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Social group dynamics predict stress variability among children in a New Zealand classroom

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A R T I C L E I N F O

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A B S T R A C T

Previous research proposes stress as a mechanism for linking social environments and biological bodies. In particular, non-human primate studies investigate relationships between cortisol as a measure of stress response and social hierarchies. Because human social structures often include hierarchies of dominance and social status, humans may exhibit similar patterns. Studies of non-human primates, however, have not reached consistent conclusions with respect to relationships between social position and levels of cortisol. While human studies report associations between cortisol and various aspects of social environments, studies that consider social status as a predictor of stress response also report mixed results. Others have argued that perceptions of social status may have different implications for stress response depending upon social context.

We propose here that characteristics of children's social networks may be a better predictor of central tendencies and variability of stress response than their perceptions of social status.

This is evaluated among 24 children from 9.4 to 11.3 years of age in one upper middle-class New Zealand primary school classroom, assessed through observation within the classroom, self-reports during semi-structured interviews and 221 serial saliva samples provided daily over 10 consecutive school days. A synthetic assessment of the children's networks and peer-relationships was developed prior to saliva-cortisol analysis. We found that greater stability of peer-relationships within groups significantly predicts lower within-group variation in mid-morning cortisol over the two-week period, but not overall within-group differences in mean cortisol.

Introduction

A growing body of anthropological research investigates stress as a mechanism for bridging social environments and biological bodies through the activation of the hypothalamic-pituitary-adrenal (HPA) system in response to perceived stressors (e.g. Marmot et al., 1991; Sapolsky, 1990; Seeman and McEwen, 1996). Among children, anthropological studies demonstrate how a wide variety of circumstances influence response to stressors measured through cortisol. These include homelessness in rural and urban Nepal (Panter-Brick and Pollard, 1999; Panter-Brick et al., 1996) and urban Afghanistan (Panter-Brick et al., 1999; Panter-Brick et al., 2008), socioeconomic conditions in the Caribbean (Flinn and England, 1997), and household composition and family events (Flinn and England, 1995; Flinn et al., 1996, 2005; Flinn, 1999). The emphasis on children's socio-demographic characteristics and family context, while important, has left a gap in understanding another important sector of children's lives – their peer relationships. Developmental psychology studies of children in school contexts suggest that social relationships are likely to play a role in children's

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stress reactivity (Steptoe et al., 2003; Gunnar et al., 1997, 2003), making the classroom a worthwhile environment for an investigation of the biological effects of social structures.

A large body of primate literature suggests that aspects of social relationships are important predictors of HPA activation. In particular, this literature has investigated the relationship between cortisol as a measure of stress response and social hierarchy. A case can be made for correlation in either direction; being the target of aggression is expected to increase the stress experienced by socially subordinate animals, while the glucocorticoid secretion of dominant animals might be expected to reflect the energetic demands of defending their position in the hierarchy (Creel et al., 2013). Extensive studies of cercopithecine monkeys suggested that socially subordinate males exhibit chronically elevated levels of glucocorticoids during stable periods, reflecting greater anxiety or unpredictability of experience (Bergman et al., 2005; Sapolsky, 1983, 1992; Setchell et al., 2010), while cortisol levels of dominant males may increase during unstable periods (Sapolsky, 1992). However, in a more recent long-term study of a baboon species, higher-rank individuals generally had lower cortisol than subordinates regardless of hierarchy stability. The *highest*-ranking (alpha) males, however, exhibited much higher stress hormone levels than beta males (Gesquiere et al., 2011), suggesting that being at either the very top or the bottom of the ladder could be costly.

Furthermore, a number of other factors that are independent of rank complicate relationships between dominance, stability and social status. These include how dominance is acquired (Goymann and Wingfield, 2004; Sapolsky, 2005), behavioral styles (Virgin and Sapolsky, 1997), affiliative relationships (Gust et al., 1993; Sapolsky and Ray, 1989; Ray and Sapolsky, 1992), aggression (Kalbitzer et al., 2015) and sex (Saltzman et al., 1991; Vogt et al., 1980). In a meta-analysis across four old-world and three new-world primate species, Abbott et al. (2003) concluded that subordinate individuals have higher cortisol in circumstances where subordinates experienced higher rates of stressors and lower levels of social support than more dominant individuals. This supports the idea that it is not dominance, but the features associated with dominance in a given context that may be key to hormonal variation.

Human studies

Because human social structures often also include hierarchies of dominance and social status known to be associated with differences in mortality and morbidity (Adler et al., 1993, 1994; Marmot et al., 1991), relationships between social stressors and cortisol found among other primates could have analogies in human contexts. As such, there has been considerable focus in human research on the concept of social status (or variants of, such as social competence or leadership) as a predictor of cortisol variation (Abbott et al., 2003; Booth et al., 1989; Brandtstadter et al., 1991; Decker, 2000; Gunnar et al., 1997, 2003; Tennes et al., 1986; West et al., 2010). However, the relationships between social status and cortisol in humans are complicated firstly by variable definitions and measures of social status across studies, and secondly by the variable implications of status in different contexts. While non-human primates tend to have unilinear dominance hierarchies within local groups that can usually be evaluated based on an established repertoire of dominant and submissive behaviors, human social systems are dynamic and multi-dimensional, meaning that there is no single equivalent of primate social hierarchies. Instead, studies have considered variable forms of social status, including socio-economic status (Brandtstadter et al., 1991; Chen and Paterson, 2006; Cohen et al., 2006a,b; Evans and English, 2002; Kunz-Ebrecht et al., 2004; Lupien et al., 2000; Steptoe et al., 2003; West et al., 2010), dominance in competitive sports (Booth et al., 1989; Salvador et al., 1987), formal military or government rank (Bourne et al., 1968; Sherman et al., 2012), or measures of sociometric status (the degree of influence, admiration or respect from peers) (Decker, 2000; Gruenewald et al., 2006; Hellhammer et al., 1997; von Rueden et al., 2014; West et al., 2010). Previous research on children's peer relationships in school contexts has uncovered very complex and highly stratified social structures (Adler and Adler, 1998; Merten, 2011), and in the classroom environment, forms of sociometric status have been shown to be more important predictors of cortisol than other measures (West et al., 2010).

Additionally, scholars have pointed out that among humans, there is more than one road to social status. Henrich and Gil-White (2001) argue for two distinct human strategies for acquiring status: dominance, which is achieved through force, aggression and coercion; and prestige, achieved through persuasion. The authors draw on evolutionary theory to argue that while dominance strategies are a legacy of primate heritage, prestige strategies evolved as part of human reliance on cultural learning and shared knowledge. Though these do not have to be exclusive strategies (Cheng et al., 2013; Cheng and Tracy, 2013), it is likely that the stress effects would manifest quite differently. Already, evidence of distinct testosterone profiles has been found for individuals using dominance or prestige strategies (Johnson et al., 2007).

The diversity of investigations into human social status have, unsurprisingly, produced mixed associations with cortisol, and the nature of these relationships remain unresolved. However, existing research can usefully inform hypotheses in several ways. Firstly, a number of studies suggest that relative, rather than absolute social status is a more important mediator of stress for humans (Norton, 2013). This finding emerges from studies of socio-economic status (SES), which has been robustly associated with various measures of morbidity and mortality (Adler et al., 1993; Elo et al., 2006; Poulton et al., 2002), but not consistently correlated with cortisol measures (Dowd et al., 2009). Local income ranks, however, which compare people with their neighbours or contemporaries have been found to be better predictors than traditional SES for measures of happiness (Luttmer, 2005) and distress (Wood et al., 2012). This may suggest that it is not material factors per se (at least, not once above a certain threshold) but the psychosocial implications of inequality that represent the key mediator of variation in stress responses in humans. Relative social status among classmates could therefore be expected to be particularly relevant to children's stress experiences – a premise supported by the present study. While Wood and colleagues suggest defeat and entrapment as the cognitive mechanisms here, another explanation is that normative cultural models shift along with rising local economic standards, and more effort is required for a lower income person in a higher-income neighbourhood to 'keep up appearances' and match the cultural model – the stress of the incongruity or additional energy required resulting in increased allostatic load. The ability of individuals to approximate the cultural model for lifestyle and kin support, referred to as 'cultural consonance' (Dressler and Bindon, 2000, p. 244) has been repeatedly associated with arterial blood pressure among samples of Brazilian city-dwellers (Dressler et al., 2005, p. 527; Dressler and Bindon, 2000).

Alternatively, local income rank may function as a proxy for social rank (Wood et al., 2012), particularly if affluence is culturally valued. Sociometric status, or the degree to which individuals are respected and admired by their peers, can be a stronger predictor of social wellbeing than socio-economic status (Anderson et al., 2012). Being of high status may also mean having greater access to social support, which has been found to mediate the relationship between social status and cortisol (von Rueden et al., 2014). However, relationships between sociometric status and cortisol are again variable. In a study of Scottish 15-year-olds, West et al. (2010) found a direct linear relationship between self-identified position in the peer hierarchy and cortisol level for boys, and elevated cortisol for girls in the top position. By contrast, in Decker's (2000) study of Dominican men, individuals rated by peers as less trustworthy, agreeable, influential and helpful had higher cortisol. Similarly, in von Rueden et al.'s (2014) study of Tsimane forager-horticulturalists in Bolivia, men with greater political influence had lower cortisol.

One explanation is that while being of higher social status is generally beneficial, the loss, or threat of losing one's high status confers greater stress than being comfortably in the middle of the hierarchy. Von Rueden and colleagues note that although hierarchies among their sample were mostly stable over the four-year study period, the loss of influence did seem to be especially stressful, and greater declines in influence were associated with increases in cortisol. This also accords with two studies which report greater responses to stress tests among individuals of higher peer status (Gruenewald et al., 2006; Hellhammer et al., 1997). Loss of influence for individuals likely means reduced social power and ability to control their circumstances and the circumstances of others, which some evidence suggests may mediate the relationship between social status and cortisol (Smith et al., 2008). The degree to which control is associated with a higher rank may be context specific, however; in one study of military personnel the higher ranked officers were found to have higher cortisol, which the authors interpreted as reflecting the greater stress of having to both take orders from higher ups outside the conflict zone and hold responsibility for immediate decision-making and directing the enlisted men underneath them (Bourne et al., 1968). On the other hand Sherman et al. (2012) found that the greater social control held by high ranking military and civil service personnel was associated with lower cortisol.

The allostatic effects of social hierarchies may therefore depend on multiple factors, including the implications of a given hierarchy, strategies for achieving status, and the stability of position within that hierarchy. During periods of relative stability, higher status individuals may enjoy the stress-buffering effects of greater access to social support, while lower status individuals carry the psychosocial effects of inequality or invest more energy into matching the cultural model. Meanwhile, an unstable hierarchy may threaten both the sense of control and assurance of social support for high status individuals, while having relatively less impact on low-status individuals. Pursuing high status, therefore, could represent a high-risk, high-reward social strategy.

Yet as the implications of social status vary across different socio-cultural contexts, the dynamics of risk and reward may shift, meaning that we might expect relationships in cortisol patterns to vary widely as well (Decker, 2000; Sapolsky, 2005; Tennes et al., 1986; Tennes and Kreye, 1985). In some highly stratified cultural contexts being of low status may be experienced as stressful, while in others being of high status may be more demanding. In less stratified contexts, social status may have less impact, while other features of social life such as predictability may have more influence on individual experiences of stress.

Given the complications of alternative strategies, mediators, and socio-cultural circumstances, predictions might be more accurate if local context and meanings are explicitly taken into account. Here is where an ethnographic approach can be useful. The present study directly considers the features of children's social worlds in socio-cultural context in order to, for example, explicate the nature and salience of social hierarchies and the relationships between social status and social support. Status hierarchies might, for example, significantly influence the social experiences of children and thus correlate with cortisol patterns. The degree and direction of the relationship would likely depend on the local cultural meaning and implications of social status, however, as well as whether prestige or dominance strategies are most often used. Furthermore, a number of other social dynamics are also playing out in the classroom, including peer groups that directly support children as they cope with school life (Boocock and Scott, 2005). As social support can attenuate chronic HPA activation (Dressler, 1995; Kemp and Hatmaker, 1989; Seeman et al., 1994), and may mediate the relationship between status and cortisol (von Rueden et al., 2014) we anticipate that peer group stability likely influences experiences of classroom social stress.

To untangle these myriad factors, we therefore began with a qualitative approach through mixed ethnographic methods, including observation and interviews, in order to generate hypotheses of expected cortisol patterns based on dynamics particular to the social context of this classroom. Although clear hierarchies were present in this peer ecology, these were most salient at the group, rather than individual level, although some intra-groups sub-hierarchies were present also. Based on our understanding of these social dynamics, we anticipated that for these children, predictability of relationships and perceptions of reliable social support were more likely to reduce intra-group variability in stress reactivity. Less stable social relationships were anticipated to be a direct source of stress because of greater risks of conflict and uncertainty in how relationships should be managed.

Participants and methods

Following ethics approval by the University of Auckland Participants Ethics Committee, we recruited participants – 26 pupils – in a year-six New Zealand primary school class. All of these pupils and their parents assented and consented, respectively, to participate in at least some of the data gathering activities. Most children participated in all activities, 12 of 14 girls and 10 of 12 boys. Participants' ages ranged from 9.4 to 11.3 years, with an average age of 10.4 years. All names used below are pseudonyms.

The New Zealand Ministry of Education allocates decile ratings to schools which are based on five socio-economic descriptors of enrolled pupils' families. The participants' school was ranked a decile nine, indicating relative affluence. Observations of the children's homes suggest that most were comfortable, middle-class dwellings. The ethnic backgrounds of students in this school and the classroom considered here were diverse. About 30% of the families have parents born in New Zealand, most families originating from different countries across Asia, Europe and Africa. Like SES (Brandtstadter et al., 1991; Cohen et al., 2006; Evans and English, 2002; Bush et al., 2011), in some contexts ethnic background has been associated with variation in cortisol (Bush et al., 2011). While subtle differences in family SES and perceptions of ethnicity may have contributed to differences in serial cortisol variability reported below, we only consider this aspect within our qualitative focus on self-defined social networks in the present study.

This study tailored a range of ethnographic methods to engage the children as active participants in the project and build relationships that allowed the children freedom of expression. Rapport, developed between participants and the first author through sustained contact, improved the level of participation, and probably the quality of data.

We collected data using three sorts of activities. The first activity involved five weekly interactive sessions with all 26 pupils participating together as a class. Sessions were designed to facilitate an understanding of research processes in a fun and engaging way. They involved a learning component about research methods and an opportunity for participants to collect their own data on the background and lives of their classmates, as well as to share their own experiences. These sessions also provided an opportunity for the first author to observe how participants interacted with one another, providing a sense of what the social groups were and what the group dynamics were like.

The second activity involved one-on-one recorded interviews with 22 of the 26 participants. The first author conducted these semi-structured interviews at the participant's preferred location, usually home or school (after class). We scheduled interviews to capitalize on the level of comfort and rapport established during the class activities, and outside of the saliva collection window to reduce the possibility that they affected cortisol measures. These interviews typically lasted about one hour. The interview questions dealt with the participant's family, school and after-school life, experiences of stress and coping, friendships and the social networks of the class. Participants were encouraged to talk about whatever they felt was relevant or interesting to them. Participants' emphasis on peer relationships as a central part of their experiences guided the direction of interviews and later analyses.

The participants' own emphasis on their peer networks indicated that their social relationships within the classroom were central and powerful parts of their lives. In order to test specific hypotheses, we first evaluated how consistently individuals characterized social networks, and the nature of relationships within. Consistent with descriptions of children's social structures elsewhere (Adler and Adler, 1998; Skelton, 2001), the children described and often drew diagrammatically the relationships as being hierarchically structured around a number of core social groupings. Overall, the accounts were very consistent. Based on the qualitative data, we grouped participants according to their reciprocated friendships and peer relationships as a way of examining patterns across individuals in similar and different social circumstances. Characterization of these groups, their internal relationships and relative stability, was based on these descriptions of relationships and events. These included the frequency and degree of reported conflicts, the degree of friendship reciprocity, the apparent steepness of intra-group hierarchies, and indications of how secure individuals perceived their social position and relationships to be. This picture primarily represents a snapshot in time, with only limited time depth from historical data offered retrospectively in interviews.

These groupings largely represent the acknowledged friendship groups, though we occasionally found inconsistencies. For example, the popular group of six girls (described below) included hierarchical sub-groups and reported rifts between members. However, outsiders consistently grouped these six girls together and they interacted as a group with enough consistency to suggest their self-classification was appropriate. Variations among self-reports were reconciled by layering the 22 perspectives and triangulating these with observations. Though probably incomplete, multiple accounts allow a good approximate understanding of social relationships arising from their classroom experiences.

Data suggest variation in the degrees to which children understood the way they were perceived, the nature of their relationships and the relationships of others, and how they managed their social relationships. For example, during their interviews a pair of best friends, Aimee and Mia, each described their close friendship with two popular girls in the class (Ruby and Jamie). Aimee and Mia's descriptions were, however, inconsistent with all other descriptions from class members, including this popular pair, who identified the two individuals as only friends with each other.

Based on this understanding of participant perceptions and social contexts, predictions were then made about the corresponding patterns of cortisol variation over time. Importantly, test implications about how children's social networks were expected to influence patterns of cortisol variation were developed before hormonal assays were accomplished to avoid the possibility that assay results inappropriately influenced specific test implications described below.

The third classroom activity involved saliva collection from 24 participants each morning over a two-week period. After a short demonstration by the first author on the first day, the class managed their own saliva collection. As in another study of children in New Zealand (Mavoa, 2004), participants enthusiastically contributed saliva samples. They spat through short drinking straws into a self-labeled sterile container for two minutes as timed by the teacher. Participants then collected the containers and placed them into a zip-lock bag pre-labeled with the date and time. They were then frozen immediately, a storage method verified as effective (Kirschbaum and Hellhammer, 1994).

Saliva samples were collected just before morning tea (11 am) for a total of 221 samples. Times since rising, eating and physical exercise are all known to affect salivary cortisol levels (Decker, 2000; Pollard, 1995; Schwartz et al., 1998). The chosen time was a realistic compromise that allowed the most complete data set for the class given the busy routines of most families immediately after rising. Judging from observations by the first author, by 11 am the participants were settled into the classroom, had not eaten or exercised for the previous two hours, and cortisol levels were assumed to primarily reflect the classroom environment that morning. Because analyses focus upon the possibility of differences in intra-individual variation among self-defined social groups, we explicitly assume that each child's morning routine was consistent. Evidence from interviews supports this assumption with, perhaps, one exception: Luke, who spends alternate nights with each parent. Luke's cortisol measures show a relatively high CV, however he was the only boy in his social group with a full set of cortisol measures and so was excluded from inter-group comparisons.

After the analysis of qualitative data and specification of hypotheses test implications, the first author assayed the saliva samples for cortisol under supervision of the head technician at the Liggins Institute in Auckland via liquid-chromatography mass-spectrometry (LCMS). Assay preparation was accomplished by the first author, including quality controls, following standard procedures (described in Rumball et al. (2008)). The inter-assay coefficients of variation (CV) for low, medium and high controls were 10.9%, 7.4%, and 3.4%, respectively. The intra-assay CV values for the same controls were 12.6%, 6.2%, and 3.4%.

Evaluation of the hypotheses involved considerations of both cortisol central tendencies and variation. All tests were conducted using SYSTAT 13. Given that cortisol measurements were auto-correlated within individuals, we analyzed central tendencies in cortisol within a hierarchical linear mixed model (HLMM) with individuals' log-transformed daily cortisol measurements as the criterion variable and the pseudonyms of children as random effects within social groups as predictors. An auto-regressive error term was included to account for relationships among residuals over the 10 school-day period. Log-transforms were used to meet assumptions of approximate normality as judged from probability plots. Comparisons of how variable individuals were within social groups were assessed using log-transformed CVs. Preliminary tests indicated the use of CVs was appropriate as cortisol means and standard deviations were moderately strongly positively correlated whether calculated for individuals over the 10 school day period or by groups per day. All CVs were adjusted for sample size following guidelines in Sokal and Braumann (1980).

Results

Summary analysis of ethnographic data

The qualitative data pointed to a number of social network features that we used to inform our predictions based on what the children themselves identified as important to their experiences of stress. While the children described a distinct social hierarchy, it was group membership, and the loyalty and support that was expected to accompany it, that emerged as a critical part of friendships and social support systems. These children consistently identified close friendships as particularly important, and described how friendship groups provided social support in a number of ways. Social groups provided protections from bullying or isolation, and secured that in the absence of one friend, another was there to take their place.

As much as social groups were important sources of social support, when friendships were threatened, they could be the cause of stress. For example, one girl explained that she does not really get stressed at school, except "maybe when people don't talk to me… like my friends." This suggests that losing social support (or the fear of losing social support) may be a source of stress within this context. Likewise, another girl describes a cycle of arguing and reconciling that was a main cause of stress for her at school.

Peer relationships were also an overt cause of stress through conflict, rejection, harassment, or bullying. While this school has a strong anti-bullying policy which teachers said reduced the rate of overt bullying, incidences still occurred. For example, one boy described the stress of on-going bullying by another that morning, "[the bully] kept stuffing things in my desk and trying to stick [tissues] in my mouth."

Another example given was of exclusionary behavior, where children were made to feel unwelcome by a particular group or individual. One girl describes how she is isolated from her friends by another girl. Among the boys, bullying or harassment often masquerades as a joke, making it difficult for the victim to complain or react without being seen as lacking a sense of humor – particularly when the victim was trying to become friends with the perpetrators. One boy was often the subject of 'jokes' due to his turban. These 'jokes' ranged from songs to cartoons, all superficially funny, and the boy was expected to laugh along too. As expressed by one member of the popular boys group, "…sometimes he thinks they're quite funny, some of them? But sometimes he thinks they're quite rude and he doesn't like them but he doesn't show it and sometimes he does when he gets really annoyed." Higher status children were more likely to instigate such teasing or harassment, while children who were not a member of a stable social group were more likely to be the victims, regardless of social status.

Avoiding stressors such as harassment and maintaining the relationships required to solidify social support also can require a large investment of energy or social capital (Adler and Adler, 1998). One girl described how she memorized the social relationships within the class in order to have a better sense of her own place. This was one of a number of different approaches to managing peer relationships identified during this study. Overall, social status of children was less consistently linked to described stress experiences than their social group membership and the dynamic of these groups. Specific aspects of these social group structure and dynamic are described below.

Social network structure

Girls' and boys' groups were similarly complex, but somewhat different in structure. As shown in Fig. 1, the girls clustered into two main groups, along with the pair described earlier (labeled "Climbers") and their former friend, Nathalie, who was then somewhat isolated within the class but who maintained a close friend in another classroom. The two main girls' groups were self-labeled and labeled by others as the 'popular' group (six individuals; labeled "Popular Girls" here) and the 'shy' or 'normal' group (five individuals; labeled "Shy Girls" here). Friendships within the Popular Girls group appeared fragmented. Reciprocation was less consistent, and competition between group members over friendships meant that this group saw more conflict and tension than in the other groups. The Shy Girls as a group were noticeably more stable. They called themselves 'the gang' and consistently named each

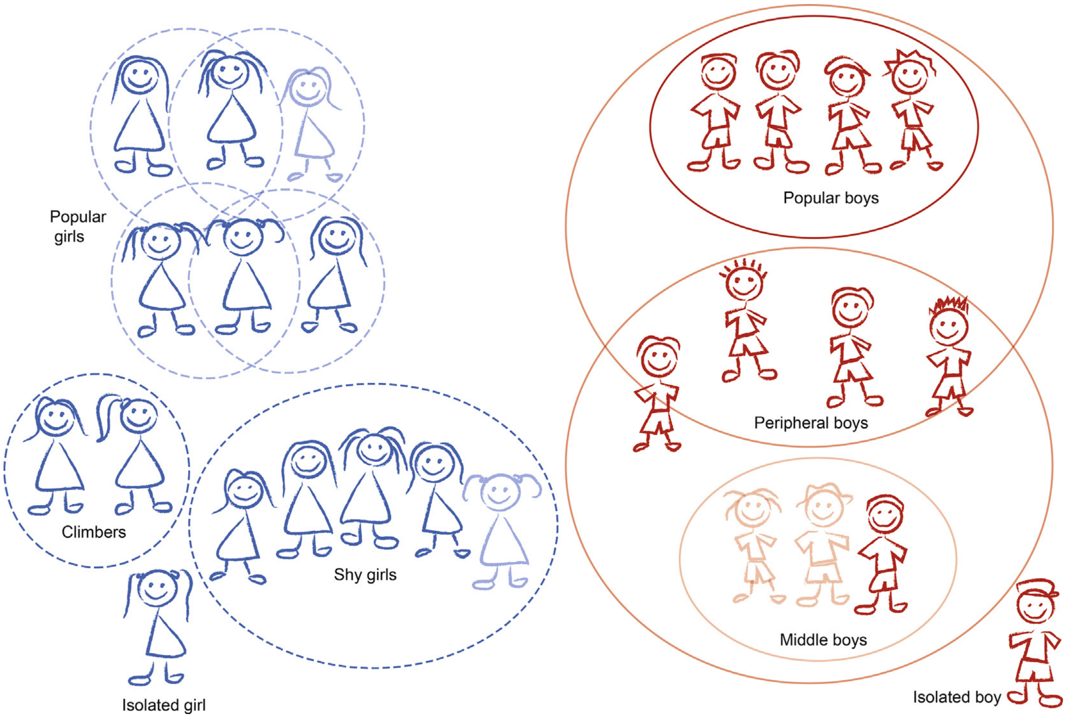

Fig. 1. A representation of the classroom social groups as determined through consistencies in reporting by students and from classroom observations by the first author. Members of boys' groups are in red, those in girls' groups are in blue. Children in lighter colour included three who provided no saliva samples and one who provided only four samples. Vertical organisation indicates social status. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

other as members, forming a close-knit unit who tended to stick together.

Like the girls, the boys had two main groups and a number of additional individuals. Boys and girls often referred to one group as the 'popular boys' (labeled "Popular Boys"). Both individuals within and outside the group consistently named the same four boys as members of a cohesive unit. Though there were occasional tensions between them, these tended to be put aside in favor of keeping their group constant and exclusive. These boys were secure in the loyalty of their friendships, and appeared to have collective control over group membership.

Another group of three boys was of 'middle' status (labeled "Middle Boys"), but was not considered in analyses as only one member participated in interviews. Four other boys were peripheral to one or both groups. Like the 'social climbing' girls, these 'peripheral' boys often described themselves as close friends with either or both of the core boys' groups, but were identified by members of the popular group as not particularly liked (although not necessarily disliked) but 'still let in anyway'. While these boys did not represent a social group, appearing to operate mostly independently of each other, their shared peripheral status was relevant in developing expectations regarding their cortisol profiles. Lastly, one other boy was frequently brought up as a person disliked by others. This boy, labeled "Isolated Boy", struggled to make any friends. Participants described him as aggressive and anti-social. Predicting this individual's cortisol pattern was difficult given the complexity of the relationship between adverse circumstances and HPA regulation. This boy's cortisol could be either high and very variable, or consistently very low, representing an individual with a down-regulated HPA axis.

Salivary cortisol results

Tables 1 and 2 report the range, median, mean, standard deviation and adjusted CV of serial 11 am cortisol measurements per individual, and their group, as assessed from saliva samples provided each school day by girls and boys, respectively, over 10 consecutive school days. These descriptive statistics are reported for all available data from the 24 children who provided saliva samples. Data from the ten school days are relatively complete; 15 of 24 participants donated saliva every day and another six missed only one day. Families of two children declined, and one (Cameron) only participated on the last four occasions. Few children had high cortisol levels; only 2.3% (5/221) of all values exceeded 5.7 nmol/l. Statistics are also reported with probably real but extreme values from the first day omitted for one girl (Hanna, Popular Girls) and one boy (Mitchell, Peripheral Boys). Virtually all girls provided samples on every occasion (99%; 129/130), but boys missed somewhat more often (83%; 92/110). This was partially because of their participation in sporting activities, but also reflected their more frequent absence from school.

Preliminary tests indicated that, overall, there were no statistically significant differences in either mean log-cortisol or cortisol variability among boys and girls in this class ($P \geq 0.30$). Although median and mean values within the Popular Girls group were

Table 1
Individual girl's 11 am cortisol (nmol/l) range, median, and mean, SD and CV[a] by group.

Alias	Group	N[b]	Range			Median	Mean	SD	CV
Holly	Shy Girls	10	0.66	–	4.22	1.98	2.21	1.09	50.40
Sarah	Shy Girls	10	0.97	–	4.74	1.61	2.19	1.20	56.33
Alison	Shy Girls	10	0.74	–	2.97	1.87	1.90	0.83	44.79
Chloe	Shy Girls	10	0.66	–	3.60	1.15	1.65	1.08	66.89
Lucy	Shy Girls	10	0.68	–	2.17	0.94	1.29	0.60	47.45
Total	Shy Girls	50				1.54	1.85	1.01	54.87
Hanna	Popular Girls	9	0.52	–	25.68	0.90	3.99	8.21	211.75
Hanna[c]	Popular Girls	(8)	(0.52)		(4.21)	(0.87)	(1.28)	(1.22)	(98.29)
Jamie	Popular Girls	10	0.65	–	4.32	3.22	2.91	1.31	46.09
Ellie	Popular Girls	10	1.27	–	3.94	2.21	2.43	0.87	36.79
Ruby	Popular Girls	10	0.07	–	11.70	0.84	2.32	3.62	160.05
Bianca	Popular Girls	10	0.42	–	3.02	2.08	1.69	0.97	59.11
Total	Popular Girls	49				2.04	2.64	3.86	146.96
Total[c]	Popular Girls	(48)				(1.96)	(2.16)	(1.93)	(89.82)
Aimee	Climbers	10	1.02	–	4.32	2.54	2.62	1.05	41.28
Mia	Climbers	10	1.16	–	3.16	2.09	2.06	0.66	32.67
Total	Climbers	20				2.34	2.34	0.90	38.94
Nathalie	Isolated Girl	10	0.63	–	5.59	2.36	2.61	1.38	54.12
Grand Total		129				2.04	2.28	2.52	110.74
Grand Total[c]		(128)				(2.04)	(2.10)	(1.44)	(68.71)

[a] Coefficient of variation adjusted following Sokal and Braumann (1980).
[b] N represents the number of cortisol measurements per individual from a potential 10 saliva samples gathered on 10 consecutive school days; 99% (129/130) of possible measurements from participating girls were collected.
[c] (Values) for individual, their group, and the grand total when one extreme, but probably biologically real, value has been omitted.

Table 2
Individual boy's 11 am cortisol (nmol/l) range, median, mean, SD and CV[a] by group.

Alias	Group	N[b]	Range			Median	Mean	SD	CV
Oliver	Popular Boys	7	0.63	–	4.63	2.92	3.04	1.29	43.83
Ben	Popular Boys	9	1.42	–	4.23	1.90	2.14	0.90	43.08
Simon	Popular Boys	9	0.78	–	2.07	1.21	1.24	0.37	30.82
Alex	Popular Boys	10	0.77	–	2.14	1.06	1.16	0.46	40.59
Total	Popular Boys	35				1.47	1.81	1.06	58.98
Mitchell	Peripheral	6	3.90	–	43.66	9.72	13.95	14.79	110.47
Mitchell[c]	Peripheral	(5)	(3.90)	–	(10.61)	(9.18)	(8.00)	(2.92)	(38.33)
John	Peripheral	9	1.05	–	5.38	1.62	2.47	1.62	67.55
Harry	Peripheral	9	0.76	–	2.44	0.95	1.19	0.64	55.33
Andrew	Peripheral	10	0.30	–	1.01	0.65	0.66	0.23	36.23
Total	Peripheral	34				1.03	3.62	7.61	211.77
Total[c]	Peripheral	(33)				(1.02)	(2.41)	(2.85)	(119.15)
Cameron	Middle Boys	4	1.63	–	4.09	2.25	2.56	1.17	48.65
Luke	Middle Boys	10	0.82	–	4.53	1.87	2.32	1.31	57.95
Total	Middle Boys	14				1.87	2.39	1.23	52.38
Blake	Isolated Boy	9	0.63	–	2.11	1.14	1.30	0.51	40.37
Grand Total		92				1.45	2.52	4.74	188.61
Grand Total[c]		(91)				(1.42)	(2.07)	(1.92)	(93.01)

[a] Coefficient of variation adjusted following Sokal and Braumann (1980).
[b] N represents the number of cortisol measures per individual from a potential 10 saliva samples gathered on 10 consecutive school days; 83% (92/110) of possible measurements from participating boys were collected.
[c] (Values) for individual, their group, and the grand total when one extreme, but probably biologically real, value has been omitted.

higher than those for any of the other social groups (see Tables 1 and 2), when individual log-transformed daily cortisol values were statistically evaluated within group using HLMM, results indicated that central tendencies were insignificantly different among the groups ($P > 0.42$). Differences in CV among the social groups assessed tend to support the hypothesis that intra-group social stability contributed to reduced cortisol variability. The linear mixed models analysis of within group variation in individuals over the 10-day period indicates that members of the Popular Boys were least variable. Members of the Popular Girls group were significantly more variable than the Popular Boys (coefficient of fixed effects: 0.665 ± 0.208 SE, $t = 3.197$, $df = 11$, $P = 0.009$). When the one first day extreme value from a member of Popular Girls was removed, the contrast between the two groups was weaker, but remained

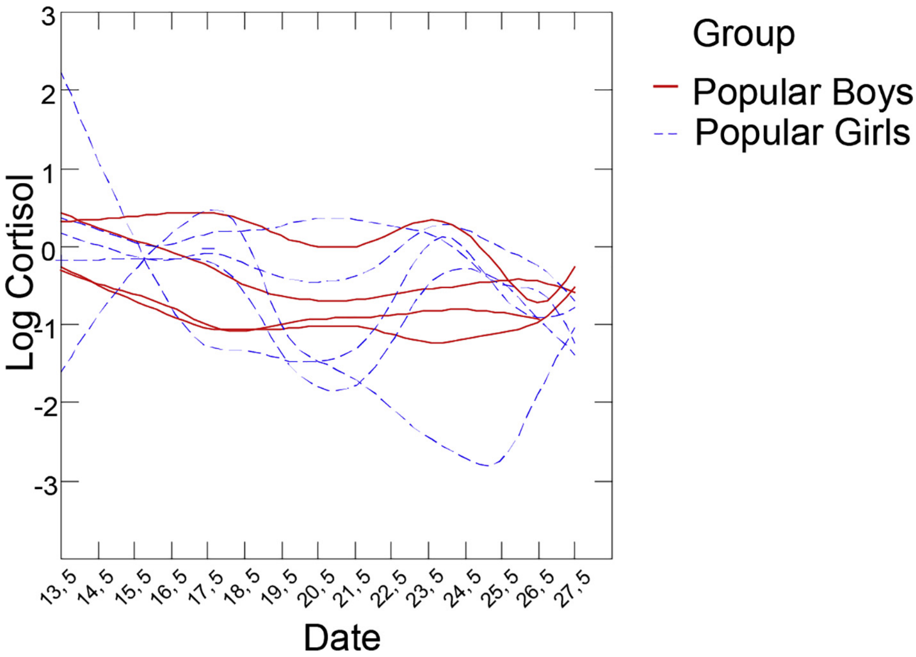

Fig. 2. Logged cortisol for the Popular Boys and Popular Girls groups over the sampling period (excluding weekend). Group membership is identified by colour.

statistically significant (t = 2.472, df = 11, P = 0.031) (Fig. 2). Members of Popular Boys were not significantly less variable than members of the stable Shy Girls group (t = 1.115, df = 11, P = 0.27) (Fig. 3).

These results are consistent with the many qualitative indications of greater stability and support within the Popular Boys and Shy Girls groups. All their values fall within a fairly narrow range, reflecting both low intra-individual and inter-individual variability.

Additional comparisons

As anticipated, differences in cortisol patterns appear marked among the four Peripheral Boys. The boy Andrew has consistently

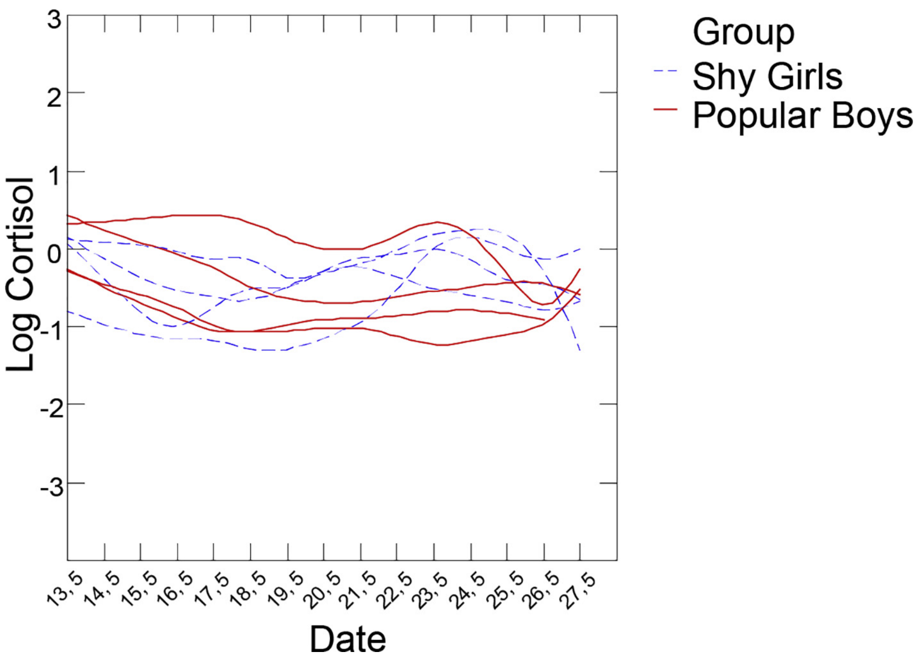

Fig. 3. Logged cortisol for the male 'Popular Boys' and female 'Shy Girls' groups over the sample period.

low cortisol values that fall below any of those of the Popular Boys group while Mitchell has consistently very high values (Table 2). The other two 'peripheral' individuals appear to show more intra-individual variability. This dissimilarity was anticipated given the observed and reported differences in their social relationships and social experiences within this classroom. Although cortisol data were relatively complete, missing values constrained how much we could say in comparisons that included the one peripheral boy, Mitchell, who had consistently high cortisol values. Meanwhile, the isolated boy, who was anticipated to have either quite variable cortisol levels, or consistently low values if stressors were chronic, had values that, while lower than average, were within the range of other boys. Given the extremes of his anti-social behavior, this finding is unexpected.

Discussion

On the basis of this study, we infer that being part of a social group is an important pathway towards wellbeing for children, but stability and cohesiveness of those groups, rather than high social status, may foster more supportive social relationships and predictable circumstances and thus represent better predictors of stress variability. This study suggests that individual cortisol patterning can show consistencies within social groups, the extent of variability in cortisol over time mirroring the nature of the social relationships within them. Shared experiences elicited similar hormonal responses among members of the two closely-knit, more egalitarian groups. In the more hierarchical, less closely knit Popular Girls group, however, shared interactions tended to result in more varied cortisol responses both within and among group members. This would be consistent with evidence that having stable, close social relationships provides a buffering effect that mitigates extreme responses to environmental stress, while minimizing the conflict and insecurity that generate social stressors (Seeman and McEwen, 1996).

As expected from the literature, evidence from this study does not support a straightforward relationship between cortisol variability and social status. Among the girls in this study, the high-status Popular Girls group shows significantly more variability than the Shy Girls group, while for the boys the high-status group shows low variability similar to the Shy Girls group. One possibility may be that the implication of social status differs by sex for New Zealanders around this age, so that social status is a greater source of ongoing competition among high-status girls than boys. There is no evidence of this in the present study, but if true, this would contrast with previous research which has found boys to be more status oriented (reviewed in Rose and Rudolph (2006)). Such reported sex differences in dominance goals could also reflect gendered cultural norms, rather than actual behavior; in this New Zealand context overt pursuit of social status (with the exception of sporting dominance) was not culturally mandated for either gender.

We suggest that our findings, and those reported in other studies, might be reconciled by considering the nature and implications of the social hierarchy and local cultural meanings of social status in the different contexts. In this case, although social hierarchies were salient, they were not as overt or steep as those reported in other Western contexts (Adler and Adler, 1998; Skelton, 2001). In this study, children in high-status groups denied the existence of popularity as a construct within their school; it was only children in groups of lower status who identified others as the popular children. Popular children's discourse reflected a kind of 'faux egalitarianism' and they tended to practice a 'benevolent leadership'; deliberately being kind or pretending to be friends with children they did not consider friends in order to enhance their overall likeability. Individuals in both popular groups described such 'prestige' strategies (Henrich and Gil-White, 2001) to acquire influence, as well as 'dominance' strategies such as teasing or bullying (more common to boys) or exclusion (both sexes). This suggests that high-status individuals could flexibly draw from a range of tactics, as well as maintain their 'kind' image while simultaneously engaging in behaviors that were not very kind.

The more covert way social hierarchies manifested in this class could be a reflection of values promoted by the school; they ran a program which focused on promoting a particular value each term, and the current one at the time of interviews was 'kindness'. It could also be a reflection of wider cultural values in New Zealand, which discourage overt claims of accomplishment (Belich and Wevers, 2008) and foster a 'myth of classlessness' (Tap, 2007). Hence, the way social status was defined in this classroom looked quite different, and was likely experienced quite differently, from what has been reported in other cultural contexts.

The costs and benefits of social status are therefore likely to vary along with the local social meaning of that status. For some individuals, either overtly or covertly aspiring to high status may be a strategy to achieve more secure social relationships. Being of high social status may increase network diversity, and this may provide a greater pool of social support to draw from. Furthermore, children of higher social status appeared to have more power to influence the other children in the class; this may further increase their ability to manipulate social situations to their advantage. However, the desirability of high status may mean that maintaining social position against competitors is more difficult, and social power can come at the risk of instability. As a result, while being of high social status may confer some advantage, it could also come at a cost if status was not secure. The differences in serial cortisol variability between members of the Popular Boys and Popular Girls groups in our study might be a result of such differences in cost and benefits. Meanwhile, in this study *not* being of high social status was *not disadvantageous* when individuals had close friends who supported them socially. Hence, as suggested by von Rueden's and colleagues (2014), social support may be the key mediator here. Aspiring to social status may represent one strategy for obtaining social support, while maintaining close and stable bonds within a friendship group may be a successful alternative.

While group dynamics appear to influence the extent of cortisol variability, social status or social stability were not significantly associated with differences in median or mean log-transformed cortisol. This may be partially because of the relatively small number of groups and group size. Overall, these results highlight the importance of context for any consideration of relationships between social dimensions and stress response. We can better understand such contexts by combining ethnographic methods with multiple measurements of cortisol, focusing on patterns of variation, not just central tendencies. Additionally, interpretations offered here do not exhaust plausible possibilities.

Because cortisol measures are linked to personality or temperament in several studies (Tennes et al., 1986; Flinn and England, 1995; Tout et al., 1998; McBurnett et al., 2000; Gunnar et al., 2003; Davies et al., 2011), we also considered whether our within-group similarities might be a function of shared behavioral styles. We expected that if this were the case, individuals with similar outgoing temperaments would have cortisol patterns most similar to each other and different from shyer individuals. While our study does not examine this hypothesis in depth, results do not appear to be consistent with these expectations. For example, members of the Shy Girls group look most similar to those of the outgoing Popular Boys group. Members of both look different from the majority of the outgoing Popular Girls group (see Tables 1 and 2).

Another explanatory model, derived from baboon ethology (Sapolsky et al., 1997; Sapolsky, 1992; Virgin and Sapolsky, 1997) and supported by evidence from human studies (Sherman et al., 2012; Smith et al., 2008), suggests that individuals who control social interactions are more likely to exhibit lower basal cortisol values and fewer markers of stress. Results of our study partially support this idea. For the members of the Popular Girls group, the lack of predictability as a result of unstable group dynamic may have resulted in a more sensitized HPA system response among some of its members contributing to the higher variability recorded. At the same time, the boys in the Popular Boys group shared the perception that they collectively chose who among the peripheral boys joined them for a given activity. This sense of control may have contributed to their relatively similar, less variable, cortisol patterns. However, members of the less-influential Shy Girls group appear to have achieved similar group stability and exhibit similarly low cortisol variability. This suggests that maintaining control over interactions is perhaps one strategy, but stable peer support may create a similar effect even in the absence of control over others. Hence stability, rather than control, may be a key predictor of cortisol variability, although control may be one means to achieving stability.

As part of future investigations, the concept of stability requires further development. Here we evaluated stability through the cohesiveness and consistency of friendships within peer networks. However, we acknowledged, for example, that the Popular Girls group characterized here as “unstable” did have supportive friendships as well. Importantly, too, the degree to which members perceived the social environment as stable probably varied within and among them even within the two-week period considered here. It is also possible that the pattern of substantial intra-individual variability reported on here represented an intermediate phase during group formation and that a social equilibrium of some sort might have emerged had data been collected for a longer period, or at a later point, when power dynamics within the group stabilized (Gunnar et al., 1997).

Although almost all of the children in this class participated in the study, our ability to test hypotheses is limited by the availability of only one classroom, the small numbers of individuals per group, and the relatively short time frame for observations and data collection. Despite these constraints, fine-grained analysis of data from a mixture of sources suggests that from the perspective of children, their social groupings are a central part of their social world, and that the dynamic and position of these groups may translate into an important influence on biological variability. Further exploring children’s group structures within cultural context and in relation to adrenocortical function could be a valuable direction for future research. A larger scale study of multiple classrooms and assessment of morning-afternoon cortisol steepness over a longer period could help to clarify the findings of this study. For a larger study, social network analysis techniques may be a useful and efficient supplement. Such a study could also take into account a wider variety of factors associated with cortisol measures, including more detailed estimates of energy expenditures, health status and medication use, sleep patterns, and behavioral and measures of familial socioeconomic status. The present study assumes that differences in factors such as rising time are likely to be randomly distributed across groups. However, we acknowledge the possibility that differences, if non-randomly distributed among groups, could confound tests of difference in mean cortisol. While we found no evidence to suggest rising time and group membership would be correlated, it is plausible that factors such as energy expenditure could be.

Although this study has identified differences in social environment and connected these differences to variation in stress responses, it remains unclear what this means for children’s welfare and development. High or abnormal cortisol has been linked to changes in metabolic (Brillon et al., 1995) and immune function (Baker, 1987), and associated with increased risk of cardiovascular disease (Krantz et al., 1988), suppressed fertility (Nepomnaschy et al., 2007), anxiety and depression (Brown et al., 2004; Mantella et al., 2008). Differences seen in this study, however, largely fall within the normal range of variation for healthy humans. Whether there are any implications for the sorts of cortisol variability documented here and physical or social development is unknown. A paucity of data on human variation in stress responses in the field, coupled with the complexity of the relationship between human environments, culturally mediated perception, coping and the HPA axis, makes it difficult to interpret cross-study comparisons with confidence. Despite this, the possible implications of an association between variable stress responses and children’s peer relationships make this a worthy question of further investigation. We hope that our study encourages further research to understand the relationship between individual biology and social processes within varying socio-cultural contexts.

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