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Sleep and risk-taking propensity in life history and evolutionary perspectives

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Introduction

Aside from a few notable exceptions, evolutionary ecological theories of human sleep have been little studied within anthropology (McKenna 1986; Ferreira de Souza Aguiar, Periera da Silva et al. 1991; Worthman and Melby 2002; McKenna and McDade 2005; Worthman and Brown 2007; Worthman 2008; Gettler, McKenna et al. 2012). Sleep provides essential maintenance and repair as a counter to waking-state activities of production and reproduction (Siegal 2005), and because time and energy used for one state cannot then be used by the other, a fundamental tradeoff between waking and sleeping states exists (Shneerson, Ohayon et al. 2005). Owing to the fact that humans have biological sleep needs for optimal physiological functioning and maintenance, it can be predicted from evolutionary theory that individuals should only take away from sleep in order to divert additional time and energy to solving the problems of production and reproduction. Such tradeoffs from sleep to waking will be more frequent in stressful and uncertain environments. Therefore, the amount and quality of sleep achieved by individuals should be reflective of local ecological stress and uncertainty, such that high stress environments should result in lower sleep-wake ratios. Consequently, such a shift should also translate into psychological and behavioral attitudes reflective of future discounting and fast life histories, states that tend to prioritize immediate reproductive and productive rewards at the risk of waiting for uncertain future opportunities and payouts.

Life history theory, derived from evolutionary biology and ecology, posits that psychological and behavioral traits may manifest in the presence of particular social, biological or ecological factors in attempts to optimally solve adaptive problems (Hill and Kaplan 1999). Essentially, each individual exists somewhere along the life history continuum, whereby those at the low (fast) end favor current versus future productive and reproductive opportunities, and those at the high (slow) end invest more heavily in the future, even at the risk of reduced immediate rewards. This is because they anticipate ultimately greater rewards later resulting from their earlier investments.

Evidence supports that unpredictable, unstable, and resource poor environments tend to produce faster life histories. Such environments may include living in poverty with unpredictable or unstable resource acquisition, low parental investment for children, or high extrinsic mortality either through more violence or higher rates of illness (Wilson and Daly 1997; Quinlan 2007; Quinlan and Quinlan 2007; Quinlan 2010; Schechter and Francis 2010). Parallel to this, a growing body of work indicates that the similar stressed ecologies, which typify faster life histories, also produce comparatively lowered sleep quantity and quality. For example, unpredictable noise in the local environment negatively affects total sleep time (Topf, Bookman et al. 1996; Buxton, Ellenbogen et al. 2012). Further, poor parenting ecology, as measured by both marital instability (Mannering,

Harold et al. 2011) and child sex abuse (Noll, Trickett et al. 2006), result in significant sleep problems in infants and toddlers. Other studies focused on local resource quality and predictability show that living in poor inner-city neighborhoods as measured by higher crime, litter, and unpleasantness is associated with lower quality sleep and more sleep disorders (Spilsbury, Storfer-Isser et al. 2006; Caldwell and Redeker 2009; Hale, Hill et al. 2012). Likewise, exposure to neighborhood crime through witnessing the violent trauma of seeing someone cut, stabbed, or shot has also been shown to result in sleep disturbances for up to a year (Umlauf, Bolland et al. 2011), and actual victims of violent crime show overall lower total sleep time and increased insomnia (Germain, Hall et al. 2006). Resource poverty, as measured by unemployment also leads to poor sleep outcomes, including both poorer sleep quality and more sleep disturbances (Blank and Diderichsen 1997).

While, some research points to acute effects of sleep deprivation resulting from ecological instability and resource poverty, others point to longer-term effects and/or the diminished ability to adjust sleep to chronic ecological stress. For example, a longitudinal study found that children who witness homicide experience inconsistent sleep for many years beyond the event (Spilsbury 2012), and, living under the conditions of chronic traumatic threat from terrorism and combat results in significant sleep deficiencies that do not seem to improve much over time (Caldwell and Redeker 2005; Palmieri, Chipman et al. 2010). Food shortages, as supported by findings about Holocaust survivors who experienced chronic starvation, also show significant sleep problems many years later in life (Kuch and Cox 1992).

Conversely, resource rich, stable and predictable environments tend to produce slower life histories (Kaplan and Bock 2001), and generally better sleep. In children, increased maternal investment as measured by more body massages (Ferber, Laudon et al. 2002), greater maternal warmth, and more time spent at meals (Adam, Snell et al. 2007) all result in significantly better sleep. Better financial security as measured by employment status, white-collar work, and higher household income correlates to better sleep quality (Geroldi, Frisoni et al. 1996; Arber, Bote et al. 2009), whereas poverty and lower education do the opposite (Patel, Grandner et al. 2010). Positive parental ecologies, like those that invest in familial co-sleeping, tend to improve the regulation of infant and adolescent sleep patterns and circadian rhythms (McKenna and Mosko 1994; Worthman and Brown 2007). Finally, studies with both humans and non-human primates indicate that they actively search to secure safe ecological spaces in order to improve sleep (Anderson 1998; Spörrle and Stich 2010).

Figuerdo et al. (2006) identify a core set of components of a fast life history that employs activities focused on short-term gains with longer-term costs, which we expect to be more prevalent in ecologies producing low sleep-wake ratios. These core behavioral traits include low parental investment, impulsivity, disregard for social rules, short-term thinking, promiscuous sexual behavior, and extensive risk-taking (Figueredo, Vasquez et al. 2005; Figueredo, Vasquez et al. 2006). And indeed emerging work bolsters the idea that sleep loss may result in a host of physiological shifts that increase the likelihood of decision-making and behavioral alterations reflective of fast life history strategies, such as greater impulsivity (Schmidt, Gay et al. 2008), delay discounting (Reynolds and Schiffbauer 2004; Venkatraman, Chuah et al. 2007), increased risk-taking (O'Brien and Mindell 2005; Acheson, Richards et al. 2007), lowered inhibitions (Anderson and Platten

2011), greater competitiveness or aggression (Ireland and Culpin 2006), and reduced parental investment through more domestic violence (Hoshino, Pasqualini et al. 2009).

Risk-taking, a key component of the fast life history strategy (Wang, Kruger et al. 2009), is associated with and strongly influences many of the other core components (Nettle 2010). Further, it tends to appear under the same ecological stressors as low sleep-wake ratios (Hill, Ross et al. 1997). Therefore, we propose that the amount and quality of sleep encountered by individuals may cue ecological quality and that several different proximate physiological mechanisms may function to shift risk-taking propensity in ways predicted from life history theory.

Psychological and behavioral studies typically analyze a wide variety of risk-taking activities such as drug use, smoking, gambling, risky sexual behaviors, and sensation seeking such as skydiving, reckless driving, and extreme sports. Recently, however, evolutionary scientists identified five particular domains of risk that make better theoretical sense for use in the context of evolutionary ecological studies (Kruger, Wang et al. 2007). They include behaviors associated with risk-taking such as within-group competition (WGC) and between-group competition (BGC) in order to acquire resources for improved fitness; survival risks taken in the local environment for self and kin (E); reproductive function risks taken in exchange for immediate production resources (R); and finally risk-taking to increase quantity-mating opportunities and outcomes (M).

Previous work on the relationship between sleep deprivation and risk inclination indicate that physiological processes maintained and altered during sleep may act as proximate mechanisms subtly shifting human psychology to better optimize particular circumstances by influencing behavior in the directions of slower or faster life history strategies. For example, experimental data show that sleep-deprived individuals take more risks when focused on gains (Mckenna, Dickinson et al. 2007), and neuronal response observation highlights that this may be due to the fact that sleep loss results in greater activation of the right nucleus accumbens, an area associated with elevated reward expectations (Venkatraman, Chuah et al. 2007). An additional explanation for this finding may be that risk-taking propensity is strongly influenced by the frontal lobe, or executive function, which is impaired following sleep deprivation (Jones and Harrison 2001). In particular, sleep loss reduces cerebral metabolism in the prefrontal cortex, a region responsible for higher order cognitive functions and judgments (Killgore, Balkin et al. 2006). The behavioral hormone cortisol, which rises during (Treuer, Norman et al. 1996) and after sleep deprivation (Leproult, Copinschi et al. 1997), has been shown to influence greater risk-taking when decisions involve losses (Porcelli and Delgado 2009). Further, increased dopamine is strongly, positively correlated to impulsivity and future discounting (Pine, Shiner et al. 2010), and it drops in response to rising melatonin, which occurs during greater exposure to darkness and fewer nighttime sleep disruptions. Finally, in a rare but intuitive theoretical leap for most sleep research, a developmental connection has been made for understanding the relationship between REM sleep to attachment and reproductive development (McNamara 1996; McNamara, Dowdall et al. 2002). This line of work supposes that diminished parental investment ecologies may result in REM sleep patterning that could result in a fast life history outcome of earlier onset of reproductive development. In all of these ways, sleep loss results in proximate and developmental brain

and hormone changes that subtly shift human biology, psychology, and decision-making into either fast or slow life history trajectories.

Despite significant work on sleep and risk-taking inclinations and behaviors (Brown, Tickner et al. 1970; Harrison and Horne 1998; Harrison and Horne 2000; O'Brien and Mindell 2005; Killgore, Balkin et al. 2006; Chaumet, Taillard et al. 2009; Killgore, Kamimori et al. 2010; Gujar, Yoo et al. 2011), it appears that no sleep study has attempted to separate risky behaviors into ultimate and evolutionary-specific domains to understand and evaluate their particular ecological significance and whether relationships may be context specific. Because previous work clearly demonstrates that the effects of life history variables on risk-taking propensity are domain specific (Kruger, Wang et al. 2007), it seems prudent that further evolutionary studies attempt to utilize this survey instrument for two reasons: 1.) Risk-taking activities are thoughtfully identified and parceled into logical categories that pertain to known types of behavior intended to ultimately influence inclusive fitness in particular ways, and 2.) It allows one to test for differential effects of predictor variables, like sleep, on separate domains of risk. Additional description of this instrument and its domains are discussed in the following section and specific questions from the instrument can be observed in Appendix A.

In particular, we predict that impaired sleep should correlate to greater risk-taking propensity in all the domains described previously that revolve around the activities of reproducing, surviving, producing, and same-sex competition. We make this prediction because sleep is most often traded off during times when more energy and effort are needed for the waking activities that promote inclusive fitness, such as production and reproduction. However, we expect the effect to be most pronounced with the domain of higher-quantity mating and resource allocation for mate attraction (M) since this domain directly targets investments in reproductive success via the mechanism of attracting multiple mates.

Evolutionary ecological theory predicts that access to mates is the most influential variable predicting male reproductive success, and therefore men should be more willing to take risks in this domain than all others when the ecology demands a lower sleep-to-wake time ratio. While we generally expect overall that sleep loss will increase reproductive function risk-taking (R), since firefighters typically earn a significant salary, they should be less likely to trade of risk-taking that result in higher production at the cost of reproduction (which is the case with the R domain) than other domains like mating (M) that more immediately and directly increase reproductive success. In this way, we expect that in the presence of sleep loss, direct investments in reproduction will be prioritized over direct investments in production.

We further predict a relationship between sleep loss and environmental challenges (E), since this domain allows one to survive in order to produce or reproduce. However, we expect that firefighters should be less likely to engage in significant reproductive (R) risks than all other domains since this category, as designed by the survey authors, actually poses a trade-off of reproductive potential in favor of higher productive output. In this case, we expect firefighters to be less influenced by sleep-loss effects in this condition, since financial incentives to bear reproductive costs are less valuable to them due to their relatively higher salaries.

Finally, we predict that impaired sleep will also increase inclinations for within and between group competition (WGC and BCG), but perhaps in a reduced way, from mating (M) and environmental risk (E) inclinations. In general, the literature attests that this is because same-sex competition and coalition-making activities are more indirectly and over longer periods of time influencing greater inclusive fitness through a variety of circuitous and oblique pathways that might affect disparate things such as social status, resource acquisition, and competition elimination through mechanisms such as warfare, raiding, and hierarchical positioning.

Materials and Methods

Participants and Location

Research was conducted among emergency response personnel of the CAL FIRE-Riverside Unit and Riverside County Fire Department, one of the largest fire operations in both California and the United States. Emergency response personnel in the Riverside Unit are responsible for defending approximately 7,300 square miles of diverse territory in inland Southern California, often during extreme weather conditions such as heat, wind storms, and thunder and lightning complexes. In 2009, the year before this research was conducted, Riverside personnel responded to more than 115,700 local emergency calls, which is among the largest total-call volumes in California.

Owing to large demographic differences and variable population densities of the 2.1 million residents in Riverside County, and the highly variable physical ecology and geography of the area, employees are trained to respond to a large array of emergencies such as medical aids, traffic collisions, structure fires, rescues, and hazardous materials threats. Also because of these differences, some stations are situated in areas with higher emergency call volumes, like those stations located in densely populated city areas.

Due to the unpredictable nature of emergency response work, nighttime wakeful events for Riverside firefighters are variable over the course of a typical 72-hour work shift. This lends to a possibility of compromised sleep quality and quantity and related outcomes for several consecutive nights, especially for those firefighters assigned to busier stations in the Unit. Furthermore, the risk of large wildland fire emergencies, sometimes lasting for weeks or even months at a time, is particularly high for the area defended by Riverside Fire.

Procedures

Battalion Chiefs escorted researchers to randomly selected fire stations over a period of five weeks during June and July 2010. Personnel at each station were invited to participate in a “sleep study” as part of a larger life history research project that has resulted in two recent publications related to the current study (Miller and Rucas 2012; Rucas and Miller 2013). Participants were limited to individuals on-shift during the day of the researcher’s visit, and most commonly three male career firefighters were present at each station.

Consenting participants were instructed to log onto an online survey and complete a series of online questionnaires including demographics, the Risk-Taking Propensity Scale (Kruger, Wang & Wilke 2007), and an occupationally targeted sleep survey that included questions regarding the amount and quality of sleep achieved on average while

sleeping at the fire station. Many questions for the occupationally targeted sleep survey used in this analysis were gathered from the Pittsburgh Sleep Quality Index (Buysse, Reynolds et al. 1989). Informal and semi-structured interviews were also conducted with several Chief Officers and on-shift firefighters to better understand the relationship between emergency response shift work and sleep acquisition. Table 1 in the results section provides descriptive details of the participants. Owing to the fact that a large body of research points to robust sex differences, with greater propensity and actual risk-taking behavior by men due to both proximate and ultimate effects (Wilson and Daly 1985; Byrnes, Miller et al. 1999; Archer 2004; Harris, Jenkins et al. 2006; Apicella, Dreber et al. 2008; Pawlowski, Atwal et al. 2008; Wang, Kruger et al. 2009; Cross 2010; Cross, Copping et al. 2011), and because one of our hypotheses is specific to men, all data analysis in this study is restricted to the male firefighters in the sample.

Dependent Evolutionary Domain-Specific Risk-Taking Measure

Kruger and colleagues developed an evolutionarily relevant risk-taking propensity scale that was used for dependent variables in analysis (2007). The questionnaire delineated five separate risk domains that were used in linear regression with sleep quantity and quality variables. This survey was developed as a more valid measurement device for use within human evolutionary ecological studies, since the domains correspond to established areas of ecological significance to humans during the hominid evolutionary trajectory, such as investment in risk-taking for competition with neighbors of the same or different groups, reproductive risks to improve immediate resource circumstances, risk investment needed for immediate survival of self and kin within the local environment, and risk investment in quantity-mating strategies and multiple mate attraction. These five domains are respectively termed; 1.) Within-group competition (WGC), 2.) Between-group competition (BGC), 3.) Reproductive risk (R), 4.) Environmental challenge (E), and 5.) Mating and resource allocation for mate attraction (M).

The Risk-Taking Propensity Scale was used to gauge individual firefighter motivations to engage in risky behaviors. It is a fifteen-item questionnaire that requires participants to rate the likelihood of engaging in risky behaviors related to each of the five risk domains (WGC; BGC; R; E; and M) on a 5 point Likert scale ranging from 'very unlikely' to 'very likely'. Questions on the online survey were listed in a random order, as opposed to leaving them grouped into their evolutionary domains. Appendix A lists the items included on the risk-taking scale.

Independent Sleep Variables

Predictors included one sleep quantity variable, 1). Self-reported average number of minutes slept per night at the fire station, and three measures of sleep quality: 2). Psychological impairment related insomnia; 3). Physical health related insomnia; and 4). Sleep latency insomnia. These were gathered via self-report online surveys. The self-reported average number of minutes slept was limited to only the amount of sleep firefighters had on average per night while at the station, as opposed to their overall average between home and the fire station, to provide insight into the most proximate relationship between sleep quantity and risk-taking propensity.

Two composite variables are designed to represent different aspects of sleep quality. Psychological sleep quality is measured by additive Likert scale questions that gauge firefighter's inability to sleep or difficulty falling asleep due to worry, and stress

from nightmares or bad dreams. Similarly, physical sleep quality is measured by health-related reasons for insomnia such as inability to sleep due to being too hot, snoring, pain, difficulty breathing, and a general low overall satisfaction of the health quality of one's sleep. An increased score in these variables indicates higher sleep quality from fewer psychological or physical insomnia complaints. The sleep latency insomnia (sometimes called sleep onset latency or SOL) variable is a self-reported measure of the average amount of time it takes a firefighter to fall asleep at the station. In sleep medicine and psychiatric survey instruments, such as the PSQI, sleep latency can be used as a measure of sleep quality when evaluating an individual's overall sleep quality (Buysse, Reynolds et al. 1989).

Results

	<i>n</i>	mean	±s.d.	min	max
Age	138	37.36	±7.16	22	54
Biological children	133	1.48	±1.16	0	5
Body mass index	113	28.97	±24.45	20	43
Sleep quantity: Avg. number of minutes slept	130	342.47	±93.10	120	568
Sleep quality (low psychological related insomnia)	128	9.63	±2.34	3	12
Sleep quality (low physical pain related insomnia)	128	15.13	±2.70	4	20
Sleep latency insomnia	127	28.01	±2.70	2	120

Multiple linear regression in STATA v 11 was used to test the hypotheses that sleep quantity and quality are inversely related to domains of risk. Descriptive sample statistics of dependent sleep variables can be observed in Table 1, and risk domain means are displayed in Table 2. The majority, 89% of firefighter participants, reported no previous medically diagnosed sleep disorders. Firefighters in this study show the highest mean scores for Within-group competition (WGC) risk propensity, followed by Environmental challenge (E), Between-group competition (BGC), Reproduction (R), and finally Mating and resource allocation for mate competition (M). These scores differed markedly from those of the Wang et al. (2009) study only in the areas of WGC, BCG and E domains, whereby firefighters show an overall greater propensity for WGC and E risks, and a lower propensity for BCG risks than the University of South Dakota sample used previously.

Risk Domain	mean	±s.d.
Within-group competition (WGC)	11.87	±1.66
Between-group competition (BGC)	8.87	±2.87
Environmental challenge (E)	11.52	±2.26
Mating and resource allocation for mate attraction (M)	6.46	±2.83
Reproduction (R)	6.67	±3.34

Multiple regression analysis was used to test for the main sleep quantity and quality effects on the five evolutionary domains of risk (WGC, BGC, E, M, and R) while controlling for participant age, body mass index (BMI), and number of biological children. These were chosen as controls since they are common life history variables that are generally known to influence risk-taking behaviors. It should be noted that in the presence of the sleep variables, with the exception of higher BMI reducing environmental challenge risks, none of these controls significantly predicts any evolutionary domains of risk-taking propensity. We also investigated the potential for stimulant consumption effects on dependent variables, but neither coffee nor energy drink consumption independently or in the model with other predictors had any effect on risk-taking propensity so they were left out of the final analysis. Main effects for each regression can be observed in Table 3. Diagnostic analysis confirms that the models did not diverge from the assumptions of multiple linear regression, and diagnostic analysis showed no influential outliers.

Within-group competition (WGC) risk propensity, which is the highest mean of any domain, is only significantly predicted by sleep latency, a measure of sleep quality via insomnia. Men who report better sleep quality due to decreased time needed to fall asleep show significantly lower within-group competition tendencies ($\beta = .31, p = .008$). For example, men who are least likely to engage in within-group competition take, on average, 16 fewer minutes to fall asleep than those who report the highest inclinations to compete with others of their same group. Separate Pearson correlation analyses indicate that the number of other firefighters at the station is not correlated to sleep latency ($r = .03, p = .71$), and the number of other men does not significantly predict within-group competition ($r = .04, p = .63$). Thus it would appear that low sleep quality as measured by greater sleep latency influences men's tendencies to risk more in competition with others of their own group regardless of the total number of other men residing at their station.

Between-group competition (BGC) risk propensity, a significantly lower-rating domain than WGC, is only marginally affected by low sleep quality resulting from physical pain related insomnia ($\beta = -.22, p = .097$) and sleep loss ($\beta = -.19, p = .069$). Risk-taking propensity for mating and resource allocation for mate attraction (M) is greatest among firefighters experiencing sleep loss ($\beta = -.41, p < .001$) and only marginally for those reporting lower psychological sleep quality ($\beta = -.23, p < .065$). Reproductive risk-taking propensity was significantly predicted by lower psychological sleep quality ($\beta = -.36, p = .005$), and positively by sleep quantity ($\beta = .007, p = .047$). Finally, firefighters experiencing sleep loss exhibited marginally greater inclinations to take environmental challenge risks ($\beta = -.19, p = .059$).

A final regression test was conducted to examine whether a particular ecological stress component, such as job status, might have any effect on risk inclination and sleep quality. Controlling for income, age and biological children, it was found that the stress of a firefighter's occupational status, as defined by his job title, does predict sleep latency. In particular, those with higher job rankings take fewer minutes to fall asleep than those firefighters with lower job rankings ($\beta = -.443, p = .003$). However there was no statistical relationship between job title and any particular domain of risk taking even controlling for sleep or other demographic variables.

Table 3. Multiple linear regression testing for effects of sleep quantity and quality as measured by the number of minutes slept on average, psychological worry related insomnia, physical pain related insomnia and sleep latency insomnia on various domains of risk-taking propensity including controls for biological children, body mass index and age (β , unstandardized regression coefficient; p , two-tailed significance; Std. Err., standard errors; n , sample size; R^2 , adjusted variance accounted for by all predictors.)

Predictors	B	std. err.	p	model statistics
Within-group competition (WGC)				
Sleep quantity: Avg. number of minutes slept	-0.13	0.00	0.210	
Sleep quality (low psychological related insomnia)	0.12	0.09	0.334	$n=104$
Sleep quality (low physical pain related insomnia)	0.11	0.08	0.387	$R^2=0.04$
Sleep latency insomnia	0.31	0.01	0.008	$p=0.15$
<i>body mass index</i>	0.13	0.04	0.237	
<i>biological children</i>	-0.06	0.16	0.577	
<i>age</i>	0.09	0.03	0.453	
<i>Constant</i>	8.02	2.00	0.000	
Between-group competition (BGC)				
Sleep quantity: Avg. number of minutes slept	-0.19	0.00	0.069	
Sleep quality (low psychological related insomnia)	0.19	0.16	0.135	$n=103$
Sleep quality (low physical pain related insomnia)	-0.22	0.14	0.097	$R^2=0.07$
Sleep latency insomnia	0.03	0.01	0.803	$p=0.05$
<i>body mass index</i>	0.12	0.08	0.260	
<i>biological children</i>	0.11	0.27	0.306	
<i>age</i>	-0.17	0.05	0.128	
<i>Constant</i>	11.73	3.43	0.001	
Mating & Resource Allocation for Mate Attraction (M)				
Sleep quantity: Avg. number of minutes slept	-0.41	0.00	0.000	
Sleep quality (low psychological related insomnia)	-0.23	0.15	0.065	$n=101$
Sleep quality (low physical pain related insomnia)	0.16	0.13	0.204	$R^2=0.14$
Sleep latency insomnia	0.04	0.01	0.740	$p=0.00$
<i>body mass index</i>	0.00	0.07	0.991	
<i>biological children</i>	-0.03	0.26	0.738	
<i>age</i>	0.10	0.00	0.361	
<i>Constant</i>	9.42	3.32	0.006	
Reproduction (R)				
Sleep quantity: Avg. number of minutes slept	0.19	0.00	0.065	
Sleep quality (low psychological related insomnia)	-0.36	0.18	0.005	$n=102$
Sleep quality (low physical pain related insomnia)	0.08	0.15	0.533	$R^2=0.08$
Sleep latency insomnia	-0.11	0.02	0.349	$p=0.00$
<i>body mass index</i>	0.20	0.09	0.060	
<i>biological children</i>	0.06	0.31	0.568	
<i>age</i>	-0.09	0.05	0.410	
<i>Constant</i>	4.98	3.94	0.210	

(Table 3, cont.)**Environmental challenge (E)**

Sleep quantity: Avg. number of minutes slept	-0.19	0.00	0.059	
Sleep quality (low psychological related insomnia)	-0.02	0.13	0.896	$n=104$
Sleep quality (low physical pain related insomnia)	-0.12	0.11	0.332	$R^2=0.04$
Sleep latency insomnia	-0.10	0.01	0.368	$p=0.15$
<i>body mass index</i>	0.25	0.06	0.024	
<i>biological children</i>	0.00	0.21	0.964	
<i>Age</i>	0.00	0.04	0.967	
<i>Constant</i>	19.13	2.76	0.000	

Discussion

It was generally expected and found in this study that detriments to sleep quantity and/or quality would increase risk-taking propensity across the various domains even while controlling for age, body mass index (BMI), and number of biological children. Most notably, lack of sleep results in increased propensity for between-group competition (BGC), mating and resource allocation for mate attraction (M), and environmental challenges (E). And, as predicted, low sleep quantity had the greatest magnitude of effect on mating (M) risks. No effect of the number of minutes slept was found with risk-taking propensity of within-group competition (WGC), and a significantly opposite effect than predicted was found with the reproduction (R) domain, which contrasted with the effects of sleep *quality* on the reproductive domain.

The value of using the Kruger et. al scale is that questions of evolutionary and ecological significance can be better examined with the parceled domains and how they individually relate to sleep. For example, a previous study by the authors looking at how sleep affects the sensation-seeking component of the Brief UPPS impulsivity scale did not elucidate results (Miller and Rucas 2012). While this previous study indicated a link between some other impulsivity traits and sleep loss (namely premeditation and urgency), the sensation-seeking portion of the Brief UPPS scale did not show a significant interaction with sleep variables. We identify a particular problem with the use of UPPS sensation seeking scale for evolutionary ecological work, in that the UPPS, similar to many other scales, does not recognize different target domains of risk-taking beyond sensation-seeking, thus its use is limited.

With respect to overall male-male competition, it appears that losing total sleep minutes and experiencing low sleep quality due to psychological reasons makes firefighters marginally more competitive with outsiders (BGC), but not necessarily so with comrades (WGC). Lower sleep quality as measured by higher sleep latency insomnia, though, does result in greater WGC inclinations. In short, lack of sleep in minutes could reflect a tendency to cooperate in-group, or at the very least not compete with in-group members, while at the same time compete with out-group others. Such a strategy may be beneficial in ecologically stressful environments with food scarcity or low survivorship that may shift sleep-wake states in favor of waking time at the expense of needed sleep in order to allow greater time for individuals for production in their environment through

cooperation with in-group members while at the same time competing with outsiders. Evidence for this line of reasoning can be found in that lower sleep time in minutes was also associated with a greater willingness to engage in environmental challenges (E).

Supporting predictions, loss of sleep minutes had the strongest impact on willingness to engage in quantity-mating strategy risks such as spending larger portions of income on costly signals such as sports cars, engaging in unprotected sex, or maintaining long-term relationships with more than one partner at a time (M). Put together with the previous findings, these results imply that in the presence of sleep loss, individuals become more motivated toward risks that will lead to greater and more immediate production and reproduction activities with a priority for improving proximate reproduction options, implying that lack of sleep could lead predictably to adaptive shifts in life history strategies.

Low sleep quality was associated with greater propensity to engage in within-group competition (WGC), between-group competition (BGC) and reproductive risks (R). And while sleep loss in total minutes (sleep quantity) did not increase competitiveness with other members of one's group, taking a longer time to fall asleep (sleep quality) does seem to predispose one to competitiveness with others of one's group. Higher sleep latency insomnia is most often caused by social, financial, or work-productive environmental stresses (Hanson and Östergren 1987; Bazargan 1996; Dollander 2001; Knutsson 2003; Linton 2004; Nakata, Haratani et al. 2004; Åkerstedt 2006; Kamel and Gammack 2006). In this study, controlling for income, age, and biological children, it was found that the stress of a firefighter's occupational status, as defined by his job title, increases insomnia, causing those with lower job rankings take more minutes to fall asleep than those firefighters with higher job rankings. And while these data support previous study results showing that production and social stress due to low position in the dominance hierarchy directly affect sleep quality, it is not true that job stresses resulted in more risk taking since in our analyses job title did not statistically significantly predict any domain of risk inclination.

Low sleep quality due to physical pain-induced insomnia only resulted in inclinations to take greater between-group competitive risks (BGC). This is interesting since between-group competition among men typically carries the greatest physical costs than perhaps all the other risk-taking domains. Indeed, the first survey question for BGC overtly mentions the possibility of causing a fight given the option to behave competitively, thus directly introducing an explicit potential physical cost into the equation. Interpretation of the relationship to low sleep quality is uncertain; however, it may be speculated that men already in poor health, experiencing insomnia from the state of their poor physical condition, are pressed with expectations for diminished residual life prospects as a result and may therefore be willing to take more costly risks as apparent in the BGC questions. Indeed, separate post-hoc analyses indicate that both overall reported better health ($r = .22, p = .02$), and higher sleep quality ($r = .17, p = .05$), are Pearson-correlated to higher life expectancy. For these reasons, and in line with behavioral ecology theory, firefighters in poorer physical condition may be more willing to take costly physical risks in out-group competition for the benefit of the in-group since they perceive that they have less of a future to lose, and likewise will preference immediate rewards over later-invested gains that may never materialize.

Consistent to initial predictions, reproductive risk propensity was found to be marginally lower in men who experience sleep loss in minutes. This, of course, is opposite from the below finding that R is higher in those with low sleep quality resulting from psychologically related insomnia. It is important to consider the context of the questions in this domain, though, in order to better understand these seemingly contradictory results. The reproductive risk survey questions involve tradeoffs between the benefit of significant sums of money posed against the cost of potential reproductive hazards; essentially it is a forced tradeoff between production on the one hand and reproduction on the other. Post-hoc multiple regression indicates that men who log more overtime income sleep fewer minutes on average ($\beta = -.374, p = .01$) due to the multiplying effects of additional shifts on their total sleep time. But in a twist, the additional income from working extra shifts logically predisposed them to taking fewer reproductive risks in return for more money compared to other men. Since firefighters reporting insomnia do not make any more or less money than others, there exists the possibility that at least some might occasionally be willing to accept tradeoffs of money in return for taking reproductive risks. And as point in fact, psychologically induced insomnia exhibited strong effects on inclinations for taking reproductive risks (R), though it had no effect on other domains. Understanding exactly what conditions are producing the worry insomnia could be key to further understanding the relationship between impaired sleep and inclinations to take reproductive risks to increase productive income. For example, this study did not differentiate between social versus financial insomnia stresses, so it is unknown whether they have differing consequences on reproductive risk-taking propensity. But predictably, psychologically induced insomnia resulting from worries over resource shortages or high debt obligations that some firefighters might experience should result in greater inclinations for reproductive risks since these particular questions in the survey pose the opportunity to receive significant immediate financial rewards in exchange for sacrifices to their reproductive function.

This work is limited in that all sleep measures were subjective self-reported data, and as such are subject to reporter biasing errors. This does not invalidate the findings, however, since experimental work supports the use of retrospective self-report sleep data which have been found to significantly correlate to both sleep diaries and actigraphs (Wolfson, Carskadon et al. 2003). Even so, actigraphy is not without documented inconsistencies. For example it is known to key onto earlier sleep onset than polysomnography (Tryon 2004). Future work might still, however, attempt to use actigraphy as a more objective sleep measurement device, since even though research consistently finds a significant correlation between the two measurement techniques of self-report and actigraphy, the former is more subject to reporter bias (Lauderdale, Knutson et al. 2008). It should also be noted that all risk-taking scales measure inclinations or psychological motivations in order to assess the propensity to take risks, and that no actual risky behaviors were observed or recorded. Still, this particular risk-taking propensity scale has been validated using life history variables (Wang, Kruger et al. 2009), and several lines of research indicate that a variety of other risk-inclination scales also correlate to actual risky behavior indicating that self-report measures on risk inclination correlate to actual risk-taking behaviors (Sitkin and Weingart 1995; Wagner 2001; Lejuez, Read et al. 2002;

Killgore, Cotting et al. 2008; MacPherson, Magidson et al. 2010; Horcajo, Rubio et al. 2013).

Future work might also attempt to determine the exact causes of psychologically deprived sleep, since evolutionary ecological theory might predict that social problems causing sleep loss may result in differing domain risk-propensity effects than for example sleep loss resulting from productive work problems or financial debt stress. Finally, direction of effect remains a question of importance. The theory presented presupposes that ecological risk affects sleep, which cues alterations in psychology and behavior. The statistical results, however, imply but do not necessarily confirm cause and effect. Therefore, additional longitudinal studies parceling the direction of the effect could be useful for confirming the nature of the relationship of sleep to behavior and psychology.

In conclusion, our data provide strong support that lack of sleep and insomnia due to high sleep latency, psychological, or physical causes may cue ecological stress, which appears to result in greater future discounting with an increased willingness or propensity to predictably engage in various evolutionary domains of risk-taking, the most significant of which is the inclination to prioritize mating opportunity risks (M) in order to receive immediate reproductive rewards. Sleep is affected by conditions in the local environment and since sleep helps regulate all physiological and psychological systems and rhythms, shifts in sleep-wake state ratios and quality of the sleep condition may predictably alter life history strategies observable through alterations in measures of motivations to behave.

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Appendix A. Items of the Risk-Taking Propensity Scale (Kruger, Wang & Wilke 2007)

Within-group competition

Standing up to your boss in front of coworkers when your boss is being unfair
Trying to take a leadership role in any peer group your join
Physically intervening between two friends who are aggressively pushing each other, to prevent a fight

Between-group competition

Adamantly defending the honor of your local team against a fan from a different sporting team even if it might cause a fight
Sitting in the section for fans of the opposing team with a group of friends while wearing your team's colors
Driving to a rival university at night and stealing the school's flag pole at the center of campus

Environmental challenge

Chasing a bear out of your wilderness campsite area while banging pots and pans
Swimming far out from shore to reach a platform
Exploring an unknown city or section of town

Mating and RA for mate attraction

Spending a large portion of your salary to buy a sporty new convertible
Engaging in unprotected sex during a one-night stand
Maintaining long-term romantic relationships with more than one partner

Reproduction

Getting sterilized so you cannot have children but have more leisure time and more financial flexibility
Exposing yourself to chemicals that might lead to birth defects for a high-paying job
Participating in medical research that pays \$10,000 but has some chance of making you sterile