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Diurnal Cortisol in a Socioeconomically Disadvantaged Sample of Chinese Children: Evidence for the Shift-and-Persist Hypothesis

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Abstract

Objectives: Low socioeconomic status (SES) is one of the most well-established social determinants of health. However, little is known about what can protect the health of individuals (especially children) living in low-SES circumstances. This study explored whether the psychological strategy of “shift-and-persist” protects low-SES children from stress-related physiological risks, as measured through blunted (unhealthy) diurnal cortisol profiles.

Methods: A sample of 645 children (aged 8–15) from low-SES backgrounds and having at least one HIV positive parent completed a battery of psychological scales. Diurnal cortisol assessments included collection of saliva samples four times a day for three days, from which three cortisol parameters (cortisol at awakening, cortisol awakening response, and cortisol slope) were derived.

Results: Higher levels of shift-and-persist, considered as a single variable, were associated with higher cortisol at awakening ($B = 0.0119$, $SE = 0.0034$, $p < 0.001$) and a steeper cortisol slope ($B = -0.0007$, $SE = 0.0003$, $p = 0.023$). These associations remained significant after adjusting for covariates and did not vary by age. In supplementary analyses, where shifting and persisting were treated as separate variables, the interaction between these two coping strategies significantly predicted cortisol at awakening ($B = 0.0250$, $SE = 0.0107$, $p = 0.020$) and the cortisol slope ($B =$

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–0.0022, $SE = 0.0011$, $p = 0.040$), suggesting that the combination of shift-and-persist is important for predicting diurnal cortisol profiles.

Conclusions: Our findings demonstrate that shift-and-persist is associated with healthier diurnal cortisol profiles among socioeconomically disadvantaged children and introduce the possibility that this coping strategy is protective against other stressors, such as those uniquely faced by children in our study (i.e., being affected by parental HIV).

Keywords

shift-and-persist; socioeconomic status; cortisol; children; China

INTRODUCTION

Low socioeconomic status (SES) is one of the most striking and robust social determinants of health. For example, research has shown that low SES is associated with shorter life expectancy, even among young individuals (1). The detrimental effects of low SES on health are seen across a variety of diseases, irrespective of whether morbidity or mortality rates are investigated (2–4). Recent research has identified childhood as a crucial time during which low SES seems to have especially potent influences on health. For example, compared with children from higher SES families, children from lower SES families typically suffer worse health outcomes, including higher rates of certain acute and chronic conditions and childhood mortality (5). Over the years, researchers have focused their efforts on investigating the biopsychosocial pathways to explain why low SES in childhood is detrimental to health (6, 7). However, an equally important question regarding the factors that can promote positive adaptation among children living in low-SES circumstances has gone largely unexplored (8).

Shift-and-Persist: Theoretical Model and Empirical Evidence

Recently, Chen and colleagues developed a theoretical hypothesis describing a combination of psychological characteristics—labeled “shift-and-persist”—which is associated with salutary physiological profiles among low-SES individuals (9–11). The shift-and-persist strategy entails both shifting (accommodating oneself to current stressors via cognitive reappraisal and emotion regulation) and persisting (enduring adversity with strength by being oriented toward the future) (10, 12). The model posits that this combined coping approach may be particularly adaptive in low-SES contexts where stressors are largely uncontrollable, and resources for dealing with stressors are limited (10). It has also been proposed that socioeconomically disadvantaged individuals might be less likely to select or influence their life situations, thus, shift-and-persist represents a more realistic and feasible approach than proactive efforts (e.g., problem solving) to eliminate stressors in low-SES contexts (10).

The health-related benefits of shift-and-persist among low-SES children have been demonstrated in several recent studies (12–15). For example, in a clinical sample of 121 youths (aged 9–18) diagnosed with asthma, youths who came from low-SES backgrounds, but engaged in shift-and-persist strategies, displayed lower levels of asthma-related

inflammation at baseline and less asthma impairment prospectively at the 6-month follow-up than low-SES youths who scored low in shift-and-persist (13). A similar protective effect of shift-and-persist strategies was found in a sample of healthy adolescents (aged 13–16) (12). Specifically, in this study higher shift-and-persist scores were associated with lower levels of interleukin-6 among low-SES adolescents. Notably, shift-and-persist strategies were not found to be beneficial among high SES youths in both studies (12, 13).

Biological Mechanisms: Role of Physiological Responses

Chen and Miller (10) proposed that shift-and-persist strategies are protective for health because they alter stress-physiology pathways. That is, shift-and-persist strategies mitigate perceptions of stress, thereby reducing acute physiological activation of the hypothalamic–pituitary–adrenal (HPA) axis and the sympathetic nervous system (SNS). In the long-term, these effects might prevent pathogenic processes and, ultimately, decrease the risk of diseases that stressors associated with low SES normally set into motion. In previous studies, the benefits of shift-and-persist among low-SES children were documented for long-term pathogenic processes (inflammation) and clinical outcomes (obesity, asthma) (12–15). However, the direct stress-physiology mechanisms that might underlie shift-and-persist dynamics have not yet been investigated.

Cortisol, the end product of the HPA axis, is one of the most widely used physiological indicators of psychosocial stress. Generally, cortisol secretion follows a strong diurnal rhythm, with high levels upon awakening, a rapid elevation in the first 30 minutes after awakening (i.e., cortisol awakening response, CAR), and a slower decline throughout the rest of the day. To track individual differences in the diurnal patterning of HPA axis activity in naturalistic settings, sampling cortisol at specific times per day for multiple days is essential (16). When the brain perceives an experience as stressful, the HPA axis increases the production of cortisol to coordinate the mobilization of the body's resources to ensure survival. As the stressor withers, this response is shut off, allowing cortisol to return to baseline levels (17). Cortisol reactivity to acute stress has been most often assessed by exposure to psychosocial stressors in laboratory settings (18). The reactivity of HPA axis, in the short term, is necessary and adaptive to the demands of the stressful situation. Over time, however, a prolonged and repeated activation of HPA axis by chronic stress may be detrimental, resulting in alterations of the HPA axis functioning (19–21). The presence of a robust diurnal rhythm in cortisol secretion is thought to be indicative of a healthy HPA axis functioning, and deviations from this rhythm provide important information about the presence of environmental stressors and the HPA axis's role in health (16).

Exposure to chronic stress (including low SES) modulates the circadian activity of cortisol, with lower waking levels and a flatter daily slope (22, 23). Both of these alterations in cortisol, flatter cortisol slope in particular, have been associated with poor health profiles (16, 24). A recent systematic review and meta-analysis has provided evidence to the notion that a flatter diurnal cortisol slope is a robust and consistent predictor of poorer mental and physical health outcomes (25). Hence, the primary goal of this study was to test the link between shift-and-persist and diurnal cortisol parameters. In our sample of uniformly low-SES children, we hypothesized that higher shift-and-persist scores would be associated with

“healthier” diurnal cortisol profiles. Further, the assumption that shift-and-persist, but not problem solving, is more beneficial to low-SES children, has not yet been tested. Thus, the second goal of the present study was to simultaneously test the predictive value of shift-and-persist and problem solving for diurnal cortisol profiles.

Age Differences in Benefits of Shift-and-Persist

Chen and colleagues (12) postulated that shift-and-persist strategies might be more widely used by adolescents (ages 13–16 and 14–18, see (12, 14)) than younger children because of the cognitive abilities underlying this coping strategy (e.g., reframing of stressful situations and focusing on one’s future to maintain hope). However, health-related benefits of shift-and-persist have been demonstrated among low-SES youths of a wider age span, ranging from childhood through adolescence (e.g., 9–18 years in (13) and 9–15 years in (15)). Thus, based on these studies it seems likely that shift-and-persist is associated with health-related biological responses throughout childhood and adolescence. Notably, no study to date has formally tested whether the predictive value of shift-and-persist for health outcomes increases with age or remains stable across different development periods. Thus, the third goal of the current report was to address this gap in the literature by testing the moderating effect of age on the associations between shift-and-persist and diurnal cortisol parameters.

The Present Study

This study sought to address three goals in a large sample of children from low-SES backgrounds: (1) testing the associations of shift-and-persist with diurnal cortisol parameters (cortisol levels at awakening, size of the CAR, and diurnal cortisol slope from wake-up to bedtime); (2) testing the independent predictive value of shift-and-persist and problem solving for diurnal cortisol profiles; and (3) examining the moderating effect of age on the associations between shift-and-persist and diurnal cortisol parameters.

METHODS

Participants and Procedure

Data for this study were drawn from the baseline assessment of a randomized controlled trial of a resilience-based psychological intervention project (26, 27). The total sample for the intervention study consisted of 790 children and their current primary caregivers. Children were between the ages of 6 and 17 years and affected by parental HIV (i.e., having at least one parent living with HIV). Of those 790 children, only one child was 16 years old and one child was 17 years old, thus these two children were excluded from analyses so as not to draw conclusions about this age group. Participants were recruited from five rural villages in the Henan province in central China, where a large HIV epidemic has existed since the early 1990s, primarily resulting from unhygienic commercial blood and plasma collection practices (27). Eligibility criteria for the intervention study required that children with known HIV infection were not included.

Following previous studies on the same sample (28, 29), a subsample consisting of 746 children aged from 8 to 15 years was chosen to match the age range for which the self-report measures used in present analyses were normed. Of those 746 children, 645 (86.4%)

children provided valid saliva samples for cortisol analyses, therefore constituting the final sample for the current study. In the final sample ($N = 645$), about 94% of the caregivers had 9 years of education (middle school diploma) or less, and 88% of caregivers reported a monthly household income under 2,000 Chinese Yuan (CNY; approximately 1 CNY = 0.16 USD at the time of data collection), which was much lower than the national average of monthly household income (4,340 CNY) in 2011 (30). Thus, this sample was characterized by high socioeconomic disadvantage.

Baseline data collection occurred in 2012, prior to the intervention. Children and caregivers both completed confidential surveys in Chinese, reporting detailed demographic information and completing several psychosocial questionnaires. Most of the child surveys were self-administered in small groups while two trained interviewers were present to answer any questions or provide necessary clarification, such as explaining the meaning of each option of 4- or 5-point scales. For a few children with limited literacy, interviewers read the questionnaire items and recorded their responses. Children also self-collected saliva samples for assessments of cortisol over three days. Appropriate informed consent/assent was obtained before participation. The protocol was approved by the Institutional Review Boards at Wayne State University in the United States and Henan University in China. Caregivers and children received gifts at completion of the survey as a token of appreciation. More detailed descriptions of the sample and assessment protocols for this project can be found elsewhere (27, 28).

Measures

Salivary Cortisol—Salivary cortisol was collected using Salivettes (Sarstedt, Rommelsdorf, Germany). Children provided saliva samples four times a day on three consecutive days (two weekdays and one weekend day following the surveys). The daily collection time points occurred immediately upon awakening, 30 min after awakening to assess the CAR, 1 hr before dinnertime, and at bedtime. Prior to saliva collection, the investigators gave each child a signaling wristband with a slogan “Did you collect saliva today?” to remind them of the timing of saliva collection and emphasized the importance of compliance with the collection time. Collection compliance was monitored with paper-and-pencil logs included in the collection kits. Cortisol concentrations were quantified via chemiluminescent immunoassay (Access Cortisol kit YZB/USA 2802, Beckman Coulter, Fullerton, CA) with 8.4% intra-assay and 11.4% inter-assay coefficients of variation as reported by the manufacturer. Of the 645 children, 96% provided at least 8 of the 12 possible saliva samples across the 3 days. As for CAR sample compliance, of the available 1,810 CAR cortisol values (i.e., the second saliva samples of each day), 525 self-reported deviating by 10 min or more from the requested 30-min interval and were considered noncompliant as suggested by Adam et al. (31). These cortisol values were excluded from the analyses (i.e., treated as missing values). Cortisol values were logarithmic transformed to correct for positive skew in the distribution (16), and a constant of 1 was added before the transformation to ensure that all transformed values were positive.

Shift-and-Persist—Based on theoretical notions of shift-and-persist (14), a battery of items reflecting shifting and persisting constructs were drawn from other existing measures

that tap into similar constructs. Following a similar approach used in previous research (15), 10 items were used to capture the tendency to shift oneself via cognitive reappraisal and emotion regulation in response to stressors. Specifically, four items were taken from the cognitive reframing subscale (e.g., “I tell myself that everything will be all right”) of the Coping Strategies Checklist (29), and six items were taken from the emotional regulation skills subscale (e.g., “I can calm myself down when I am in trouble”) of the Social Competence Scale (32). Children were asked to indicate how well each statement described themselves when they faced difficulties and problems on a 4-point scale ranging from 1 (not at all) to 4 (very well). Responses to all the items were averaged to create a shift score ranging from 1 to 4, with higher scores indicating the use of more shift strategies. In the current investigation, Cronbach’s alpha for this scale was 0.72.

As suggested by Chen et al. (12), a measure of positive thinking about the future was included as an indicator of persisting (i.e., holding on to hope that the future may be better despite present adversities). The Future Expectations Scale (33) measures the extent to which children have positive expectations for their future. This scale has been validated in the target population (i.e., children affected by parental HIV/AIDS in China) and demonstrated good psychometric properties (34). Children were asked to report to what extent they would feel confident about their future (e.g., “My life will be great in the future”; “I will stay out of trouble in the future”). This measure consists of 7 items rated on a 5-point scale (1 = not at all, 5 = very much). Responses to all the items were averaged to create a persist score ranging from 1 to 5, with higher scores reflecting greater persisting. In the present study, Cronbach’s alpha for this scale was 0.85.

The shifting score was positively associated with the persisting score ($r = 0.430$, $p < 0.001$). Further, a confirmatory factor analysis was conducted using AMOS 21.0 that indicated that the two-factor (shifting and persisting) model demonstrated an acceptable fit (35) to the data: $\chi^2/df = 2.87$, GFI = 0.94, AGFI = 0.92, TLI = 0.90, CFI = 0.91, RMSEA = 0.05. Following a similar procedure in previous studies (12, 13), responses to the shifting measure and persisting measure were first standardized (because they are on different scales) and then summed to create a total shift-and-persist score, with higher scores indicating using a higher combination of both shifting and persisting strategies.

Problem Solving—Problem solving was measured by a 4-item problem solving subscale from the Coping Strategies Checklist (29). Children were asked to report how well each statement (e.g., “I will keep trying different approaches to solve the difficulties”) described themselves on a 4-point scale (from 1 = not at all to 4 = very well). The mean scores of all items were calculated, with higher scores reflecting the use of more problem solving strategies. In the current investigation, Cronbach’s alpha for this scale was 0.62.

Demographic, Psychological, and Health Covariates—At the momentary level (Level 1), children were asked whether they smoked (0 = no, 1 = yes) or engaged in any physical exercise (0 = no, 1 = yes) 30 min prior to each saliva sample collection. These variables were included at Level 1 as health covariates. Mode imputation was used to replace missing cases for these two variables (the incidence of missing data for these two variables was 1.4%).

Day of the week (0 = weekday, 1 = weekend) and time of waking on each day of salivary cortisol sampling were included as daily-level (Level 2) covariates for diurnal cortisol parameters. The Expectation Maximization (EM) algorithm (for more details see the Analytic Strategy section) was used to impute missing data of time of waking (the incidence of missing data of time of waking was 3.0%).

Children's sex (0 = boy, 1 = girl), age, perceived health status, and depressive symptoms were included as person-level (Level 3) covariates in the analyses. Children's overall health status was rated by each child and by his or her caregiver on a 5-point scale ranging from 1 (very poor) to 5 (very good). Scores on this scale were obtained by averaging responses of child and caregiver, with higher scores indicating better health status. Depressive symptoms were measured using a short form of the Center for Epidemiologic Studies Depression Scale for Children (36, 37). Children responded to 10 items (e.g. "I didn't sleep as well as I usually sleep") asking how often each mood or symptom occurred in the previous week on a 4-point scale (from 1 = not at all to 4 = a lot). A score was obtained by averaging all item responses (after reversing the positive mood items), with higher scores representing more depressive symptoms. Cronbach's alpha for this scale in the current study was 0.62.

Analytic Strategy

The incidence of missing data was 0.2% at the person-level. Data were missing completely at random as suggested by the Little's MCAR test ($\chi^2(31) = 21.74, p = 0.89$). To curtail the bias associated with pairwise or listwise deletion of missing data (38), we used the Expectation Maximization (EM) algorithm to impute missing data. This approach allows to obtain estimates that are less biased than ad hoc methods (e.g., listwise deletion of missing data) (39, 40).

In order to properly account for the nested nature of the cortisol data (samples nested within days, days nested within individuals), a three-level hierarchical linear modeling (HLM) was employed. HLM allows for the simultaneous estimation of multiple cortisol parameters (cortisol at awakening, CAR, and diurnal slope) at Level 1 along with the prediction of both daily-level (Level 2) and person-level (Level 3) predictors of diurnal cortisol profiles. Furthermore, HLM handles missing data at the lowest level of the hierarchy (in this case, the cortisol level) by using the maximum likelihood estimation method (41).

Following prior diurnal cortisol research (16, 31), time since awakening, time since awakening squared, and CAR were modeled at Level 1 to provide estimates of each child's diurnal cortisol rhythm. Specifically, cortisol values were predicted by the time of each saliva sample collection, scaled as hours since awakening each day (i.e., at awakening = 0), with the intercept reflecting cortisol level at awakening and the coefficient on the hours since awakening reflecting the slope of cortisol from wake-up to bedtime. To account for the curvilinear nature of the diurnal secretion of cortisol, both linear (hours since awakening) and quadratic (hours since awakening squared) time terms were included. The 30-min after awakening cortisol sample was assessed with a dummy coded variable (i.e., 30-minute after awakening samples = 1, other samples = 0), with the coefficient on this variable reflecting the size of CAR. The cortisol intercept and linear slope (effect of time) and the size of CAR were allowed to vary randomly at Level 2 and Level 3, while the curvilinear effect of cortisol

was fixed and without predictors at Level 2 or Level 3. At Level 2, the associations of wake-up time and day of the week (i.e., weekend vs. weekdays) with diurnal cortisol parameters were estimated. At Level 3, the associations of variables at the person-level (e.g., shift-and-persist) with diurnal cortisol parameters were estimated.

A series of models were run to test our research hypotheses. First, an unconditional three-level growth-curve model was run to estimate the average diurnal cortisol rhythm across all participants. Second, some potential covariates identified in previous diurnal cortisol research (16) were added each separately to the unconditional growth-curve model to examine whether each covariate had a significant association with diurnal cortisol parameters. To preserve model parsimony, covariates were removed in the subsequent analyses if they had no significant associations with any of the diurnal cortisol parameters. Third, we separately tested the associations of shift-and-persist and problem solving with cortisol parameters. Next, shift-and-persist and problem solving were included simultaneously as predictors of diurnal cortisol parameters to compare the predictive value of shift-and-persist and problem solving. Lastly, we included the shift-and-persist $\times$ age interaction term (calculated as the product of mean-centered shift-and-persist and mean-centered age), examining the potential moderating effect of age on the association between shift-and-persist and cortisol parameters. Continuous daily-level and person-level variables were grand-mean centered. All models were analyzed with HLM 7.0, and all significance tests were 2-tailed with robust standard errors.

RESULTS

Descriptive information about the sample is provided in Table 1, and the bivariate correlations between personal-level predictors are reported in Table 2.

Unconditional growth-curve model of diurnal cortisol profiles suggested that children's average cortisol concentrations at awakening were greater than zero ($\gamma_{000} = 0.6623$, $SE = 0.0064$, $p < 0.001$) and then significantly decreased throughout the day ($\gamma_{200} = -0.0386$, $SE = 0.0019$, $p < 0.001$). However, there was not a detectable average CAR ($\gamma_{100} = 0.0019$, $SE = 0.0068$, $p = 0.78$), suggesting a nonsignificant overall increase from awakening to 30 min later in the sample. Covariates models showed no significant associations of depressive symptoms and health status with cortisol at awakening, CAR, or diurnal slope (all $ps > 0.05$). Therefore, these two variables were removed from subsequent analyses. Smoking, sport exercise, day of the week, wake-up time, sex, and age were linked to at least one cortisol parameter and were used as covariates.

Associations of Shift-and-Persist with Diurnal Cortisol Rhythm

In the initial HLM analyses, we entered shift-and-persist and problem solving separately as predictors of diurnal cortisol parameters at Level 3 without any other covariates. Neither shift-and-persist nor problem solving was related to CAR ($\gamma_{101} = -0.0030$, $SE = 0.0040$, $p = 0.44$; $\gamma_{101} = -0.0068$, $SE = 0.0110$, $p = 0.54$, respectively), and notably, the average CAR in this sample was nonsignificant; thus, following previous studies (28, 29), CAR was set as a fixed effect with no predictors in subsequent analyses. Results showed that higher levels of shift-and-persist were associated with higher cortisol levels at awakening ($\gamma_{001} = 0.0119$, SE

= 0.0034, $p < 0.001$) and a steeper cortisol slope ($\gamma_{201} = -0.0007$, $SE = 0.0003$, $p = 0.023$). Problem solving was significantly associated with higher cortisol at awakening ($\gamma_{001} = 0.0235$, $SE = 0.0099$, $p = 0.018$) but not with the cortisol slope ($\gamma_{201} = -0.0007$, $SE = 0.0009$, $p = 0.44$).

In HLM, a pseudo- R^2 statistic can be estimated using the formula ($var_{unconditional} - var_{conditional}$)/ $var_{unconditional}$, where var can represent any level of variance. This formula provides an estimate of the proportion of reduction in variance for any random parameter (e.g., cortisol at awakening and cortisol slope at Level 3) in an HLM when one predictor variable is added (e.g., shift-and-persist) to an unconditional growth-curve model (empty model, with no predictors at Level 2 and Level 3). In the current study, when shift-and-persist was added to the unconditional growth-curve model, the proportional variance reductions in the Level 3 intercept (cortisol at awakening) and Level 3 slope (cortisol slope) were 4.1% and 11.1%, respectively.

We then examined separately the associations of shift-and-persist and problem solving with cortisol levels at awakening and cortisol slope adjusting for covariates. As displayed in Table 3, after adjusting for covariates, the associations of shift-and-persist with cortisol levels at awakening ($p < 0.001$) and cortisol slope ($p = 0.027$) remained significant (Model 1); problem solving was still associated with higher levels of cortisol at awakening ($p = 0.014$), and not associated with the cortisol slope ($p = 0.39$) (Model 2).

Associations of Shift-and-Persist with Diurnal Cortisol After Adjusting for Problem Solving

We then tested the differential predictive value of shift-and-persist strategies and problem solving on cortisol parameters by adding both variables simultaneously as predictors of cortisol secretion after adjusting for covariates. As shown in Table 3 (Model 3), analyses revealed that the associations of shift-and-persist with cortisol levels at awakening and cortisol slope remained significant ($p = 0.016$, $p = 0.038$, respectively) after adjusting for problem solving. In contrast, problem solving did not significantly predict cortisol levels at awakening or the cortisol slope ($p = 0.53$, $p = 0.63$, respectively) while adjusting for shift-and-persist.

Moderating Effect of Age on the Association Between Shift-and-Persist and Cortisol Secretion

As displayed in Table 3 (Model 4), we included the interaction term between shift-and-persist and age to examine whether age moderated the associations between shift-and-persist and diurnal cortisol parameters. The results of these analyses showed that the interaction term between shift-and-persist and age did not significantly predict cortisol levels at awakening or the cortisol slope ($p = 0.40$, $p = 0.49$, respectively), suggesting that the associations of shift-and-persist and diurnal cortisol profiles did not vary by children's age in our sample (aged 8 to 15).

The Necessity of Combining Shifting and Persisting

To explore what drives the found associations of shift-and-persist with cortisol levels at awakening and cortisol slope, we ran two supplemental models without combining shifting

and persisting, but rather considering them as separate variables. First, we tested the associations of shifting strategy and persisting strategy simultaneously with cortisol levels at awakening and cortisol slope, along with the previously described covariates (smoking, sport exercise, day of the week, wake-up time, sex, and age). Continuous daily-level and person-level variables were grand-mean centered. Results showed that higher levels of shifting were marginally significantly associated with higher cortisol levels at awakening ($\gamma = 0.0232$, $SE = 0.0127$, $p = 0.069$) and significantly associated with a steeper cortisol slope ($\gamma = -0.0026$, $SE = 0.0012$, $p = 0.031$). Higher levels of persisting were significantly associated with higher cortisol levels at awakening ($\gamma = 0.0145$, $SE = 0.0073$, $p = 0.046$) but not with the cortisol slope ($\gamma = -0.0001$, $SE = 0.0007$, $p = 0.86$). Then we added the shifting $\times$ persisting interaction term (calculated as the product of mean-centered shifting and mean-centered persisting) into the above model, examining the interaction effect of shifting and persisting. The interaction between shifting and persisting significantly predicted cortisol levels at awakening ($\gamma = 0.0250$, $SE = 0.0107$, $p = 0.020$) and the cortisol slope ($\gamma = -0.0022$, $SE = 0.0011$, $p = 0.040$), such that high shifting in combination with high persisting resulted in the highest levels of cortisol at awakening and the steepest diurnal slope (see Figure 1). These findings suggest that the combination of shift-and-persist is important for predicting cortisol levels at awakening and the rate of decline of cortisol throughout the day.

DISCUSSION

The results presented in this paper confirmed our initial hypothesis: in a sample of homogeneously low-SES children, those who engaged in shift-and-persist strategies exhibited healthier diurnal cortisol profiles. In other words, lower-SES children who worked to accept stress and adjust the self (shifting) while holding onto hopes for the future (persisting) had higher levels of cortisol at awakening and steeper cortisol slopes. These associations were found both when treating shift-and-persist as a single variable (for a similar approach, see (14, 15)) and when treating shifting and persisting as separate variables (for a similar approach, see (12)). We also note that the associations of shift-and-persist and diurnal cortisol profiles did not vary by age in our sample.

This study is novel in linking shift-and-persist to diurnal cortisol profiles among low-SES children. Findings are consistent with previous research on shift-and-persist strategies by Chen et al. and Kallem et al., who found that shift-and-persist strategies were protective against the severities of pathogenic risk (inflammatory) (12, 14) and certain clinical outcomes (asthma, obesity) (13, 15) in low-SES children and adolescents. Our work extends existing evidence by focusing on more direct stress-physiology mechanisms underlying shift-and-persist. But, how does shift-and-persist serve as a salutary factor against the physiological wear and tear of daily stressors, such as living in low-SES contexts? One possibility is that shift-and-persist directly alters how lower-SES individuals respond to stressors; for example, by enabling children to be less reactive to stressors and by reducing the repeated activations of their HPA axis, thus preventing the development of HPA axis dysregulation over time (10). In addition, this is one of the first studies to empirically test at what developmental stage it might be most beneficial to endorse a shift-and-persist strategy. The finding that the associations of shift-and-persist and diurnal cortisol profiles did not vary by age in our sample suggests that the links between shift-and-persist and diurnal cortisol

may not be specific to a particular developmental stage but exist across different age periods from childhood to adolescence. Nonetheless, these results need to be replicated in other samples in order to further validate this finding.

Not surprisingly, our findings support that the shift-and-persist approach is more beneficial to low-SES children than problem solving. Given that low-SES individuals on average live under circumstances consisting of more uncontrollable stressors (10), this work suggests the importance of considering context-specific psychological profiles; that is, the notion that certain psychological qualities, for example, shifting oneself to adapt to stress and holding positive future expectations versus making active efforts to dealing with stressors, may be particularly beneficial in a low-SES context. In addition, the findings linking shift-and-persist and diurnal cortisol profiles in this socioeconomically disadvantaged sample of Chinese children, along with previous research on shift-and-persist in low-SES youths from North America (12–15), might suggest that shift-and-persist might be beneficial for low-SES youths of different cultures. The possibility that shift-and-persist could be a cultural universal dimension of coping is intriguing; however, the present findings are not sufficient to buttress this hypothesis, which is in contrast with the idea that individuals from different cultural background perceive and respond to stressors differently with regard to coping goals, strategies, and outcomes (42). Future cross-cultural and multicultural coping studies will help shed light on the universality of shift-and-persist.

It should be noted that this study found evidence of associations of shift-and-persist with cortisol levels at awakening and cortisol slope, but not with CAR. A few reasons might explain this null effect. First, it is possible that these cortisol parameters may tap into different aspects of HPA axis physiology (43). We note that our findings are consistent with previous research among low-SES adults, wherein psychological resources were associated with higher waking cortisol levels and steeper cortisol slopes, but not with CAR (23, 44). Unlike steeper cortisol slopes, which are robustly linked to better psychological and physical health outcomes (25), the CAR literature is largely inconsistent with regard to its associations to psychological wellbeing and physical health (16, 45). Second, the lack of findings with CAR in our study may have been due in part to the overall CAR levels being too low (i.e., the average CAR in our sample was not significant) and not having enough variability to find a significant association of shift-and-persist with CAR. The absence of a statistically significant average CAR in this sample might relate to the problems with compliance in terms of the timing of CAR saliva collection. An alternative explanation might be related to the characteristics of our at-risk sample, which comprises mostly low-SES children that have at least one parent living with HIV, as previous research has shown that stressful childhood experiences might result in a blunted CAR (46, 47). These possible explanations require further investigation.

Limitations

Several limitations of this study may constrain the generalizability of its findings. First, because this study was correlational, we cannot draw firm conclusions about causality. Ideally, longitudinal research could assess shift-and-persist strategies during childhood, and its ability to prospectively predict trajectories of physiological profiles over adulthood.

Second, the large sample size precluded us, financially, from being able to use electronic devices to monitor children's compliance with the timing of saliva sampling. Third, the uniqueness of our sample might affect the interpretation and generalizability of our findings. Children in this sample not only came from low-SES backgrounds, but also were exposed to the chronic stress associated with having at least one HIV positive parent. According to Chen and Miller (10), the shift-and-persist approach may be particularly adaptive in low-SES contexts because it enables individuals to manage uncontrollable stressors associated with such environment. However, they further posit that the concept of shift-and-persist could apply to other populations confronting other types of uncontrollable situations (10). Having a parent with HIV can be viewed as an uncontrollable stressor (e.g., stress of potentially losing a parent to HIV, the uncertainty of the clinical course of parental HIV/AIDS) (48). It is difficult to disentangle whether the observed findings of shift-and-persist in this study were due to the intrinsic chronic stress associated with coming from a low-SES background or with having a HIV-positive parent as both stressors can fit the presupposition (i.e., uncontrollable stressors) on which the shift-and-persist model is predicated upon. In addition, this sample was recruited for a psychological intervention project, which may have led to sampling biases due to volunteering and being interested in the intervention program (e.g., self-selection bias). Because of these caveats, the present results should be interpreted with caution.

A last set of limitations in the current study has to do with the type of self-report measures adopted. To reduce participants' burden, some of the constructs were measured using the brief version of certain scales, which might affect the reliability and validity of such measures. For example, the relatively low Cronbach's alpha (0.62) for the problem solving scale (a four-item subscale derived from a larger scale) might constrain the conclusions about the role of problem solving in modulating cortisol parameters. It is also noteworthy that there was not a specific shift-and-persist measure at the time when this study was conducted, thus, we drew on existing measures to derive a shift-and-persist score (for a similar approach, see (12) and (15)). Future research should employ the newly developed measure specifically intended to assess shift-and-persist (14). Moreover, a culturally appropriate Chinese version of the shift-and-persist scale should be developed and used in the target population. Lastly, complementing validated self-report measures with observer reports and behavioral indicators for the psychological constructs of interest would be worthwhile in future studies.

Conclusions and Implications

In summary, among a socioeconomically disadvantaged sample of Chinese children, we found that those who engaged in shift-and-persist strategies showed higher levels of morning cortisol and steeper cortisol slopes. Rather than focusing on external resources (e.g., social support), we focused on children's internal psychological coping strategies that can protect them from adverse physiological outcomes. Aspects of the external environment might not always be easy to change; thus, an approach that focuses on the psychological qualities that low-SES children could learn and develop to adapt to the day-to-day stressors might be both practical and effective in reducing SES health disparities. Our findings suggest the

importance of promoting shifting strategy and persisting strategy in tandem, if benefits for physiological and, ultimately, health outcomes among low-SES children are to be achieved.

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Abbreviations used:

SES	socioeconomic status
HPA	hypothalamic-pituitary-adrenal
CAR	cortisol awakening response

REFERENCES

1. Braveman PA, Cubbin C, Egerter S, Williams DR, Pamuk E. Socioeconomic disparities in health in the United States: What the patterns tell us. *American Journal of Public Health* 2010;100:S186–S96. [PubMed: 20147693]
2. Adler NE, Boyce T, Chesney MA, Cohen S, Folkman S, Kahn RL, Syme SL. Socioeconomic status and health: The challenge of the gradient. *American Psychologist* 1994;49:15–24. [PubMed: 8122813]
3. Brophy PD, Shoham DA. Early-life course socioeconomic factors and chronic kidney disease. *Advances in Chronic Kidney Disease* 2015;22:16–23. [PubMed: 25573508]
4. Vathesatogkit P, Batty GD, Woodward M. Socioeconomic disadvantage and disease-specific mortality in Asia: Systematic review with meta-analysis of population-based cohort studies. *Journal of Epidemiology and Community Health* 2014;68:375–83. [PubMed: 24407596]
5. Chen E, Matthews KA, Boyce WT. Socioeconomic differences in children's health: How and why do these relationships change with age? *Psychological Bulletin* 2002;128:295–329. [PubMed: 11931521]
6. Miller GE, Chen E, Parker KJ. Psychological stress in childhood and susceptibility to the chronic diseases of aging: Moving toward a model of behavioral and biological mechanisms. *Psychological Bulletin* 2011;137:959–97. [PubMed: 21787044]
7. Taylor SE, Way BM, Seeman TE. Early adversity and adult health outcomes. *Development and Psychopathology* 2011;23:939–54. [PubMed: 21756443]
8. Roubinov DS, Hagan MJ, Boyce WT, Adler NE, Bush NR. Family socioeconomic status, cortisol, and physical health in early childhood: The role of advantageous neighborhood characteristics. *Psychosomatic Medicine* 2018;80:492–501. [PubMed: 29742755]
9. Chen E Protective factors for health among low-socioeconomic-status individuals. *Current Directions in Psychological Science* 2012;21:189–93.
10. Chen E, Miller GE. “Shift-and-persist” strategies: Why low socioeconomic status isn't always bad for health. *Perspectives on Psychological Science* 2012;7:135–58. [PubMed: 23144651]
11. Chen E, Miller GE. Socioeconomic status and health: Mediating and moderating factors. *Annual Review of Clinical Psychology* 2013;9:723–49.
12. Chen E, Lee WK, Cavey L, Ho A. Role models and the psychological characteristics that buffer low-socioeconomic-status youth from cardiovascular risk. *Child Development* 2013;84:1241–52. [PubMed: 23278857]
13. Chen E, Strunk RC, Trethewey A, Schreier HMC, Maharaj N, Miller GE. Resilience in low-socioeconomic-status children with asthma: Adaptations to stress. *Journal of Allergy and Clinical Immunology* 2011;128:970–6. [PubMed: 21824649]

14. Chen E, McLean KC, Miller GE. Shift-and-persist strategies: Associations with socioeconomic status and the regulation of inflammation among adolescents and their parents. *Psychosomatic Medicine* 2015;77:371–82. [PubMed: 26167560]
15. Kallem S, Carroll-Scott A, Rosenthal L, Chen E, Peters SM, McCaslin C, Ickovics JR. Shift-and-persist: A protective factor for elevated BMI among low-socioeconomic-status children. *Obesity* 2013;21:1759–63. [PubMed: 23671041]
16. Adam EK, Kumari M. Assessing salivary cortisol in large-scale, epidemiological research. *Psychoneuroendocrinology* 2009;34:1423–36. [PubMed: 19647372]
17. Koss KJ, Gunnar MR. Annual Research Review: Early adversity, the hypothalamic–pituitary–adrenocortical axis, and child psychopathology. *Journal of Child Psychology and Psychiatry* 2018;59:327–46. [PubMed: 28714126]
18. Dickerson SS, Kemeny ME. Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin* 2004;130:355–91. [PubMed: 15122924]
19. McEwen BS. Protective and damaging effects of stress mediators. *The New England Journal of Medicine* 1998;338:171–9. [PubMed: 9428819]
20. Busso DS, McLaughlin KA, Sheridan MA. Dimensions of adversity, physiological reactivity, and externalizing psychopathology in adolescence: Deprivation and threat. *Psychosomatic Medicine* 2017;79:162–71. [PubMed: 27428857]
21. Lê-Scherban F, Brenner AB, Hicken MT, Needham BL, Seeman T, Sloan RP, Wang X, Diez Roux AV. Child and adult socioeconomic status and the cortisol response to acute stress: Evidence from the Multi-Ethnic Study of Atherosclerosis. *Psychosomatic Medicine* 2018;80:184–92. [PubMed: 29215456]
22. Miller GE, Chen E, Zhou ES. If it goes up, must it come down? Chronic stress and the hypothalamic–pituitary–adrenocortical axis in humans. *Psychological Bulletin* 2007;133:25–45. [PubMed: 17201569]
23. Zilioli S, Imami L, Slatcher RB. Socioeconomic status, perceived control, diurnal cortisol, and physical symptoms: A moderated mediation model. *Psychoneuroendocrinology* 2017;75:36–43. [PubMed: 27768982]
24. Gunnar MR, Vazquez DM. Low cortisol and a flattening of expected daytime rhythm: Potential indices of risk in human development. *Development and Psychopathology* 2001;13:515–38. [PubMed: 11523846]
25. Adam EK, Quinn ME, Tavernier R, McQuillan MT, Dahlke KA, Gilbert KE. Diurnal cortisol slopes and mental and physical health outcomes: A systematic review and meta-analysis. *Psychoneuroendocrinology* 2017;83:25–41. [PubMed: 28578301]
26. Harrison SE, Li X, Zhang J, Chi P, Zhao J, Zhao G. Improving school outcomes for children affected by parental HIV/AIDS: Evaluation of the ChildCARE Intervention at 6-, 12-, and 18-months. *School Psychology International* 2017;38:264–86.
27. Li X, Harrison SE, Fairchild AJ, Chi P, Zhao J, Zhao G. A randomized controlled trial of a resilience-based intervention on psychosocial well-being of children affected by HIV/AIDS: Effects at 6- and 12-month follow-up. *Social Science & Medicine* 2017;190:256–64. [PubMed: 28215430]
28. Chi P, Slatcher RB, Li X, Zhao J, Zhao G, Ren X, Zhu J, Stanton B. Perceived stigmatization, resilience, and diurnal cortisol rhythm among children of parents living With HIV. *Psychological Science* 2015;26:843–52. [PubMed: 25888685]
29. Slatcher RB, Chi P, Li X, Zhao J, Zhao G, Ren X, Zhu J, Stanton B. Associations between coping and diurnal cortisol among children affected by parental HIV/AIDS. *Health Psychology* 2015;34:802–10. [PubMed: 25581701]
30. Gan L, Yin Z, Jia N, Xu S, Ma S. Research report of China household finance survey 2012. Chengdu: Southwestern University of Finance and Economics Press; 2012.
31. Adam EK, Hawkey LC, Kudielka BM, Cacioppo JT. Day-to-day dynamics of experience–cortisol associations in a population-based sample of older adults. *Proceedings of the National Academy of Sciences* 2006;103:17058–63.

32. Corrigan A Social Competence Scale—Parent Version: Grade 1/Year 2 (Fast Track Project Technical Report) Available from the Fast Track Project Web site, <http://www.fasttrackprojectorg> 2002.
33. Wyman PA, Cowen EL, Work WC, Kerley JH. The role of children's future expectations in self-system functioning and adjustment to life stress: A prospective study of urban at-risk children. *Development and Psychopathology* 1993;5:649–61.
34. Fang X, Li X, Stanton B, Hong Y, Zhang L, Zhao G, Zhao J, Lin X, Lin D. Parental HIV/AIDS and psychosocial adjustment among rural Chinese children. *Journal of Pediatric Psychology* 2009;34:1053–62. [PubMed: 19208701]
35. Lt Hu, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal* 1999;6:1–55.
36. Andresen EM, Malmgren JA, Carter WB, Patrick DL. Screening for depression in well older adults: Evaluation of a short form of the CES-D. *American Journal of Preventive Medicine* 1994;10:77–84. [PubMed: 8037935]
37. Fendrich M, Weissman MM, Warner V. Screening for depressive disorder in children and adolescents: Validating the Center for Epidemiologic Studies Depression Scale for Children. *American Journal of Epidemiology* 1990;131:538–51. [PubMed: 2301363]
38. Collins LM, Schafer JL, Kam C-M. A comparison of inclusive and restrictive strategies in modern missing data procedures. *Psychological Methods* 2001;6:330–51. [PubMed: 11778676]
39. Schafer JL, Graham JW. Missing data: Our view of the state of the art. *Psychological Methods* 2002;7:147–77. [PubMed: 12090408]
40. Peng C-YJ, Harwell M, Liou S-M, Ehman LH. Advances in missing data methods and implications for educational research. *Real Data Analysis* 2006:31–78.
41. Raudenbush SW, Bryk AS. *Hierarchical linear models: Applications and data analysis methods* Thousand Oaks, CA: Sage; 2002.
42. Kuo BCH. Culture's consequences on coping: Theories, evidences, and dimensionalities. *Journal of Cross-Cultural Psychology* 2011;42:1084–100.
43. Saxbe DE. A field (researcher's) guide to cortisol: tracking HPA axis functioning in everyday life. *Health Psychology Review* 2008;2:163–90.
44. Zilioli S, Imami L, Slatcher RB. Life satisfaction moderates the impact of socioeconomic status on diurnal cortisol slope. *Psychoneuroendocrinology* 2015;60:91–5. [PubMed: 26142240]
45. Chida Y, Steptoe A. Cortisol awakening response and psychosocial factors: A systematic review and meta-analysis. *Biological Psychology* 2009;80:265–78. [PubMed: 19022335]
46. Knack JM, Jensen-Campbell LA, Baum A. Worse than sticks and stones? Bullying is associated with altered HPA axis functioning and poorer health. *Brain and Cognition* 2011;77:183–90. [PubMed: 21839567]
47. Quevedo K, Johnson AE, Loman ML, LaFavor TL, Gunnar M. The confluence of adverse early experience and puberty on the cortisol awakening response. *International Journal of Behavioral Development* 2012;36:19–28. [PubMed: 22383860]
48. Chi P, Li X. Impact of parental HIV/AIDS on children's psychological well-being: A systematic review of global literature. *AIDS and Behavior* 2013;17:2554–74. [PubMed: 22972606]

FIGURE 1. Associations of Shifting and Persisting with Diurnal Cortisol Levels

Note: For illustrative reasons, non-transformed cortisol level is graphed as a function of time since awakening for children who reported high and low levels of shifting, and high and low levels of persisting (i.e., 1 SD above and below the mean). Collection of daily saliva samples occurred immediately upon awakening, 30 min after awakening, 1 hr before dinnertime, and at bedtime; however, the values of time since awakening were plotted at multiple time values (i.e., every 2 hours) to depict an estimated curve of diurnal cortisol secretion.

TABLE 1.Descriptive Information of Sample ($N = 645$)

Descriptive variables	N (%) or Mean $\pm$ SD	Range
Sex		
Boy	335 (51.9%)	–
Girl	310 (48.1%)	–
Age (years)	10.67 $\pm$ 1.79	8–15
Depressive symptoms	2.02 $\pm$ 0.43	1–4
Health status	4.08 $\pm$ 0.78	1–5
Shift-and-persist	0.00 $\pm$ 1.69	–5.72–4.82
Shifting strategies	2.73 $\pm$ 0.51	1–4
Persisting strategies	3.08 $\pm$ 0.83	1–5
Problem solving	2.95 $\pm$ 0.61	1–4

TABLE 2.

Bivariate Correlations Between Personal-Level Predictors (N = 645)

Variables	1	2	3	4	5	6	7
1. Sex	–						
2. Age	–0.087 [*]	–					
3. Depressive symptoms	–0.105 ^{**}	–0.024	–				
4. Health status	0.040	–0.086 [*]	–0.095 [*]	–			
5. Shifting strategies	0.092 [*]	0.032	–0.218 ^{***}	0.071	–		
6. Persisting strategies	0.069	0.064	–0.131 ^{**}	0.063	0.430 ^{***}	–	
7. Shift-and-persist	0.095 [*]	0.057	–0.206 ^{***}	0.079 [*]	0.846 ^{***}	0.846 ^{***}	–
8. Problem solving	0.066	–0.003	–0.200 ^{***}	0.083 [*]	0.628 ^{***}	0.345 ^{***}	0.575 ^{***}

Note: Sex: 0 = boy, 1 = girl.

^{*}
 $p < 0.05$.^{**}
 $p < 0.01$.^{***}
 $p < 0.001$.

TABLE 3.

HLM Models of Diurnal Cortisol Parameters (N = 645)

Fixed effect	Model 1			Model 2			Model 3			Model 4		
	Estimate (SE)	p		Estimate (SE)	p		Estimate (SE)	p		Estimate (SE)	p	
Intercepts												
Average awakening cortisol	0.7036(0.0092)	<0.001		0.7026 (0.0092)	<0.001		0.7037(0.0092)	<0.001		0.7038(0.0091)	<0.001	
Day of the week	-0.1101 (0.0091)	<0.001		-0.1100(0.0091)	<0.001		-0.1102(0.0091)	<0.001		-0.1101 (0.0091)	<0.001	
Time of waking	-0.0197 (0.0060)	0.001		-0.0200 (0.0060)	<0.001		-0.0197(0.0060)	0.001		-0.0198 (0.0060)	0.001	
Sex	-0.0169 (0.0119)	0.16		-0.0148(0.0119)	0.22		-0.0170 (0.0119)	0.15		-0.0166(0.0119)	0.17	
Age	0.0082(0.0034)	0.016		0.0089 (0.0034)	0.009		0.0083(0.0034)	0.016		0.0085 (0.0035)	0.014	
Shift-and-persist	0.0119 (0.0034)	<0.001					0.0103 (0.0043)	0.016		0.0113(0.0036)	0.002	
Problem solving				0.0243 (0.0099)	0.014		0.0078(0.0123)	0.53				
Shift-and-persist $\times$ Age										-0.0018 (0.0022)	0.40	
CAR												
Average CAR	-0.0013 (0.0068)	0.85		-0.0014(0.0068)	0.84		-0.0013 (0.0068)	0.85		-0.0013(0.0068)	0.85	
Time since awakening												
Average cortisol slope	-0.0395(0.0021)	<0.001		-0.0394(0.0021)	<0.001		-0.0395(0.0021)	<0.001		-0.0395(0.0021)	<0.001	
Day of the week	0.0082 (0.0009)	<0.001		0.0082 (0.0009)	<0.001		0.0082 (0.0009)	<0.001		0.0082 (0.0009)	<0.001	
Time of waking	-0.0003(0.0006)	0.62		-0.0003(0.0006)	0.66		-0.0003(0.0006)	0.63		-0.0003(0.0006)	0.62	
Sex	-0.0001(0.0011)	0.95		-0.0003(0.0011)	0.81		-0.0001(0.0011)	0.95		-0.0001(0.0011)	0.93	
Age	-0.0007 (0.0003)	0.024		-0.0007 (0.0003)	0.016		-0.0007(0.0003)	0.026		-0.0007 (0.0003)	0.022	
Shift-and-persist	-0.0007 (0.0003)	0.027					-0.0008 (0.0004)	0.038		-0.0007(0.0003)	0.041	
Problem solving				-0.0008(0.0009)	0.39		0.0005 (0.0011)	0.63				
Shift-and-persist $\times$ Age										0.0001 (0.0002)	0.49	
Time since awakening squared												
Average cortisol curvature	0.0009(0.0001)	<0.001		0.0009(0.0001)	<0.001		0.0009(0.0001)	<0.001		0.0009(0.0001)	<0.001	
Smoking												
Intercept	0.1419 (0.0464)	0.002		0.1425(0.0465)	0.002		0.1419(0.0466)	0.002		0.1420 (0.0465)	0.002	
Exercise												
Intercept	0.0201 (0.0082)	0.015		0.0193 (0.0083)	0.020		0.0201(0.0083)	0.015		0.0200(0.0082)	0.016	

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Note: Intercepts indicate average cortisol values at awakening; CAR = cortisol awakening response; indicating amount of change in cortisol during the 30 min after waking; average slope of time since awakening indicate change in cortisol per 1-hr change in time; average slope of time since awakening squared indicate change in cortisol per 1-hr change in time². Sex: 0 = boy, 1 = girl; Day of the week: 0 = weekday, 1 = weekend; Smoking: 0 = no, 1 = yes; Exercise: 0 = no, 1 = yes.