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The Association between Circulating Androgen Levels, Body Composition, and Physical Performance in Female Soccer Players and Cross-Country Skiers

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ABSTRACT

Background: In recent research, links have been found between androgens and anabolic body composition. Some findings suggest that androgen hormones in female athletes are positively associated with both power and aerobic performance, while other studies have found that body composition is associated with aerobic performance. The study is intended to investigate the association between circulating androgen levels, body composition, and physical performance in female athletes.

Methods: This research consists of a cross-sectional study of 34 high-level Norwegian female athletes aged between 18 and 34 years (mean 22 years). The participants consisted of 25 soccer players and 9 cross-country skiers. For physical performance examinations, VO_2 max tests on treadmill were conducted, and squat jumps on a power platform. Lactate concentration after VO_2 max test was also measured. Bloods samples were drawn after an overnight fast. Free testosterone index (FTI) was used as androgen variable in the analyses. DEXA scans were used to estimate body composition.

Results: The analyses did not show statistically significant associations between FTI and body composition, or between FTI and physical performances. Some significant associations were found between the body composition variables and the physical performance measures. The soccer players and cross-country skiers were similar to each other in terms of androgen levels, age, height, and lean body mass (LBM), but statistically significant differences were found in fat percentage, weight, body mass index (BMI), and performance on squat jump power and VO_2 max. Compared to cross-country skiers soccer players developed significantly more power in the squat jump ($p = 0.01$), but not in squat jump height ($p = 0.21$) while cross-country skiers performed better on VO_2 max test ($p<0.001$). Fat percentage was negatively associated with squat jump height in soccer players ($\beta = -0.551$, $p = 0.016$). In regression analyses fat percentage and LBM were negatively associated with oxygen consumption in cross-country skiers (β -1.144, $p = 0.043$ and β -1.251, $p = 0.045$).

Conclusion: The most important finding in this research is that androgen levels, given by FTI, are not associated with either body composition or physical performance. This contradicts previous research. The statistically significant associations found among the participants were related to sport discipline and body composition.

Keywords: Female athletes, circulating androgens, physical performance, body composition.

PREFACE

This master's thesis is part of a larger, ongoing research program, on female athletes. The focus in the research program is the association between hormone levels, physical capacity and wellbeing of the athletes. The research program will examine the possible associations between androgens and lean body mass, fat mass, bone mass density, and gynecological health. Mental health, eating attitudes and competitiveness is also part of the research program. In this thesis only data from limited hormone analyses, physical performance, and parts of body composition will be used. The data collection for this thesis ended February 2012. At that time 36 athletes had participated in the different tests and measurements.

Several departments from the Norwegian University of Science and Technology (NTNU) are involved in the research program: Unit for Applied Clinical Research at Department of Cancer Research and Molecular Medicine, Faculty of Medicine, Department of Psychology, and Department of Human Movement Science, Faculty of Social Science and Technology Management. In addition, Department of Endocrinology and Department of Obstetrics and Gynecology, St. Olavs Hospital is involved. Olympiatoppen Mid-Norway has assisted in the recruitment process and under physical examinations of the subjects.

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Finally, I owe great thanks to the athletes who took their time to participate.

TERMS AND ABBREVATIONS

The following terms and abbreviations will be used in this thesis:

- **Androgens**: Steroid hormones that control the development and maintenance of masculine characteristics.
- **BMD**: Bone mineral density (g/cm^2).
- **Circulating androgen levels**: Refers to androgen levels in the blood.
- **DHEAS:** Dehydroepiandrosterone sulphate.
- **FTI:** Free testosterone index. Calculated independent of unit of measurement: FTI= (testosterone/SHBG) × 10. FTI is considered to be a measure of free testosterone in the circulation, i.e. testosterone that are biologically active and exert testosterone effects.
- **Hyperandrogenism**: The state of having increased androgen levels.
- **Hypoestrogenism**: The state of having reduced estrogen levels.
- **LBM**: Lean body mass.
- **MDs**: Menstrual disturbances.
- **Oligomenorrhoea**: Menstrual periods > 35 days apart, with only four to nine periods in a year.
- **PCOS**: Polycystic ovary syndrome.
- **Secondary amenorrhoea**: Absence of menstruation for at least 6 months after a period with menstruation.
- **SHBG:** Sex hormone-binding globulin.

CONTENTS

INTRODUCTION

Top level athletes are subject to extreme physical and psychological stress, and they are in continuous need of tailored training, diet, and general lifestyle adjustments for as long as they want to stay competitive and in good health. Different disciplines seem to foster certain body types making some females more eligible to develop the necessary physics and skills [1]. An individual's ability to succeed in top athletics depends on factors such as motivation, nutrition, training, environment, and genetic inheritance [2-5]. Accordingly, only a small proportion of women become top-level professional athletes.

However, being a top athlete is not necessarily in accordance with optimal health condition [6, 7]. Hard physical exercise, in combination with caloric deficiency, may result in reduced fat mass, which may lead to menstrual and reproductive dysfunction and hypoestrogenism. This may in turn lead to reduced bone mineral density (BMD) and other health problems. Contrary to these catabolic outcomes, competitive sport is also able to induce anabolic effects for some athletes, by gaining more muscular volume and increased BMD [8]. Several findings indicate that androgens, i.e. male sex hormones, are positively correlated to lean body mass (LBM), and have an enhancing effect on physical performance [6, 9, 10]. Findings have even suggested that a state of increased androgen levels may play a role when young female athletes choose to participate in sport [11].

Extended information on the association between female athletes' hormone levels and physical performance is needed [12]. With increased knowledge one may improve abilities to customize the most ideal training and diet for each individual, to achieve best performance results and ensure the athletes' health conditions, both during the years they compete and thereafter.

The aim of the study is to investigate the association between circulating androgen levels, body composition, and physical performance in a sample of Norwegian soccer players and cross-country skiers.

Hormone Levels

Several studies using different physical tests show that some of the best performing female athletes tend to have sex hormones levels that differs from average female values [6, 9, 10]. Immediately after both resistance and endurance exercise findings show that training can induce androgen level alternations in both sexes, by increasing hormones like testosterone, androstenedione, and dehydropiandrosterone sulphate (DHEAS) [13]. According to Enea et al. the endocrine system is significantly stimulated by physical exercise, with remarkable effects on female physiology. Significantly developed musculature in females may in part derive from hyperandrogenism, while chronic state of energy deficiency in female athletes may lead to hypoestrogenism [14]. Imbalanced male and female sex hormone levels in female athletes are often expressed by menstrual disturbances (MDs) the years they exercise to compete [6, 12, 15-18].

Rickenlund et al. [6] found that hyperandrogenic female athletes had menarche approximately two years later (15.8 vs. 13.8 years) than normoandrogenic female athletes, indicating that there is an initial difference, prior to the years of hard training. Eliakim [11] suggested that hyperandrogenism in a young female athlete may influence the selection to participate and perform in sport. Findings indicate that there are critical periods during intrauterine life where increased androgen levels influence the fetus' hormonal balance more, with lifelong effects [19, 20]. Irrespective of cause and effect, it is known that longstanding hyperandrogenism and anovulation are associated with polycystic ovary syndrome (PCOS), and accompanying metabolic and reproductive complications [6, 21].

Hagmar et al. [8] studied 90 female Olympic athletes from 27 various disciplines, and found that 13 % of power athletes and 66 % of endurance athletes had MDs. A Norwegian survey of 1276 elite female athletes and controls suggest that it is not training volume, but participation in leanness sports that associates with menstrual dysfunction [22] . In Drinkwater et al.'s sample mean running distance per week (67.3 km vs. 41.8 km), but not caloric intake, differed substantially between athletes with and without MDs [17]. The investigators also detected estradiol levels approximately 50 % lower in the athletes with MDs, suggesting hypoestrogenic status. MDs in endurance sport athletes are more extensively reported compared to power sport athletes, though this may be subject to publication bias, as this relationship tends to be investigated more for endurance athletes.

If MDs are unrelated to energy intakes, they appear to be more typical for power and strength sports. In Hagmar et al.'s study [8] most MDs were due to hyperandrogenism. They detected polycystic ovaries, which is one out of three criteria for PCOS diagnosis, in 37 % of females in their sample not using hormonal contraception and 12.5 % among users. Among the participants with polycystic ovaries 42 % were power athletes, 33 % endurance athletes, and 22 % technical athletes.

Body Composition

As results from discipline-specific training and the athlete's biological basis, the distribution between lean and muscular athletes, vary between disciplines [2, 23, 24]. Endurance sports suggest a more marked aerobic metabolism where low body fat is more important than muscle strength [7]. Tomten et al [15] found a linearly associated relationship between MDs and lowering of BMD in Norwegian female runners. One of the most important hormonal factors involved in bone health is estradiol [14]. Estradiol is an estrogen, which like all other steroids is derived from cholesterol [25].

Strength and power sport athletes are known to possess higher BMD, LBM and upper-lower fat mass ratio [8]. Weight training can be similar to aerobic exercise in regards to achieving fat loss, and at the same time increase fat-free mass [26]. Milanese et al.'s study [27] comparing elite and sub-elite handball players showed higher bone mineral content lower fat percentage and a clear tendency to accrue more LBM, especially in upper limbs, in elite handball players.

Hickey et al. [28] found a positive linear relationship between FTI and increasing weight in a sample of 244 unselected post-menarchal adolescents. In a sample of 60 non-athletes, the normal weight females with PCOS exhibited higher amounts of adipose tissue compared to healthy controls, and a tendency towards central obesity patterning, i.e. fat localized in trunk and upper body [29]. Other studies on both athlete and non-athlete females, have found that hyperandrogenic women have higher BMI, LBM, waist circumference, and percentage of body fat compared to normoandrogenic athletes with MDs, healthy athletes, and sedentary controls, even when similar dietary habits are reported [6, 30]. Neassen [31] state that androgens have appetite-increasing effects. These findings may indicate that hyperandrogenic women may have more difficulties maintaining a slim body and might thereby be less suitable for lean-weight sports. Furthermore, the relationship between cholesterol, estradiol and BMD mentioned above may explain why hyperandrogenic females are prevented against low BMD.

Physical Performance

Several findings indicate that there are positive associations between androgens and the amount of muscle mass, and that androgens enhance physical performance [6, 9, 10]. Cardinale et al. [9] found a significant positive relationship between testosterone levels and countermovement jump in male and female elite athletes. Rickenlund et al.'s study [6] support this finding, as females with the highest androgen levels had significantly higher isometric leg strength, and the highest maximal oxygen uptake. Numerically higher values for blood lactate concentration were found for hyperandrogenic females, possibly due to longer running duration. An alternative explanation may be that hyperandrogenic athletes are more motivated and able to push themselves more in tests. No differences were found in perceived dypsnea-exertion indicating that hyperandrogenic females are able to provide more effort without feeling more exhausted. Interestingly, Rickenlund et al. found no differences between normoandrogenic and hyperandrogenic women in hand grip muscle strength, and interpret this finding as an indication that the hyperandrogenic females may have performed better due to task-specific training condition, and not because of their androgen levels alone [6].

METHOD

DESIGN

This is a cross-sectional study of female soccer players and cross country skiing athletes.

SUBJECTS

The study sample consists of 34 female athletes aged between 18 and 34 years (mean age 22 years), all Caucasian. Due to incomplete data two athletes were excluded, reducing the sample size from 36 to 34. Of these, 25 were soccer players from two different teams, and nine were cross-country skiers. The participants were under supervision of Olympiatoppen Mid-Norway, competing at high level in soccer or cross-country skiing. Athletes that were injured, pregnant, or breast feeding, were excluded from participation in the study in order to avoid potentially misleading values. All subjects reported feeling well on the day when the tests were performed.

PROCEDURES

Subjects were recruited between September 2011 and February 2012, an information letter and declaration of consent can be found in appendix 1 and 2, respectively.

Testing started in December 2011 and was completed in February 2012. The subjects visited Department of Human Movement Science, Dragvoll, NTNU, for physical performance tests at one occasion, at their preferred time. Further, they had a DEXA scan and a gynecological examination at St. Olavs Hospital, Trondheim University Hospital. Blood samples were drawn in the fasting state between 08 and 10 am, preferentially within 3 days of the physical testing. There was little exchange in test personnel to ensure consistency in instructions and implementation method during testing throughout the study. The test personnel conducting the physical performance tests were master students, performing power tests, and two employees from Olympiatoppen Mid-Norway, performing aerobic capacity tests. All data was stored for offline analysis.

MEASUREMENTS

Anthropometric Data

Measurements were performed at Department of Human Movement Science at Dragvoll, NTNU. Height and weight were measured. Height (to the nearest centimeter) was measured without shoes, and weight was measured while the subjects wore light-weight training clothes.

Physical Examinations of Performance

There were three physical performance examinations of each subject, of which two is included in the scope of this thesis; maximal power in lower body (squat jump height), and oxygen consumption (average last minute VO_2).

Maximal muscular power in the lower body was assessed by explosive power in a squat jump performed on AMTI Biomechanics Force Platform[1]. The subject was instructed to hold their hands on the hips and start in a freely chosen squat depth where they felt most capable of producing the highest possible squat jump. We recorded until each subject had delivered 3 approved trials, i.e. a jump with both arms attached to the hips, without any countermovement registered. Jump height, maximal power, rate of force development and time to peak power was calculated from the Biojump force plate[2], and used to determine maximal muscular power. The focus of interest here is the actual jump performance in centimeters and therefore this was used in the analyses.

Aerobic capacity was measured by VO_2 max test on a treadmill. The subject warmed up for approximately 15 min on around 60 % of maximal heart rate. Test duration lasted between 5-8 minutes for most of the athletes (minimum 4, maximum 11.20), performed on 10.5 % incline with stepwise speed increase by 1 km/h every minute. VO_2 was measured through pulmonary gas exchange, using an Oxycon Pro[3] throughout the test with a sample frequency of 0.1 Hz. The average of the six highest 10-s consecutive measurements determines VO_2 max. Heart rate was measured continuously during the test and blood lactate was measured after completing the test using Lactate Pro[4]. The test was considered maximal effort when two of the following criteria are met: a plateau in VO_2 with increasing intensity,

[1] Model bp6001200, Massachusetts, USA
[2] Biojump program version 2.2, Oslo, Norway
[3] Jaeger GmbH, Hoechberg, Germany
[4] LT-1710, ArkRay Inc, Kyoto, Japan

respiratory exchange ratio (R-value) above 1.10, and blood lactate concentration exceeding 8 mmol/L. In the analysis we called the oxygen consumption variable Last Minute VO_2.

Biochemical Hormone Analyses

All of the nine cross-country skiers and 23 out of 25 soccer players participated in the hormone analyses. The participants were instructed to have an overnight fast before blood samples were drawn. Between 8 am and 10 am blood samples were drawn from an antecubital vein. For a maximum of 14 days serum was stored at -20 degrees centigrade. After this period serum was transmitted to a -80 degrees centigrade freezer. Organic solvent extractions (dichloromethane for testosterone and ethyl ether for androstenedione) were used before testosterone and androstenedione analyses. Androstenedione was measured with a competitive immunoassay based on the use of antibody-coated tubes, the Coat-A-Count® Direct Androstenedione procedure, using reagents and calibrators from Siemens[5]. Enzyme-linked immunosorbent assay (ELISA) was used for quantitative determination in serum for measuring testosterone, DHEAS, SHBG, and 17-hydroxy-progesterone. Intra-assay coefficients of variation were 5.6 % for androstenedione, 9.5 % for testosterone, 2.8 % for DHEAS, 6.6 % for SHBG, and 1.8 % for 17-hydoxy-progesterone. In all estimations samples were measured in duplicates and the mean of the two measurements was used. Free testosterone index (FTI) is the focus variable in further analysis as it is considered the biologically active testosterone. FTI was calculated by the formula FTI = (testosterone/SHBG) × 10, where testosterone and SHBG are both measured in nmol/L.

Dual-Energy X-ray Absorptiometry

Dual-Energy X-ray Absorptiometry (DEXA) scan were performed with a Hologic Discovery A scanner[6]. Method of analysis was Whole Body Auto Fan Beam. This scan determines total fat mass and total lean mass in kilogram, in addition to total fat mass and total lean mass in percentage of total body mass.

STATISTICS

In the analysis the sample were separated into two groups. The characteristics of the sample

[5]Siemens Medical Solutions Diagnostics, Los Angeles, CA, USA
[6] Version 12.7.3.1, Hologic, USA

were presented as frequencies and means in a descriptive analysis, with standard deviations (SD) and range. The two groups' means were compared with Independent Sample t-test, statistical significance were set as $p<0.05$. Scatter plots illustrate the sample distributions in the different exercises. Bivariate Pearson's correlation analysis was used to investigate the associations between the variables. Multivariate linear regression analyses were conducted, adjusting for all androgens, body composition and age, to evaluate whether any of these had confounding effects on the performances. All statistical analyses were two-sided. All analyses were conducted with SPSS version 19.0 for Windows[7].

ETHICS

The project was approved by The Regional Ethical Committee in Mid-Norway (appendix 3). Participants were included in the study only after a declaration of consent was signed (appendix 2). Results were anonymously stored and analyzed. Study participation was evaluated to involve minimal health risk. The Declaration of Helsinki was followed throughout the study.

[7] SPSS Inc., Chicago, Illinois, USA

RESULTS

A total of 34 female athletes were included in the statistical analyses, all competing in high level soccer or cross-country skiing. The athletes were divided into two groups based on discipline, as shown in Table 1. The difference between the cross-country skiers and soccer players was not statistically significant in terms of age, height or LBM. However, they were significantly different from each other in terms of BMI, weight and body fat percentage.

The t-test showed that squat jump results were higher on maximal power in soccer players, this difference was statistically significant, but it was not for jump height. Cross-country skiers had significantly higher last minute VO_2 and speed at the end of the test, and numerically lower lactate concentrations, compared to soccer players. There were no statistically significant differences in the measured hormones between the groups, but the soccer players had numerically higher values in androstenedione, testosterone, DHEAS, 17-OH-progesterone, and FTI, and lower levels of SHBG compared to the skiers.

Table 1 - Descriptive statistics of the study participants

Female athletes, total N=34						
	Soccer player athletes N=25		CC skiing athletes N=9		t-test	
Variables	Mean (SD)	Range	Mean (SD)	Range	t (df)	p
Age (years)	22.6 (3.7)	18-34	22.7 (2.9)	19-28	-0.02 (32)	0.985
Height (cm)	167.8 (5.0)	161-178	168.3 (5.2)	161-176	-0.29 (32)	0.820
Weight (kg)	63.3 (6.7)	52-76	58.4 (4.0)	54-66	2.27 (32)	0.030
Body mass index (kg/m^2)	22.3 (1.9)	19.5-25.3	20.5 (0.9)	19.1-22.3	2.77 (32)	0.009
Lean body mass (kg)	48.6 (4.9)	40.3-58.1	47.7 (3.6)	42.0-51.7	0.48 (30)	0.635
Total body fat percent (%)	20.5 (2.8)	14.4-24.1	15.8 (2.5)	12.5-19.1	4.29 (30)	<0.000
Physical performances						
Squat jump height (cm)	28.3 (4.8)	19.5-39.0	25.9 (4.5)	19.8-32.2	1.27 (32)	0.211
Max power, squat jump (N)*	1320 (169.9)	1040-1658	1152 (109.3)	987-1394	2.74 (32)	0.010
Last Minute VO_2 (ml/kg/min)	53.3 (3.6)	46.3-60.4	63.3 (3.0)	59.3-66.9	-7.38 (31)	<0.000
Lactate (mmol)	11.2 (2.0)	5.7-14.7	9.9 (1.7)	8.0-13.4	1.59 (32)	0.121
Speed at end of test (km/h)	11.1 (.8)	10-13	13.3 (.5)	13-14	-7.12 (29)	<0.000
R-value (CO_2/O_2)	1.13 (.04)	1.06-1.25	1.10 (.06)	0.99-1.19	1.86 (32)	0.072
Hormone levels						
SHGB (mmol)	122 (74.2)	42-325	131 (45)	81-199	-0.32 (30)	0.748
Testosterone (mmol/L)	1.36 (0.41)	0.6-2.2	1.17 (0.36)	0.6-1.76	1.21 (30)	0.238
Androstenedione (mmol/L)	9.7 (2.9)	4.4-15.9	8.8 (2.9)	5.0-13.0	0.79 (30)	0.433
DHEAS (µmol/L)	4.5 (1.7)	1.7-8.2	3.5 (1.1)	2.1-5.1	1.55 (30)	0.131
FTI	0.16 (0.11)	0.03-0.47	0.10 (.05)	0.04-0.22	1.38 (30)	0.177

N= total number of athletes included

*Measured in Newton

Scatter plots of the unadjusted associations between FTI and LBM, as well as the associations between FTI and fat percentage, are shown in Figure 1. None of the associations were statistical significant. Individual data and regression lines are shown for soccer players (heavy lines and filled dots) and cross-country skiers (grey line and open circles) in all of the following scatter plots.

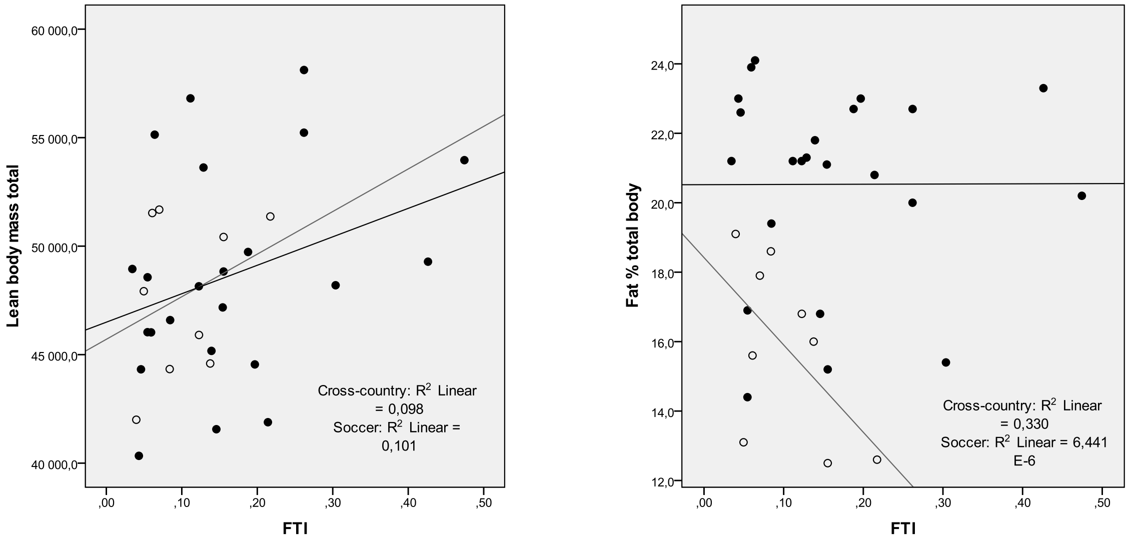

Figure 1 - The correlation between FTI and LBM (left), and between FTI and fat percentage (right).

Unadjusted associations between FTI and performance on squat jump and VO_2 max test in scatter plots are shown in Figure 2. None of the associations were statistically significant.

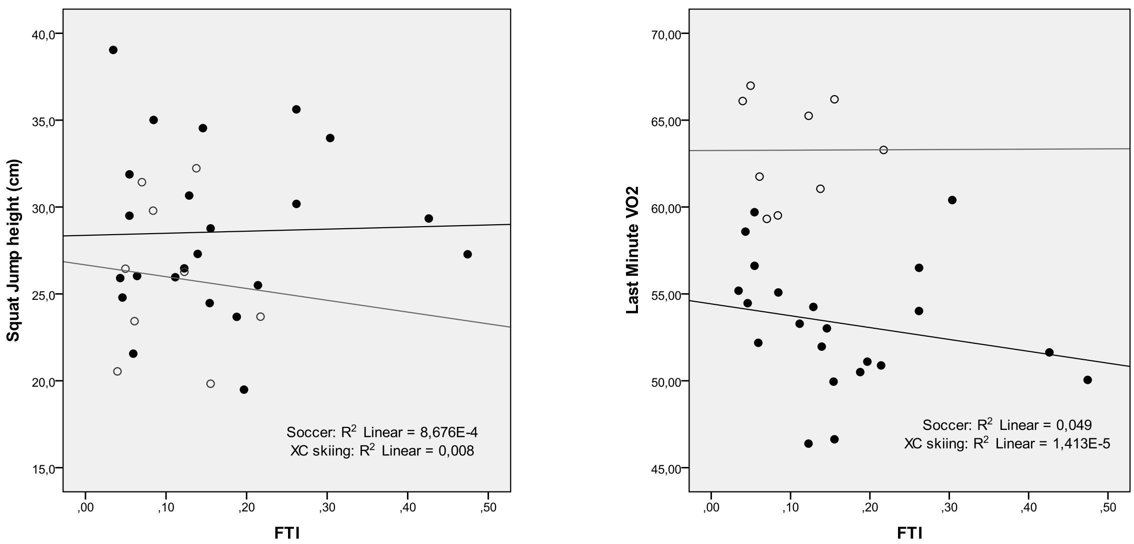

Figure 2 - The correlations between FTI and squat jump height (left), and between FTI and last minute VO_2 (right).

Figure 3 shows unadjusted correlation between fat percentage and physical performance. The only statistical significant correlation in this case, identified using Pearson's analysis, is between fat percentage and squat jump height in soccer players (r = -0.502, p = 0.015).

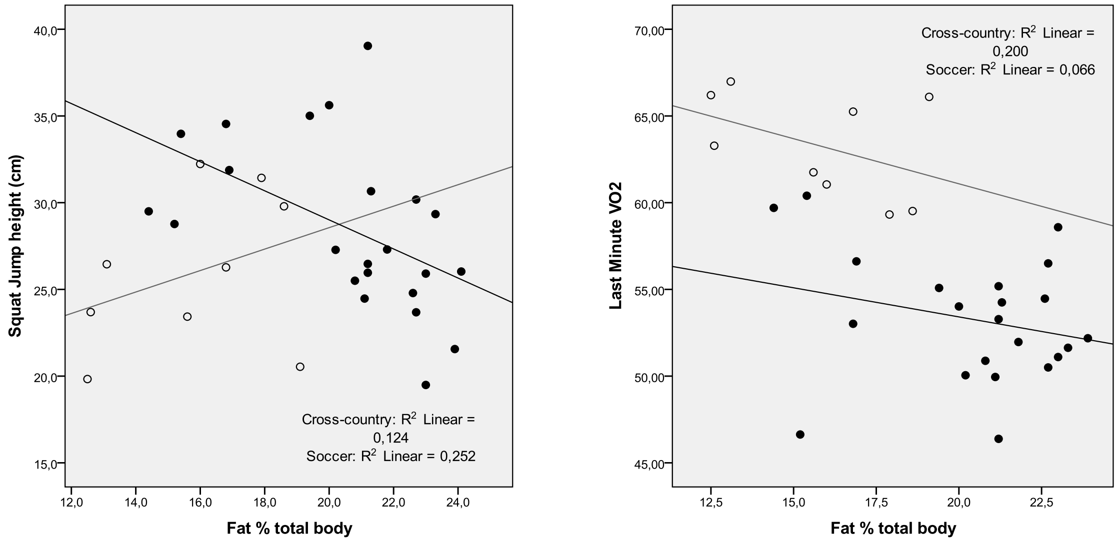

Figure 3 - The unadjusted associations between fat percentage and squat jump height (left), and between fat percentage and last minute VO_2 (right).

The Bivariate Pearson correlation analysis was conducted with all measured hormones included, both for the total group, and stratified with respect to sport discipline. According to these analyses there were no statistically significant correlations between FTI and physical performance, or between FTI and body composition. Correlations were found between body composition and performance, both in total and stratified sample. BMI and fat percent correlated inversely with last minute VO_2 for total sample. More details can be found in appendix 4.

Multivariate regression analyses for hormones, physical performance, and body composition were conducted both for total and stratified sample. Numeric results from the regression analyses are included in appendix 5. Due to co-linearity with FTI, testosterone and SHGB variables were excluded from this analysis. Since fat percentage and LBM co-varies with BMI, BMI was removed in all regression analyses. Table 2 below show the main findings from both correlation and regression analyses.

Table 2 – Summary of primary findings

	FTI and body composition	FTI and physical performance	Body composition and physical performance
Pearson correlations	Total group: SS correlation between FTI and fat percentage. Soccer players: The SS correlation between FTI and fat percentage persisted.	NS.	Total group: SS correlations between BMI and sport discipline, and between fat percentage and sport discipline. Soccer players: SS correlation between fat percentage and squat jump height.
Multivariate regression analyses	NS.	NS.	Total group: SS association between fat percentage and sport discipline. Soccer players: SS association between fat percentage and squat jump height. Cross-country skiers: SS associations between last minute VO_2 and LBM, and between last minute VO_2 and fat percentage.

Abbreviations: SS= statistically significant, NS= not statistically significant

The multivariate regression analysis on squat jump height, adjusting for all hormones, body composition variables, and age showed no significant associations. However, when stratifying into sports group, there was a significant negative association between fat percentage and squat jump height in soccer players ($\beta = -0.551$, $p = 0.016$).

Multivariate regression analysis on last minute VO_2 of total sample, adjusted for all hormones, body composition variables, and age was also performed. Sport discipline was statistical significant associated with last minute VO_2. When stratifying in sport groups, negative associations was found between last minute VO_2 and LBM ($\beta = -1.144$, $p = 0.043$), as well as between last minute VO_2 and fat percentage (β-1.251, $p = 0.045$) in cross-country skiers.

In addition, multivariate analyses were conducted with the different body composition measures (fat percentage and LBM). None were significant using LBM as dependent variable. Sport discipline was statistically significant associated in multivariate regression analysis with fat percentage as dependent variable, adjusted for age, androgens, LBM and sport discipline.

DISCUSSION

Among the athletes in this sample there were no statistically significant associations between FTI and any of the body composition variables, or between FTI and any of the physical performance exercises. This contradicts previous research [6, 9]. There were some significant associations between body composition and physical performance, but the associations were mainly related to fat percent and sport discipline.

Previous research has shown that cytosine adenine guanine (CAG) repeat polymorphism within the androgen receptors, may determine the effectiveness of androgens [32]. Some studies claim that the length and number of androgen receptor CAG repeats, associates with PCOS [33, 34]. Skrgatic et al. [35] states that CAG repeat polymorphism in the androgen receptor gene is not directly associated with PCOS, but is a predictor for serum testosterone levels. This may partially explain the absence of associations in this study, as these components are not included.

Details of the findings will be discussed in the following sections, while Appendix 4 and 5 contains numeric details on the correlation and regression analyses.

The Association between FTI and Body Composition

There were no statistically significant associations between FTI and LBM, or between FTI and fat percentage among the athletes in this sample. However, Pearson correlations of total group show values relatively close to statistical significant between FTI and LBM. This tendency corresponds with other studies who have found associations between FTI and anabolic body composition [6, 8, 30]. In general these studies have a greater sample size than the present study.

There were negative tendencies between FTI and fat percentage in our sample of cross-country skiers. The skiers' fat percentages were relatively low, ranging between 12.5 – 19.1 %, with a mean of 15.8 %. This is beneath previously recommended values for females in the general population. Frisch [36] claims that there is evidence that necessary body fat percentages for regular ovulatory cycles in mature women exceed 26 %. In contrast to this statement, Loucks [37] state that ovulatory function depends more on energy balance than body fat mass, since menstrual function in some cases may regain long before an increase in body fat.

In this sample of soccer players FTI did not correlate with fat percentage. The mean BMI of 22.3 kg/m^2 in our sample of soccer players is perfectly within normal range of 18.5-24.99 kg/m^2, as defined by World Health Organization [38]. From other studies on hyperandrogenism we see that this sample of soccer players, rather than cross-country skiers, have androgen levels most similar to those in hyperandrogenic females [6, 8]. These tendencies implies higher mean values on androstenedione, testosterone, DHEAS, 17-OH-progesterone, and FTI, and lower on SHGB, in accordance with athletes with PCOS in Hagmar et al.'s study [8].

If the tendencies persist in a larger study sample with statistical significant results, it may indicate that the relationship between FTI and fat percentage is influenced by training and sport discipline. An interesting question in this regard is whether it would indicate that FTI enhance the right exercise-specific body composition. Androgens are associated with motivational balance and risk-taking behavior [39]. Accordingly one may assume that androgens promote will to exert necessary efforts to succeed. In endurance sports like cross-country skiing low fat is more important than high power, while soccer players are advantaged by versatile abilities as the sport demands certain levels of both explosive power and aerobic capacities [7, 40].

The Association between FTI and Physical Performance

Surprisingly, there were no statistical significant correlations between FTI and measured physical performance on either squat jump height or last minute VO_2.

These findings stand in contrast to a number of other studies who have found positive correlations between FTI and physical performance, both on power and aerobic capacity tests [6, 9, 10]. Storer et al. [10] states that testosterone correlates positively with maximal power, but does not affect fatigability. In Rickenlund et al.'s study [6] , hyperandrogenic females were performing better on VO_2 max and Beep test, as well as having higher lactate concentrations compared to normoandrogen athletes with MDs and regular menstruating athletes. Thus, these hyperandrogenic female athletes show higher ability to perform during physical tests, despite of lactate accumulation, which may indicate more persistent will. This is in accordance with androgens and lactate concentrations measured in our sample of soccer players, being higher than those of cross-country skiers. However, it is expected that skiers perform better on aerobic capacity tests due to the nature of their sport. Number of training sessions per week, years of training, and a number of other factors, may have more impact on physical performance than hormone levels [1, 5, 41, 42].

The Association between Body Composition and Physical Performance

When performing multivariate analyses with different body composition variables as dependent values, the statistically significant findings were related to sport discipline and fat percentage.

It was expected that LBM would associate positively with performance on squat jump height. Multivariate regression analysis showed virtually no associations. When stratifying into sport groups, a statistical significant inverse correlation between fat percentage and squat jump height in soccer players was found. In this sample of soccer players, fat percentage generally seems to associate more with the physical exercises, than LBM and FTI. This seems logic as fat mass may act as extra load to carry when jumping or running.

Stratified multivariate regression analysis of last minute VO_2, adjusting for all variables, show that LBM tend to associate negatively in cross-country skiers. This was relatively close to statistical significant level. LBM may increase the load one has to carry while running, and accordingly more work must be done. The tendency of negative association between BMI and running performance in this study (appendix 5) matches findings from several other studies [42, 43]. Emphasizing other factors than the latter studies, a comparison study between novice and experienced marathon athletes suggest that improved performance is associated with higher aerobic capacity and years of training rather than with body dimensions [44]. Physical performance may depend more on factors like previous and current training amounts covered, lactate threshold, and genetics [5, 41]. The cross-country skiers exercise more specific to increase aerobic capacity, compared to soccer players. The fact that age associated positively with last minute VO_2 in this sample of cross-country skiers, but not soccer players, may confirm that oxygen consumption to a large degree depend on aerobic training amount covered.

Strengths and Limitations of the Present Study

This study has involved comprehensive measurements conducted on each participant. All biochemical measurements followed the normal biochemical procedures at St. Olavs Hospital. Though the two sport disciplines investigated are quite different, a denominator between them is the fact that participation is related to performance capacities, not esthetic demands or weight classes. This results in a more comparable sample.

Time and resource limitations resulted in a small sample of participants, and they represented only two sport disciplines. As noted earlier, this study marks the beginning of a larger research program, and was dependent on the number of available athletes at the time. With comparison groups outside elite sport one might have found hormonal differences between top athletes and females doing recreational physical activity or sedentary females. Further, it is possible that this study is subject to selection bias. The characteristics of the athletes that choose to participate could differ from the ones that ignored or rejected the invitation.

Conclusion

Results in this study indicated that associations between circulating androgen levels, physical performance, and body composition, are not statistically significant. Significant associations were related to sport discipline and body composition, rather than the free testosterone index. This contradicts findings in other reports [6, 8], but the latter research was based on more heterogeneous samples of athletes, including also technical and esthetic disciplines. The sample in this study is more homogenous, which may explain why some of the differences from previous studies were not confirmed in the present study.

Stratified multivariate regression analyses yielded significant results related to body composition, basically showing that higher fat percentage has negative effect for jump performance in soccer players, and that both fat percentage and LBM are negative factors for VO_2 max in cross-country skiers. These findings are intuitively reasonable. When comparing differences in body composition and physical performance between sport disciplines, it is reasonable to assume that type, amount, and intensity of training may influence more than hormone levels. However, these exercises measured in this study do not necessarily predict the athletes' performance in the sport where they compete.

Recommendations for further research include increased sample size in longitudinal studies and random clinical trials. In addition athletes from different sport disciplines should be included, as well as comparison groups with lower physical activity levels. It is also important to study genetic and behavior factors' effect on physical performance, body composition, and circulating androgens.

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APPENDICES

Appendix 1 – Information Letter

Forespørsel om deltagelse i forskningsprosjekt:

”The Female Competitiveness Study” – er det sammenheng mellom hormonnivåer og konkurranseinstinkt hos kvinnelige toppidrettsutøvere?

Bakgrunn og hensikt

Toppidrettsutøvere presser sin fysiske og psykiske kapasitet til det ytterste. De fysiske og psykiske aspektene og sammenhengen med hormonnivåer har vært studert tidligere, spesielt hos menn. Sammenhengen mellom hormonnivåer, fysisk kapasitet og mentale faktorer hos kvinner er derimot lite studert.

Nivået av androgene hormoner (hormoner med testosteronvirkning) og spesielt testosteron er noe forhøyet hos kvinner med polycystisk ovarialsyndrom (PCOS). Kvinner med PCOS utgjør 10-15 % av kvinner i fruktbar alder, de synes å ha høyere konkurranseinstinkt og delta mer i idrett enn kvinner uten PCOS. Det synes også å være en svak sammenheng mellom PCOS, humørsvingninger og spiseadferd. Vi tror mye av dette kan ha sammenheng med de noe økte nivåene av hormoner med testosteronvirkning og at kvinner med økte testosteronnivå i spesiell grad trekkes mot idrett generelt og toppidrett spesielt.

Vi henvender oss til deg fordi du er en kvinnelig toppidrettsutøver for å be om ditt samtykke til deltakelse i dette forskningsprosjektet. Formålet med studien er å få økt kunnskap om sammenhengen mellom hormonnivåer hos kvinnelige toppidrettsutøvere og konkurranseinstinkt, muskelmasse, fysisk kapasitet, beintetthet, mentale forhold inkludert seksuell orientering og forekomsten av PCOS. Studien er et samarbeidsprosjekt mellom Avdeling for endokrinologi, St. Olavs hospital, Institutt for Bevegelsesvitenskap og Psykologisk Institutt, Norges teknisk-naturvitenskaplige universitet (NTNU) og Olympiatoppen Midt-Norge. Denne forespørselen går til toppidrettskvinner mellom 18 og 40.

Hva innebærer deltagelse i studien?

Den enkelte deltager vil få utført en DEXA-scan og taking av fastende blodprøve ved Avdeling for endokrinologi, St. Olavs hospital. Ved DEXA-scan ligger man stille i truse på ryggen i 10 minutter og det hele er helt smertefritt. Ved denne undersøkelsen bestemmes fettmasse, muskelmasse, beinmasse og beintetthet. I tillegg besvares spørreskjema om konkurranseinstinkt, spenningssøking, spiseadferd, mental helse og seksuell orientering. Vi vil også registrere resultatene fra fysiske tester (VO_2 max, laktat, maksimal muskelkraft ved spensthopp og benkpress). Medisinbruk, spesielt hormonpreparater (p-pille, p-stav, p-sprøyte, hormonspiral etc.) vil bli registrert.

I tillegg håper vi å kunne tilby en gynekologisk undersøkelse for deltagerne i studien.

Mulige fordeler og ulemper

Som deltager har du mulighet til å bidra til ny kunnskap om sammenhengen mellom forhold knyttet til idrettsprestasjoner og toppidrettskvinners helse. Deltagelse i prosjektet medfører testing og analyse av blant annet beintetthet og muskelmasse. Lav beintetthet og menstruasjonsforstyrrelser kan være et problem hos kvinner som trener mye. Dersom dette påvises kan fagpersonene i prosjektgruppen vurdere spesielle tiltak dersom du ønsker det.

Opplever du noen av spørsmålene som ubehagelige er det greit å unnlate å besvare dem. Data vil uansett ikke kunne spores tilbake til enkeltpersoner etter at de er registrert i en database. Vi har dessverre ikke anledning til å gi deltagerne økonomisk kompensasjon så deltagere i prosjektet må selv dekke eventuelle reiseutgifter.

Den fysiske testingen vil bli gjennomført etter standard prosedyrer for slik fysiologisk testing og risikoen for at noe kan skje er minimal. VO_2 max kan oppleves som anstrengende, men gi nyttig informasjon som kan brukes til videre treningsplanlegging. Prestasjonstester vil også være standard og gjennomføres i tråd med trening du som utøver gjennomfører til daglig. Den eneste reelle forskjellen fra den daglige trening og testing er at dataene fra testene vil bli systematisert og lagret for brukt i prosjektet.

Viktig! Dine forberedelser

Blodprøvene vil bli tatt om morgenen, og du må faste 8 timer (dvs. fra midnatt) i forkant (inkludert røyk/snus-avhold). Dersom du er veldig tørst kan du evt. drikke et halvt glass vann morgenen før prøvene tas.

Hva skjer med testene og informasjonen om deg?

Dine resultater fra undersøkelsene vil bli behandlet i ikke identifiserbar form, dvs. uten navn, fødselsnummer eller andre identifiserende opplysninger. En kode knytter deg til dine opplysninger og prøver, gjennom en navneliste. Denne koden oppbevares uavhengig av selve databasen med alle opplysningene fra studien. Det er kun autorisert helsepersonell knyttet til prosjektet som har adgang til navnelisten og som eventuelt kan finne tilbake til deg. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres. Når prosjektet er avsluttet vil også koden som knytter deg til enkeltdata i databasen slettes.

Dersom du ønsker det kan vi gi deg tilbakemelding på testresultatene (som for eksempel kroppssammensetning, VO_2 max, styrketestene, og evt. gynekologisk undersøkelse). Vi kan eventuelt også informere om eventuelle andre helseproblemer vi måtte påvise ved de undersøkelsene du gjennomgår. Dette vil foregå ved studiemedarbeiderne (kroppssammensetning, VO_2 max, styrketestene) eller lege (gynekologisk undersøkelse, beintetthet, evt. andre forhold). Olympiatoppen, trenere eller andre vil ikke på noe tidspunkt få tilgang til informasjon om enkeltpersoner utover resultater fra de fysiske testene Olympiatoppen får tilgang på slik de gjør ved tilsvarende rutinetesting av utøvere.

Studien er vurdert og godkjent av Regional komité for medisinsk forskningsetikk, Midt-Norge og vil bli gjennomført etter de regler og retningslinjer som er nedfelt i Helsinkideklarasjonen. Når studien er avsluttet vil resultatene bli publisert i et engelskspråklig internasjonalt medisinsk tidsskrift.

Frivillig deltakelse

Studien er frivillig, du kan på hvilken som helst tidspunkt trekke deg uten nærmere begrunnelse eller uten at det får noen negative konsekvenser for deg. Dette gjelder selvfølgelig også videre oppfølging fra Olympiatoppen. Dersom du trekker deg fra studien har du rett til innsyn i data registrert om deg. Du kan også trekke tilbake samtykket. Da vil alle innsamlede opplysninger om deg bli slettet og frosne blodprøver vil bli destruert med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskaplige publikasjoner.

Vi ber også om tillatelse til eventuelt å kontakte deg senere for oppfølgning. Dette er kun en forespørsel om vi får lov å ta kontakt med deg senere og ikke noe løfte fra deg om at du vil stille opp. Dette er ingen forutsetning for å delta i studien. Hvis du samtykker i å delta i studien må du undertegne en samtykkeerklæring lik den som er vedlagt før du deltar. Personopplysninger som knytter deg til data vil bli oppbevart til utgangen av 2014 og deretter slettet.

Personvern

Opplysninger som registreres om deg er:

- Helseopplysninger som du selv gir oss
- Opplysninger om din aktuelle medisinbruk
- Resultater av blodprøveanalyser som tas
- Opplysninger om de tester og undersøkelser du gjennomgår
- Svar på de spørreskjema du besvarer
- Enkle kliniske data (høyde, vekt, blodtrykk etc.)

Opplysningene legges inn i en database ved Enhet for anvendt klinisk forskning, NTNU i avidentifisert form, dvs. ikke med ditt navn eller fødselsnummer men kun med ditt deltagernummer.

Alt personell som er involvert i studien og behandlingen av innsamlede data har taushetsplikt.

Representanter for kontrollmyndigheter kan få utlevert studieopplysninger og gis innsyn i relevante deler av din journal. Dette er lovpålagt. Formålet er å kontrollere at studieopplysningene stemmer overens med tilsvarende opplysninger i din journal. Alle som får innsyn i informasjon om deg har taushetsplikt.

Forskningsbiobank

Blodprøvene som blir tatt og informasjonen utledet av dette materialet vil bli lagret i en forskningsbiobank som professor Sven M. Carlsen er ansvarlig for. De vil bli lagret i ikke personidentifiserbar stand, dvs. bare identifisert med deltagernummer.

Utlevering av materiale og opplysninger til andre

Hvis du sier ja til å delta i studien, gir du også ditt samtykke til at prøver og avidentifiserte opplysninger kan utleveres til våre samarbeidspartnere i forskning.

Innsynsrett og oppbevaring av materiale

Hvis du sier ja til å delta i studien, har du rett til å få innsyn i hvilke opplysninger som er registrert om deg. Du har videre rett til å få korrigert eventuelle feil i de opplysningene vi har registrert.

Dersom du trekker deg fra studien, vil det ikke samles inn flere opplysninger eller mer materiale. Opplysninger som allerede er innsamlet fra deg vil ikke bli slettet.

Finansiering

Studien og biobanken er søkt finansiert av forskningsmidler fra Olympiatoppen og forskningsmidler som professor Sven M. Carlsen har innestående ved Unimed Innovation. Sponsor (ansvarlig myndighet for studien) er Institutt for kreftforskning og molekylærmedisin, NTNU.

Forsikring

Du er forsikret gjennom Pasientskadeerstatningsordningen.

Med vennlig hilsen

____

Sven M. Carlsen

Professor dr. med. Prosjektleder

Prosjektledelse:

Prosjektleder og medisinsk ansvarlig: Sven M. Carlsen, professor, spesialist i indremedisin og endokrinologi,

Enhet for anvendt klinisk forskning, NTNU og Avdeling for endokrinologi, St. Olavs hospital Email: sven.carlsen@ntnu.no, Tlf: 73550263, Mobil: 91769528

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Appendix 2 – Declaration of Consent

SAMTYKKEERKLÆRING

For deltakeren:
Jeg bekrefter med dette at jeg har fått den informasjon jeg ønsker om og er villig til å delta i ***"The Female Competitiveness Study"***. Jeg vet at jeg uten nærmere begrunnelse kan trekke med fra studien på et hvert tidspunkt dersom jeg skulle ønske det uten at det vil ha konsekvenser for meg. Jeg er klar over at de innsamlede data brukes utelukkende til forskning og eventuell egen nytte ved økt kunnskap om meg selv.

Jeg samtykker i å delta i prosjektet som innebærer følgende:

- Testing av fysisk kapasitet (maksimal muskelkraft og VO_2max)
- Dexa-scan av kroppssammensetning
- Blodprøvetaking for hormonanalyser
- Spørreskjema angående konkurranseinstinkt, spenningssøking, spisevaner, mental helse og seksuell orientering
- Gynekologisk undersøkelse (ingen betingelse for å delta i resten av studien)
- Enkel klinisk undersøkelse (høyde, vekt, blodtrykk etc.)
- Fotokopi av hendene

Dersom du godkjenner at vi kontakter deg for eventuell oppfølgende forskning på et senere tidspunkt, vennligst kryss av her: ☐

Dersom du ønsker å bli kontaktet dersom blodprøver eller andre av undersøkelsene gir mistanke om spesielle medisinske problemer hos deg, vennligst kryss av her: ☐

Sted:______________________________ Dato:___/___- 2011

Navn:____
(Deltakers fulle navn med BLOKKBOKSTAVER)

____
Deltagers underskrift

Jeg bekrefter med dette at deltageren har fått muntlig og skriftlig informasjon om studien, har fått svar på de muntlige spørsmål hun hadde og har underskrevet på denne deltagerformasjonen:

Sted: ____________________________ Dato:___/___- 2011

Studiemedarbeider: ____

Ansvarlige lege for undersøkelsen:Sven M. Carlsen, Professor, Enhet for anvendt klinisk forskning, NTNU, Overlege, Avdeling for endokrinologi, St. Olavs hospital

Appendix 3 – Approval from the Regional Ethics Committee

Below is the approval from Regional Ethics Committee, Mid-Norway, recieved October 2011.

2011/1460 Konkurranseinstinkt hos toppidrettsutøvere

Prosjektleder: Professor Sven Magnus Carlsen

Forskningsansvarlig: St. Olavs Hospital, Medisinsk klinikk v/klinikksjef Eiliv Brenna

Med hjemmel i lov om behandling av etikk og redelighet i forskning § 4 og helseforskningsloven (hfl.) § 10 har Regional komité for medisinsk og helsefaglig forskningsetikk Midt-Norge vurdert prosjektet i sitt møte 21. oktober 2011. Komiteen viser til prosjektprotokoll, målsetting og plan for gjennomføring, og finner at prosjektet har et forsvarlig opplegg som kan gjennomføres under henvisning til evt. merknader og vilkår for godkjenning, jf. hfl. § 5.

Merknader og vilkår:

- -Komiteen ber om at grunnlagsdata ikke blir anonymisert, slettet eller destruert, men blir oppbevart på en betryggende måte i minimum 5 år etter prosjektslutt av kontrollhensyn. Instanser som kan tenkes å kontrollere grunnlagsmaterialet er f.eks. forskningsansvarlige, Uredelighetsutvalget for forskning og Helsetilsynet.
- -Komiteen minner om at de aller fleste kliniske studier skal registreres i det offentlig tilgjengelige registeret www.clinicaltrials.gov. Prosjektleder er ansvarlig for å avgjøre om forskningsstudien omfattes av kravet til registrering.
- -Prosjektleder skal sende sluttmelding til den regionale komiteen for medisinsk og helsefaglig forskningsetikk når forskningsprosjektet avsluttes. I sluttmeldingen skal resultatene presenteres på en objektiv og etterrettelig måte, som sikrer at både positive og negative funn fremgår, jf. hfl. § 12.

Vedtak

”Regional komité for medisinsk og helsefaglig forskningsetikk, Midt-Norge godkjenner at prosjektet gjennomføres med de vilkår som er gitt.”

Vennlig hilsen

Sven Erik Gisvold

Professor, dr.med.

Leder, REK midt

Arild Hals

Appendix 4 – Pearson Correlation Analyses

Below is the Pearson correlations analysis of total group, showing how the hormones covariates with body composition and physical performance, and how the different body composition variables covariate with each other. The statistically significant values are marked by ** and with red colour.

		Age	BMI	Lean total	Fat total %	Squat Jump height cm	LastMINVO2	Gruppe12
Age	Pearson Correlation	1	-,004	,184	-,246	,116	-,113	,003
	Sig. (2-tailed)		,984	,315	,175	,513	,532	,985
BMI	Pearson Correlation	-,004	1	,625**	,640**	,125	-,412*	-,440**
	Sig. (2-tailed)	,984		,000	,000	,482	,017	,009
Lean total	Pearson Correlation	,184	,625**	1	,050	,134	-,080	-,087
	Sig. (2-tailed)	,315	,000		,785	,463	,670	,635
Fat total %	Pearson Correlation	-,246	,640**	,050	1	-,079	-,631**	-,617**
	Sig. (2-tailed)	,175	,000	,785		,669	,000	,000
17_OH-progesteron (nmol/L)	Pearson Correlation	-,051	,438*	,413*	,316	,007	-,367*	-,301
	Sig. (2-tailed)	,780	,012	,019	,078	,968	,043	,094
Testosteron (nmol/L)	Pearson Correlation	-,071	,262	,325	,246	-,052	-,286	-,215
	Sig. (2-tailed)	,698	,148	,069	,175	,777	,119	,238
SHBG (nmol/L)	Pearson Correlation	-,230	,004	-,232	,177	,069	,227	,059
	Sig. (2-tailed)	,205	,982	,202	,333	,709	,218	,748
Androstendion (nmol/L)	Pearson Correlation	,057	,059	,330	,035	,000	-,259	-,144
	Sig. (2-tailed)	,756	,747	,065	,851	,999	,159	,433
DHEAS (mikromol/L)	Pearson Correlation	-,131	,372*	,431*	,163	,208	-,186	-,273
	Sig. (2-tailed)	,476	,036	,014	,373	,253	,317	,131
FTI (testosteron * 10/SHBG)	Pearson Correlation	,094	,135	,325	,094	,072	-,321	-,245
	Sig. (2-tailed)	,608	,461	,070	,610	,695	,079	,177

Pearson correlations of stratified group below show how the hormones correlate with body composition and physical performance, and how the different body composition variables covariate with each other.

Sport			Age	BMI	Lean total	Fat total %	Squat Jump height cm	LastMIN VO2
Soccer	Age	Pearson Correlation	1	-,024	,132	-,346	,203	-,246
		Sig. (2-tailed)		,908	,548	,106	,329	,246
	BMI	Pearson Correlation	-,024	1	,728**	,547**	-,031	-,074
		Sig. (2-tailed)	,908		,000	,007	,883	,732
	Lean total	Pearson Correlation	,132	,728**	1	,137	,176	-,032
		Sig. (2-tailed)	,548	,000		,533	,422	,887
	Fat total %	Pearson Correlation	-,346	,547**	,137	1	-,502*	-,257
		Sig. (2-tailed)	,106	,007	,533		,015	,248
	17_OH-progesteron (nmol/L)	Pearson Correlation	,033	,391	,553**	,217	-,128	-,210
		Sig. (2-tailed)	,882	,065	,006	,320	,560	,347
	Testosteron (nmol/L)	Pearson Correlation	-,204	,220	,257	,325	-,107	-,186
		Sig. (2-tailed)	,350	,313	,237	,131	,628	,407
	SHBG (nmol/L)	Pearson Correlation	-,265	-,016	-,267	,229	,138	,344
		Sig. (2-tailed)	,222	,943	,219	,293	,531	,117
	Androstendion (nmol/L)	Pearson Correlation	-,014	-,003	,300	,086	,061	-,301
		Sig. (2-tailed)	,949	,990	,164	,695	,783	,173
	DHEAS (mikromol/L)	Pearson Correlation	-,140	,340	,438*	,134	,254	-,001
		Sig. (2-tailed)	,524	,112	,037	,541	,243	,997
	FTI (testosteron * 10/SHBG)	Pearson Correlation	,078	,063	,318	,003	,029	-,220
		Sig. (2-tailed)	,724	,776	,139	,991	,894	,324
Cross-country skiing	Age	Pearson Correlation	1	,165	,453	-,084	-,220	,119
		Sig. (2-tailed)		,671	,221	,831	,570	,760
	BMI	Pearson Correlation	,165	1	,215	,368	,427	-,462
		Sig. (2-tailed)	,671		,579	,330	,252	,211
	Lean total	Pearson Correlation	,453	,215	1	-,588	-,112	-,147
		Sig. (2-tailed)	,221	,579		,096	,774	,707
	Fat total %	Pearson Correlation	-,084	,368	-,588	1	,352	-,447
		Sig. (2-tailed)	,831	,330	,096		,353	,228
	17_OH-progesteron (nmol/L)	Pearson Correlation	-,464	,085	-,355	-,014	,158	-,161
		Sig. (2-tailed)	,208	,828	,348	,972	,685	,680
	Testosteron (nmol/L)	Pearson Correlation	,511	,016	,565	-,485	-,127	-,128
		Sig. (2-tailed)	,160	,968	,113	,186	,744	,743
	SHBG (nmol/L)	Pearson Correlation	-,035	,485	,003	,507	-,159	-,044
		Sig. (2-tailed)	,928	,186	,994	,163	,682	,911
	Androstendion (nmol/L)	Pearson Correlation	,345	-,029	,414	-,558	-,328	,068
		Sig. (2-tailed)	,364	,940	,268	,118	,388	,862
	DHEAS (mikromol/L)	Pearson Correlation	-,067	-,127	,357	-,696*	-,315	,206
		Sig. (2-tailed)	,864	,746	,346	,037	,409	,595
	FTI (testosteron * 10/SHBG)	Pearson Correlation	,299	-,354	,313	-,574	-,088	,004
		Sig. (2-tailed)	,435	,350	,412	,106	,822	,992

Appendix 5 – Multivariate Regression Analyses

The two first regression analyses are Squat jump height (cm), adjusted for all androgens, body composition and age, for total and stratified sample.

Coefficients[a]

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	37,007	14,543		2,545	,018
Age	,116	,272	,087	,426	,674
Lean body mass total	6,767E-5	,000	,064	,301	,766
Fat % total body	-,488	,335	-,356	-1,457	,158
Androstendion (nmol/L)	-,257	,488	-,154	-,526	,604
DHEAS (mikromol/L)	,674	,734	,229	,918	,368
FTI	-1,837	14,086	-,041	-,130	,897
Sport discpline	-4,555	2,578	-,433	-1,767	,090

a. Dependent Variable: Squat Jump height (cm)

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients		
Sport	Model	B	Std. Error	Beta	t	Sig.
Cross-country	(Constant)	2,800	58,848		,048	,966
	Age	-,943	1,229	-,609	-,767	,523
	Lean body mass total	,001	,001	,558	,728	,542
	Fat % total body	1,056	1,513	,600	,698	,558
	Androstendion (nmol/L)	-,523	1,817	-,332	-,288	,800
	DHEAS (mikromol/L)	-2,094	4,885	-,513	-,429	,710
	FTI	68,865	72,871	,894	,945	,444
Soccer	(Constant)	32,036	12,634		2,536	,022
	Age	,159	,261	,129	,609	,551
	Lean body mass total	,000	,000	,112	,510	,617
	Fat % total body	-,919	,342	-,551	-2,688	,016
	Androstendion (nmol/L)	,420	,520	,254	,807	,431
	DHEAS (mikromol/L)	1,172	,674	,424	1,739	,101
	FTI	-17,689	13,775	-,437	-1,284	,217

a. Dependent Variable: Squat Jump height (cm)

These regression analyses show Last Minute VO_2, adjusted for all androgens, body composition and age, for total and stratified sample.

Coefficients[a]

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	60,978	10,801		5,646	,000
Age	-,250	,194	-,158	-1,293	,209
Lean body mass total	3,713E-5	,000	,029	,224	,825
Fat % total body	-,474	,245	-,283	-1,936	,065
Androstendion (nmol/L)	-,263	,351	-,132	-,750	,461
DHEAS (mikromol/L)	,313	,540	,088	,580	,568
FTI	-3,794	10,159	-,071	-,373	,712
Sport discipline	7,645	1,836	,612	4,164	<,000

a. Dependent Variable: Last Minute VO2

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients		
Sport		B	Std. Error	Beta	t	Sig.
Cross-country	(Constant)	110,177	12,478		8,830	,013
	Age	,952	,261	,930	3,652	,067
	Lean body mass total	-,001	,000	-1,144	-4,659	,043
	Fat % total body	-1,456	,321	-1,251	-4,536	,045
	Androstendion (nmol/L)	-,299	,385	-,286	-,776	,519
	DHEAS (mikromol/L)	1,720	1,036	,637	1,660	,239
	FTI	-43,669	15,451	-,857	-2,826	,106
Soccer	(Constant)	68,785	11,521		5,970	,000
	Age	-,374	,227	-,401	-1,645	,121
	Lean body mass total	,000	,000	,164	,648	,527
	Fat % total body	-,464	,306	-,355	-1,518	,150
	Androstendion (nmol/L)	-,449	,460	-,352	-,976	,344
	DHEAS (mikromol/L)	,173	,601	,081	,287	,778
	FTI	-,322	12,071	-,010	-,027	,979

a. Dependent Variable: Last Minute VO2

The two last tables show the multivariate regression analyses of fat percentage, adjusted for age, androgens, LBM and sport discipline, for total and stratified sample.

Coefficients[a]

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	28,878	6,480		4,456	,000
Age	-,244	,155	-,251	-1,573	,128
Lean body mass total	6,067E-5	,000	,079	,454	,654
Androstendion (nmol/L)	-,052	,291	-,043	-,178	,860
DHEAS (mikromol/L)	-,120	,438	-,056	-,274	,786
FTI	,117	8,407	,004	,014	,989
Sport discipline	-4,789	1,205	-,625	-3,975	,001

a. Dependent Variable: Fat % total body

Coefficients[a]

Sport		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Cross-country	(Constant)	32,521	12,310		2,642	,078
	Age	,103	,465	,117	,221	,840
	Lean body mass total	,000	,000	-,462	-1,051	,371
	Androstendion (nmol/L)	,157	,687	,175	,229	,834
	DHEAS (mikromol/L)	-1,075	1,757	-,463	-,612	,584
	FTI	-12,124	26,906	-,277	-,451	,683
Soccer	(Constant)	20,386	7,475		2,727	,014
	Age	-,260	,174	-,351	-1,491	,154
	Lean body mass total	,000	,000	,177	,690	,500
	Androstendion (nmol/L)	,132	,368	,134	,360	,723
	DHEAS (mikromol/L)	,053	,478	,032	,112	,912
	FTI	-3,608	9,732	-,149	-,371	,715

a. Dependent Variable: Fat % total body