Possible Hormone Predictors of Physical Performance in Adolescent Team Sport Athletes

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THE RELATIONSHIP BETWEEN SALIVARY STEROID HORMONE CONCENTRATIONS AND PHYSICAL PERFORMANCE IN YOUTH TEAM SPORT ATHLETES

HORMONE-PHYSICAL PERFORMANCE RELATIONSHIPS IN TEAM SPORT ATHLETES

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ABSTRACT

The research aim of this study was to determine possible hormone predictors of physical performance in adolescent team sport athletes. Saliva samples were collected immediately prior to performance testing sessions from 114 state squad athletes (77 male, 37 female) participating in either Australian football, basketball, hockey, or netball. Participants completed tests of aerobic and anaerobic capacity, agility, power and speed. Samples were collected over 22 months at quarterly, six-monthly and/or yearly intervals depending on the testing schedule of the athlete. Saliva was analysed for testosterone (T), cortisol (C), estradiol (E) and progesterone (P) levels. A strong negative correlation existed between multistage fitness test performance and T:E ratio (r=-0.76, p=0.01) in females not taking oral contraceptives and a strong positive correlation existed between repeat agility total time and estradiol levels (r=-0.71, p=0.001) in females taking oral contraceptives. In males, strong negative correlations were evident for individual changes in planned agility time and estradiol levels (r=0.87, p=0.02), and CMJ height and T:C (r=-0.88, p=0.01). In females taking oral contraceptives a strong positive correlation was noted between individual change in yo-yo intermittent recovery test performance and T:E (r=0.74, p=0.01) and a strong negative correlation was noted between 20m speed and T:P (r=0.73, p=0.01). In females not taking oral contraceptives a strong negative correlation was found between individual change in CMJ height and T:P (r=-0.72, p=0.02). The findings show that in adolescent team sport athletes the P:E, T:E and the T:P ratios are important predictors of performance in tests of physical capacity. The findings also indicate estradiol and progesterone have a predictive function in the physical performance of adolescent male team sport athletes.

Keywords: Testosterone; estradiol; progesterone; Cortisol; exercise

INTRODUCTION

Team sports, such as Australian football (AF), basketball, field hockey and netball, require athletes to perform game related skills in combination with various movement patterns. These include rapid accelerations, decelerations and changes of direction, often with jumping or leaping movements, sustaining high levels of intensity with little opportunity for sufficient recovery (19). Talented adolescents (aged 15-19 years) involved in team sports often represent school and club teams at numerous levels, as well as completing training commitments for state teams, and in some cases state institutes or academies (4). Training loads are not often co-ordinated across different commitments potentially exposing athletes to high physical and psychological loads (4). Selection into national squads even as a junior athlete often results in talented adolescent athletes competing year round without an off-season. Traditionally, monitoring of adolescent athletes to predict performance, injury risk, or overtraining/overreaching has involved training diaries and physical test batteries. These methods add an additional load to athletes who may already be at risk of being overloaded. Saliva analysis of specific hormones related to performance provides another possible tool for monitoring adolescent athletes.

The use of biochemical markers for both short term and long term monitoring of exercise stress is widespread in adults. Testosterone and cortisol levels and the testosterone to cortisol ratio (T:C ratio) have been identified as markers of training stress (20). A decrease in testosterone levels and an increase in cortisol levels, or a reduction in the T:C ratio, is thought to indicate an increase in catabolic activity, representative of a state of overstrain or insufficient recovery (20). Increases in performance however have been identified in professional soccer players during high intensity training despite a significant decrease in salivary T:C of over 30% (10). The authors suggested that a decrease in T:C ratio may not necessarily lead to a decrease in performance or a state of overtraining, but instead may reflect an optimal state (10). During adolescence steroid hormone secretion is increased to meet the developmental demands of the body (Kerrigan & Rogol 1992). Increased demands on the hormones during adolescence may result in different relationships between changes in hormone levels and changes in performance in adolescents than in adults. In adolescent soccer athletes changes in testosterone levels have positively correlated with changes in countermovement jump height (CMJ) (r=0.48), drop jump height (r=0.40) and relative VO2max: (r=0.32) and a negatively correlated with changes in 30-m sprint speed (=0.34) (16). These results suggest that testosterone levels may influence performance in adolescent athletes but more research is needed to confirm this result and to identify if other hormones also influence performance.

In addition to their use as biomarkers in the monitoring of exercise stress, steroid hormones have been identified as predictors of motor performance. Testosterone has been identified as a predictor of countermovement jump (CMJ) performance (33%) and yo-yo intermittent recovery test (yo-yo) performance (21%) in adolescent male soccer athletes (13). Testosterone was also identified as a predictor of CMJ performance (16%) in adolescent male Australian Football athletes however had no relationship with multistage fitness test (MSFT), speed or agility performance (14). In the adolescent male Australian Football athletes progesterone and estradiol were both identified as predictors of speed and agility, though predictive power was greatest when both hormones were factored into the analysis (10m speed: 19.1%, 20m speed: 20.2% and agility: 30.9%) (14). The above studies suggest that pre-exercise hormone levels may be related to motor performance in adolescent team sport athletes however, more information is needed in this area particularly on female participants.

This study had two main aims: firstly to establish whether a predicitive relationship exists between salivary hormone (testosterone, cortisol, estradiol and progesterone) levels and physical performance in state level adolescent team sport athletes, and secondly, to assess if individual changes in hormone levels provided stronger predictive markers of changes in physical capacity than baseline values alone. Three hypothesises were developed. 1. Progesterone level would be a predictor of speed, and progesterone, estradiol and the progesterone to estradiol ratio (P:E ratio) would be a predictor of agility. 2. Testosterone levels and the T:C ratio would be predictors of endurance and power. 3. Stronger hormone predictors of performance would be evident when individual changes in hormone levels and motor performance were analysed than when predictors were calculated for the pooled data.

METHODS

Experimental approach to the problem

The aim of this prospective cohort design was to establish hormonal predictors of physical performance in state-level adolescent team sport athletes. We utilized athletes that were undergoing their routine testing by the Tasmanian Institute of Sport (TIS).

Between April 2013 and February 2015 team sport athletes were evaluated at their pre-scheduled physical testing sessions. Information on the frequency of testing and the tests completed by each sporting group is listed in table 1. The physical performance tests were selected and conducted according to the national protocols for each sport (19) and were administered by the TIS physiologists assigned to that sport by the TIS. Although not included in the national protocol netball athletes also completed a repeat agility test and AF athletes completed an isometric handgrip test for strength.

Participants arrived at the testing venue at approximately 10am. Upon arrival at the testing venue participants completed anthropometry testing then provided a saliva sample. Participants completed a warm-up of approximately 15 minutes consisting of low-intensity running followed by a series of dynamic warm-up exercises including lunge walks, butt-kicks and leg swings and then short accelerations. Participants then completed the physical tests in the order listed in table 1.

TABLE 1 ABOUT HERE

Prior to actual testing, participants were thoroughly familiarized with all testing equipment and procedures. For all testing days, participants were asked to refrain from exhaustive physical activity for 48 hours preceding testing.

Subjects

One hundred and fourteen (n=114) adolescent athletes were recruited to participate in this study (mean ± standard deviation; Male n = 77, age 16.87 ± 1.2 y, height 184.5 ± 6.6 cm, body mass 77.1 ± 6.5 kg; Female n = 37, age 16.4 ± 1.1 y, height 175.0 ± 5.9 cm, body mass 68.9 ± 9.8 kg). All participants were members of the TIS or their state sporting organisation representative squads for either AF, basketball, hockey or netball. Participants were included if they were uninjured and free from any medical conditions. Details of hormonal contraceptive use, including the type and brand of contraceptive, was obtained with the participant's permission from the TIS athlete database. The study was approved the Charles Darwin University Human Research Ethics Committee (Approval Number: H12155). The subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study. Parental or guardian signed consent was also obtained when participants were under the age of 18 years of age.

Procedures

Anthropometry: Body mass and height were measured with standard techniques to the nearest 0.1 cm and 0.1 kg, respectively for each participant. To estimate adiposity, skinfold thicknesses were measured at seven sites on the right side of the body (triceps, biceps, subscapular, supraspinale, abdominal, calf and thigh) using a Harpenden skinfold caliper (British Indicators Ltd., Luton). The same International Society for the Advancement of Kinanthropometry (ISAK) accredited investigator took all measurements at each test occasion.

Countermovement Jump (CMJ): CMJ height was used as a test of explosive leg power and was determined with Yardstick© jumping device (Swift, Brisbane, Australia). Participants were required to stand with their feet together side on to the Yardstick©. Keeping their heels on the floor and looking straight ahead, they were required to reach upward with their dominant hand as high as possible, fully elevating the shoulder to displace the Yardstick© vanes. This value was recorded as the reach height. The participant then performed a CMJ with no preliminary steps (except for the basketball athletes who as per the national protocol were permitted one preliminary step) or shuffling with the aim of displacing the highest vane possible. At least three trials were performed with the participant continuing to jump when they felt they were ready until missing three consecutive times. The highest vane displaced was recorded as the jump height. CMJ height was then calculated as the difference between reach height and jump height (cm). TIS reliability scores are high for this test where ICC is r = 0.89.

Sprints: The participants were instructed to run as fast as possible in a straight line through electronic light gates (Fusion Sports, Australia, serial number 70019522) spaced at 10, 30 and 40m on a synthetic turf for field hockey athletes and spaced at 5, 10 and 20m on an indoor wooden basketball court for AF, basketball and netball athletes. Participants were instructed to start from a stationary position with their front foot touching the edge of the start line and to ensure that their first movement was in the forward direction (i.e. no rocking). Participants were able to start in their own time once they were informed that the timing system was ready and were instructed not to slow down until they were 5m past the final timing gate. Sprint times began when the participant passed the laser positioned across the start line and concluded when they passed the laser positioned across the final marker. The fastest 5, 10 and 20m time for the AF basketball and netball athletes and the fastest 10 and 40m time for the hockey athletes was used for analysis. TIS reliability scores are high for this test where ICC is r = 0.97.

Multistage Fitness Test (MSFT): The MSFT was used as a measure of aerobic endurance in the AF and hockey athletes. Participants were required to run back and forth on a measured 20m synthetic turf hockey field track keeping in time with a series of audio signals from an mp3 provided by the Australian Institute of Sport and validated against the MSFT compact disc (Australian Coaching Council, Belconnen, ACT, 1998). Each end on the 20m track was marked with cones. A test administrator was positioned at each line to ensure that the athlete placed a foot on or over the line before the audio signal and to ensure that the participant did not attempt the next shuttle until the audio signal had sounded. Participants received a warning the first time they failed to reach the line before the audio signal and were eliminated the second consecutive time. The total distance covered in metres that was reached in time with the audio signal was recorded as their final score. TIS reliability scores are high for this test where ICC is r = 0.97.

Yo-yo Intermittent Recovery Test (yo-yo): The yo-yo test was used as a measure of aerobic endurance in the basketball and netball athletes. Participants were required to run 40m on an out and back course (20 m each way turning around at a line marked by cones) in time with an audio recording. Upon reaching the start point, the participants were to walk around a set of cones 5m away before returning to the start line to await the next audio cue indicating to begin the next shuttle. The time between the audio cues gradually decreased. Participants received a warning the first time they failed to reach the start line before the audio signal and were eliminated the second time. The total distance covered in metres was recorded as their final score. TIS reliability scores for this test are r = 0.75.

Sit and Reach: The sit and reach test was used as s a measure of combined hamstring and spinal flexibility in the basketball athletes. Participants were required to sit on the floor with their legs extended out in front of them placing their bare feet against the edge of the sit and reach box (Flextester, Novel Products, Illinois USA). Keeping one hand directly on top of each other the participant was then required to slide their hands along the top of the sit and reach box and hold the end-stretch for two seconds whilst maintaining straight legs. The distance of the fingers past the toes as marked on the sit and reach box was recorded to the nearest 0.5cm. TIS reliability scores are high for this test where ICC is r = 0.98.

Basketball Agility (Agility Left and Right): A schematic diagram of the agility test is presented in figure 1. The agility test involved maximal effort trials of a predetermined course consisting of four 30cmx30cm taped ‘pivot boxes’ and was timed using electronic timing lights (Fusion sports, Australia). Basketball athletes completed three maximal trials beginning first with the front left box and then three trials beginning with the front right box with at least 30 seconds recovery between trials. The fastest of the three trials for each direction was recorded. TIS reliability scores are high for this test where ICC is r = 0.85.

FIGURE 1 ABOUT HERE

Line Drill: The line drill was used as a test of anaerobic capacity in the basketball athletes. Participants were required to run as fast as possible to the closest free throw line (5.8m), back to the base line (5.8m), to the centre line (14m), back to the base line (14m), to the distant free throw line (22.2m), back to the base line (22.2m), to the opposite base line (28m) and finally to the base line where the test commenced (28m). Electronic light gates (Fusion sports, Australia) positioned on the base line recorded the start and finish time (seconds), Each participant completed one trial, with the time taken to complete the trial recorded as the final score. TIS reliability scores for this test are r = 0.78.

Planned Agility: The planned agility test was completed by the netball and AF athletes. It involved maximal effort trials around a pre-determined course with poles comprising three left and two right 90° turns and was timed using electronic timing lights (Fusion sports, Australia) placed at the start and finish lines. Athletes completed three maximal trials with at least 2 minutes recovery between trials. The fastest of the three trials was recorded. Figure 2 is a schematic of the planned agility test. TIS reliability scores are high for this test where ICC is r = 0.94.

FIGURE 2 ABOUT HERE

Repeat Agility Test: The repeat agility test (4 x planned agility circuit on a 20 s cycle), which measures anaerobic capacity, was also completed by the netball participants. The total time in seconds of the four agility trials was used as the repeat agility score.

Handgrip Strength: The handgrip strength of the AF athletes was measured bilaterally using a hand-held dynamometer (Original Smedley Dynamo Meter 100kg; TTM, Tokyo, Japan). The participants performed three maximal effort contractions with a rest period of 15 to 20s between each effort. The maximum value from the 3 trials was recorded (ICC r=0.98) (11).

Saliva Analysis: The participants were instructed to refrain from eating, drinking fluids other than water, or brushing their teeth for one hour prior to saliva collection to avoid sample contamination. Approximately 2 ml of saliva was collected by the passive drool method in sterile containers immediately prior to the participants' warm-up. All samples were coded and kept at -80°C until analysis. After thawing, the samples were centrifuged at 4000 rpm for 5 minutes. The samples were then analysed in duplicate for testosterone, cortisol, progesterone and estradiol by commercially available kits as per manufacturer's instructions (Salimetrics LLC, USA). The minimum detection limit was 1.0 pg/mL for testosterone (mean 4.6% CV), 0.003 μg/dL for cortisol (5.2% CV), 0.1 pg/mL for estradiol (5.2% CV) and 5 pg/mL for progesterone (6.1% CV).

Statistical Analyses

All variables were tested for normality using the Shapiro-Wilk test prior to analysis. Non-normally distributed data was log-transformed prior to analysis to create a normal distribution when possible. Due to well-known gender differences in human physiology (see (3) for a comprehensive review) data for males and females were analysed separately. During analysis the female participants' results were grouped according to whether the subject was taking hormonal contraceptives at the time of testing (NOC = not taking oral contraceptives, OC = taking oral contraceptives) as the exogenous hormones found in oral contraceptives are able to bind to other steroid receptors and either inhibit the receptors activation or induce transactivation.(18) Associations between baseline and relative changes in hormone levels (change (Δ) in absolute values from session 1 to each subsequent test session) and physical performance were determined using Pearson's correlation for normal data and Spearman's correlation for non-normal data. Correlations were considered very strong if r=0.90 to 1.0 or -0.90 to1.0, strong if r=0.7 to 0.9 or -0.7 to -0.9, moderate if r=0.5 to 0.7 or -0.5 to -0.7 and weak if r=0.3 to 0.5 or -0.3 to -0.5.(17) Statistical analysis was performed using SPSS software (version 16; SPSS Inc., Chicago, IL, USA), with significance set at $p \leq 0.05$.

RESULTS

Over 22 months 161 samples (Male, n=90; Female NOC, n=39; Female OC, n=32) were collected. Mean saliva hormone values and physical test results for the male and female participants (including NOC and OC groups) are presented in table 2. In males, agility (n=56) was weakly correlated with estradiol levels (r=0.47, p=<0.001), and the P:E (r=-0.43, p=0.001), and T:E ratios (r=-0.35, p=0.01). Weak correlations were evident between 10m (n=78) and 20m speed (n=64) and the P:E (10m r=-0.36, p=0.002; 20m r=-0.34, p=0.002) and T:P ratios (10m r=0.33, p=0.003; 20m r=0.37, p=0.001). Handgrip strength (n=34) was weakly correlated with estradiol levels (r=-0.48, p=0.04) and the T:E ratio (r=0.35, p=0.04), and running left VJ height (n=56) was weakly correlated with the T:E ratio (r=-0.35, p=0.01). In the NOC group, distance covered in the MSFT was strongly correlated with the T:E ratio (r=-0.76, p=0.01) and moderately correlated with the T:P ratio (r=-0.68, p=0.02). In the NOC group, 1 step CMJ height (n=10) was correlated with estradiol (r=0.81, p=0.01), agility left (n=10) was correlated with estradiol (r=-0.71, p=0.01) and the T:E (r=-0.82, p=0.01) and T:P ratios (r=0.71, p=0.03), and the line drill performance (n=10) correlated with estradiol (r=-0.86, p=0.001), progesterone r=-0.79, (p=0.01) and the T:P (r=0.70, p=0.04) and T:E ratios (r=0.78, p=0.01). In the OC group, repeat agility total time (n=20) was strongly correlated with estradiol levels (r=-0.71, p=0.001) and moderately correlated with progesterone levels (r=-0.51, p=0.01) and the T:E ratio (r=0.63, p=0.004).

TABLE 2 ABOUT HERE

Mean individual changes in saliva values and physical test results over time for the male and female participants (including NOC and OC groups) are displayed in table 3. Correlations between individual changes in physical performance and individual changes in salivary hormone parameters are presented in table 4. In males, strong correlations were evident between a Δ in planned agility time and a Δ in estradiol levels (p=0.02), and a Δ in CMJ height and a Δ in the T:C ratio (p=0.01). In the NOC group, a strong correlation was evident between a Δ in CMJ height and a Δ in the T:P ratio (p=0.02) and a moderate correlation was evident between a Δ in CMJ height and a Δ in the T:E ratio (p=0.03). A moderate correlation was also evident between a Δ in 10 m speed and a Δ in testosterone levels (p=0.003). In the OC group, a Δ in the distance covered in the yo-yo test was strongly related to a Δ in the T:E ratio (p=0.01) and moderately related to a Δ in estradiol levels (p=0.02) and the P:E ratio (p=0.05). A strong correlation was evident between a Δ in 20 m speed and a Δ in the T:P ratio (p=0.01) and moderate correlations were evident between a Δ in 20 m speed and a Δ in the T:C ratio (p=0.03), and a Δ in 5 m speed and a Δ in the T:P ratio (p=0.04).

TABLE 3 AND 4 ABOUT HERE

DISCUSSION

The aim of this study was to determine possible hormone predictors of physical performance in adolescent team sport athletes and to assess if individual changes in hormone levels provided stronger predictive markers of changes in physical capacity than discrete values. Our results identified some significant hormonal predictors of physical performance. Individual changes in estradiol levels were a stronger predictor of planned agility performance than pooled estradiol levels in the male athletes.

Published research on adolescent Australian football athletes identified estradiol and progesterone as predictors of 10 and 20m sprint speed (14). Given this, we hypothesised that salivary progesterone levels would be positively associated with speed and power test performance in our sample of adolescent athletes. This is the first study of its kind to identify a positive association between the P:E ratio and speed and agility performance, and a negative association between the T:P ratio and speed in males. It is proposed that this finding may be due to progesterone's antagonistic effects of estradiol at a receptor level. Progesterone functions as an inhibitor of estrogen (21), and estrogen receptors (12). Progesterone represses estrogen receptor transcriptional activity, antagonizes estrogen action at the molecular level and prevents estrogen induction by down-regulating estrogen protein concentration (12). Progesterone has also been found to affect estrogen stimulated responses, though the mechanisms in which this occurs is unclear (5-7). In the female OC and NOC groups, progesterone levels were not associated with speed and agility, however, moderate to strong negative associations between changes in speed and salivary testosterone levels, T:C and T:P ratios were identified in both groups. To the best of our knowledge, no study has directly investigated possible associations between speed or agility and testosterone levels in females, though a study on male Rugby Union athletes did identify a positive relationship between both salivary testosterone levels and T:C ratio and speed (8). This result in male Rugby Union athletes contrasts with our finding in female team sport athletes. Recent research suggests that testosterones responses during exercise may be mediated by cortisol levels however the mechanisms are yet to be elucidated (9). The finding that cortisol levels may mediate testosterones responses compliment findings in behavioural studies. Behavioural studies have reported testosterone relationships that are mostly positive when cortisol levels are low and negative when cortisol levels are high (15). Female participants in this study had notably higher cortisol levels (NOC = 12.8±7.6 nmol/L, OC = 11.2±4.6 nmol/L) than the male Rugby Union athletes (Backs = 5.1±2.4 nmol/L, Forwards = 7.3±3.5 nmol/L) in the study by Crewther, Lowe, Weatherby, Gill and Keogh (8) which may explain why a the T:C ratio in our study had a negative relationship with speed whereas the relationship was positive in the male Rugby Union athletes.

In contrast to previous findings in male adolescent athletes (1), individual changes in the T:C ratio were negatively associated with individual changes in CMJ height in male participants. A decrease in the bioavailable T:C ratio has been previously linked to overtraining (20), however increases in performance have been identified in professional soccer players during high intensity training despite a significant decrease in salivary T:C of over 30% (10). It has been suggested that a decrease in T:C ratio may not necessarily lead to a decrease in performance or a state of overtraining, but instead may reflect an optimal performance state (10). Rather than a measure of overtraining, the T:C ratio may be indicative of training stress (20). Training stress is necessary to induce positive changes in response to training, however the optimal level of stress required, and how it is reflected in the T:C ratio, remains unknown.

This study is not without limitations. Interpretation of our results is limited by the small sample size for some of the physical performance tests. The results of this study are restricted to the population of athletes tested and may not be indicative of the general population or other athlete groups. For research outcomes to be adopted and utilised effectively within sports they must be proven to be feasible and effective in real world settings (2). As a consequence of this concept, the researchers were interested in identifying hormone predictors of performance that were independent of other factors such as training phase, diet, clothing and sleep patterns. As a result training phase, diet, clothing and sleep patterns were not reported or considered in the analysis of this study..

In conclusion, the current results showed that in adolescent team sport athletes the P:E, T:E and the T:P ratios are important predictors of motor performance in tests of physical capacity. The current findings also allow us indicate estradiol and progesterone have a role in the physical performance of adolescent male team sport athletes. Contrary to the initial hypothesis, in most cases analysis of individual changes in hormone levels did not act as stronger predictors of performance than discrete values.

PRACTICAL APPLICATIONS

This study provides insights into possible hormone predictors of performance in adolescent team sport athletes. Coaches and support staff should keep in mind when using hormone levels to predict athlete performance that monitoring changes in hormone levels and performance, and looking at discrete variables of hormones and performance do not yield identical results. In adolescent female team sport athletes, the preferred method of monitoring should be individual changes in hormone levels (testosterone, P:E, T:P and T:E ratios) and performance. It is also important to note whether female athletes are taking hormonal contraceptives at the time of testing, as the exogenous hormone contained in hormonal contraceptives may affect the results. In adolescent male team sport athletes, the method of prediction should depend on the variable being predicted. The results of this study indicate that changes in estradiol levels may provide a useful biomarker of agility, and support the use of the T:C ratio as a marker of training stress in adolescent male team sport athletes. Additionally discrete measurements of the P:E ratio may be useful in predicting speed and agility in adolescent male team sport athletes. This has possible implications as an initial screening tool for talent identification models applied in different sports.

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Table 1. Performance testing frequency, time and tests performed by sport

Sport	Test occasions	Testing frequency	Testing time	Performance tests
AF	2	yearly	10:00	handgrip strength, CMJ, running left VJ, running right VJ, 5 m,10 m and 20 m sprint, planned agility, MSFT.
Basketball	2	quarterly	10:00	sit and reach, 1 step CMJ, 5m,10m and 20 m sprint, left and right sided agility, line drill, yoyo.
Hockey	2	half yearly	10:00	CMJ, 10 m, 40 m sprint, MSFT.
Netball	6	quarterly	10:00	CMJ, 5 m, 10 m and 20 m sprint, planned agility, repeat agility, yoyo.

Abbreviations: AF = Australian Football; CMJ = countermovement jump; MSFT = multi stage fitness test; TIS = Tasmanian Institute of Sport; VJ = vertical jump; yoyo = yoyo intermittent recovery test level 1.

Table 2. Hormone levels and ratios by test group (mean ± standard deviation)

	Male	NOC	OC
HORMONE VALUES			
Estradiol (pg/mL)	2.1 ± 1.1	2.4 ± 1.0	3.1 ± 3.6
Progesterone (pg/mL)	106.3 ± 70.7	119.4 ± 56.0	123.5 ± 65.5
Testosterone (pg/mL)	142.5 ± 44.3	90.9 ± 35.5	81.1 ± 31.1
Cortisol (nmol/L)	9.4 ± 5.7	12.8 ± 7.6	11.2 ± 4.6
P:E ratio	54.6 ± 34.4	52.1 ± 118.9	52.8 ± 25.9
T:C ratio	0.7 ± 0.5	0.3 ± 0.2	0.3 ± 0.2
T:P ratio	1.9 ± 1.3	0.9 ± 0.4	0.8 ± 0.5
T:E ratio	79.8 ± 35.6	42.2 ± 18.9	37.6 ± 20.9
PHYSICAL TESTS			
Handgrip Strength (kg)	49.4 ± 6.5	-	-
5m Sprint (s)	1.11 ± 0.07	1.22 ± 0.07	1.20 ± 0.07
10m Sprint (s)	1.84 ± 0.09	2.05 ± 0.09	2.00 ± 0.09
20m Sprint (s)	3.12 ± 0.12	3.55 ± 0.17	3.43 ± 0.14
40m Sprint (s)	5.59 ± 0.19	6.33 ± 0.21	-
Planned Agility (s)	8.31 ± 0.28	9.07 ± 0.39	8.77 ± 0.26
CMJ (cm)	60 ± 7	42 ± 5	47 ± 4
Running Left VJ (cm)	74 ± 12	-	-
Running Right VJ (cm)	71 ± 10	-	-
1 step CMJ (cm)	69 ± 7	45 ± 5	-
Line Drill (cm)	27.46 ± 0.75	31.13 ± 1.19	-
Sit and Reach (cm)	12 ± 4	11 ± 4	-
Agility Left (s)	5.36 ± 0.28	6.08 ± 0.17	-
Agility Right (s)	5.39 ± 0.25	6.02± 0.20	-
Repeat Agility Total Time (s)	-	38.52 ± 1.59	37.71 ± 1.90
MSFT Distance (m)	2542 ± 229	1871 ± 209	-
Yoyo Distance (m)	2507 ± 413	1097 ± 441	1093 ± 299

Abbreviations: NOC = females not taking oral contraceptives; OC = females taking oral contraceptives; P:E ratio = progesterone to estradiol ratio; T:C ratio = testosterone to cortisol ratio; T:E ratio = testosterone to progesterone ratio; T:P ratio = testosterone to progesterone ratio; CMJ = countermovement jump; MSFT = multi stage fitness test; VJ = vertical jump; yoyo = yoyo intermittent recovery test level 1, - = not applicable

Table 3. Individual change in hormone levels and physical test performance by test group (mean ± standard deviation)

	Male	NOC	OC
HORMONE VALUES			
Estradiol (pg/mL)	-1.1 ± 2.0	0.3 ± 1.2	2.4 ± 5.0
Progesterone (pg/mL)	-14.2 ± 67.0	12.1 ± 57.1	25.1 ± 96.4
Testosterone (pg/mL)	-14.2 ± 67.4	-11.5 ± 33.0	5.5 ± 30.6
Cortisol (nmol/L)	-3.8 ± 6.4	-0.5 ± 7.1	1.4 ± 5.1
P:E ratio	53.4 ± 51.6	5.9 ± 25.9	-5.6 ± 32.7
T:C ratio	0.1 ± 0.9	-0.05 ± 0.1	0.003 ± 0.2
T:P ratio	-1.5 ± 3.0	-0.5 ± 0.7	0.06 ± 0.6
T:E ratio	27.8 ± 37.8	-17.4 ± 18.9	-6.0 ± 18.2
PHYSICAL TESTS			
5m Sprint (s)	-0.04 ± 0.08	-0.01 ± 0.04	0.05 ± 0.08
10m Sprint (s)	-0.06 ± 0.06	-0.0006 ± 0.05	0.06 ± 0.09
20m Sprint (s)	-0.11 ± 0.08	0.04 ± 0.08	0.08 ± 0.11
Planned Agility (s)	-0.34 ± 0.31	0.15 ± 0.10	0.16 ± 0.17
CMJ (cm)	-1 ± 2	0 ± 3	2 ± 4
MSFT Distance (m)	42 ± 122	-	-
Yoyo Distance (m)	-	-60 ± 153	-147 ± 273

Abbreviations: NOC = females not taking oral contraceptives; OC = females taking oral contraceptives; P:E ratio = progesterone to estradiol ratio; T:C ratio = testosterone to cortisol ratio; T:E ratio = testosterone to progesterone ratio; T:P ratio = testosterone to progesterone ratio; CMJ = countermovement jump; MSFT = multi stage fitness test; NOC = females not taking oral contraceptives; OC = females taking oral contraceptives; VJ = vertical jump; yoyo = yoyo intermittent recovery test level 1, - = not applicable

Table 4. Correlations between individual changes in physical performance and individual changes in salivary hormone parameters

Test	Estradiol (pg/mL)	Progesterone (pg/mL)	Cortisol (nmol/L)	Testosterone (pg/mL)	P:E	T:C	T:P	T:E
MALES								
ΔPlanned Agility (n=7)	0.87*	0.58	-0.08	0.48	0.34	0.32	0.14	-0.35
Δ5m (n=8)	<0.01	-0.02	-0.21	0.02	0.06	0.15	-0.12	-0.44
Δ10m (n=12)	0.10	-0.10	-<0.01	0.14	0.02	0.14	0.33	-0.23
Δ20m (n=8)	0.15	-0.23	-0.42	0.15	-<0.01	0.45	0.31	0.04
ΔMSFT (n=11)	0.27	0.57	-0.28	0.18	0.41	-0.20	0.04	-0.35
CMJ (n=7)	-0.71	-0.25	0.42	-0.47	-0.22	-0.88*	-0.51	0.20
OC								
ΔPlanned Agility (n=10)	0.46	-0.08	0.10	0.31	-0.48	-0.18	-0.06	-0.66
Δ5m (n=12)	<0.01	0.42	-0.22	-0.07	-0.12	0.37	0.63*	0.02
Δ10m (n=13)	0.46	0.50	-0.31	0.26	-<0.01	0.46	0.31	-0.28
Δ20m (n=12)	0.44	0.21	-0.55	-0.15	-0.35	0.69*	0.73*	-0.14
ΔYoyo (n=12)	-0.68*	0.36	-0.09	-0.25	0.58*	0.38	-0.34	0.74**
ΔCMJ (n=11)	-0.36	0.39	0.65	0.02	0.28	-0.56	-0.37	0.31
NOC								
ΔPlanned Agility (n=10)	-0.29	0.37	0.37	-0.19	0.43	-0.29	-0.03	0.17
Δ5m (n=13)	0.04	0.08	-0.07	0.38	0.12	0.03	-0.04	-0.21
Δ10m (n=16)	-0.05	0.22	0.02	0.68*	0.34	0.14	-0.04	0.21
Δ20m (n=13)	-0.18	0.17	-0.04	0.60	0.53	-0.15	-0.22	0.06
ΔYoyo (n=13)	0.06	-0.10	-0.08	0.51	-0.51	0.49	0.46	0.36
ΔCMJ (n=10)	0.44	0.23	0.07	-0.40	0.29	-0.46	-0.72*	-0.69*

*P≤0.05, **P≤0.01, Abbreviations: CMJ = countermovement jump; MSFT = multi stage fitness test; yoyo = yoyo intermittent recovery test level 1

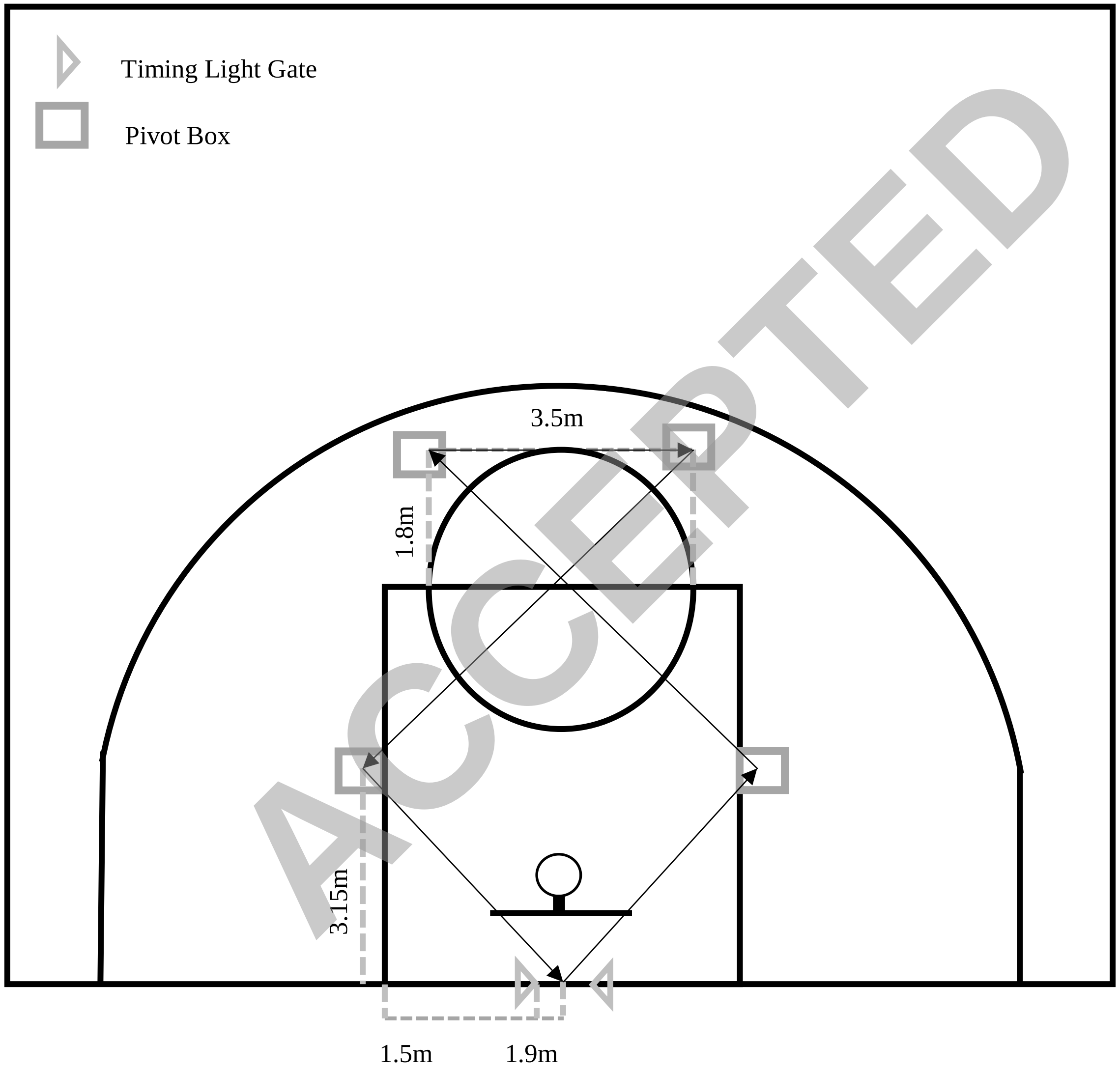

Figure 1. Schematic diagram of the basketball agility test

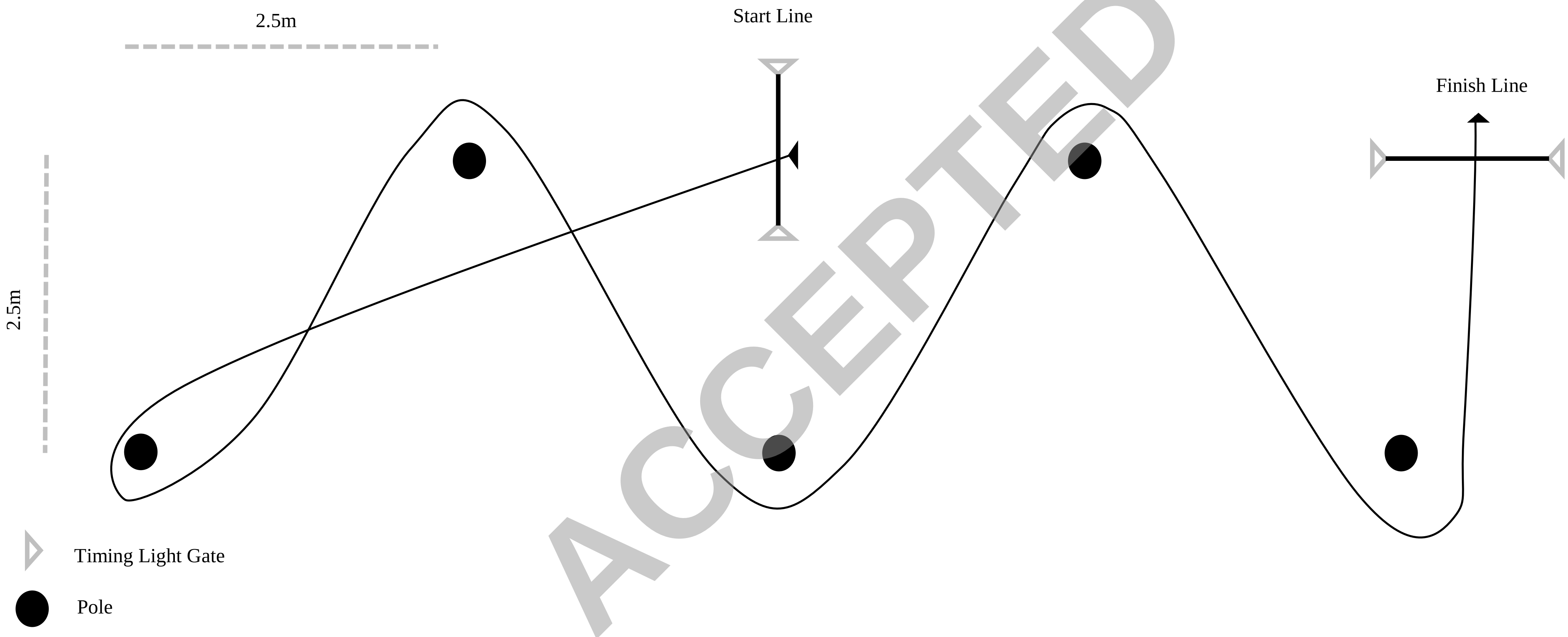

Figure 2. Schematic diagram of the planned agility test