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Athletes' Testosterone Levels by Sports Team:

An Exploratory Analysis

Mark R. Pillay

Simon Fraser University

Abstract

Testosterone has been associated with a variety of athletic qualities, including aggressive behavior and spatial abilities. Research investigating sport-related differences however has received limited attention, particularly in terms of comparing athletes in different sports. The present study examined whether 94 varsity athletes differ in testosterone levels depending on their sport. Data was obtained from the following sports: soccer, wrestling, basketball, softball, and swimming. A saliva sample was obtained from each participant and measured for testosterone levels. Results suggest that both male and female athletes in high-ranked aggressive sports have higher testosterone levels. Cognitive measures remain speculative, but support Kimura (1999) findings that elevated testosterone levels in women positively influence performance on spatial tasks.

Difference in Testosterone Levels and Athletes in

Varsity Athletes: An Exploratory Analysis

Androgens, like testosterone, have been associated with muscle development, spatial abilities, physical exercise, aggression, and competition in human research (Archer, 1991). Athletes are commonly associated with these factors as well because many athletic environments tend to be highly physical, aggressive, and visually demanding. These factors commonly associated with athletic performance tend to vary among athletes in different competitive sports. The role of testosterone has been associated with competitive aggression in several animal studies but is still open to debate in humans, with numerous contradictory findings causing reviewers to draw different conclusions (Salavodor, Suay, Sanchis, Simon, & Brain, 1999). The diversity of approaches employed to examine aggressive behaviors in humans reflects the basic assumption that hormones and behavior have reciprocal influences.

In males, testosterone is produced primarily by the testes, with minor amounts secreted by the adrenal glands (Gray, Telford, & Weidmann, 1992); in females, testosterone is produced in the ovaries, with some production also occurring in the adrenal glands (Kraemer et al., 2001). Testosterone has anabolic (muscle-building) and masculinizing effects on the human body. It produces sexual differentiation in utero and during adolescence, and in adults it affects virtually every organ system in the body (Dabbs, 1992). High prenatal levels of testosterone are believed to promote development of the right more than the left side of the brain, leading to high spatial ability and low verbal ability (Dabbs, 1992). The effects of testosterone in males and females occur by the way of two main mechanisms: by activation of the androgen receptor (directly or as

DHT - 5α dihyrdrotestosterone), and by conversion to estradiol and activation of certain estrogen receptors (Christiansen, 2001).

Several studies have attempted to investigate the role of testosterone in athletes. A study by Passelergue and Lac (1999) found elevated testosterone levels in wrestlers compared to age-matched controls. The authors suggest that athletes from sports focused on offensive physical behaviors tend to exhibit elevated testosterone - offensive behaviors include hitting, kicking, punching, pushing, and tackling of an opponent. These behaviors are common in “aggressive” sports, however there has been little attention focused on the differences in testosterone levels between athletes in different sports that might differ by aggressivity. Passelergue and Lac’s (1999) interpretation of higher testosterone levels in wrestlers due to the offensive/aggressive nature of wrestling is speculative, since they compared wrestlers to non-athletes, and not to other athletes in non-offensive sports.

Testosterone has been associated with a variety of athletic qualities, however as these qualities may differ in importance between different sports, testosterone levels may also differ between sports. For example, wrestling is a sport characterized by a high frequency of physical aggressive behaviors and advanced muscular development. Testosterone has been associated with all of these qualities and therefore, based on previous studies such as Passelergue and Lac’s (1999), baseline testosterone levels may be elevated in wrestlers in association with the aggressive nature of wrestling. Athletes in a sport such as basketball, which requires fewer offensively aggressive behaviors and is less dependent on advanced muscle mass for offensive physical acts, may exhibit lower testosterone levels than wrestlers. These athletic factors are only a few examples of some sport-related differences that have been associated with testosterone.

The relationship between sports and testosterone is a controversial one, in part because testosterone can be discussed as a state or trait variable. Individuals have characteristic baseline levels, but they fluctuate around these levels. As a trait variable, the range of individual differences is large; men are about ten times as high in testosterone as women, and within each sex some individuals are more than twice as high as others (Dabbs, 1992). Given this variability, individuals may self-select into sports on the basis of their baseline physiology and testosterone levels. Conversely as a state variable, it is important to know how rapidly testosterone levels can change. Gladue, Boechler, and McCaul (1989) found detectable changes 15 minutes after experimental laboratory competition and more substantial changes 45 minutes after the competition. These reactive changes in association with the competitive activities of different sports will most likely have an influential effect on testosterone levels. An athlete, and their associated testosterone levels, may be reflective of either a state or trait condition.

Spatial ability may be an integral component in some competitive sports and has also been linked to testosterone in past research. Spatial ability is the ability to judge the relations of objects in space, to judge shapes and sizes, to mentally manipulate objects, to visualize the effects of putting objects together, and to mentally turn objects over or around (Hurt & Brous, 1986). Some researchers suggest that frequent exposure to spatial experiences, like those that occur in some sports, may positively influence performance on spatial abilities tasks (Lord & Leonard, 1997). The extent of this exposure should vary between sports as different sports have different spatial requirements. A basketball player will repeatedly encounter spatial experiences in training and competitive situations, whereas a swimmer will rarely face these types of experiences. As such, athletes in visually demanding sports will have far more experiences with many of the qualities associated with spatial ability.

Most athletes engage in rigorous training in order to achieve optimal performance levels in competitive settings. These training practices vary between sports because the athletic requirements tend to be different for each sport. Endurance training is commonly implemented in these training regimes as either an integral component, or a compliment to fitness. High amounts of endurance training have generally been associated with reduced plasma testosterone (Chennaoui, Gomez-Merino, Drogou, Bourrilhon, Sautivet, & Guezennec, 2004). The extent to which athletes engage in endurance training is often reflective of the athletic requirements of the sport.

Research comparing athletes in different sports is rather limited. As noted above, many studies have examined athletes in comparison to controls, or to athletes in the same sport. Additionally, few studies have examined differences in both male and female athletes. One purpose of this present study is to provide some exploratory analysis and to further understand the differences, particularly those related to testosterone, between male and female athletes.

Aggression and Testosterone

Participation in competitive sports is one way in which aggressive behavior is ritualized. However, "aggressive" is a global term in sports and is frequently used to describe behaviors when assertive, enthusiastic, or confident might be more accurate (Bushman & Anderson, 2001). Within the field of psychology, aggression is categorized in a number of different ways: maternal aggression, instrumental (social) aggression, hostile aggression, defensive aggression, therefore any examination of human aggression requires a definition of aggression. In terms of competitive sports, psychologists stress the distinction between hostile and instrumental aggression (Bushman & Anderson, 2001). Hostile aggression is impulsive behavior that is motivated by a desire to hurt someone. Instrumental (social) aggression is premeditated behavior used as a means to some non-hostile end (Bushman & Anderson, 2001). Instrumental aggression is the form of aggression commonly associated with competitive sports. The biological influences on this form of aggression however remain debated in human research. This reflects the difficulty of studying this topic in humans.

In several animal studies, the relationship between testosterone and aggression has been demonstrated using experimental methods. This often involves manipulation of testosterone levels through castration or injection of testosterone. Results overwhelmingly indicate that testosterone and aggressive behaviors are related (Turner, 1994). For example, studies of inter-male competition in mice have shown a positive relationship between testosterone and observable aggressive behaviors. Similarly, studies have shown that injections of testosterone consistently increase aggressiveness in a variety of species such as rats, monkeys, hamsters, dogs, and deer (Brain, 1983; Monoghan & Glickman, 1992). Females of most species exhibit less hostile, social, and defensive aggression; maternal aggression however is seen as extremely aggressive behavior (Archer, 1991). Additionally, they have far lower testosterone levels than do males. This is taken by some as evidence of a biological link between testosterone and aggression in non-humans (Archer, 1991). Although this relationship appears clear in animals, the connection becomes more complex as the range of species being studied widens (Rubinow & Schmidt, 1996).

The results in human research and testosterone are inconsistent and a number of possible influential factors have been identified. One such factor may be the poor reliability in measuring testosterone levels. In part, this is because testosterone is released in spurts from moment to moment (Mazur & Booth, 1998), and testosterone is found to be affected by circadian rhythms and seasonal effects as well. These influences can clearly affect measurement error and lead to inconsistent results in hormonal research. However, Mazur and Booth (1998) note that overall, testosterone levels remain relatively stable. Others suggest that the vast majority of research on hormones and social behavior in humans has relied on methods quite different from those used in animal studies and consequently has produced inconsistent results in comparison. For example, most studies on hormones and human aggression have been based upon three sources of data, namely, aggression questionnaires, interviews, and criminal records (Book, Starzyk, & Quinsey, 2001). Given that human aggressive behavior is often a complex sequence of physiological, emotional, and cognitive components (Floody, 1983), it is unsurprising human aggression remains controversial.

A meta-analysis by Archer (1991) highlighted the methodological differences that occur when studying aggression in human research. The type of participant, the form of aggression, and the measurement of aggression differed substantially between studies (Archer, 1991). Archer (1991) believes the diversity of approaches in human research on aggression reflects the difficulty of studying this topic in humans, mainly as a consequence of ethical limits of manipulating hormones and the difficulty in defining different forms of aggression. Furthermore, most of the studies have been correlational. The conclusions surrounding hormone behavior interactions in human research are often derived from data that are different from the data generated from experimental animal studies (Archer, 1991). These variations may explain some of the discrepancies found between animal and human research.

Researchers are beginning to recognize the advantages of examining the relationship between aggression and testosterone in competitive sports. Instrumental (social) aggression has been associated with a number of different competitive sports (Bushman & Anderson, 2001; Salavodor et al., 1999) and provides researchers with the opportunity to examine instrumental aggression under a natural-setting. Direct observations of offensive/aggressive behaviors can be used to measure instrumental aggression without any manipulation or direct involvement of the researcher. For example, a study by Salavodor et al. (1999) examined competitive judo combat and instrumental aggression in relation to testosterone levels. Salavodor et al. (1999) found a positive relationship between testosterone and offensive/aggressive behaviors in male judoists: the higher the testosterone levels, the more threats, fights, and attacks. This suggests that testosterone may be linked to instrumental aggression and expressed in offensive behaviors. These results support the view that testosterone can be linked to the expression of instrumental aggression in some competitive sports (Salavador et al., 1999) and further highlight the advantages of investigating human aggression through competitive sports.

Hormones and Spatial Ability

Although it is often difficult in humans to find clear links between overt behaviors and testosterone, relationships have been shown between hormones and cognitive skills. Sex differences in large and small scale spatial tasks have been identified by researchers in a variety of fields (Kimura, 1999; Self, Gopal, Golledge, & Fenstermaker, 1992; Watson & Kimura, 1991). Generally, mental rotations, direction-sense tests (maps), and embedded figures tasks are cognitive tests that show a male advantage on average (Kimura, 1999). Women tend to do better on average with tasks involving verbal fluency, spatial location, and verbal memory (Kimura, 1999). Since hormones appear to be the main mechanism behind biological sexual differentiation, it is plausible to hypothesize that the effects of hormones mediate performance on these tasks, where biological influence is to be found. Although hormones play a large role in organizing sexual differentiation, they can also have activational influence later in life.

Mounting evidence supports the idea that some aspects of cognitive performance are mediated by fluctuations in hormones. Several studies have investigated the effects of testosterone on men's and women's cognition. Moffat and Hampson (1996) found that men's and women's performance on spatial tasks fluctuated throughout the day in relation to their testosterone levels. In particular, they found that men performed best on spatial tasks later in the day when their testosterone titres were at a moderate level. In the early morning, when testosterone was highest, the men's scores were lower than the afternoon scores. Women performed best in the morning when their testosterone levels were highest. Their findings replicated those of Gouchie and Kimura (1991), which demonstrated that men with higher testosterone performed more poorly on spatial tasks compared to men with lower levels of testosterone. Women showed the opposite pattern with high testosterone women performing better on spatial tasks than low testosterone women.

In a study with female-to male transsexuals taking exogenous testosterone, participants showed a decline in verbal fluency after three months of hormone treatment, as well as an improvement in spatial performance (Van Goozen, Cohen-Kettenis, Gooren, Frijda, & Van De Poll, 1995). Berenbaum, Korman, and Leveroni (1995) found that high levels of early (organizing) testosterone may impair performance on typical female-favoring tasks, whereas high levels of estrogens should impair performance on tasks that favor males. Both the latter studies support the idea that testosterone not only influences performance on male-favoring tasks such as spatial rotations, but also impairs performance on woman-favoring tasks such as verbal fluency.

Although a number of studies support a link between hormones and cognitive performance and clear hormone-cognitive patterns have been substantiated, some researchers continue to questions such claims. Janowsky, Chavez, Zamboni, and Orwoll, (1998) found that there was no predictable link between basal hormone levels and performance on cognitive tests that showed a sex difference. However, Janowsky et al. study did not show sex differences on tasks that usually show sex differences, such as verbal fluency. It may be reasonable to conclude that hormones such as testosterone play a role in cognitive function throughout life, however any causal model will have to recognize the complex and reciprocal nature that environment and androgens have on each other.

Training Programs and Testosterone

According to Gray, Telford, and Weidemann (1993), different forms of repeated exercise will have an effect on testosterone levels. An athlete often repeats specific physical activities relevant to the nature of their sport and training program. Some sports such as long-distance running, swimming, and basketball rely heavily on endurance ability and consequently, will implement high amounts of endurance training in their training programs. In contrast, sports such as football, wrestling, and rugby implement endurance training to compliment fitness and favor weight-resisting exercises instead (Jaric, 2002). The structure, nature, duration, and intensity of an athletic training program will vary between sports (Gray, Telford, & Weidemann, 1993) because different sports rely on different physical abilities to achieve competitive success.

A recent study by Izquierdo (2003) found that basal testosterone levels were significantly lower in cyclists than age-matched weightlifters or untrained controls. Izquierdo (2003) suggests that testosterone levels are lower in sports characterized by a high endurance requirement. Some researchers claim that the lower testosterone levels in endurance athletes marks a positive adaptation for these athletes (Fellmann, 1992). Hackney, Szczepanowska, and Viru (2003) support this claim stating that the development of excess muscle mass in the body could unduly tax the oxygen delivery system during prolonged exercise activities and thus limit endurance performance.

Weight training or weight-resistance exercises are commonly implemented in athletic training programs to increase the power and strength of athletes. Long-term strength training has shown a significant increase in basal testosterone levels after two years of weightlifting (Haikkinen, Pakarinen, Alen, Kauhanen, & Komi, 1988). These results suggest that testosterone, and the anabolic qualities associated with testosterone, increase in response to weight training. Therefore, when addressing testosterone levels between different sports, endurance and weight training may be of relevance.

Current Study

The present study explored hormonal differences in athletes in different sports. There are several questions and hypotheses involved in this study: 1) Do athletes in different sports differ in testosterone levels and does testosterone correlate with ranked aggressiveness of sports? If yes, does this occur for both sexes? Past studies have identified a relationship between instrumental aggression and testosterone in human research. Based on these findings, it is hypothesized that individuals in more physically aggressive/explosive sports will exhibit higher basal testosterone.

2) Does spatial performance, measured with the Mental Rotations Test, differ by sport, if the sports differ by trait testosterone and/or spatial requirements? Several studies investigating endogenous androgen detected a curvilinear relationship; high levels of testosterone in females but low androgen levels in males were associated with superior performance in visual-spatial tasks (Gouchie & Kimura, 1991). It is hypothesized that male athletes with high testosterone levels will perform poorly in relation to male athletes with moderate testosterone levels. Female athletes with high testosterone levels are hypothesized to score higher on the MRT than female athletes with lower levels of testosterone.

3) Are high amounts of endurance training associated with lower testosterone levels in athletes of different sports? Research has shown that athletes who engage in high amounts of endurance training tend to have lower testosterone levels (Chennaoui, et

al., 2004). It is then hypothesized that sports with the highest amount of endurance training will be associated with lower testosterone levels.

Methods

Participants

Participants were 94 male and female varsity athletes recruited from Simon Fraser University. Participants included: 23 male wrestlers, 14 female wrestlers, seven male swimmers, five female swimmers, 14 male basketball players, 13 female basketball players, 10 male soccer players, and eight female softball players. Participants range in age from 18 – 40 (M = 22). All participants were undergraduate students, except for one who was a graduate student. Sixteen of the female participants reported current usage of hormonal contraceptives, which alter endogenous hormonal functioning. Furthermore, five female participants and 10 male participants reported using medication for cited health reasons.

Procedures

Ethics approval was received from the SFU Research Ethics Office. Each team was tested prior to a practice session, in a group, and before any physical exercise had taken place. Before beginning the study, a researcher explained the study to the participants, answered any questions, and asked each participant to sign a consent form. Participants then proceeded to complete a health and demographic questionnaire and a spatial abilities test (described below). In order to measure baseline testosterone levels, each participant provided a saliva sample that was assayed for testosterone. Participants provided this saliva sample while simultaneously completing the demographics questionnaire to avoid unwanted fluctuations in testosterone levels in response to some of the questions. The spatial abilities task was the final component of the testing session. All participants were tested between 4:00pm and 6:00pm, except the female basketball players who were tested at 10:00am. This methodological flaw occurred due to a combination of time restraints, group testing procedures and the practice schedule of the basketball team. Due to this flaw, time of day was controlled for during analyses. Additionally, testing did not occur if the athletes had recently competed in any form of athletic competition as a number of studies have shown elevated testosterone levels after a competition. According to a review done by Mazur and Booth (1998), testosterone levels in men increase before a competition, and after competition winners have higher testosterone levels than losers.

Measures

Testosterone. Testosterone titres were measured in saliva. Participants collected their own saliva in12 mL test tubes pretreated with sodium azide as a preservative. Participants rinsed their mouths with water prior to giving the sample, and were given sugarless chewing gum to stimulate saliva production. Each participant provided five to seven mL of saliva per sample. Saliva was stored in a freezer until being transported on dry ice to the assay lab. Assays were performed by the Endocrine Core Lab, a research support unit at the Yerkes Primate Research Center at Emory University, using radio-immunoassay to determine testosterone titres in the saliva samples. Saliva is found to correlate highly with participants' free testosterone concentration in serum (Wang, Plymate, Nieschlag, & Paulsen, 1981).

Demographics Questionnaire. The questionnaire covered basic demographic information for the participants, as well as specific health information required for this study. For example, questions concerning age, sex, weight, and stress levels were asked as each of these factors have been associated with testosterone in past research. Of particular concern in this study was the possible use of anabolic steroids, hormonal supplements, or medications/drug use, as each of these factors may significantly affect hormone levels. Participants were specifically asked to disclose any hormone supplements or medications they were taking and the purpose for these supplements. Contextual situations that might alter hormonal levels were also addressed. Participants were asked questions pertaining to their earlier food and liquid consumption that may alter testosterone levels. Further to this, questions regarding the participants sleep/wake cycles were asked in order to gain insight into their circadian rhythms. It has been well recognized that testosterone is characterized by a diurnal rhythm with highest levels in morning and nadir in the late afternoon (Diver, Imtiaz, Ahmad, Vora, & Fraser, 2002). Descriptions of participants sleep/wake cycles were addressed in order to protect against inconsistent results that may be obtained from differing circadian rhythms. Studies with women have shown that testosterone levels are elevated around the middle of the menstrual cycle (Hedricks, Piccinino, Udry, & Dawood, 1987). Therefore, female participants were asked questions pertaining to their menstrual cycle status. Questions regarding pregnancy and any abnormal menstruation addressed circumstances which inevitably affect testosterone levels as well.

As noted earlier, instrumental aggression is linked to testosterone and competition in human studies. A range of questions addressed instrumental aggression in athletes in different sports. Athletes were asked to rate the degree to which they feel instrumental aggression is found, required, and integral to success in their particular sport. Athletes also were asked questions pertaining to the amount of aggressive physical contact that occurs in their sport. Specifically, athletes were asked to rate on average the number of offensive physical acts that occur in competitive play. Offensive acts were defined as physical behaviors that are confrontational, oppositional, or hostile such as kicking, hitting, tackling, pushing, or shoving.

Participants also described their weekly training regimes and the amount of hours spent engaging in different physical activities. Specially, the amount of time spent endurance training and weight lifting were addressed.

Mental Rotations Test (MRT) (Vandenberg & Kuse, 1978) The MRT is a paper and pencil measure that consists of two-dimensional drawings representing three-dimensional objects. Participants were presented with 24 sets of items in which they are shown a "criterion figure" along with four other figures. Two of the four figures are rotations of the criterion figure and participants had to identify the correct two for each set of items. Participants had four minutes to complete as many of the items as possible. Each item is scored out of two for a maximum possible total of 48. Men have been found to perform better on average than women do on this task and all other tasks of spatial orientation (Kimura, 1999).

Classification

Each sport was rank ordered pertaining to the amount of aggression and spatial awareness required per sport. A blind panel of five undergraduate raters was used to rank order different sports using their own knowledge of the sports involved in this study. The panel was selected from the HumanWatson Lab at Simon Fraser University. The panel was given five questions regarding aggressivity in sports and five questions regarding spatial awareness in sports. They were asked to rank each sport with (1) being the most aggressive or visually demanding and (5) being the least aggressive or visually demanding. An average rating for each sport was calculated and the sports were ranked accordingly.

Results

All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) v. 13.0. Baseline testosterone levels for the male participants in this sample ranged from 41.27 to 321.70 pg/mL. The latter value was judged to be an outlier as it was more than three standard deviation units above the mean and was thus excluded from all analyses. Without this data point, the upper limit of the range was 252.08 pg/mL. The mean testosterone levels for the male participants per sport were: wrestling 120.56 pg/mL (*SD* = 34.75), swimming 92.88 pg/mL (*SD* = 12.23), basketball 87.53 pg/mL (*SD* = 29.09), soccer 105.59 pg/mL (*SD* = 53.90) respectively.

Baseline testosterone levels for the female participants in this sample ranged from 6.49 to 46.82 pg/mL. The mean testosterone levels for the female participants per sport were: wrestling 23.68 pg/mL (*SD* = 10.35), swimming 10.99 pg/mL (*SD* = 3.17), basketball 21.12 pg/mL (*SD* = 6.62), softball 20.32 pg/mL (*SD* = 12.38) respectively.

Sports and Testosterone

A Univariate Analysis of Variance (ANOVA) using the General Linear Model (GLM) was conducted to test the differences in testosterone levels between athletes in different sports. Because sports teams differed by sex, analyses were conducted separately by sex (see Figure 1 and 2). Results for the male participants revealed a trend for sports, $F(3, 49) = 2.74$, $p = .053$. After controlling for medications, this main effect became significant, F (3, 47) = 4.14, p = .01. Post-hoc comparisons were conducted using the Least Significant Difference (LSD) and revealed a significant difference between wrestling and basketball, p = .01 (see Figure 1).

Results for the female participants revealed a trend for sports, F = (3, 36) = 2.34, p = .087. Because oral contraceptive use was equally represented in each sport, they were not controlled for. Time of day however was controlled for because the female basketball team was the only team tested in the morning. Post-hoc comparisons using the Least Significant Difference (LSD) were conducted and revealed a significant difference between wrestling and swimming p = .01, and basketball and swimming p = .04 (see Figure 2).

Spatial Abilities and Testosterone

A one-way ANOVA was used to test the differences in MRT scores between sports for each sex. The male athletes' MRT performance did not reveal a significant difference between MRT scores and sport, F = .83, p = .483, nor did the female participants, F = 1.06, p = .378. Furthermore, there were no sex differences on MRT scores F (1, 92) = .69, p = .41 (see Figure 5). Correlations were also calculated between MRT scores and testosterone levels for each sex . For the female participants, a partial Pearsons Product Moment Correlations (PPMC) was calculated. While partialling out oral contraceptive use, a significant correlation between testosterone and MRT scores was observed, r = .63, p < .001 (see Figure 3). There was no significant relationship observed between MRT scores and testosterone in the male participants, r = -.024, p = .87 (see Figure 4).

Aggression, Spatial Abilities, and Testosterone

To examine the association between testosterone and sports ranked by aggressiveness and spatial requirements, Spearmen's Correlation for Ranked Data was calculated. The rank ordering obtained from the panel on aggressivity was ordered as follows: wrestling (1.56), soccer (2.05), basketball (2.45), softball (3.95), swimming (5.00), with one being the most aggressive and five being the least aggressive. The rank orderings for the male sports on aggression and testosterone levels revealed a significant correlation $r = .32$, $p = .02$. (See Table 2). The rank ordering obtained from the panel on the spatial requirements was ordered as follows: basketball (1.75), softball (1.85), soccer (3.15), wrestling (3.65), and swimming (4.75). Rank orderings of spatial requirements and MRT scores did not reveal a significant relationship $r = -.16$, $p = .24$.

The rank orderings of sports on aggression and testosterone levels for the female participants show a significant relationship, $r = .31$, $p = .048$. (See Table 2). However, there was no significant relationship between rank ordering of sports on spatial awareness and MRT scores $r = .24$, $p = .14$.

Training

All participants were asked to estimate the amount of endurance training they engage in, and this was correlated with testosterone. Pearsons Product Moment Correlations (PPMC) was then employed to examine the relationship between endurance training and testosterone. As expected, both men's and women's sports revealed a significant correlation between x and y, $r = -.32$, $p = .02$ and $r = -.36$, $p = .04$.

Discussion

The purpose of this study was to examine differences in varsity athlete's testosterone levels by sport in terms of their aggressivity, spatial requirements, and endurance training. The first hypothesis proposed in this study was that there would be a difference in testosterone levels between athletes in different sports. A significant difference in testosterone levels between sports was observed in men. It appeared that wrestlers had the highest mean testosterone levels in comparison to athletes from the other athletic teams. This supports Passelergue and Lac's (1999) findings that suggest wrestlers tend to have elevated testosterone levels. However, Passelergue and Lac's (1999) study compared wrestlers to age-matched controls, not to other athletes. The results reported here not only support Passelergue and Lac's findings, but also suggest that wrestlers may have higher testosterone levels compared to other athletes as well. This claim however is speculative as there were no other sports involved in this study that were seen as aggressive as wrestling. Perhaps future studies will incorporate multiple "aggressive/explosive" sports in order to examine whether elevated testosterone levels are unique to wrestlers, or merely the reflective of the aggressive nature of their sport.

A trend was also observed between the female athletes in different sports and similar to the findings with the male varsity athletes: female wrestlers had the highest mean testosterone levels. This finding further supports the notion that sports characterized with aggressive behaviors tends to be associated with higher testosterone levels. However, a methodological flaw that limits interpretability is that the women's basketball team was tested in the morning while all other women's teams were tested in the late afternoon. It is well established that circulating concentrations of testosterone in all forms (total, bioavailable and free) are characterized by a diurnal rhythm, with highest levels occurring in the morning (Cooke, McIntosh, & McIntosh, 1993). As such, the overall testosterone levels for the female basketball players are most likely elevated. This inconsistency, although statistically controlled, may have affected the results and should be avoided in future research.

A group of undergraduate students were asked to rank order the sports involved in this study on aggressivity and these results were correlated with testosterone and revealed a significant relationship for both sexes. These results support previous findings that have confirmed a small but significant relationship between testosterone and aggressive acts in humans (Archer, 1994; Archer, 1991). Similarly, a positive relationship has been found between testosterone and offensive behaviors like hitting, punching, and kicking in competitive judo (Salavodor et al., 1999). These behaviors tend to occur in sports that are seen as “aggressive”. Based on these findings, the general manner in which we perceive aggressivity in sports may be associated with higher testosterone in those sports.

Sex differences in MRT scores were not observed in this study. This finding is concerning as several studies have documented a robust sex difference in spatial performance between males and females (Kimura, 1999). However, little research has examined whether this sex-difference is still evident amongst athletes. Athletes also tend to have elevated androgens in comparison to sedentary controls (Fellmann, 1992), as such the sex-difference commonly reported in spatial tasks between men and women may not be as robust in athletes. It may be that female athletes with higher androgens are self-selecting into visually demanding sports. Additionally, because men score poorly on spatial tasks when testosterone levels are high, which they tend to be in athletes, they may score more poorly.

A strong positive correlation was observed between testosterone and MRT scores for the female participants. This finding supports previous studies by Gouchie and Kimura (1991) that claim that in females, higher testosterone levels are associated with higher performance on spatial tasks. Although no significant finding was observed in the spatial performance for the male athletes, the testing conditions in which the MRT was administered for both sexes was not optimal. All testing took place prior to a practice and in a group setting. These conditions were apparently distracting and athletes, particularly the male athletes, appeared more concerned with beginning their practice session than completing the MRT. Individual testing would have been preferable and a more accurate measure of spatial abilities, but due to time constraints of this study, group testing was the only viable option.

Many researchers have proposed that environmental factors such as socialization of sex-differentiated play, leisure activities such as sports, and educational experiences contribute to sex differences in spatial skills (Sharps, Price, & Williams, 1994). Based on findings such as these, this study explored whether different spatial experiences between sports influenced performance on the MRT. However, no relationship was observed for both sexes between sports rank ordered on spatial requirements and spatial performance. Several factors may have contributed to these findings. The most likely factor may be that the MRT is not associated with the spatial requirements of sports. Further to this, only one spatial abilities task was utilized in this assessment. Perhaps future studies in this area will employ a battery of spatial tasks in order to examine whether spatial experiences in sport influence spatial performance at all, as the MRT captures only one aspect of spatial processing.

A significant correlation was observed between estimated endurance training and testosterone for both sexes. It appears that high amounts of endurance training may decrease testosterone levels in both men and women. This supports previous findings that endurance training has generally been found to reduce plasma testosterone (Gomez-Merino et al., 2002). However, others suggest lower testosterone levels may in fact be reflective of overtraining, and not specifically endurance training (Hackney et al., 1988). Some of the sports teams that were tested for this study were in the middle of their competitive season, whereas other teams were not. Given this variability, some teams may have endured far more training than others. This makes it difficult to draw any clear conclusions in regards to the effects of endurance training on testosterone in this study.

Conclusion

There does appear to be a trend that athletes in explosive/aggressive sports tend to have higher testosterone levels. In support of this finding, both men's and women's wrestlers had the highest mean testosterone levels in comparison to the other sports utilized in this study. Additionally, the group of undergraduate raters used in this study, using their own subjective knowledge of aggression in sports, rank ordered the sports similarly to the ordering of mean testosterone levels. Two interesting questions are (1) whether differences in testosterone levels could be attributed to the competitive activities of different sports, or, (2) are individuals with high testosterone self-selecting into aggressive sports? Future research utilizing longitudinal studies may provide some answers to these speculative questions.

It is important to note that the sample used in this study were university students. A university population may not be representative of all athletes because these athletes were also students. University students are under a considerable amount of stress and stress has been shown to affect testosterone levels (Christiansen, 2001). Hopefully future studies of this nature will have access to a population of elite athletes focused solely on sport.

The data obtained from the spatial abilities component of this study support previous findings that higher testosterone levels in females enhance performance on spatial abilities tasks. The data obtained from the male participants however is inconclusive in this study as the testing conditions in which the MRT was administered had a number of distractible influences. In regards to the spatial requirements of different sports, there does not appear to be any evidence that exposure to spatial experiences in sports influence spatial ability. There is limited research however that has examined this topic. The complex visual environments of sports such as basketball and soccer may indeed influence spatial abilities, however in order to accurately assess if there is an effect at all, a number of different spatial abilities tasks, or ones more closely linked to sports' spatial requirements, should be administered. Follow-up studies should also consider examining whether sex-differences in spatial abilities occur between male and female athletes, as no difference was documented in this study and yet this relationship has been documented several times in past research.

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References

Archer, J. (1991). The influence of testosterone on human aggression. *British Journal of Psychology,* 82, 1-28.

Ahiainen, J.P., Kraemer, W.J., & Hakkinen, K. (2004). Acute hormonal responses to heavy resistance exercise in strength athletes versus non-athletes. *Canadian Journal of Applied Phys*iology, 29, 527-543.

Berenbaum, S.A., Korman, K., & Leveroni, C. (1995). Early hormones and sex differences in cognitive abilities. *Learning and Individual Differences, 7,* 303-321.

Book, A.S., Starzyk, K. B., & Quinsey, V. L. (2001). The relationship between testosterone and aggression: A meta-analysis. *Aggression and Violent Behavior,* 6, 579-599.

Brain, P.F. (1983). Pituitary-gonadal influences on social aggression. *Hormones and Aggressive Behavior,* 3-25.

Bushman, B.J. & Anderson, C.A. (2001). Is it time to pull the plug on the hostile versus instrumental aggression dichotomy? *Psychological Review,* 108, 273-279.

Chennaoui, M., Gomez-Merino, D., Drogou, C., Bourrilhon, C., Sautivet, S., & Guezennec, C.Y. (2004). Hormonal and metabolic adaptation in professional cyclists during training. *Canadian Journal of Applied Physiology*, 29(6), 714-730.

Christiansen, K. (2001). Hormones and sport. *Journal of Endocrinology,* 170, 39-48.

Cooke, R. R., McIntosh, R. P., & McIntosh, J. E. A. (1993). Circadian variation in serum free and non-SHBG-bound testosterone in normal men. *Clinical Endocrinology,* 32, 165-175.

Dabbs, M., J. (1992). Testosterone measurements in social and clinical psychology. *Journal of Social and Clinical Psychology,* 3, 302-321.

Diver, M.J., Komal, E.I., Aftab, M., Vora, J.P., & Fraser, W.D. (2003). Diurnal rhythms of serum total, free and bioavailable testosterone in middle aged men compared with those in young men. *Clinical Endocrinology,* 58, 710-717.

Fellmann, N. (1992). Hormonal and plasma volume alterations following endurance exercise. *Sports Medicine,* 13, 37-49.

Floody, O. R. (1983). Hormones and aggression in female mammals. *Hormones and Aggressive Behavior,* 39-90.

Gladue, B., Boechler, M., & McCaul, D. (1989). Hormone response to competition in human males, *Aggressive Behavior, 15,* 409 – 422.

Gomez-Merino, D., Chennaoui, M., Drogou, C., Bonneau, D., & Guezennec, C. Y. (2002). Decrease in serum leptin following prolonged physical activity in men. *Medical Science and Sports Exercise,* 34, 1594-1599.

Gorostiaga, E.M., Izquierdo, M., Ruesta, M., Iribarren, J., Badillo, J.J., & Ibanez, J. (2004). Strength training effects on physical performance and serum hormones in young soccer players. *Eur J Appl Physiol,* 91, 698-707.

Gouchie, C. & Kimura, D. (1991). The relationship between testosterone levels and cognitive ability patterns. *Psychoneuroendocrinology,* 16, 2323-334.

Gray, A.B., Telford, R.D., & Weidmann, M.J. (1993). Endocrine response to intense interval exercise. *European Journal of Applied Physiology,* 66, 366-371.

Hackney, A.C., Sinning, W.E., & Brunot, B.C. (1988). Rreproductive hormonal profiles of endurance trained and untrained males. *Medicine and Science in Sports and*

Exercise, 20, 60-65.

Hakkinen, K., Parkarinen, A., Alen, M., Kauhanen, & Komi, P.V. (1988). Neuromuscular and hormonal adaptation in elite athletes to strength training in two years. *Journal of Applied Physiology,* 65, 2406-2412.

Hurt, R. E., & Brous, C. W. (1986). Spatial visualization: Athletic skills and sex differences. *Perceptual and Motor Skills*, 63, 163-168.

Izquierodo, M., Ibanez, J., Hakkinen, K., Kraemer, J.W., Ruesta, M., & Gorostiaga, M. (2003). Maximal strength and power, muscle mass, endurance, and serum hormones in weightlifters and road cyclists. *Journal of Sports Sciences,* 22, 465 – 478.

Janowsky, J.S., Chavez, B., Zamboni, B.D., & Orwoll, E. (1998). The cognitive neuropsychology of sex hormones in men and women. *Developmental Neuropsychology, 14,* 421-440.

Jaric, S. (2002). Msucle strength testing: Use of normalization in body size. *Sports Medicine,* 10, 615-631.

Kimura, D. (1999). *Sex and cognition*. Cambridge, MA: MIT Press.

Lord, T., & Leonard, B. (1997). Comparing scores on spatial-perception tests for intercollegiate athletes and nonathletes. *Perceptual and Motor Skills*, 84, 299-306.

Lucia, A., Diaz, B., & Hoyos, J. (2001). Hormone levels in world class cyclists during the tour of Spain stage race. *British Journal of Sports Medicine,* 35, 424-430.

Mazur, A. & Booth, A. (1998). Testosterone and dominance in men. *Behavioural and Brain Sciences, 21*, 353-363.

Monoghan, E., & Glickman, S. (1992). Hormones and aggressive behavior. *Behavioral Endocrinology,* 134, 692-694.

Rubinow, D., & Schimdt, P. (1996). Androgens, brain, and behavior. *American Journal of Psychiatry,* 53, 974-984.

Self, C. M., Gopal. S., Golledge, R. G., & Fenstermaker, S. (1992). Gender-related differences in spatial abilities. *Progress in Human Geography,* 16(3), 315-342.

Sharps, M. J., Price, J., L., & Williams, J. K. (1994). Spatial cognition and gender: Instructional and stimulus influences on mental image rotation. *Psychology of Women Quarterly,* 18, 413-425.

Turner, A.K. (1994). Genetic and hormonal influences on male violence. In: J. Archer (Ed.), *Male Violence,* (233-252). New York: Routledge.

Van Goozen, S.H., Cohen-Kettenis, P.T., Gooren, L.J.0, Frijda, N.H., & Van De Poll, N.E. (1995). Gender differences in behaviour: Activating cross-sex hormones. *Psychoneuroendocrinology, 20,* 343-363.

Wang, C., Plymate, S., Nieschlag, E., & Paulsen, C.A. (1981). Salivary testosterone in men: Further evidence of a direct correlation with free serum testosterone. *Journal of Clinical Endocrinology and Metabolism, 53,* 1021-1024.

Watson, N. V., & Kimura, D. (1991). Nontrivial sex differences in throwing and intercepting: Relation to psychometrically-defined spatial functions. *Personality and Individual Differences,* 12(5), 375 – 385.

Table 1.
PPMC between testosterone levels and MRT scores, and between testosterone and endurance training.

	PPMC (r)	*p* Value
MRT (men)	-.02	.87
MRT (women)	.63	.00**
Endurance Training (men)	-.32	.02*
Endurance Training (women)	-.36	.04*

* = significant at $p < .05$ level
** = significant at $p < .01$ level

Table 2.
Spearmen's Rho between ranked aggression and testosterone, and between ranked spatial requirements and MRT scores.

	Spearmen's (r_s)	*p* Value
Ranked Aggression (men)	.32	.02*
Ranked Aggression (women)	.31	.04*
Ranked Spatial (men)	-.16	.24
Ranked Spatial (women)	.24	.14

* = significant at $p < .05$ level

Figure 1.

Mean testosterone levels by sport for male participants. The ordering on the x-axis is ordered by the panel of raters. ‘1’ represents the most aggressive, ‘5’ least aggressive. ‘*’ represents a significant difference between wrestling and basketball at $p < .05$.

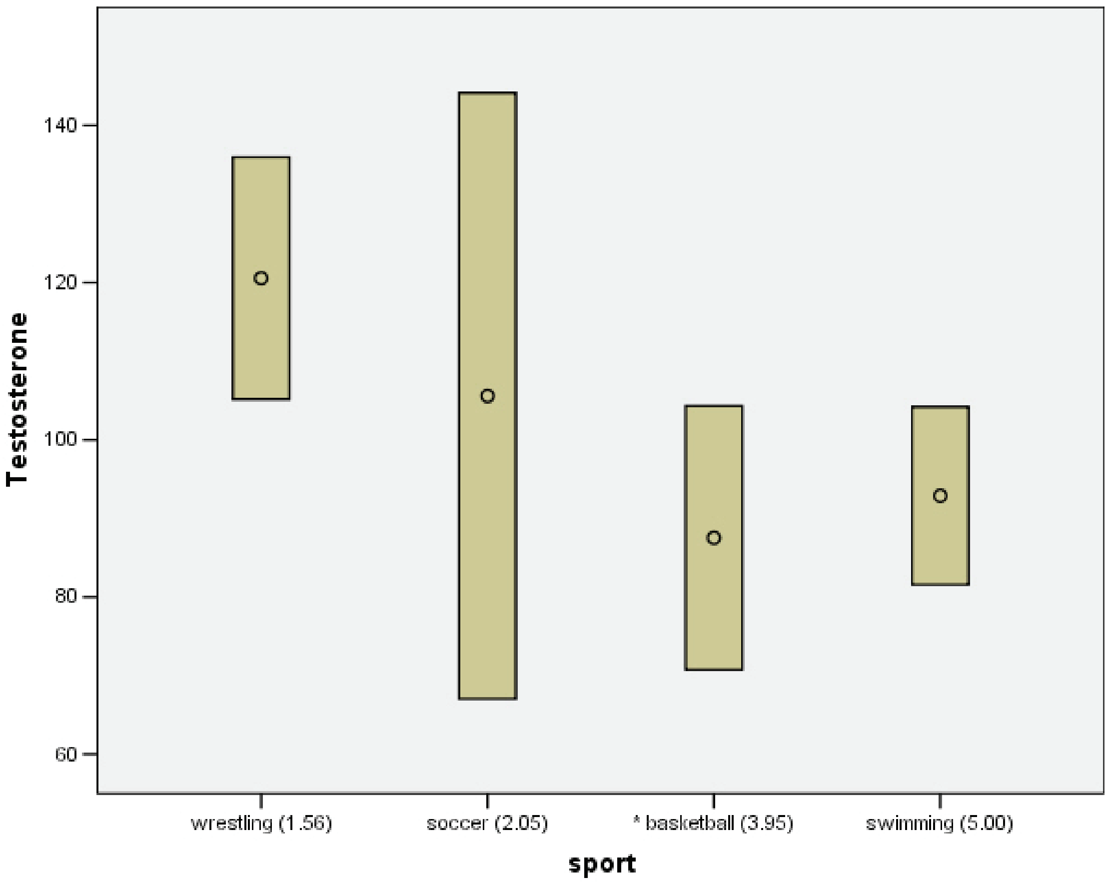


Figure 2.

Mean testosterone levels by sport for female participants. The ordering on the x-axis is ordered by the panel of raters. ‘1’ represents the most aggressive, ‘5’ represents the least aggressive. ‘*’ represents a significant difference between swimming and wrestling, and swimming and basketball at the p < .05.

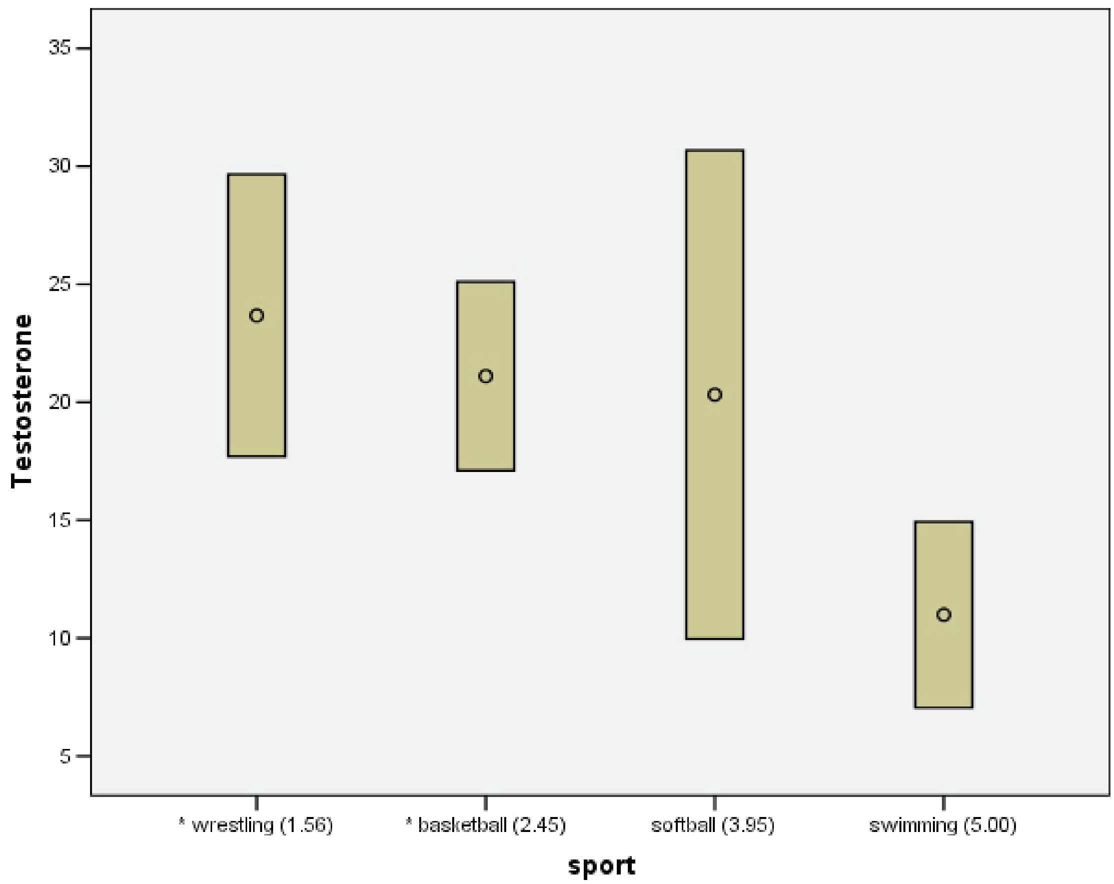


Figure 3.

MRT scores as a function of testosterone in female athletes.

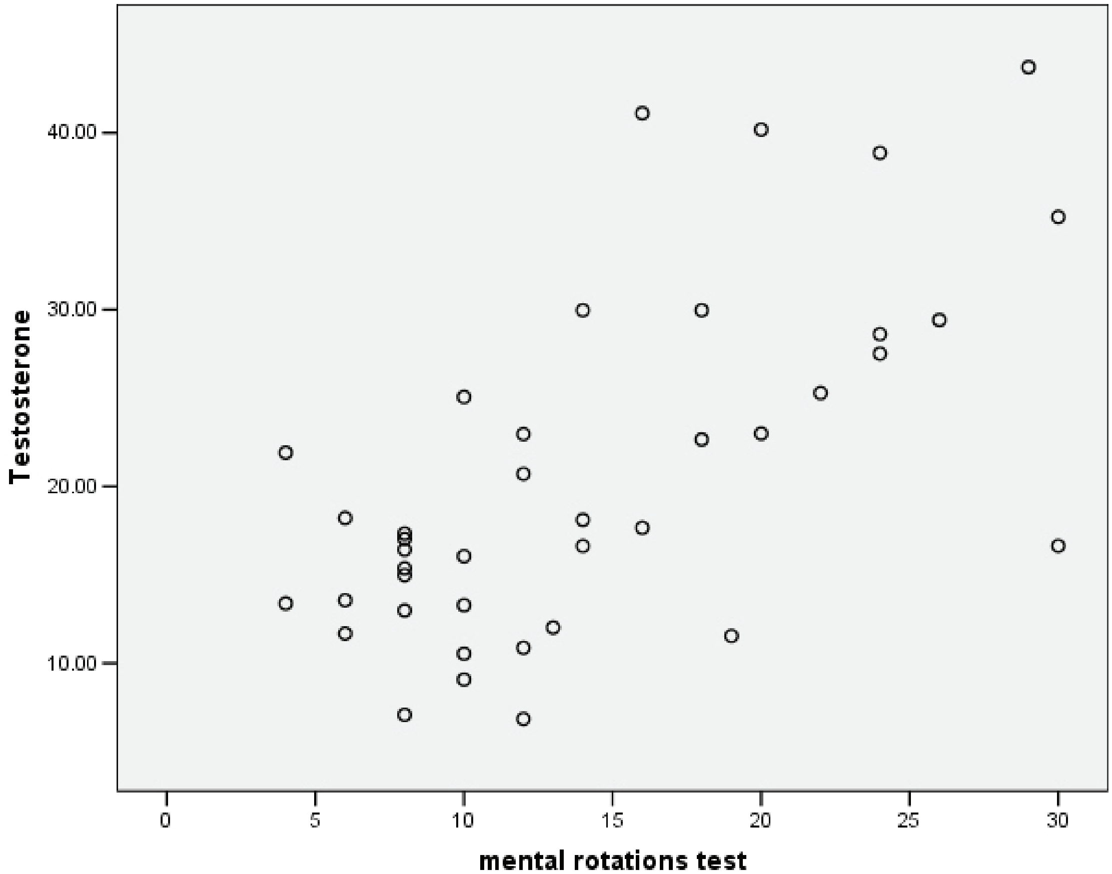


Figure 4.

MRT scores as a function of testosterone in male athletes.

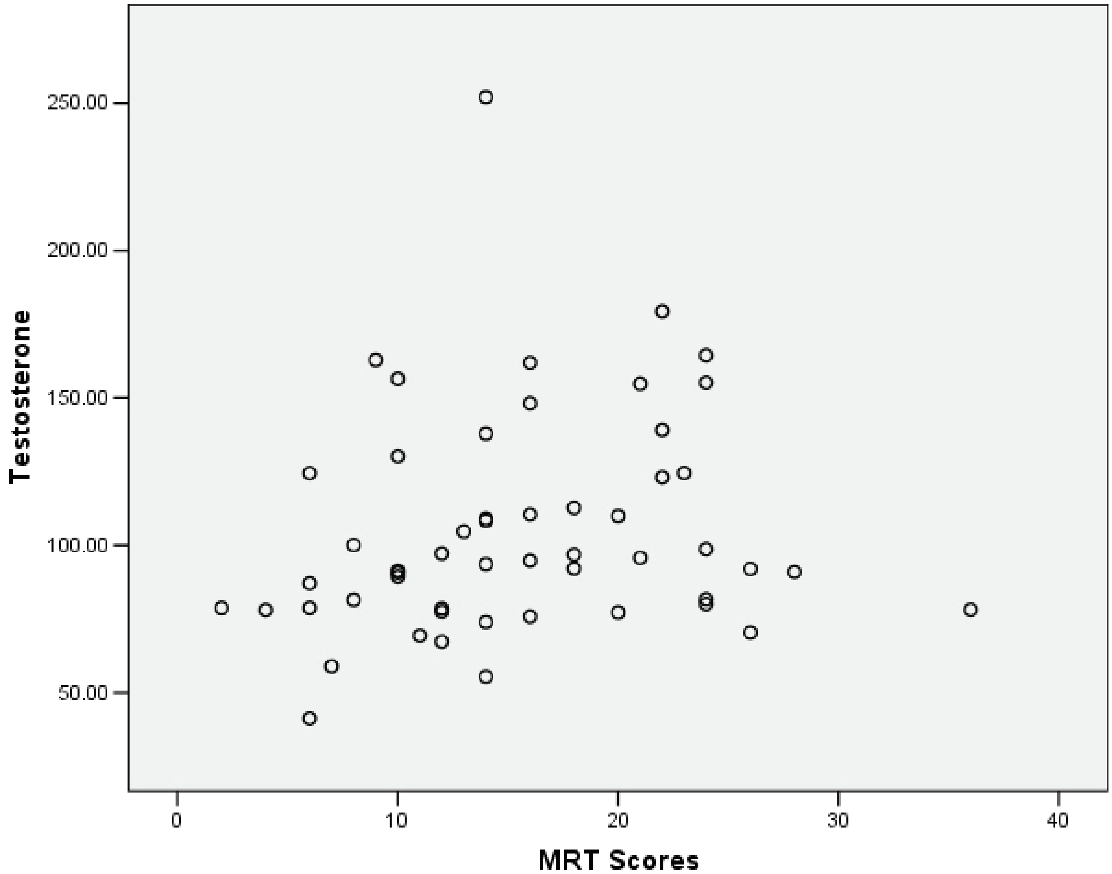
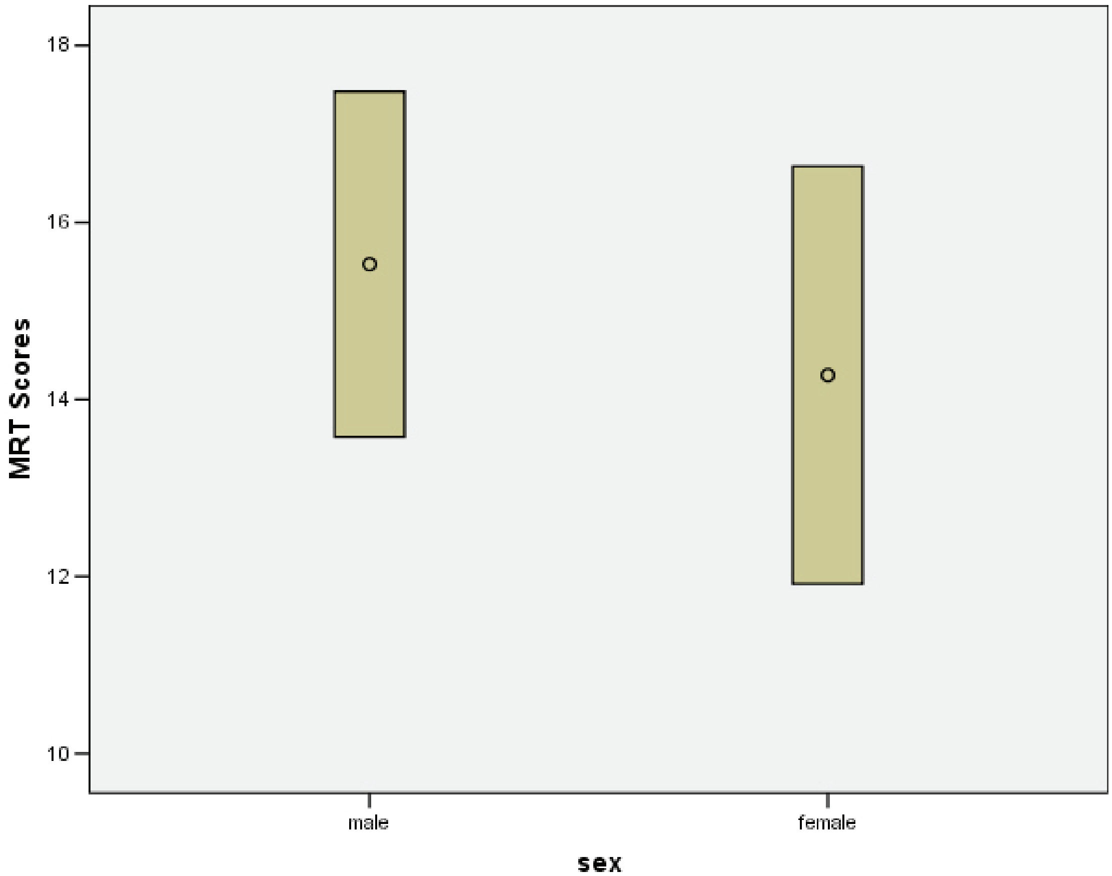


Figure 5.

Mean MRT scores by sex.



Appendix A.

Health and Demographics Questionnaire

1. Age: _________
2. Sex: _________
3. In the last hour, have you: (please circle your answers)
   a. Had anything to eat? YES NO
   b. Had a beverage other than water? YES NO
   c. Had a cigarette or other nicotine? YES NO
   d. Brushed your teeth? YES NO
4. Are you a student? (please circle one) YES NO
   Undergrad YES Grad YES
5. Are you currently taking any hormone supplements? (please circle one)
   a. NO, I am not currently taking any hormone supplements.
   b. YES, (please list the supplements you are taking):
6. Are you currently taking any prescription drugs? (please circle one)
   a. NO, I am not currently taking any prescription drugs.
   b. YES, (please list medications you are taking):
   ____
7. What is your weight (please indicate kg or lbs): ______________________
8. What is your height (please indicate m, cm, inches, feet): _______________
9. Have you ever been treated for seizures, a head injury, any serious neurological condition, or a psychiatric condition? YES NO
10. At present, do you have any type of infection or physical condition that might alter your hormone levels? YES NO
11. What varsity athletic are you involved in?____________________________
12. How many hours a week (on average) do you train for your sport?
    Overall____
    Endurance Training____
    Weight Training____

13. During what month(s) of the year is of peak activity in your sport?

____

14. Do you train through the off season? If so, what kind of training do you do?

____

____

____

15. How did you first become involved in the sport you are training for today?

____

____

16. Rate how important the following aspects are to your involvement in your sport.

Social Experience:

1 2 3 4 5 6 7 8 9

little importance somewhat important very important

Competition:

1 2 3 4 5 6 7 8 9

little importance somewhat important very important

Daily Training:

1 2 3 4 5 6 7 8 9

little importance somewhat important very important

Aggressive physical contact:

1 2 3 4 5 6 7 8 9

little importance somewhat important very important

High Fitness Level:

1 2 3 4 5 6 7 8 9

little importance somewhat important very important

17. How long have you been involved in this sport? ______________________

18. What other sport(s) do you:

    Play recreationally: ____

    Play competitively: ____

    Watch:____

19. How psychologically stressful do you find your sport?

    a. not at all

    b. a little bit

    c. somewhat

    d. quite

    e. very

20. How physically aggressive do you find your sport?

    a. not at all

    b. a little bit

    c. somewhat

    d. quite

    e. very

21. How competitive would your friends and family perceive you to be?

    a. not at all

    b. a little bit

    c. somewhat

    d. quite

    e. very

22. What time do you normally wake up on weekdays? (please indicate am/pm)

    ____

23. What time do you normally wake up on weekends? (am/pm) ____________
24. What time do you normally go to sleep on weekdays? (am/pm) __________
25. What time do you normally go to sleep on weekends? (am/pm) __________
26. What time did you go to sleep last night? (am/pm) ____________________
27. What time did you get up this morning? (am/pm) _____________________
28. If you didn't have to wake up because of external circumstances like school or work, when would you most prefer to wake up? (am/pm) _______________

29. Please rank your competitive nature compared to your team members? (please circle one)

    much less   less   same   more   much more

30. To what extent do you believe that an aggressive nature enhances success in your sport?

    not at all   very little   somewhat   quite a bit   very much

31. On average, how often do you engage in offensive physical behaviors in competitive play? (pushing, shoving, kicking, hitting, tackling)

    1   2   3   4   5   6   7   8   9

    Seldom   sometimes   all the time

32. How much physical contact occurs in your sport? (please circle one)

    a. continuous

    b. intermittent

    c. sometimes

    d. seldom

    e. never

33. What personality attributes do you think one needs to possess in order to be highly successful in your sport?

    ____

    ____

    ____

34. What physical attributes do you think one needs to possess in order to be highly successful in your sport?

    ____

    ____

Questions Relevant to Women

1) At what age did you get your first period? ______________________________

2) If you menstruate, what is the normal length of your menstrual cycle, from the first day of one menstrual period to the first day of the next menstrual period?
   a) 23 days or less   b) 24-26 days   c) 27-30 days
   d) 31-34 days   e) 35 days or more   f) N/A

3) If you menstruate, how regular are your menstrual cycles in their time of onset?
   a) perfectly regular   b) varies by 1-2 days
   c) varies by 3-4 days   d) varies by 5-6 days
   e) varies by 7 days or more   f) completely unpredictableg) N/A

4) Are you pregnant or breast-feeding an infant at present?   YES   NO

5) If you menstruate, do you ever go through long periods of time without having menstrual periods (for reasons other than pregnancy)?   YES   NO
   a) If yes, has this happened in the last 12 months?   YES   NO

6) Are you having your period today?   YES   NO
   a) If yes, what date did your current period begin? ____________________
   b) If no, what date did your last period begin? _______________________

7) If you do not menstruate, why?
   a) I am a post-menopausal woman
   b) I have a clinical condition such that I do not menstruate
   c) I am taking hormonal contraceptives that prevent menstruation
   d) Another reason: ____