessive weight gain relative to height (i.e., body mass index [BMI]) during development to adulthood in Black and White girls in the National Heart Lung and Blood Institute (NHLBI) Growth and Health Study (NGHS). The question remains: Is stress-related weight gain inevitable? Here we examine whether remaining physically active mitigates the relationship of long-term stress and BMI changes.

Studies exposing adults in the laboratory to an acute stressful experience have shown that physically active or fit individuals have faster biological stress reactivity recoveries compared to those inactive or unfit (Hamer, 2012). The few studies examining the interaction between chronic stress and long-term maintenance of physical activity have found similar health effects (Holmes, Ekkekakis, & Eisenmann, 2010). For example, chronically stressed adults who do not maintain activity at levels recom-

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mended by the Center for Disease Control and Prevention (CDC) have increased obesity-related biological risks, such as impaired glucose tolerance (Puterman, Adler, Matthews, & Epel, 2012). Yin, Davis, Moore, and Treiber (2005) demonstrated that stressful life events reported to have occurred over one year were associated with BMI in 303 Black and White youths aged 12 to 24, but that physical activity significantly dampened this relationship. No study to date has prospectively examined whether maintenance of physical activity over time mitigates the relationship between stress and BMI. To fill this gap in the literature, and in light of the independently reported findings that cumulative stress promotes (Tomiyama et al., 2013) and maintenance of physical activity mitigates (Kimm et al., 2005) excessive weight gain relative to height from age 10 to 19 in the NGHS girls, we hypothesized that the stress–BMI relationship would be modified by physical activity.

Method

The UCSF Committee on Human Research and the UCLA Institutional Review Board approved all research activities.

Participants

NGHS enrolled 2,379 girls (1,213 Black and 1,166 White; mean age at study entry = 10.1) and followed them for 10 measurement points, interviewing them annually. Inclusion criteria included being 9 or 10 years of age at the time of the first visit, Black or White racial identification, and living with racially concordant parents/guardians willing to consent for the girl's participation and complete demographic measures. Girls were recruited and tested at local schools and health clinics in Cleveland, OH, Washington, DC, and Richmond, CA. Follow-up assessments were completed at schools, clinics, and home for convenience. Information about the number of girls approached and who participated is not available, however 2,351 (98.8%) of those enrolled completed the final assessment. Trained and certified study staff obtained information from the participant and parent/caregiver.

Measures

Anthropometry. Each year, weight and height were measured twice using a Detecto Health o Meter electronic scale and a stadiometer, respectively. We used BMI rather than BMI percentile, based on recommendations for longitudinal adolescent BMI data (Berkey & Colditz, 2007).

Cumulative psychological stress. The 14-item Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) is an extensively validated measure of perceived psychological stress. The Psychosocial Measures Subcommittee of the original NGHS Investigator team simplified the wording for use in children based on their expertise. For example, "How often have you been able to control irritations in your life?" was changed to "I was able to do something about the things that bothered me." The PSS was administered at ages 11, 13, 15, 17, and 19, and averaged for a cumulative psychological stress score. Only 1.1% of data was missing.

Physical activity. At ages 10, 12, 14, and 16 through 19, the Physical Activity Patterns Questionnaire (Ku, Shapiro, Crawford,

& Huenemann, 1981; Obarzanek et al., 1994) asked about usual activities including classroom and sport activities in and out of school during the school year and during the summer. The original NGHS research group derived metabolic equivalent values, taking into account the duration and frequency of reported activities. An average score for these time points was calculated. Physical activity data were available for 86% of the seven assessments across the 2,379 girls. The activity questionnaire used here is related to accelerometry data recorded in years 3 and 5 ($r = .09$, $p = .002$; Kimm et al., 2000).

Covariates were based on previous findings in the NGHS study suggesting significant effects on girls' health (Biro et al., 2001; Ritchie et al., 2007; Tomiyama et al., 2013). Race (black = −1, white = 1), primary caregiver education (≤high school = −1, 1–3 years post high school = 0, and ≥4 year college degree = 1), and menarche (single-item question asking whether participant has had no period yet [= 0] or has had period [= 1]). Total Calorie intake (Crawford et al., 1995) centered around mean calories (= 1886) for the study period from a 3-day recall interview was also included at each year as a covariate for BMI.

Analytic Approach

In the current set of analyses, we report descriptive statistics and correlations for demographics, cumulative psychological stress, physical activity, and BMI across the study. We tested change in BMI across time with growth curve models using restricted maximum likelihood estimation (REML) for the years that stress was measured, as outlined by Singer and Willet (2003). REML accounts for nonindependence in the data (i.e., repeated measures within participants) and allows for the inclusion of data from individuals even if data are missing. Random intercept models with fixed slopes and an unstructured covariance matrix were specified. We tested the effects of chronic stress and physical activity, and their interaction, in which BMI at baseline (B_0) and slope, or growth over time, (B_{time}), were regressed on grand-mean centered stress, grand-mean centered activity, and their interaction in three separate analyses. We probed significant three-way interactions with methods outlined by Cohen, Cohen, West, and Aiken (2003). Our models included all identified covariates. We tested a four-way interaction to examine whether race modified the moderating effects of activity on stress-BMI associations.

Results

Girls were evenly distributed across race (51% Black girls). At study entry, 36.8% had $40,000/year or more household incomes, 31.0% between $20,000 and $39,999, 14.4% between $5,000 and $19,999, and 17.9% less than $5,000. Also at study entry, 25.9% of parents had less than a high school education, 38.9% had 1 to 3 years post high school, and 35.2% had a 4-year college degree or more. Girls with higher stress also had lower reports of physical activity ($r = -.15$, $p < .001$).

First, we partitioned unexplained between- and within-person variations in BMI in an unconditional model. The estimates of the residual and intercept covariance parameters were 12.31 ($SE = 0.25$) and 25.59 ($SE = 0.90$), respectively. Thus, the intraclass correlation was .66, suggesting that 34% of BMI change occurred within-persons. At average activity and stress, with all covariates

fixed, estimated BMI at baseline was 19.74 ($SE = 0.13$) and significantly increased 0.64 BMI ($SE = 0.01$, $p < .001$) units/year. Time (i.e., aging) accounted for 56% of the variation in BMI based on the reduction of the unexplained residual variation from 12.31 ($SE = 0.25$) to 5.36 ($SE = 0.11$). Higher stress was significantly ($p < .001$) related to greater growth in BMI (1 SD > mean stress, $B_0 = 20.05$, $SE = 0.18$, $p < .001$, $B_{time} = 0.68$, $SE = 0.02$, $p < .001$; 1 SD < mean stress, $B_0 = 19.58$, $SE = 0.39$, $p < .001$, $B_{time} = 0.59$, $SE = 0.02$, $p < .001$). Greater activity was significantly ($p < .001$) related to slower growth (1 SD > mean activity, $B_0 = 20.10$, $SE = 0.16$, $p < .001$, $B_{time} = 0.68$, $SE = 0.02$, $p < .001$; 1 SD < mean activity, $B_0 = 20.97$, $SE = 0.37$, $p < .001$, $B_{time} = 0.81$, $SE = 0.03$, $p < .001$).

The three-way interaction between time, stress, and activity indicated that the relationship between cumulative stress and BMI growth varied at varying levels of physical activity (3-way interaction $p = .005$). This interaction accounted for 8.2% of the between person variation (reduction in unexplained variation to 23.50 [$SE = 0.81$]). Simple slope analyses (see Figure 1) revealed that at 1 SD < mean of activity, higher stress predicted greater BMI growth ($B_0 = 20.62$, $SE = 0.53$, $p < .001$, $B_{time} = 0.92$, $SE = 0.04$, $p < .001$) than at lower levels of stress ($B_0 = 19.58$, $SE = 0.53$, $p < .001$, $B_{time} = 0.70$, $SE = 0.04$, $p < .001$). At average activity, higher stress predicted greater BMI growth ($B_0 = 20.01$, $SE = 0.18$, $p < .001$, $B_{time} = 0.67$, $SE = 0.02$, $p < .001$) than at lower stress ($B_0 = 19.40$, $SE = 0.18$, $p < .001$, $B_{time} = 0.59$, $SE = 0.02$, $p < .001$). At 1 SD > mean of activity, higher stress predicted greater BMI growth ($B_0 = 20.18$, $SE = 0.22$, $p < .001$, $B_{time} = 0.74$, $SE = 0.02$, $p < .001$) than at lower stress ($B_0 = 19.45$, $SE = 0.24$, $p < .001$, $B_{time} = 0.62$, $SE = 0.02$, $p < .001$). These effects were consistent across race (interaction $p = .57$).
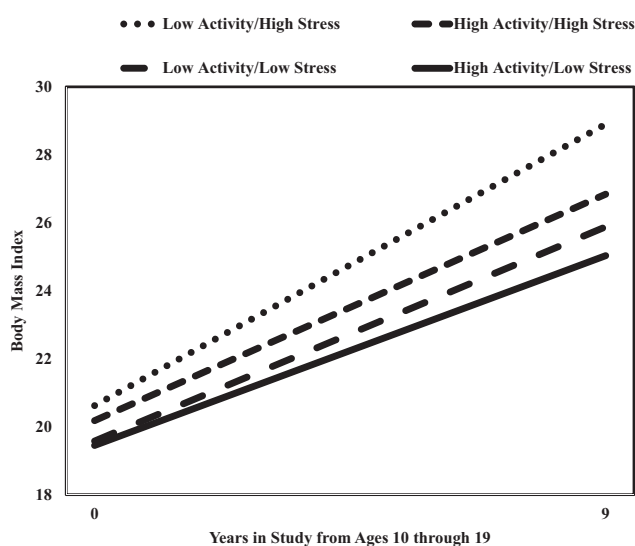

Figure 1. Predicted growth in body mass index from study entry at age 10 through age 19 in Black and White girls in the NHLBI Growth and Health Study.

Discussion

Our findings add to a converging literature suggesting that physical activity moderates the relationship between stress and poor physical outcomes (Hamer, 2012; Puterman et al., 2012; Puterman & Epel, 2012). For high-stress girls, those who reported moderate or higher levels of activity during the 10 years of the study had lower BMI growth compared with the girls who were more inactive, suggesting a possible threshold for activity at which its stress-buffering benefits are held steady when surpassed. Racial identification did not change these effects. Adolescence is a sensitive period that sets individuals on long-term health trajectories (Umberson, Crosnoe, & Reczek, 2010), and thus identifying modifiable factors during this period is key to preventing future disease. A public health challenge, however, is that adolescent girls drop in activity during their transition from childhood to adulthood, and this is especially pronounced in Black girls (Kimm et al., 2000, 2005). Additionally, we reported here that higher stress is related to lower activity. Thus, while activity might mitigate stress effects, supporting high stressed girls to be active might be even a greater challenge. Activity levels do not need to reach especially high levels, and can reach moderate levels, as suggested by these results. Interventions tailored for high stressed populations are especially warranted.

How might physical activity dampen the obesogenic properties of stress? Regardless of its source—which can vary from objective stressful events to individual personality differences—long-term stress promotes heightened threat perception, poor long-term adaptation (Smyth, Zawadzki, & Gerin, 2013), and high levels of circulating glucocorticoids that alter fat deposition (Dallman, 2010). Physically active adults have mitigated stress reactivity in the laboratory (Hamer, 2012), suggesting that maintaining activity cuts short the biological response to stress, limiting fat deposition and attenuating the trajectory toward obesity.

Our findings are limited by the following concerns. NGHS used a sample of Black and White girls, and it is unknown whether our findings replicate to other ethnic or racial groups, or extend to boys. The study is further limited to examining only the accumulation of stress and activity across the decade since reports were collected in different years, precluding within-year analysis. However, Tomiyama and colleagues (2013) demonstrated that stress at any specific year in these girls was unrelated to concurrent BMI, and that only the decade-long accumulation of stress was related to BMI growth. Perhaps, then, it is the overburdening of stress on our bodies over prolonged periods that is potentially mitigated by maintenance of an active lifestyle. An additional limitation includes the use of self-report to measure stress and activity. For example, although the activity questionnaire used here tracked well with the accelerometry data across two assessments, the cross-sectional relationships were weak (Kimm et al., 2000). The activity questionnaire has also not been validated with CDC recommendations, and thus it is unknown how the questionnaire matches national standards. Finally, although the large sample size is a significant advantage, such large sample sizes also allow for significant effects with perhaps negligible implications. Here, though, the trajectory mapped for those higher in stress and lower in activity suggests that these girls had an estimated average BMI of 28.9 at age 19, nearing the level of categorization of obesity (30

kg/m^2), whereas those at higher stress and higher activity were 2 units lower. These effects suggest clinical importance.

Despite these limitations, this study has considerable strengths. First, our sample included a younger age group from varied SES groups and a larger sample than is typically considered when examining stress effects on health and the effects of maintaining a physically active lifestyle. Few studies look prospectively at health outcomes over time. In doing so, we were able to fully characterize a decade of measurement and change in young Black and White girls. Adolescence represents a period that behaviors consolidate, setting many on the path toward future health problems. As developed nations face an obesity epidemic that starts at a young age, and as more schools de-emphasize physical activity for children, this study underscores the potential benefit of reintroducing structured activity into adolescence for better health.

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