

5-2013

Testosterone Reactivity to Skydiving

Swornim M. Shrestha
University of New Orleans

Follow this and additional works at: https://scholarworks.uno.edu/honors_theses

Recommended Citation

Shrestha, Swornim M., "Testosterone Reactivity to Skydiving" (2013). *Senior Honors Theses*. 44.
https://scholarworks.uno.edu/honors_theses/44

This Honors Thesis-Restricted is protected by copyright and/or related rights. It has been brought to you by ScholarWorks@UNO with permission from the rights-holder(s). You are free to use this Honors Thesis-Restricted in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/or on the work itself.

This Honors Thesis-Restricted has been accepted for inclusion in Senior Honors Theses by an authorized administrator of ScholarWorks@UNO. For more information, please contact scholarworks@uno.edu.

Testosterone Reactivity to Skydiving

Honors Thesis

Presented to

The Department of Biology
of University of New Orleans

In partial fulfillment

Of the requirements for the degree of
Bachelor of Science, with
University Honors and Honors in Biology

By

Swornim M. Shrestha

May 2013

Acknowledgements

I would like to thank my mentors, Dr. Elizabeth Shirtcliff and Dr. Bernard B. Rees for providing invaluable guidance and encouragement towards writing this thesis. Both my mentors are really amazing people and I feel like the luckiest person to have had the chance to work with both of them. This thesis would have been impossible without the kindness and support from my mentors.

I would also like to thank to Yoojin Lee, graduate student, from the Department of Psychology who helped me to analyze and get necessary information from the raw data. He has been vital in stimulating my interest and motivating me by engaging in discussions.

I would also like to thank my teachers, parents, and the University of New Orleans for giving me the opportunity to pursue higher education and help me learn skills that will be vital for my future career.

Contents

Acknowledgements	ii
Abstract.....	iv
Introduction	1
Testosterone and Social-emotional Behavior	5
Testosterone reactivity to competition and stress.....	12
Testosterone and Skydiving	14
Testosterone Reactivity and sex of individual.....	16
Testosterone reactivity and sensation-seeking trait.....	17
Methods	19
Samples	19
Procedures	19
Measures.....	19
Results	22
1. Testosterone Reactivity in response to skydiving.....	22
2. Sex differences in testosterone reactivity	26
3. Testosterone reactivity to sensation-seeking trait in response to skydiving.....	27
Discussion.....	29
Conclusion	35
Reference	37

Appendix 46

List of figures

Fig. 1. Testosterone change between basal day and jump day 22

Fig 2. Scatter-plot diagram showing the testosterone levels of individuals during jump day
across different time point of day 24

Fig. 3 Sex Differences in testosterone reactivity 26

Fig 4. EDIS and testosterone levels 27

Fig 5. ITAS and testosterone levels 28

Abstract

The purpose of this study is to examine if testosterone shows reactivity to skydiving and to examine whether the testosterone level and reactivity was associated with sex and sensation seeking trait of the participants. Testosterone is an important steroid hormone which has several biological and socio-behavioral effects on people and is also present in disproportionate amounts in males and females; thus, it is important to explore how this hormone acts in different sex. Furthermore, exploring the relationship between sensation-seeking and testosterone could provide insight into the relation between psychological factor and hormonal response in humans. Forty-four people were recruited to participate in the study. The sample comprised of 73% males (N=32) and 27% females (N=12) with a mean age of 24 years (SD = 4.6) and an age range of 18 to 49. The participants volunteered to jump out of an airplane and give saliva samples at different time points during that day and during another day (basal levels). This study found that testosterone shows reactivity in response to skydiving, where the peak levels in males were higher than in females. It also found that people who scored higher in experience-seeking scores had higher testosterone level at jump than people who scored lower. Furthermore, it also revealed that people who scored higher in intension-seeking scores showed more reactivity in terms of testosterone i.e. the rise was steeper in these people. In summary, we see that psychological factors and sex predicted reactivity and peak level of testosterone after skydiving.

Keywords: Testosterone reactivity, Skydiving, Sex Differences, Sensation seeking trait

Introduction

With the advent of new technologies and the beginning to the relatively modern era since the discovery of testosterone, there have been significant findings regarding the anabolic steroid hormone. Research in animals and humans to some extent has shown it is essential for development of primary and secondary male characteristics. Having more testosterone has been related to masculinity, but it is produced in both males and females and the level of hormone varies widely from person to person and from situation to situation (Sullivan, 2000). However, much remains unknown about the socio-behavioral effects of testosterone. What kind of situations leads to testosterone reactivity? Is it limited only to sexual context and competitions for social status? In this study, we explored skydiving and testosterone. So far, only one study has examined several hormones reactivity, including testosterone, in response to skydiving and found that there was no significant reactivity of testosterone in response to skydiving (Chatterton, Vogelsong, Lu, & Hudgens, 1997). If anything, testosterone levels dropped prior to skydiving in these novice jumpers. However, the sample consisted of males only and the study did not examine the sensation seeking trait of individuals. Therefore, the purpose of this study is to examine if testosterone reacts to potentially life-threatening situation like skydiving, and if it does, can it be related to sex and sensation seeking trait.

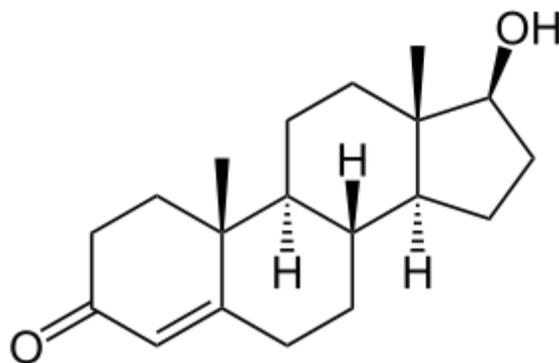


Fig. Testosterone

The chemical structure of testosterone classifies it as being a steroid hormone. It is derived from cholesterol (Waterman, & Keeney, 1992). It is primarily produced by Leydig cells of the testes in male, ovary and placenta in female, and in smaller amounts by the adrenal cortex (Coates & Herbert, 2008; Eisenegger, Haushofer, and Fehr, 2011). Testosterone synthesis is regulated by the HPG (hypothalamic-pituitary-gonadal) axis (Swerdloff, Wang, & Bhasin, 1992). When the amount of testosterone is low, it is sensed by hypothalamus which sends signal to pituitary gland in the form of gonadotropin-releasing hormone (GnRH). Pituitary gland releases Follicle stimulating hormone (FSH) and Luteinizing hormone (LH) in response to being stimulated by hypothalamus which in turn acts on gonads, thus, stimulating gonads to produce testosterone. The testosterone then acts as a control for its synthesis by acting on hypothalamus and pituitary to limit the synthesis of their respective hormone.

The steroid hormone binds to a receptor in cytosol or nucleus as they can pass through the cell membrane and bring about changes in cell or trigger various other chemical pathways. The testosterone acts on brain through several genomic and non-genomic pathways (Bos, Panksepp, Bluthe, & Honk, 2011). Furthermore, it is only the free testosterone, testosterone not bound to sex hormone binding globulin, which can

elicit biological changes because they can travel through the blood and pass through the cell membrane. However, the main mechanism by which the hormone acts on humans and vertebrates can be classified into three mechanisms: activation of androgen receptor directly by free testosterone, indirectly through conversion to a biologically active metabolite such as DHT (5 α -dihydrotestosterone), or by conversion to estradiol which acts on estrogen receptors (Hiipakka and Liao, 1998; McPhaul and Young, 2001). Free testosterone is the important chemical which binds to androgen receptor. After binding to the androgen receptor, it can activate or deactivate certain genes (Breiner, Romalo, & Schweikert, 1986). Conversely, free testosterone can be reduced to DHT by an enzyme, 5-alpha reductase which also binds to androgen receptor, which is even more potent than testosterone and can have even more pronounced effects on gene expression (Breiner, Romalo, & Schweikert, 1986). These mechanisms help to activate the relatively slow genetic effects of testosterone; however, studies have shown that testosterone can have non-genomic effects that can have very quick effects (Heinlein & Chang, 2002; Michels & Hoppe 2008). Testosterone being converted to estrogen by aromatase, can exert genomic and fast non-genomic effects (Balthazart, & Ball, 2006).

The amount of total testosterone produced by female is 10-20 times less than males (Sullivan, 2000), but within saliva which measures free testosterone, the sex difference may be less extreme as males and females have different levels of sex hormone binding globulin (Granger et al, 2004). Here, even though the amount of testosterone produced is 10-20 times more in males than females, the metabolic consumption in males is also much higher than females so that the actual difference in

levels are much less. Furthermore, testosterone exhibits a distinct developmental and activational effect on the CNS which gives rise to the obvious sexual differences between males and females (Bos, Panksepp, Bluthe, & Honk, 2011). It is also responsible for the development of secondary sexual attributes; for example, increased muscle, bone mass and body hair in men (Eisenegger, Haushofer, and Fehr, 2011). Human beings, most prominently males, experience a testosterone surge twice in their life, first in the prenatal period about 6 weeks after conception and second time during puberty which drives the development of sexual characteristics (Sullivan, 2000; Swaab and Garcia-Falgueras, 2009). Biologically speaking, testosterone is involved not only with improved muscle mass and physical strength, but also accelerated rate of recovery in physical terms and boost of energy (Sullivan, 2000). Without testosterone everyone would be growing up in their default state of being a female. Apart from its obvious biological association, testosterone is also related to several social-emotional behaviors. These behavioral effects of testosterone are of particular importance because they seem to influence the brain in archetypical situations such as mating, and social status seeking behaviors (Eisenegger, Haushofer, and Fehr, 2011; John, 2010). Besides those, studies have also suggested that testosterone is related with sensation-seeking behaviors which is associated with taking risks. However, these behavioral effects of testosterone are not fully understood and they will be explored further in the following sections.

There are classical views of testosterone and a relatively modern view of how testosterone affects behavior of individuals. The more classical view of testosterone dictates that people are predisposed to having a high or low testosterone level which in

turn dictates their behaviors. However, the relatively modern view of testosterone factors not only the nature of the person but also the environment. It examines how the environment affects testosterone and what environment results in testosterone's reactivity. Each view has its own pros and cons and each helps to explain certain conditions effectively than other. Below, I review evidence that testosterone is linked with social-emotional behavior, focusing on the main types of behaviors for which testosterone is implicated. Wherever possible, I indicate when a study examines testosterone responses to social-context according to the more modern view of testosterone in which the hormone changes in response to salient social-information and these testosterone changes help facilitate an appropriate behavioral response to that context.

Testosterone and Social-emotional Behavior

Testosterone can be related to a multitude of social and emotional, as well as economic, behaviors. Recent advances in technology have revealed that behaviors that were previously thought to be mediated by brain only without any influence of hormones seem to be untrue (Bos, Panksepp, Bluthé, & Honk, 2011). The behaviors that are mediated by the endocrine system, or more specifically testosterone, can be classified into mainly two groups.

Sexual Behavior. First of all, testosterone is related with sexual behavior in non-human as well as humans although it seems more strongly correlated in animals than humans. Studies have shown that testosterone is correlated with displaying sexual behavior in fish (Brian, Scott, & Li, 2008), rodents (Gleason, Fuxjager, Oyegbile, & Marler, 2008), as well as humans to some extent (Rubinow, and Schmidt, 1996; Tuiten

et al, 2000). Study has found strong relationship of testes size to the levels of circulating testosterone, which in turn predicted the mate-seeking behavior in sheep and birds (Preston et al, 2012; Garamszegi, Eens, Hurtrez-Boussès, & Møller, 2005). Not only that, testosterone shows reactivity to sexual stimuli and not only display of sexual behavior. Studies usually show a testosterone increase in many vertebrate species after exposure to females behind transparent barriers (Amstislavskaya and Popova, 2004; Batty, 1978; Bonilla-Jaime et al., 2006; Popova and Amstislavskaya, 2002; Purvis and Haynes, 1974) or female chemosensory stimuli such as urine or vaginal secretion and the response were seen within 20 minutes of exposure (James et al., 2006; Macrides et al., 1974; Pfeiffer and Johnston, 1994; Richardson et al., 2004).

In human, there is no direct evidence that higher testosterone levels will lead to displaying more sexual behavior however several correlations have been made. A study done by Booth and Dabbs (1993) have shown that higher testosterone is more positively related to extramarital affairs; however, the results must be viewed with caution because the sample only consisted of people who served during the Vietnam war and is not representative of the general population. Another study found that men who were higher in testosterone were positively correlated with “most invasive sexual crimes” and “sexual offense recidivism” (Studer, Aylwin, & Reddon, 2005). Another study done by Giotakos, Markianos, Vaidakis, & Christodoulou (2003) found that rapists had higher testosterone levels in comparison to normal males. These fit in line with the classical view of testosterone which argues that testosterone levels will predict the sexual behavior displayed by the individual. On the other hand, other studies conducted on whether testosterone reacts to sexual stimuli in human beings have yielded mixed

results. Few studies have reported increase in salivary or serum testosterone after exposure to sexually explicit movies (Hellhammer, Hubert, & Schürmeyer, 1985; Redouté et al, 2000; Stoléru, Ennaji, Cournot, & Spira, 1993) whereas other researchers have found no such effect after exposure to such stimuli (Carani et al, 1990; Krüger et al, 1998). The results are not particularly convincing because most of the research has been done in laboratory setting with small sample sizes, which could also serve to explain the mixed result that was obtained here. Escasa, Casey, and Gray (2011) examined testosterone responses to sexual stimuli in a naturalistic study at a U.S. sex club using non-invasive salivary testosterone and found that men's testosterone levels were significantly higher after exposure to sexual stimuli. Furthermore, they also found that the men who engaged in sexual activity had significantly greater increase in testosterone than men who only watched. In another study, researchers tried to examine men's hormonal response to non-affectionate interaction with women and found significant increase in levels of testosterone from baseline levels (Roney, Mahler, & Maestriperi, 2003). Furthermore, they showed that the change in testosterone was highly correlated with degree that female confederates thought males were trying to impress them and males rating as female confederates being potential romantic partners (Roney, Mahler, & Maestriperi, 2003). Here, the results indicate that testosterone may react not only in response to exposure to sexual stimuli in naturalistic but also to the probability of finding a potential mate as well.

Dominance and Social Status. Testosterone has also been correlated with status seeking behavior which can manifest behaviorally as dominant or aggressive or both dominant and aggressive behaviors. Animal research in rats, hamsters, and monkeys

has unequivocally shown that testosterone elevation correlates with increased aggressiveness (Hermans, Ramsey, & van Honk, 2008). Furthermore, many studies have shown that both naturally occurring and experimentally elevated levels of testosterone are positively correlated with social rank and dominant behavior and not only aggression in a variety of species, including primates (Anestis, 2006), baboons (Beehner et al, 2006; Sapolsky, 1991), lemurs (Cavigelli & Pereira, 2000), squirrel monkeys (Coe, Mendoza, & Levine, 1979), and sifakas (Kraus, Heistermann, & Keppeler, 1999; Muller & Wrangham, 2004).

Traditionally, testosterone has been closely related with aggression because of the animal research; however, caution must be taken before making any causal relationship between aggression and testosterone. Modern view has argued that the inter-individual differences in testosterone do not predict the subsequent differences in aggressive behavior among individuals which means that the basal levels of testosterone alone cannot be used as a predictor for aggressive behavior (Sapolsky, 2008). Sapolsky (2008) argues that rather than low and high testosterone individuals being less or more aggressive respectively, testosterone has a “permissive effect” in which normal levels are required for normal levels of aggression however changes in normal range do not change the individual’s aggression levels.

Modern view on testosterone also argues that more than being predictive of aggression, testosterone seems to influence the motive to gain social status (Eisenegger, Haushofer, and Fehr, 2011). The urge to gain social status could be displayed as aggressive behavior or only dominant behaviors. For example, rhesus monkeys use stares and threats without physically inflicting harm, rather than exerting

aggressive behavior to maintain high social status (Higley, et al., 1996) Furthermore, this relationship between testosterone and dominance has been more strongly associated when there was instability in the social hierarchy (Mehta, Jones, & Josephs, 2008). The study in hyena has revealed that although the females are higher in testosterone, there is significant delay in the time for them to begin socially dominating males, which can be attributed to the fact that there was pre-established social system in wild that made the females more dominant early on (Sapolsky, 2008). Sapolsky (2008) argues testosterone alone does not predict the aggression or dominance level but the interaction of testosterone with environment leads to subsequent dominant and aggressive behavior.

The relationship between testosterone, aggression, and dominance is even more complicated in human beings than animals where the behaviors that could be highly predisposed by hormones in animals can be cognitively mediated by the brain in humans (Bos, Panksepp, Bluthe, & Honk, 2011). It is also essential to distinguish aggressive behavior and dominance behavior because dominance does not necessarily include aggression and vice versa. According to Mazur and Booth (1998) an individual is acting aggressively towards member of his species if his apparent motive is to injure or harm his opponent; whereas, the individual is said to act dominantly if his apparent motive is to gain or sustain high status over somebody else. Here, status reflects power, influence, or privilege (Mazur, & Booth, 1998). Aggression can be further sub-divided into different kinds of aggression like, dominance aggression, proactive aggression, reactive aggression, and territorial aggression (Eisenegger, Haushofer, and Fehr, 2011). It is suggested the role of testosterone is likely to be limited to dominance

aggression, aggression with the aim of achieving dominance over another individual and territorial aggression, aggression between two individuals of same species fighting over resources, and mating rights (Eisenegger, Haushofer, and Fehr, 2011).

In the modern view of testosterone's relation to social status through dominance and aggression, it is suggested that basal testosterone responds to social environment which in turn affects the behavior (Eisenegger, Haushofer, and Fehr, 2011; Sapolsky, 2008). Furthermore, there have been new ideas which state that testosterone may not affect all forms of aggression but the intention to behave aggressively (Bos, Panksepp, Bluthe, & Honk, 2011). Bos, Panksepp, Bluthe, & Honk (2011) argued that "challenge hypothesis" which hypothesizes that testosterone is involved in perception of social challenge which can lead to aggression rather than aggression itself could explain the relation of testosterone and social status seeking behavior. Social challenge could lead to aggression but aggression may not always be adaptive to maintain dominance and social status (Bos, Panksepp, Bluthe, & Honk, 2011). This hypothesis is especially useful in analyzing the human aggression which could often be purely psychological or even economic rather than violent (Eisenegger, Haushofer, and Fehr, 2011). The idea of testosterone related to dominance without aggression is bolstered by some studies that have shown that testosterone's relation to aggression may be due to folk view of testosterone which holds that testosterone increases antisocial, egoistic or even aggressive behavior in humans (Eisenegger, Haushofer, and Fehr, 2011).

In context of face to face interactions, testosterone facilitates emotional mechanisms that tend to increase the ability of individual to achieve or maintain high social status (Eisenegger, Haushofer, and Fehr, 2011). Angry facial expressions, which

could be a threat to the dominance of individual, seems to elicit more vigilant response from individuals higher in basal testosterone and self-reported dominance (Van Honk, & Schutter, 2007). Such response is more evidently seen when administration of testosterone increases response to angry but not happy facial expressions, suggesting that dominant people view angry face as a challenge (Eisenegger, Haushofer, and Fehr, 2011). These results suggest that people higher in testosterone are more likely to be on a lookout for challenge to their social status. Angry facial expressions among people could be interpreted as a sign of discontent for the social hierarchy or a challenge to the present social status. It could be highly advantageous for people who aim to stay higher in social status be on the lookout for angry faces and deal with it by early by exerting dominant or aggressive behavior if necessary.

Human beings are also social creatures who are considerate in most cases to fellow human beings. However, in competition for status this awareness could be a nuisance, and it is seen that testosterone helps to impair the ability to infer emotions, intentions, and feelings from the others, but this is only seen when these emotions are inferred from the eye region (Eisenegger, Haushofer, and Fehr, 2011). Another study also found that testosterone also seems to reduce sensitivity to signals that is essential in empathetic behaviors and choices (Carney, and Mason, 2010). Thus, interfering with the empathy pathway by testosterone could help the person to be more objective and focus on the goal of achieving the high social status or maintaining it.

In the competition for status, trusting your opponents could lead the individual to lose the race for dominance. It is seen that testosterone helps to reduce the chances of being exploited by decreasing people's trust in others (Eisenegger, Haushofer, and

Fehr, 2011). However, this effect is only seen in people that were highly trusting of other people (Eisenegger, Haushofer, and Fehr, 2011). It seems that testosterone facilitates to reduce the trusting behavior of people to certain extent above which it did not have any effect. It means that people who were already not highly trusting of other people did not show any increase in behavior associated with decreased trust. When people vie for social status, there can be instances where one may have to work with one's opponent in order to overcome an obstacle which cannot be tackled by a single person himself. However, trusting the competitor too much may ultimately cause the fall of the person if he gets betrayed by the opponent; thus, being high in testosterone seems to ensure that the person is not entirely trusting of every action of the other people so there is less likely of a chance of complete loss at the competition.

Testosterone reactivity to competition and stress

Apart from being reactive to sexual stimuli testosterone also reacts to social interactions outside a direct reproductive context. It is shown that testosterone rises in anticipation to physical and non-physical competitive situations in chimpanzees and in humans (Eisenegger, Haushofer, and Fehr, 2011). It is suggested that the rise in testosterone before the competition may make individual more willing to take risks and improve co-ordination, cognitive performance and concentration (Mazur, & Booth, 1998). However, not only does testosterone increase in response to competition but the changes in social status can also cause changes in testosterone level. There is relatively high testosterone in winners than losers for an amount of time after the match, which could be related to the jubilant mood of the winner (Mazur, & Booth, 1998). In humans, testosterone rises were seen after winning tennis matches or chess

competitions (Wirth, & Schultheiss, 2007). However, it was also seen that the elevation in testosterone was lower if the individual had won by luck, or if the win is not regarded as important (Mazur, & Lamb, 1980). This phenomenon also fits with the challenge hypothesis because if the person does not feel like it is a challenge to his status than his testosterone would not rise. Moreover, after winning a competition the rise in testosterone could give the person the boost to take on bigger challenges; whereas the decrease in testosterone after defeat could be indicative of not being ready for bigger challenges so that the individual avoids it (Mazur, & Booth, 1998).

Individuals competing for status try to stress the other individual using facial and verbal cues, such that the lower status member show more stress symptoms than higher status members (Eisenegger, Haushofer, and Fehr, 2011). This finding fits with the modern view of testosterone in which rises in this hormone help an individual to obtain social status and facilitates behaviors (e.g., facial and verbal cues) that will increase the chance that they will gain greater status. In another study, exogenous administration of testosterone showed a reduction in unconscious fear (Van Honk, Peper, & Schutter, 2005), suggesting that testosterone diminishes the individual's ability to detect signals in their environment that would diminish the tendency to seek social status. The converse is also true, however, where losing status can decrease testosterone. For example, chronic stress can cause a drop in testosterone levels (Mehta, Jones, & Josephs, 2008). In a competition for status, being stressed by the opponent's actions might be detrimental so having stress resilience could be an advantage in such situations for dominant individuals. In animals, testosterone seems to downregulate the hypothalamic-pituitary-adrenal stress response (Viau, 2002). In

humans the relationship between testosterone and stress is not clearly known but it is seen that testosterone reduces the sympathetically mediated stress response to aversive stimuli (Hermans et al, 2007).

Testosterone and Skydiving

In the present study, I examined whether testosterone is reactive to skydiving. There are several competing hypotheses for this biobehavioral effect. First, the association might be null: testosterone might not react to skydiving because skydiving is usually not a situation where people could be competing for social status and dominance. So far, only one previous study has looked at testosterone reactivity to skydiving using both plasma and saliva. Chatterton, Vogelsong, Lu, & Hudgens (1997) found that the testosterone level between the skydivers and control participants who did not jump out of an airplane were not significantly different from each other.

Second, the association might be that testosterone declines during skydiving. Within the Chatterton study (1997), the salivary testosterone was significantly lower in skydivers than control subjects on the day of the jump. Furthermore, in terms of testosterone reactivity itself, the study found that there was a transient decrease in salivary testosterone while boarding (Chatterton, Vogelsong, Lu, & Hudgens, 1997). The decline in salivary testosterone could have been due to stress or anticipation of engaging in a life-threatening activity. However, the study showed that testosterone levels decreased when the cortisol levels were low suggesting that stress may not have caused the decline of testosterone (Chatterton, Vogelsong, Lu, & Hudgens, 1997). Interestingly, the level of follicle stimulating hormone was still higher during the decline of testosterone indicating that the testosterone production was suppressed directly from

testis rather than brain.

Third, the change in testosterone in response to skydiving may be a rise in testosterone reactivity. Although not significant, Chatterton and colleagues (1997) found a small rise in testosterone after jumping which restored testosterone to near-basal levels, although afterwards testosterone levels dropped further across the course of the day. Here, testosterone could have increased after landing because of their elated mood or because the challenge of skydiving was successfully met and the participant “won” or successfully skydived, often for the first time. This elation in mood has been observed in medical students who graduate from school (Mazur, & Booth, 1998). Observing a testosterone rise in face of highly stressful activity like skydiving could be indicating that testosterone is serving as a buffer to reduce fear and stress in individuals, consistent with the role of testosterone in reducing attention to fear and stress.

Regardless of whether we observe null, drop or rise in testosterone in response to skydiving, it will still be interesting to learn whether these testosterone changes are moderated by individual difference factors. Skydiving represents a potentially life threatening behavior and entails a certain amount of risky behavior or sensation-seeking behavior in order to accomplish the act. If testosterone drops in response to skydiving because the event is stressful, then sensation-seeking may moderate this as sensation seekers are less responsive to stress than non-sensation seekers (Rosenblitt, Soler, Johnson, & Quadagno, 2001). If testosterone rises in response to skydiving because the event is considered a win or mood-elating social context (McCaul, Gladue, & Joppa, 1992; Suay et al, 1999), then sensation seekers may show greater

testosterone rise as they seek out such intense activities. The next step of the study was to examine whether individual differences in sensation-seeking trait moderated effects of testosterone reactivity during the risky activity of skydiving.

Testosterone reactivity and sex of individual

As it is already known the males make 10-20 times more testosterone (free and bound) than females; however, at any given moment the difference in testosterone level between adult male and female will not be that high (Sullivan, 2000). In blood plasma, the males only have around 7-8 times more testosterone than females because testosterone is consumed in much greater amount in males than females. Furthermore, the amount of free testosterone level in male and female is not very different because there is greater number of free testosterone which is bound to sex binding hormone globulin in males than in females (Granger et al, 2004). This free testosterone can be measured in saliva. I was interested to see if the testosterone showed difference in reactivity with respect to sex because males have a greater reservoir of testosterone than females at a given moment.

Here, even though I use the term “sex” to define male and female in the study, it is essential to understand that sex and gender are sometimes hard to distinguish. Gender, as defined by the Institute of Medicine is “person’s self-representation as male or female, or how that person is responded to by social institutions on the basis of the individual’s gender presentation”, whereas, sex is defined as “the classification of living things, generally as male or female according to their reproductive organs and functions assigned by the chromosomal complement” (King, 2010). Geary (2010) argued that gender and sex should not be distinguished based on biological or social factors

because they interact with each other. However, I have decided to distinguish between sex and gender and the term “sex” has been used in my study because we are primarily studying the hormone response of individuals. Hormones, by default, are produced mainly from the gonads of individuals which is part of their reproductive organ and falls under the biological description of male and female. Furthermore, the sensation-seeking trait is something directly not related to gender roles and perception. However, it is to be noted that no visual observation was made to confirm the sex of individuals and the participants self-identified themselves as being male or female.

Testosterone reactivity and sensation-seeking trait

Sensation-seeking is a trait which is defined as a human trait that encompasses the need for “varied, novel, and complex sensations and experience and the willingness to take physical and social risks for the sake of such experience (Zuckerman, 1990). The sensation-seeking scale is used to measure the trait of sensation-seeking in an individual. The original sensation-seeking scale (SSS) contained only a general scale expressing desire to participate in exciting, risky or novel stimuli (Zuckerman, Kolin, Price, & Zoob, 1964). Subsequent scales contain a variety of subscales, and we used sensation-seeking scale VI for our analysis. Furthermore, among the different subscales of SSS VI, the one of particular importance in our study was intention to engage (ITAS VI) and experience-seeking with regard to disinhibition and boredom susceptibility (EDIS VI). Here, the ITAS VI measures intention to engage in activities that provide excitement, risk and novelty; whereas, the EDIS VI measures the “desire to seek new experience through the mind and senses and through an unconventional life-style and travel” in regards with the individuals’ susceptibility to boredom and individuals’

engagement with other people in seeking for sensations through wild party, drinking and sex.

Sensation-seeking is a personality trait which does not seem directly related to testosterone; however, there are several facets of this trait that could be related to dominance and, thus, testosterone. Speaking in terms of evolution, the presence of sensation-seeking trait in our ancestors made them more likely to travel and explore new places which helped in settlement of people in new areas (Malcolm, 1988). In a study of green iguana, researchers found that larger and more dominant males spend more time in the open exposed to predators but this makes them more successful in mating (Malcolm, 1988). In regards to the numerous animal research that show that testosterone is correlated with being aggressive and dominant, it is highly likely that these same iguanas have higher testosterone level in compared to the other iguana who do not prefer to be out in the open for long. Here, several previous studies have suggested that testosterone levels were positively correlated with some of the subscales of sensation-seeking scale in human beings (Campbell, 2010; Fink, Hamdaoui, Wenig, & Neave, 2010). However, this evidence of correlation is not consistent and some study has not found any positive correlation between testosterone and sensation-seeking (Rosenblitt, Soler, Johnson, & Quadagno, 2001). In our study, we were curious to examine whether there was correlation between the sensation-seeking trait and testosterone level and reactivity.

Methods

Samples

Forty-four participants (aged 18-49; $M=24$, $SD=4.6$), were recruited from Goldcoast Skydivers Company. The sample consisted of 73% male ($N= 32$) with a mean age of 32.12 ± 8.50 years. The remaining 27% were females ($N=12$) with a mean age of 27.08 ± 5.76 years. Eighty-eight percent of the sample was Caucasian ($N=39$). Individuals were only considered if they expressed a pre-existing desire to skydive, were between 18 and 49 years of age, and had no obvious or reported health complications. Individuals unwilling to complete the training provided by skydiving company were excluded from participation. This research protocol was approved by the Institutional Review Board at the University of New Orleans.

Procedures

Potential participants were presented the recruitment flyer and, if recruited, provided informed consent. The participants then completed ten minutes of instruction provided by the skydiving company and dressed in the proper attire. Participants boarded the plane, ascended to 14,000ft and jumped (Mean time= $2:12pm$); the free-fall period was, on average, 90 seconds and the parachute gliding was, on average, 4.5 minutes. Participants were introduced to the SSS questionnaires by a researcher; the questionnaires were sent home with participants, completed, and returned. Saliva samples were collected from the individuals during basal day and jumping day.

Measures

Each participant gave 10 saliva samples; 5 on jumping day and 5 on basal day at

the same times of day as the jump day. The testosterone level in the saliva was measured using a well-validated enzyme immuno-assay (www.salimetrics.com). Testosterone levels (pg/mL) were log transformed because the testosterone distribution was positively skewed. For the graphs, we then converted testosterone to nmol/L (logged) for greater comparability to the prior literature.

Traditional statistical analysis assumes that the observations are independent of each other. However, when people are clustered in a naturally occurring setting like class or gender, the response of people from same group could likely interact with each other and exhibit some degree of relation to each other. Hierarchical linear modeling (HLM) helps to control and model this violation of independence assumption. Hierarchical linear modeling is also advantageous because it helps examine the groups in such a way so as to explain both between and within-group variability of an outcome of variable of interest (Hancock, & Mueller, 2010). In my study, HLM analyses were used to capture the individual differences in testosterone levels (with log transformed testosterone as the dependent variable). Detailed description of the within and between subject variables used in the study are described at the appendix of the paper. To capture reactivity to skydiving, using time before the jump as a within-individual predictor of testosterone level; time after the jump captured recovery in testosterone after skydiving; this allowed the intercept to capture testosterone levels at the jump. Because participants also collected a basal sample, we included a dummy variable for basal day where samples were coded as 1 if collected on the basal day. Finally, to account for the possibility that testosterone reactivity and recovery would be different on the jump versus basal day, we included two interaction terms between basal day and

time to jump and time since jump, respectively.

Within HLM, once this base model is validated, each within-individual predictor can become an outcome of interest using a slopes-as-outcomes approach. This will then help us examine the between-individual differences. I examined whether sex was a predictor of each testosterone component, simultaneously considering within individual testosterone levels and between individual differences. This approach was also used to examine whether sensation-seeking subscales, ITAS-VI and EDIS-VI, predicted testosterone level and response to skydiving.

The Sensation-seeking Scale version six (SSS-VI) includes four subscales and a total score that is assumed to be reflective of SENSATION-SEEKING traits. Reliability estimates for the SSS-VI range from .83-.86. In this study, cronbach's alpha estimates revealed reliability of .73. Both males ($t=3.01$, $p<.0001$) and females ($t=5.69$, $p<.0001$) in this study were higher than reported means of a normal sample on the total SSS-VI scores.

Results

1. Testosterone Reactivity in response to skydiving

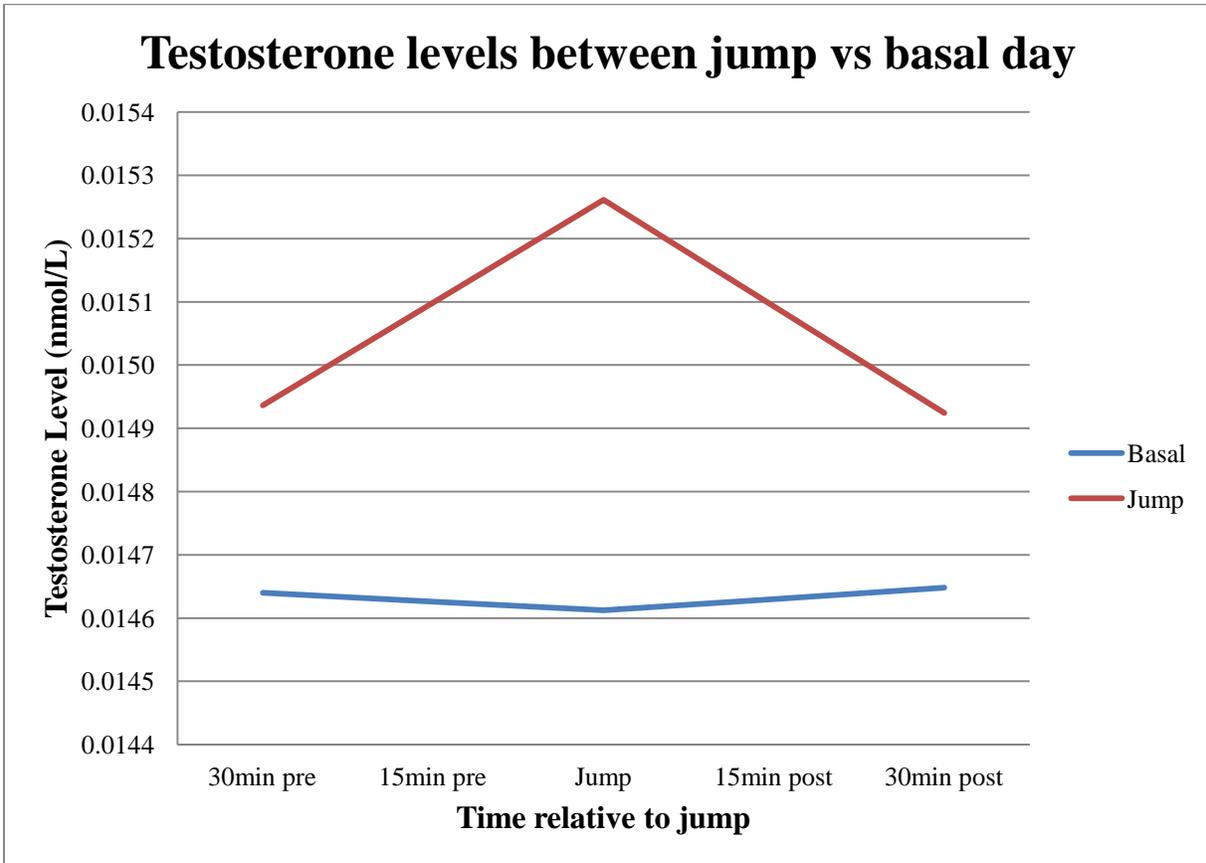


Fig. 1. Testosterone change between basal day and jump day

As seen from the graph, without taking sex of the participant into account, testosterone changed dynamically in response to skydiving. To capture these changes, I examined the within individual predictors of testosterone level which includes predictors that change over time (within the 10 samples of testosterone collected on each individual). First, based on time-before-jump as a predictor, testosterone rose significantly leading up to skydiving, $\beta = 0.17$, $t(286) = 4.77$, $p < 0.001$. At the time of the jump, testosterone levels were elevated, $\beta = 4.55$, $t(42) = 45.99$, $p < 0.001$. After the

jump, testosterone declined significantly, $\beta = -0.18$, $t(286) = 3.31$, $p < 0.001$. The variables used are explained in Appendix B.

At the same times of day as the skydiving day, participants collected 5 “basal” samples. We included a dummy variable to represent basal day, $\beta = 0.127$, $t(286) = 1.21$, $p = 0.23$, but did not find a significant difference between testosterone levels on basal versus jump day. However, this must be qualified by an interaction between basal-day and time-before-jump, $\beta = -0.15$, $t(286) = 2.52$, $p = 0.012$, which indicated that the change in testosterone leading up to the same time of jump was much smaller than it had been on the day of skydiving. This indicates that testosterone reactivity was evident on the jump day, but not on the basal day. Taken together, these findings indicate that testosterone rises leading up to skydiving but not on other days.

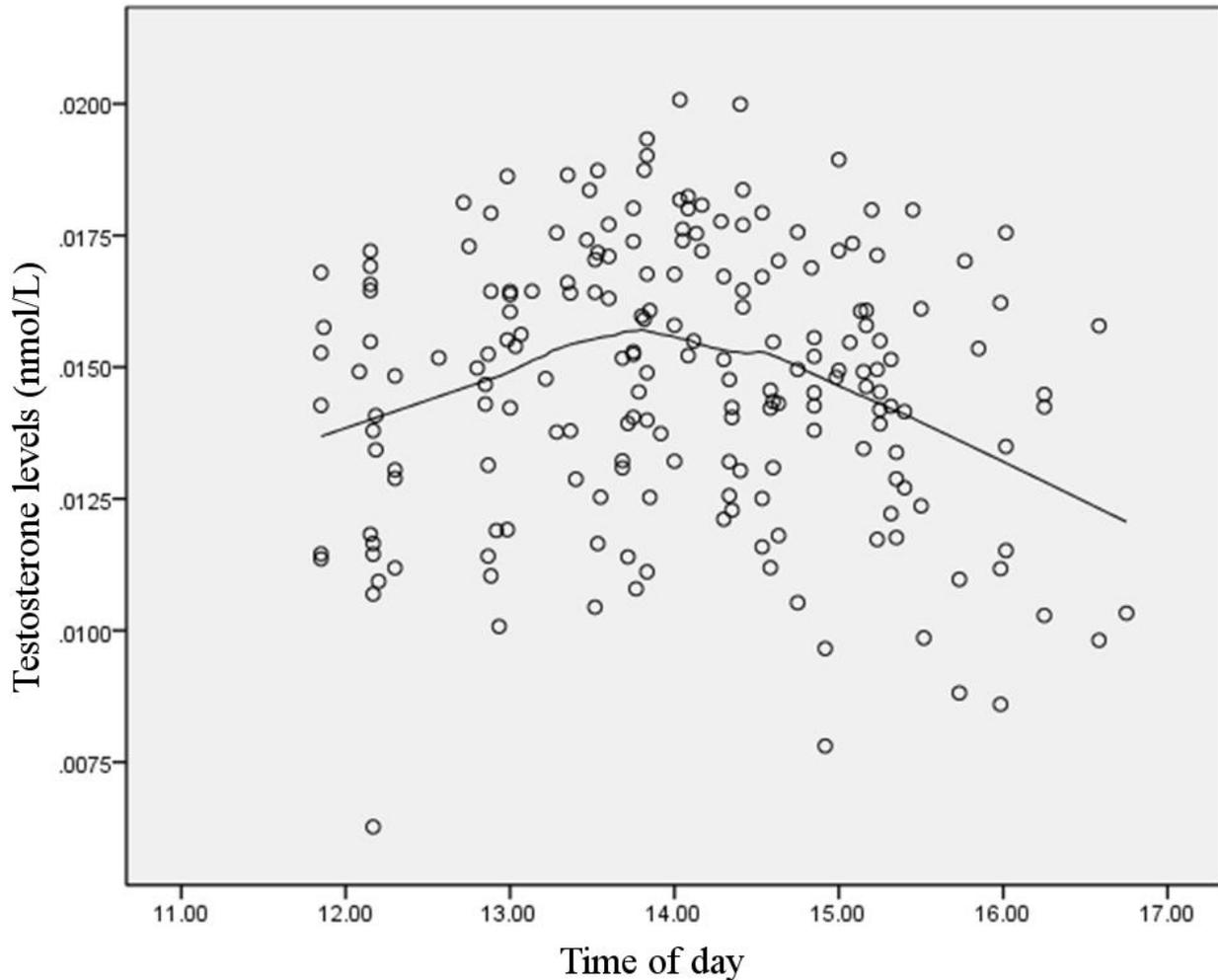


Fig 2. Scatter-plot diagram showing the testosterone levels of individuals during jump day across different time point of day

Figure 2 shows the difference in testosterone level among different individuals during the jump day. In Fig 1, it was seen that the average testosterone level stays relatively constant during the basal day and changes during jump day, but it is not yet known whether this stability in testosterone levels is significant. Within HLM, it is possible to test this statistically using the Intra-Class Correlation: $\text{within-individual variance} / (\text{within-individual} + \text{between-individual variance})$. The intra-class correlation tells how much variance in testosterone is specific to within-individual variance as

opposed to how much testosterone variance is stable across individuals; put another way, it tells how inter-correlated each measure of testosterone within a person is with their other testosterone measures across all ten samples. Finding a significant intra-class correlation is a necessary step to examining whether there are between-individual predictors of testosterone. That is, it is necessary to show that one individual's testosterone differs from another in order to show that a variable like gender or sensation-seeking predicts an individual's testosterone level or reactivity. Importantly, there is significant difference in testosterone levels among individuals. It was seen that testosterone was highly stable within an individual, $\chi^2(42) = 634.55$, $p < .0001$, with 65.2% of the total testosterone variance due to between-individual differences, suggesting that it is reasonable to examine predictors of individual differences in testosterone such as sex or sensation-seeking.

2. Sex differences in testosterone reactivity

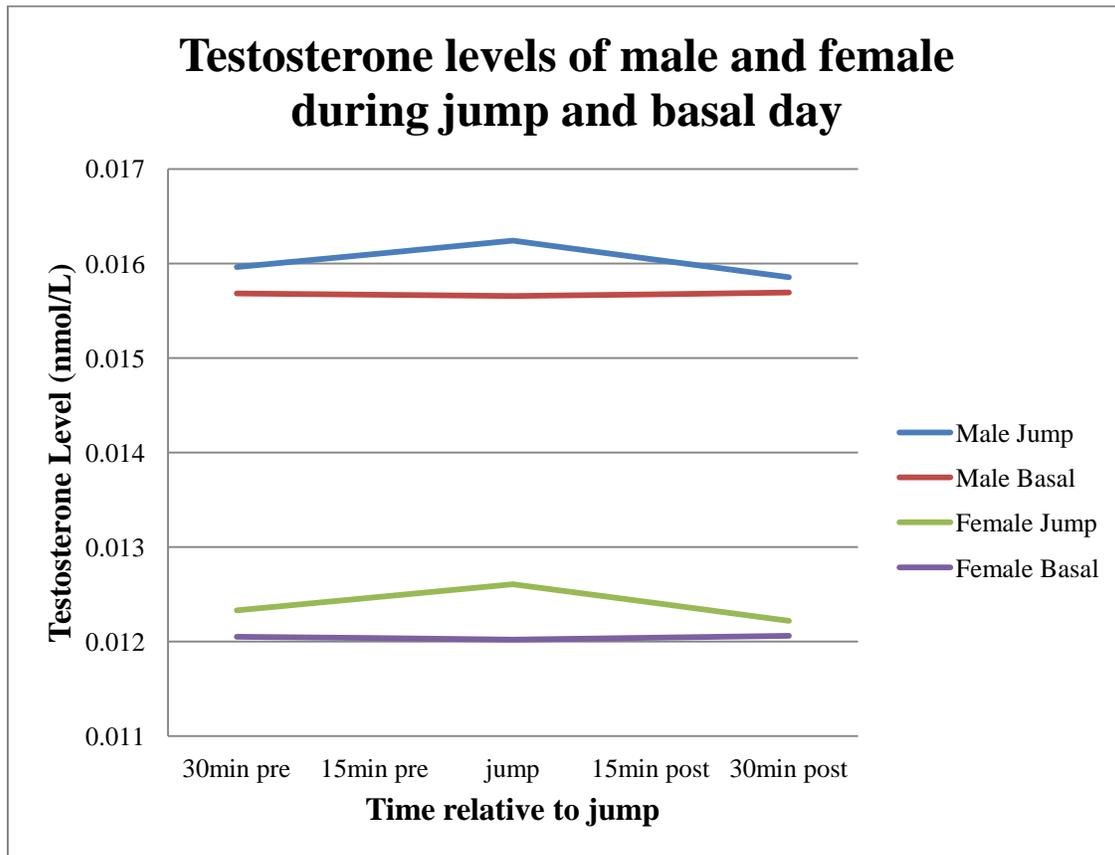


Fig. 3 Sex Differences in testosterone reactivity

Figure 3 shows the average testosterone level at different time points between jump and basal day when sorted by sex. As expected we see that the testosterone level for males is higher than females, $\beta = -1.05$, $p < 0.001$. The additional level two testosterone outcomes (i.e., reactivity, recovery, basal-day effects) were not significant (data not shown, all p -values > 0.25). This means that testosterone overall was higher in males than females, but the pattern of response to skydiving appeared similar between males than females. The variables used for this are explained in Appendix B as well.

3. Testosterone reactivity to sensation-seeking trait in response to skydiving

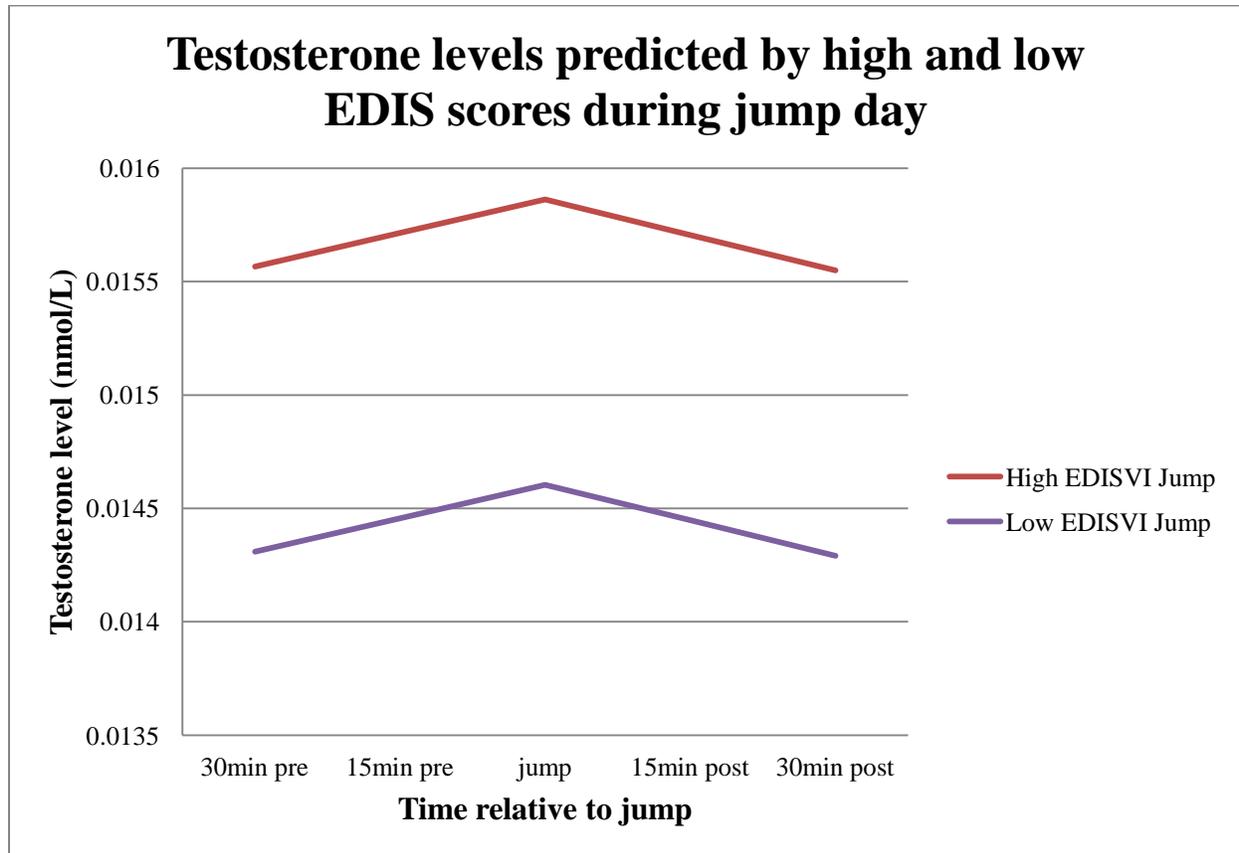


Fig 4. EDIS and testosterone levels

Here, the average score of EDIS-VI questionnaires given to participants was 95.57 ± 8.03 . Here, using the mean and standard deviation, two predictor variables were created by adding and subtracting one standard deviation from the mean. It created two predictor variables where low EDIS-VI score was 87.54 and high EDIS-VI score was 103.6. Here, the graphs were created ignoring sex of participant. Testosterone levels at the time of the jump were significantly higher in individuals with greater experience with certain sensation-seeking traits, $\beta = 0.02$, $p = 0.005$, such that during the jump the testosterone level was higher in people who scored higher in the seeking experience

with respect to disinhibition and boredom susceptibility. The variables used here are explained in Appendix C.

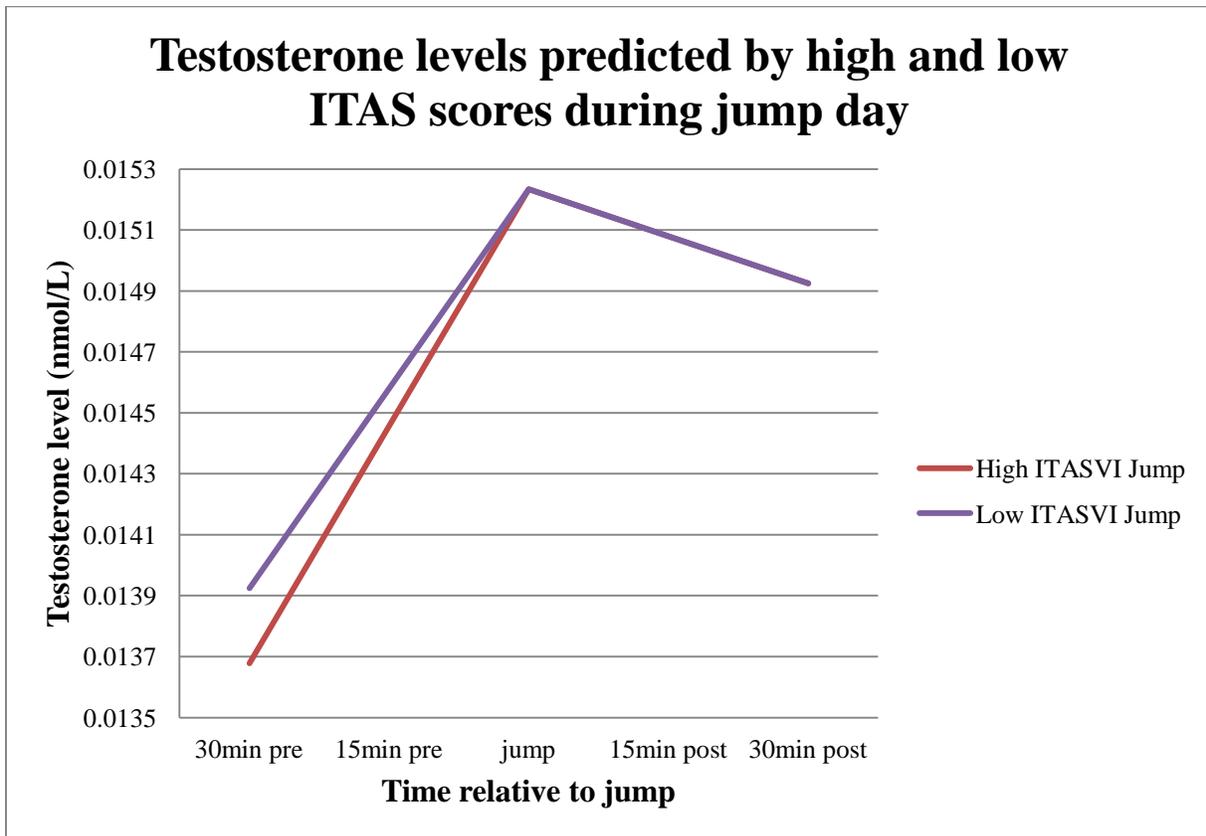


Fig 5. ITAS and testosterone levels

Here, the average score of ITAS-VI questionnaires given to participants was 50.68 ± 5.56 . Here, just like in EDIS-VI using the mean and standard deviation, two predictor variables were created by adding and subtracting one standard deviation from the mean. It created two predictor variables where low ITAS-VI score was 45.12 and high ITAS-VI score was 56.24. Here, the graphs were created ignoring sex of participant. Furthermore, figure 5 shows that there was also an effect of intention to engage in sensation-seeking traits on testosterone reactivity, $\beta = 0.01$, $p = 0.002$.

People who score higher in intension for sensation-seeking activity showed higher rise in testosterone level before they jumped out of an airplane. The variables used here are explained in Appendix D.

Discussion

First of all, testosterone can be measured in blood plasma and saliva. The blood plasma levels can be used to examine the total testosterone level in males and females however; this includes both the bound and free testosterone. The biologically active testosterone is the free form of testosterone which can pass through the nucleus and activate or turn off the intended genes. The male testosterone level in blood is only about 7 to 8 times greater than the female total testosterone level; here, the levels being measured in adult human (Torjesen, & Sandnes, 2004). Only the free testosterone passes onto saliva because most of it is bound by sex hormone binding globulin. The binding globulin is present in different amounts in males and females such that the total amount that passes onto saliva is actually very similar in males and females (Granger et al, 2004). This makes saliva a valid and non-invasive way to measure the biologically active or free testosterone in people.

The study found that testosterone reacts to skydiving, acutely elevating leading up to the jump and then falling after the individual skydives. This is in contrast to Chatterton and colleagues (1997) who found that testosterone dropped prior to skydiving. Furthermore, the present study did not find an overall difference in testosterone levels on the basal day versus skydiving day, although there was an

interaction between the basal day and time before jump such that the rise in testosterone was bigger on the skydiving day than the basal day. This is similar to Chatterton and colleagues (1997) who also found no overall difference in testosterone levels between basal and skydiving day. However, our results differ from Chatterton in that we found a rise in testosterone during skydiving especially when compared to the basal day whereas they found the largest differences were due to a drop in testosterone leading up to skydiving. Finally, we found that testosterone levels dropped significantly after the jump whereas, Chatterton and colleagues (1997) found somewhat of a rise in testosterone levels.

Thus, our findings contrast substantially from the prior investigation on testosterone and skydiving. Here, one possible explanation to the reaction in testosterone level could be the presence of female participants which was not present in previous research. It was also seen in previous research that testosterone increases in males who are interacting with females rather than males who are interacting with males (Roney, Mahler, & Maestriperi, 2003). Males and females testosterone level could have risen to the presence of potential mates such that skydiving itself was seen as a competition for social dominance. Furthermore, after skydiving, the testosterone levels of people dropped back to the original level as would the levels of people after the end of competition. There was a greater number of variance between individuals in the testosterone level at different time points suggesting that some people had greater variability in change of testosterone levels. Thus, this suggests that some people had testosterone higher than initial levels, which could be considered as being an effect of being in a good mood after winning, or here successfully skydiving. Nonetheless, our

findings make sense in terms of the function of testosterone in regards to sexual salience, competitions, dominance and social status according to the modern viewpoint of testosterone enhancing these activities.

Testosterone effects and reactivity have been related to sexual context. So, one may wonder why would it show reactivity to skydiving which is not a sexually salient context by just looking at it. Another study with this dataset found that the autonomic nervous system of individuals skydiving creates a physiological effect that is both arousal and calming emotions, characterized by reactivity of both the sympathetic (which stimulates arousal or excitement) and parasympathetic nervous system activity (which stimulates calming, relaxed emotions) (Allison et al, 2012). This is a relatively unique physiological state similar to that seen during sexual intercourse and orgasm (Kandee, Koussa, & Swerdloff, 2001; Maclean, 2005). Thus, skydiving is not sex, but it may be physiologically similar across several endocrine axes (Krüger, 1998). This interpretation fits with testosterone's role as a risk factor for thrill seeking behaviors, as high-risk sexual activity is one of the main categories in which sensation-seeking behaviors are expressed (Zuckerman, 1994).

One plausible explanation for this rise and fall in testosterone is people perceiving skydiving as a challenge on their social status or as a competition which culminated in the winner effect. According to this viewpoint, testosterone elevates during a competition to enhance one's ability to focus on the task that matters and disregard fear or anxiety. If successful, this surge in testosterone will enhance the chances of winning a subsequent context. This effect is more pronounced when the individual identifies the competition as being important to him (Mazur, & Lamb, 1980),

and much of the winner effect may be due to an elevation in positive mood and well-being. While participants of skydiving did not win a competition, they did successfully jump and may feel a mood of elation and positive affect which would be expected to enhance testosterone after successfully skydiving. Further studies regarding the people's perception of challenge and whether they felt like they had won need to be done in order to confirm this effect.

Furthermore, sex differences were also examined in the present study to examine whether there was any sex biased effects of testosterone reactivity. As expected, the results showed that males had higher testosterone level than females. However, it was also seen that the rise and fall of the testosterone level in male and female were identical suggesting that the rate of testosterone reactivity is same in males and females. This is an important new finding as there were only males in the Chatterton and colleagues (1997) investigation. In animals, studies show testosterone increase even when there was only exposure to female i.e. presence of females (Amstislavskaya and Popova, 2004; Batty, 1978; Bonilla-Jaime et al., 2006; Popova and Amstislavskaya, 2002; Purvis and Haynes, 1974) and even though the same cannot be said about human beings it could be driving the effect seen above. As mentioned above, further studies should investigate the people's perception regarding challenge in social status during the skydiving. Also, in case of studies with both males and females, it should be worthwhile to test whether individuals saw the skydiving opportunity as a chance to find mates. This could explain why such a huge reactivity was seen in our study compared to the previous. If these studies find that testosterone was not reacting to challenge in social status or sexual encounter, then testosterone might have been

related to something which has not been explored yet. This also suggests that if males saw females as being potential mates then the females also saw males as being potential mates in the skydiving event; if the testosterone levels were influenced due to sexual encounter. Due to absence of any scores on attraction of participants to each other, this cannot be verified.

Another plausible but unexplored possibility to the testosterone reaction seen above could be due to the interaction between testosterone and cortisol. Several studies have put forth the dual hormone hypothesis, which states that testosterone and cortisol jointly regulate dominance (Mehta, & Josephs, 2010). Mehta and Josephs (2010) argue that cortisol suppresses the HPG axis which blocks the testosterone action on target tissues and downregulates androgen receptors. In that same study it was found that in leaders, dominance was positively correlated when the level of cortisol was low and level of testosterone was high (Mehta, & Josephs, 2010). Moreover, they also found that following defeat (challenge in social status) people with low cortisol and high testosterone chose to compete again in the competition. In terms of future research, exploring such possibility of interaction of testosterone could help better explain the reactivity of testosterone which was observed in our study.

Another objective of this study was to look at the relation of testosterone in skydiving and sensation-seeking trait which had never been done before. Sensation-seeking trait is a personality trait which does not seem directly related to testosterone. However, evolution has suggested that people who were high in sensation-seeking were more likely to travel and explore new places which helped in settlement in new areas and find potentially new mates (Malcolm, 1988). However, this is an older view of

testosterone and I was more interested in looking at whether testosterone itself reacted to skydiving in terms of sensation-seeking trait.

In my study, I looked at the reactivity of testosterone in individuals and attempted to see if it was correlated with sensation-seeking trait. In our study, we saw that intention to engage in thrill and adventure seeking accentuated testosterone reactivity and boredom susceptibility was associated with higher testosterone levels at the time of the jump. This could be an indication that people who are higher in sensation-seeking trait saw this risky activity as an opportunity to impress the opposite sex or a competition for dominance. During the jump the testosterone level was higher in people who scored higher in the experience seeking sub-scale with respect to disinhibition and boredom susceptibility showing that people who are more likely to seek such experience would have a higher peak during the jump. This could help the person deal with the challenge in terms of the novel activity. On the other hand, people who score higher in intensity for sensation-seeking activity showed steeper rise in testosterone level. This suggests that intention to engage in sensation-seeking behaviors may heighten testosterone in a context-specific moment, enhancing the physiological response to novel, exciting and risky activities. Outside of this salient context, however, this trait may not generally change testosterone levels or functioning of the HPG axis. Also, even though our study did not find any significant interaction of testosterone reactivity to other subscales of sensation-seeking, other studies have found that other subscales of SSS are related to basal testosterone level. There are studies which have shown that the testosterone levels were significantly correlated with the sensation-seeking subscale of Boredom susceptibility subscale such that people who scored

higher in boredom susceptibility also had higher testosterone (Campbell, 2010). There were several limitations in the study. One of the major limitations of the study was the absence of any data on the person's attractiveness ratings of the other participants in skydiving. Another limitation of the study was the absence of any kind of dominance measure, even though it has been suggested that testosterone is generally related to dominance. The study was further limited by the fact that cortisol measures were not considered for the study. This significantly curtailed our capability to make any inferences on whether cortisol had any role with dominance and social. This also made it impossible to examine whether there was any interaction between testosterone and cortisol.

Conclusion

In summary, testosterone is a steroid hormone which is obviously related to sexual display. It is related with displaying particularly risky behavior at times, which can also help individuals get access to potential mates. However, the effects of testosterone do not stop there and it can affect several behaviors of people which involve displaying social status seeking behavior. Even though traditionally, it is said that testosterone is correlated with aggression, new studies suggest that testosterone may not be directly related to aggression but it may manifest itself in aggressive behavior or only dominant behavior all of which is ultimately related to displaying social status. Furthermore, it is also seen that testosterone can help to maintain or display social status by reducing stress during competitions for social status, and by showing a winner effect where the individual gets a testosterone boost when he succeeds in endeavor. Here, the amount

of boost seems to depend on how much the person wants to succeed in the task. If they really identify themselves with the task and really care about the results of the task then there seems to be a greater boost in testosterone. Here, our study found that skydiving, which is a high risk potentially life threatening activity, also results in testosterone reactivity which could be the result of stress alleviating properties of testosterone and also an effect of interaction between opposite sex. This effect is seen in both sexes. Furthermore, it was also seen that different sub-scales of sensation-seeking trait were correlated with testosterone reactivity. People who were higher for the intention to engage in sensation-seeking activity show greater reactivity in comparison to people who scored lower whereas people who scored higher in experience for sensation-seeking showed higher peak in comparison to people who scored lower for it. Thus, the study shows that testosterone is not only influenced by the environment but how it reacts is also influenced by the individual's own personality.

Reference

- Allison A. L., Peres J. C., Boettger C., Leonbacher U., Hastings P. D., & Shirtcliff E. A. (2012) Fight, flight, or fall: Autonomic nervous system reactivity during skydiving. *Personality and Individual Differences*.53(3):218-223.
- Amstislavskaya, T.G., & Popova, N.K., (2004). Female-induced sexual arousal in male mice and rats: behavioral and testosterone response. *Horm. Behav.* 46, 544–550.
- Anestis, S. F. (2006). Testosterone in juvenile and adolescent male chimpanzees (*Pan troglodytes*): Effects of dominance rank, aggression, and behavioral style. *American Journal of Physical Anthropology*, 130, 536–545.
- Balthazart, J., & Ball, G. F. (2006). Is brain estradiol a hormone or a neurotransmitter?. *Trends In Neurosciences*, 29(5), 241-249.
- Batty, J. (1978). Acute changes in plasma testosterone levels and their relation to measures of sexual behavior in the male house mouse (*Mus musculus*). *Anim. Behav.* 26, 349–357.
- Beehner, J., Bergman, T., Cheney, D., Seyfarth, R., & Whitten, P. (2006). Testosterone predicts future dominance rank and mating activity among male chacma baboons. *Behavioral Ecology and Sociobiology*, 59, 469–479.
- Bonilla-Jaime, H., Vazquez-Palacios, M., Arteaga-Silva, M., & Retana-Marquez, S. (2006). Hormonal responses to different sexually related conditions in male rats. *Horm. Behav.* 49, 376–382.
- Booth, A., & Dabbs, J. M. (1993). Testosterone and men's marriages. *Social Forces*, 72(2), 463-477.

- Bos, P. A., Panksepp, J., Bluthe, R., & Honk, J. V. (2011). Acute effects of steroid hormones and neuropeptides on human social-emotional behavior: A review of single administration studies. *Frontiers in Neuroendocrinology*, 33 (1), 17-35.
- Breiner, M., Romalo, G., & Schweikert, H.U. (1986). Inhibition of androgen receptor binding by natural and synthetic steroids in cultured human genital skin fibroblasts. *Klin. Wochenschr.* **64** (16): 732–7.
- Brian, M. B., Scott A. P., & Li W. (2008) Sex steroids and their receptors in lampreys. *Steroids*, 73, 1–12.
- Campbell, B. C., Dreber, A., Apicella, C. L., Eisenberg, D. A., Gray, P. B., Little, A. C., & ... Lum, J. (2010). Testosterone exposure, dopaminergic reward, and sensation-seeking in young men. *Physiology & Behavior*, 99(4), 451-456.
- Carani, C., Bancroft, J., Del Rio, G., Granata, A., Facchinetti, F., & Marrama, P. (1990). The endocrine effects of visual erotic stimuli in normal men. *Psychoneuroendocrinology*, 15(3), 207-216.
- Carney, D. R., & Mason, M. F. (2010). Decision making and testosterone: When the ends justify the means. *Journal of Experimental Social Psychology*, 46. 668-671.
- Cavigelli, S. A., & Pereira, M. E. (2000). Mating season aggression and fecal testosterone levels in male ring-tailed lemurs (*Lemur catta*). *Ormones and Behavior*, 37, 246–255.
- Chatterton, R. T., Vogelsong, K. M., Lu, Y. C., & Hudgens, G. A. (1997). Hormonal responses to psychological stress in men preparing for skydiving. *Journal of Clinical Endocrinology & Metabolism*, 82(8), 2503-2509.
- Coates, J. M., & Herbert, J. (2008). Endogenous steroids and financial risk taking on a

- london trading floor. *PNAS Proceedings of the National Academy of Sciences of the United States of America*. 105(16). 6167-6172.
- Coe, C. L., Mendoza, S. P., & Levine, S. (1979). Social status constrains the stress response in the squirrel monkey. *Physiology and Behavior*, 23, 633–638.
- Eisenegger, C., Haushofer, J. & Fehr, E. (2011). The role of testosterone in social interaction. *Trends in Cognitive Neuroscience*, 15(6), 263-271.
- Garamszegi, L. Z., Eens, M. M., Hurtrez-Boussès, S. S., & Møller, A. P. (2005). Testosterone, testes size, and mating success in birds: A comparative study. *Hormones*.
- Geary, N. (2010). Counterpoint: physiologists should not distinguish "sex" and "gender". *American Journal Of Physiology. Regulatory, Integrative And Comparative Physiology*, 298(6).
- Gleason, E.D., Fuxjager, M. J., Oyegbile, T.O., Marler, C.A. (2008). Testosterone release and social context: when it occurs and why. *Front. Neuroendocrinol.* 30, 460–469.
- Granger D.A., Shirtcliff E.A., Booth A., Kivlighan K.T., & Schwartz E.B. The "trouble" with salivary testosterone. *Psychoneuroendocrinology*. Nov 2004;29(10):1229-1240.
- Hancock, G. R., & Mueller, R.O. (2010). *The Reviewer's Guide to Quantitative Methods in Social Sciences*. Routledge.
- Heinlein, C. A., & Chang, C. (2002), The roles of androgen receptors and androgenbinding proteins in nongenomic androgen actions. *Mol. Endocrinol*, 16, 2181–2187.

- Hellhammer, D., Hubert, W., & Schürmeyer, T. (1985). Changes in saliva testosterone after psychological stimulation in men. *Psychoneuroendocrinology*, *10*(1), 77-81.
- Hermans, E. J., Putman, P., Baas, J. M., Gecks, N. M., Kenemans, J., & van Honk, J. (2007). Exogenous testosterone attenuates the integrated central stress response in healthy young women. *Psychoneuroendocrinology*, *32*(8-10), 1052-1061.
- Hermans, E. J., Ramsey, N. F., & van Honk, J. (2008). Exogenous Testosterone Enhances Responsiveness to Social Threat in the Neural Circuitry of Social Aggression in Humans. *Biological Psychiatry*, *63*(3), 263-270.
- Higley, J., Mehlman, P. T., Poland, R. E., & Taub, D. M. (1996). CSF testosterone and 5-HIAA correlate with different types of aggressive behaviors. *Biol. Psychiatry* *40*, 1067–1082
- Hiipakka, R.A., & Liao, S (1998). Molecular mechanism of androgen action. *Trends Endocrinol. Metab.* **9** (8): 317–24.
- James, P. J., Nyby, J. G., & Saviolakis, G. A. (2006). Sexually stimulated testosterone release in male mice (*Mus musculus*): Roles of genotype and sexual arousal. *Hormones And Behavior*, *50*(3), 424-431.
- John, M., C. (2010). From molecule to market: steroid hormones and financial risk-taking. *Philosophical Transactions Of The Royal Society B: Biological Sciences*, *365*(1538), 331-343.
- Kandeel F.R., Koussa V. K., & Swerdloff R. S. (2001) Male sexual function and its disorders: physiology, pathophysiology, clinical investigation, and treatment. *Endocr Rev.* *22*(3):342-388.

- King, B. (2010). Point: a call for proper usage of "gender" and "sex" in biomedical publications. *American Journal Of Physiology. Regulatory, Integrative And Comparative Physiology*, 298(6).
- Kraus, C., Heistermann, M., & Kappeler, P. M. (1999). Physiological suppression of sexual function of subordinate males: A subtle form of intrasexual competition among male sifakas (*Propithecus verreauxi*)? *Physiology and Behavior*, 66, 855–861.
- Krüger, T., Exton, M., Pawlak, C., von zur Mühlen, A., Hartmann, U., & Schedlowski, M. (1998). Neuroendocrine and cardiovascular response to sexual arousal and orgasm in men. *Psychoneuroendocrinology*, 23(4), 401-411.
- Macrides, F., Bartke, A., Fernandez, F., & D'Angelo, W. (1974). Effects of exposure to vaginal odor and receptive females on plasma testosterone in the male hamster. *Neuroendocrinology* 15, 355–364.
- Malcolm, W. B. (1988). For Iguanas, Place in Sun May Be Too Bright. *New York Times*. p. 1.
- Mazur, A., & Lamb, T. (1980). Testosterone, status, and mood in human males. *Hormones And Behavior*, 14(3), 236-246.
- McCaul, K, Gladue B.A., & Joppa M. (1992) Winning, losing, mood, and testosterone. *Hormones and Behavior*. 26:486-504.
- McPhaul, M.J., & Young, M. (2001). Complexities of androgen action. *J. Am. Acad. Dermatol.* 45 (3 Suppl): S87–94.
- Mehta, P., & Josephs, R. (2010). Testosterone and cortisol jointly regulate dominance: evidence for a dual-hormone hypothesis. *Hormones And Behavior*, 58(5), 898-

906.

- Mehta, P., Jones, A., & Josephs, R. (2008). The social endocrinology of dominance: basal testosterone predicts cortisol changes and behavior following victory and defeat. *Journal Of Personality And Social Psychology*, *94*(6), 1078-1093.
- Michels, G., & Hoppe, U. C. (2008). Rapid actions of androgens. *Frontiers In Neuroendocrinology*, *29*(2), 182-198.
- Muller, M. N., & Wrangham, R. W. (2004). Dominance, cortisol, and stress in wild chimpanzees (*Pan troglodytes schweinfurthii*). *Behavioral Ecology and Sociobiology*, *55*, 332–340.
- Pfeiffer, C.A., Johnston, R.E., (1994). Hormonal and behavioral responses of male hamsters to females and female odors: roles of olfaction, the vomeronasal system, and sexual experience. *Physiol. Behav.* *55*, 129–138.
- Popova, N.K., & Amstislavskaya, T.G. (2002). Involvement of the 5-HT1a and 5-HT1b serotonergic receptor subtypes in sexual arousal in male mice. *Psychoneuroendocrinology* *27*, 609–618.
- Preston, B. T., Stevenson, I. R., Lincoln, G. A., Monfort, S. L., Pilkington, J. G., & Wilson, K. (2012). Testes size, testosterone production and reproductive behaviour in a natural mammalian mating system. *Journal Of Animal Ecology*, *81*(1), 296-305.
- Purvis, K., & Haynes, N.B., (1974). Short-term effects of copulation, human chorionic gonadotropin injection and non-tactile association with a female on testosterone levels in the male rat. *J. Endocrinol.* *60*, 429–439.
- Redouté, J., Stoléru, S., Grégoire, M., Costes, N., Cinotti, L., Lavenne, F., & ... Pujol, J.

- (2000). Brain processing of visual sexual stimuli in human males. *Human Brain Mapping, 11*(3), 162-177.
- Richardson, H.N., Nelson, A.L.A., Ahmed, E.I., Parfitt, D.B., Romeo, R.D., & Sisk, C.L. (2004). Female pheromones stimulate release of luteinizing hormone and testosterone without altering GnRH mRNA in adult male Syrian hamsters (*Mesocricetus auratus*). *Horm. Behav. 138*, 211–217.
- Roney, J. R., Mahler, S. V., & Maestriperi, D. (2003). Behavioral and hormonal responses of men to brief interactions with women. *Evolution And Human Behavior, 24*(6), 365-375.
- Rosenblitt J.C., Soler H., Johnson S.E., & Quadagno D.M. (2001) Sensation seeking and hormones in men and women: exploring the link. *Horm Behav. Nov 2001;40*(3):396-402.
- Rubinow, D.R., & Schmidt, P.J. (1996). Androgens, brain, and behavior. *Am. J. Psychiatry, 153*, 974–984.
- Sapolsky, R. (2008). The trouble with testosterone. In J. Z. Spade, C. G. Valentine (Eds.) , *The kaleidoscope of gender: Prisms, patterns, and possibilities (2nd ed.)* (pp. 41-45).
- Sapolsky, R. M. (1991). Testicular function, social rank, and personality among wild baboons. *Psychoneuroendocrinology, 16*, 281–293.
- Stoléru, S., Ennaji, A., Cournot, A., & Spira, A. (1993). LH pulsatile secretion and testosterone blood levels are influenced by sexual arousal in human males. *Psychoneuroendocrinology, 18*(3), 205-218.
- Studer, L., Aylwin, A., & Reddon, J. (2005). Testosterone, sexual offense recidivism,

- and treatment effect among adult male sex offenders. *Sexual Abuse: A Journal Of Research And Treatment*, 17(2), 171-181.
- Suay, F. F., Salvador, A., González-Bono, E. E., Sanchís, C. C., Martínez, M. M., Martínez-Sanchis, S. S., & ... Montoro, J. B. (1999). Effects of competition and its outcome on serum testosterone, cortisol and prolactin. *Psychoneuroendocrinology*, 24(5), 551-566.
- Sullivan, A. (2000). The He Hormone. New York Times. Retrieved from <http://www.nytimes.com/2000/04/02/magazine/the-he-hormone.html?pagewanted=all&src=pm>.
- Swaab, D.F., & Garcia-Falgueras, A. (2009). Sexual differentiation of the human brain in relation to gender identity and sexual orientation. *Funct. Neurol.* **24** (1): 17–28.
- Swerdloff, R., Wang, C., & Bhasin, S. (1992). Developments in the control of testicular function. *Baillière's Clinical Endocrinology And Metabolism*, 6(2), 451-483.
- Torjesen, P., & Sandnes, L. (2004). Serum testosterone in women as measured by an automated immunoassay and a RIA. *Clinical Chemistry*, 50(3), 678.
- Tuiten, A., Van Honk, J., Koppeschaar, H., Bernaards, C., Thijssen, J., & Verbaten, R. (2000). Time course of effects of testosterone administration on sexual arousal in women. *Archives Of General Psychiatry*, 57(2), 149-153.
- Van Honk, J. and Schutter, D.J. (2007) Vigilant and avoidant responses to angry facial expressions. In *Social Neuroscience: Integrating Biological and Psychological Explanations of Social Behavior* (Harmon-Jones, E. and Winkielman, P., eds), pp. 197–223, The Guilford Press.
- Van Honk, J., Peper, J. S., & Schutter, D. G. (2005). Testosterone Reduces

- Unconscious Fear but Not Consciously Experienced Anxiety: Implications for the Disorders of Fear and Anxiety. *Biological Psychiatry*, 58(3), 218-225.
- Viau, V. (2002) Functional cross-talk between the hypothalamic– pituitary–gonadal and –adrenal axes. *J. Neuroendocrinol.* 14, 506–513.
- Waterman, M., & Keeney, D. (1992). Genes involved in androgen biosynthesis and the male phenotype. *Hormone Research*, 38(5-6), 217-221.
- Wirth, M. M., & Schultheiss, O. C. (2007). Basal testosterone moderates responses to anger faces in humans. *Physiology & Behavior*, 90(2/3), 496-505.
- Zuckerman, M. (1990). The Psychophysiology of Sensation Seeking. *Journal Of Personality*, 58(1), 313-345.
- Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking*. New York, NY US: Cambridge University Press.
- Zuckerman, M., Kolin, E. A., Price, L., & Zoob, I. A. (1964). Development of a sensation-seeking scale. *Journal Of Consulting Psychology*, 28(6), 477-482.

Appendix

Appendix A

Table 1. Distribution of male and females

		sex			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	32	72.7	72.7	72.7
	Female	12	27.3	27.3	100.0
	Total	44	100.0	100.0	

Table 2. Descriptives of age, EDIS-VI scores, and ITAS-VI scores

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Age	44	18.00	53.00	29.2955	7.90225
EDIS-VI	44	79.00	116.00	95.5711	8.03368
ITAS-VI	44	37.00	62.00	50.6811	5.56437
Valid N (listwise)	44				

Appendix B

This model was used to test testosterone level and reactivity differences in skydiving vs basal day; and with respect to gender.

Maximum number of level-1 units = 335

Maximum number of level-2 units = 44

Level-1 Model (Model to test within-individual differences)

$$\text{LNTESTO} = \beta_0 + \beta_1*(\text{JB}) + \beta_2(\text{TBJ}) + \beta_3(\text{TAJ}) + \beta_4(\text{JBxTBJ}) + \beta_5(\text{JBxTAJ}) + r$$

Here, β_0 is the y-intercept, β_{1-5} are the slopes, JB = jump vs basal, TBJ = Time before jump, TAJ = Time after jump, JBxTBJ = Time before jump in jump vs basal, JBxTAJ = Time after jump in jump vs basal, and r= error term.

Level-2 Model (Model to test between-individual differences)

$\beta_0 = \gamma_{00} + \gamma_{01}*(\text{SEX}) + u$	It examines the peak testosterone level, with respect to sex
--	--

$\beta_1 = \gamma_{10}$	It examines the jump vs basal interaction
$\beta_2 = \gamma_{20}$	It examines Testosterone reactivity for time before jump
$\beta_3 = \gamma_{30}$	It examines Testosterone reactivity for time after jump
$\beta_4 = \gamma_{40}$	It examines Testosterone change before jumping basal day
$\beta_5 = \gamma_{50}$	It examines Testosterone change after jumping basal day

Table 3. Final estimation of fixed effects

Fixed Effect	Coefficient	Standard Error	Approx. d.f.	p-value	Description
For intercept1, β_0					
Intercept2, γ_{00}	4.55	0.10	42	<0.001	Predicted T-level at time of jump
SEX, γ_{01}	-1.05	0.18	42	<0.001	Predicted difference in T-level between sex
For JB, Slope, β_1					
Intercept2, γ_{10}	0.13	0.10	286	0.226	Predicted T-level in jump vs basal
For TBJ, β_2					
Intercept2, γ_{20}	0.17	0.04	286	<0.001	Predicted T-rise before the jump
For TAJ, β_3					
Intercept2, γ_{30}	-0.18	0.05	286	0.001	Predicted T-fall after the jump
For JBxTBJ, β_4					
Intercept2, γ_{40}	-0.15	0.06	286	0.01	Predicted T-fall before jump in basal day
For JBxTAJ, β_5					
Intercept2, γ_{50}	0.13	0.09	286	0.13	Predicted T-rise after

					jump in basal day
--	--	--	--	--	----------------------

Appendix C

This model was used to test testosterone level and reactivity differences in skydiving vs basal day with respect to EDIS-VI scale.

Maximum number of level-1 units = 335

Maximum number of level-2 units = 44

Level-1 Model (Model to test within-individual differences)

$$\text{LNTESTO} = \beta_0 + \beta_1*(\text{JB}) + \beta_2(\text{TBJ}) + \beta_3(\text{TAJ}) + \beta_4(\text{JBxTBJ}) + \beta_5(\text{JBxTAJ}) + r$$

Here, β_0 is the y-intercept, β_{1-5} are the slopes, JB = jump vs basal, TBJ = Time before jump, TAJ = Time after jump, JBxTBJ = Time before jump in jump vs basal, JBxTAJ = Time after jump in jump vs basal, and r= error term.

Level-2 Model (Model to test between-individual differences)

$\beta_0 = \gamma_{00} + \gamma_{01}*(\text{SEX}) + \gamma_{02}*(\text{EDISVI}) + u$	It examines the peak testosterone level, with respect to EDIS-VI and sex
$\beta_1 = \gamma_{10}$	It examines the jump vs basal interaction
$\beta_2 = \gamma_{20}$	It examines Testosterone reactivity for time before jump
$\beta_3 = \gamma_{30}$	It examines Testosterone reactivity for time after jump
$\beta_4 = \gamma_{40}$	It examines Testosterone change before jumping basal day
$\beta_5 = \gamma_{50}$	It examines Testosterone change after jumping basal day

Table 3. Final estimation of fixed effects

Fixed Effect	Coefficient	Standard Error	Approx. d.f.	p-value	Description
For intercept1, β_0					
Intercept2,	2.36	0.72	41	0.002	Predicted T-

Y_{00}					level at time of jump
SEX, γ_{01}	-1.05	0.18	41	<0.001	Predicted difference in T-level between sex
EDISVI, γ_{02}	0.02	0.008	41	0.005	Predicted T-level difference in EDISVI group
For JB, Slope, β_1					
Intercept2, Y_{10}	0.13	0.10	286	0.215	Predicted T-level in jump vs basal
For TBJ, β_2					
Intercept2, Y_{20}	0.17	0.04	286	<0.001	Predicted T-rise before the jump
For TAJ, β_3					
Intercept2, Y_{30}	-0.18	0.05	286	0.001	Predicted T-fall after the jump
For JBxTBJ, β_4					
Intercept2, Y_{40}	-0.15	0.06	286	0.01	Predicted T-fall before jump in basal day
For JBxTAJ, β_5					
Intercept2, Y_{50}	0.13	0.09	286	0.12	Predicted T-rise after jump in basal day

Appendix D

This model was used to test testosterone level and reactivity differences in skydiving vs basal day with respect to EDIS-VI scale.

Maximum number of level-1 units = 335

Maximum number of level-2 units = 44

Level-1 Model (Model to test within-individual differences)

$$\text{LNTESTO} = \beta_0 + \beta_1*(\text{JB}) + \beta_2(\text{TBJ}) + \beta_3(\text{T AJ}) + \beta_4(\text{JBxTBJ}) + \beta_5(\text{JBxT AJ}) + r$$

Here, β_0 is the y-intercept, β_{1-5} are the slopes, JB = jump vs basal, TBJ = Time before jump, TAJ = Time after jump, JBxTBJ = Time before jump in jump vs basal, JBxTAJ = Time after jump in jump vs basal, and r = error term.

Level-2 Model (Model to test between-individual differences)

$\beta_0 = \gamma_{00} + \gamma_{01}*(\text{SEX}) + u$	It examines the peak testosterone level, with respect sex.
$\beta_1 = \gamma_{10}$	It examines the jump vs basal interaction
$\beta_2 = \gamma_{20} + \gamma_{21}*(\text{ITASVI})$	It examines Testosterone reactivity for time before jump with respect to ITASVI
$\beta_3 = \gamma_{30}$	It examines Testosterone reactivity for time after jump
$\beta_4 = \gamma_{40}$	It examines Testosterone change before jumping basal day
$\beta_5 = \gamma_{50}$	It examines Testosterone change after jumping basal day

Table 3. Final estimation of fixed effects

Fixed Effect	Coefficient	Standard Error	Approx. d.f.	p-value	Description
For intercept1, β_0					
Intercept2, γ_{00}	4.56	0.10	42	<0.001	Predicted T-level at time of jump
SEX, γ_{01}	-1.07	0.17	42	<0.001	Predicted difference in T-level between sex
For JB, Slope, β_1					
Intercept2, γ_{10}	0.13	0.10	285	0.227	Predicted T-level in jump vs basal
For TBJ, β_2					
Intercept2,	0.17	0.04	285	<0.001	Predicted T-

Y ₂₀					rise before the jump
ITASVI, γ_{21}	0.01	0.004	285	0.002	Predicted T-level difference in ITASVI group
For TAJ, β_3					
Intercept2, Y ₃₀	-0.18	0.05	285	0.001	Predicted T-fall after the jump
For JBxTBJ, β_4					
Intercept2, Y ₄₀	-0.15	0.06	285	0.009	Predicted T-fall before jump in basal day
For JBxTAJ, β_5					
Intercept2, Y ₅₀	0.13	0.09	285	0.13	Predicted T-rise after jump in basal day

APPROVAL SHEET

This is to certify that Swornim Shrestha has successfully completed his Senior Honors Thesis, entitled:

Testosterone Reactivity to Skydiving

Bernard B Rees Directors of Thesis
Bernard B. Rees

Elizabeth A. Shirtcliff Directors of Thesis
Elizabeth A. Shirtcliff

Abu Kabir Mostofa Sarwar for the University
Abu Kabir Mostofa Sarwar Honors Program

May 10, 2013
Date