RESPONSE OF SELECTED HORMONAL MARKERS DURING TRAINING CYCLES ON INDIAN FEMALE SWIMMERS

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ABSTRACT: The present study was taken up to monitor the fluctuations of the hormones testosterone, cortisol and T/C (Testosterone/Cortisol) ratio concentrations during the three phases of training namely preparatory phase, pre-competitive phase and competitive phase in Indian female swimmers. Blood samples were collected at the completion of each phase to study the impact of training on these hormones. Our results reveal that the testosterone and T/C ratio significantly decreases whereas cortisol increases in the subsequent periodised cycle and it was due to the intensity and volume of training. Our study concludes that the intensity and volume of training has effects on these hormones and also, a swimmer with higher testosterone, lowest cortisol and highest T/C ratio has the highest percentage difference of performance record between the preparatory and competitive phase. Hence, monitoring of these hormones is essential to avoid overtraining and to enhance the performance of the swimmers.

KEY WORDS: training, testosterone, cortisol, T/C ratio

INTRODUCTION

Competitive swimming is an endurance sport and the goal is to be the fastest over a given distance which is obtained by training. The aim of sports training is to enhance physical performance, as training improves the capacity for energy production, tolerance of physical stress and subsequently improves the physical performance. The major physical changes associated with training occur in the first 6-10 weeks. The magnitude of these adaptations depends on the volume and intensity of exercise performed during training. The rate at which an individual adapts to training is limited and cannot be forced beyond the body's capacity for development [32].

However, training too heavily (overtraining) and under training both have the opposite effects – that is, performance decrement [21]. Although the volume of work performed in training is an important stimulus for physical conditioning, there needs to be a proper balance between volume and intensity [32]. To achieve optimal adaptation, a well designed conditioning program is required that allocates the appropriate amount of aerobic and anaerobic conditioning time to match the energy demand of the sport [25].

Overreaching leads to exceeding the athlete's adaptative capacity and there will be a performance decrement, but it will be relatively short [4]. Overtraining often seems to be associated with periods of overreaching [32].

Overtraining refers to the point where an athlete starts to experience physiological mal-adaptations, chronic performance decrements and this generally leads to the overtraining syndrome [4]. The overtraining syndrome has been attributed to excessive volume or high intensity of training with inadequate periods of rest, eventually leading to an inability to train and perform at optimal levels [10]. Excessive training i.e. when the training load is too intense or the volume of training exceeds the body's ability to adequately recover and adapt, the body experiences more catabolism than anabolism [32].

Increased training volume/intensity may produce performance decrement and sign of overtraining including fatigue, hormonal changes and decrease in muscular strength and muscular endurance [12]. Hence optimal training is in need that incorporates the principles of periodisation, in that the body needs to systematically go through stages of under training, acute overload, and overreaching to maximize performance [32]. The metabolic adaptations to training are specific to the type of training we do, such as endurance training results in metabolic and cellular changes that are associates with aerobic metabolism, sprint training tends to improve the body's ability to use anaerobic metabolism and resistance training increases maximal production as well as our anaerobic capabilities [15].

To our knowledge, few studies have examined the presence of a relation between overtraining and hormonal variations, in particular testosterone and cortisol concentrations [27].

Testosterone is a steroid hormone primarily secreted in the testes of males and the ovaries of females, although small amounts are also secreted by the adrenal glands. It is essential for normal growth, development and also the anabolic effects of testosterone are responsible for the muscle protein retention and muscle hypertrophy during strength training [32].

Cortisol (stress hormone) is a major glucocorticoid hormone that enables the body to adapt external changes and stress.

Depending on the intensity and duration of a preceding physical load, hormones with anabolic or catabolic properties, such as testosterone and cortisol respectively, show quantitative changes signaling a catabolic state [6]. The ratio between plasma concentrations of free testosterone and cortisol has been used to evaluate training responses and to predict performance capacity [2]. This ratio is considered to reflect states of anabolism and tapering off when it is high and, inversely when it falls by 30% or more. Moreover a single bout of exercise induces transient changes in the anabolic-catabolic balance, depending on the intensity and duration of the exercise bouts. Repeated heavy endurance exercise without a sufficient period of recovery can cause a persistent disturbance in the balance [21].

As testosterone and cortisol are playing a significant role in metabolism of protein as well as carbohydrate, the testosterone/cortisol ratio is used as an anabolic/catabolic balance. This ratio decreases in relation to the intensity and duration of physical exercise, as well as during period of intense training or repetitive competition and can be reversed by regenerative measures [26]. So based on the above premise, the testosterone has anabolic effects and cortisol has catabolic effects, the testosterone/cortisol ratio has been proposed as a great marker for overtraining.

The purpose of the present study is to evaluate the response of selected hormonal markers like Cortisol, testosterone and T/C ratio during three phases of training namely preparative phase, pre-competitive phase and competitive phase in female swimmers.

MATERIALS AND METHODS

Seventeen national level female swimmers undergoing training in Sports Authority of India (Bangalore) were participated in this study. None of the subjects had history of usage of anabolic steroid. Each subject has been well informed about the objective of the present research. This study was approved by the ethical committee of Sports Authority of India.

A well designed training program for national swimmers is prepared for 3 months (11 weeks) and the periodisation involves dividing the training plan into three phases that is preparative phase, pre-competitive phase and competitive phase. Each phase is subdivided into mesocycle and this mesocycle is further divided into microcycle as given in the table 1.

Venous blood samples at preparatory, pre-competitive and competitive phase were drawn from the antecubital vein in the morning 08.00 to 09.00 am (12 hours fasting condition) from the female swimmers.

Serum was separated from the whole blood and ELISA (Enzyme Linked Immuno Sorbent Assay) method was used for the quantita-

TABLE 1. TRAINING PROGRAM OF INDIAN FEMALE SWIMMERS

Period		Base Training period					Precompetitive period						Competitive period								
Mesocycle		I					II						III								
Microcycle		1	2	3	4	5	1		2		3		1			2			3		
Groups		Dist/Mid/Sp					Dist	Mid/Sp	Dist	Mid/Sp	Dist	Mid/Sp	Dist	Mid	Sp	Dist	Mid	Sp	Dist	Mid	Sp
		Km					Km	Km	km	km	km	km	km	km	km	km	km	km	km	km	km
Training in water	BA	45	44	44.6	49	46	50	43	47	33	41.5	28	39	25	22	33	20	15	27	15	11
	AT	4	9	11	11	12	12	11	12	10	12	10	10	9	8	8	7	7	6	5	4
	VO2	----	----	2.4	4	7	7	7.5	8	8	8	7	7.5	6.5	6	6	5	5	5	3	3
	LT	----	----	----	----	----	----	1	1	2.5	1.5	2.5	1.5	2.5	2	1	2	2	1	1	1
	SP	1	2	2	2	2	2	2.5	2	2.5	2	2.5	2	2	2	2	1	1	1	1	1
Total Volume (km)		50	55	60	66	67	71	65	70	56	65	50	60	45	40	50	35	30	40	25	20
Dry land training		6 session, 1 hour each session: 1. Running 2. Push up 3. Chin up 4. Jumps 5. Sit up					Monday & Thursday: - Upper body Wednesday & Saturday: - Core strength, Swiss ball Tuesday & Friday: - Lower body														

BA – Base Aerobic (50-60% intensity), AT – Anaerobic Threshold (80-85% intensity), VO2 max – Aerobic Power (>95% intensity),
LT – Lactate Tolerance (>100% intensity), SP – Speed (>100% intensity)
Dist – Distance swimmer, Mid – Middle distance swimmer, Sp - Sprinter

tive estimation of testosterone and cortisol (Kits from Omega diagnostics, UK). T/C ratio was calculated from the value of testosterone and cortisol.

Data are presented as Mean ± Standard deviation. One way analysis of variance and Scheffe's post-hoc comparison were used to determine the significant differences among the variables. SPSS MS Windows release 9.0 and Minitab 14 were used for statistical computation.

RESULTS

Table-1 demonstrates the training program for female swimmers. Base training period was same for all the group middle distance, distance and sprinters but the volume is changed among the groups during the pre-competitive and competitive period. Blood sample were collected at the end of each phase in order to find out the impact of training intensity/volume to the player's hormonal status.
Table-2 depicts the physical characteristics of the female swimmers.

TABLE 2. SUBJECT'S AGE AND PHYSICAL CHARACTERISTICS

Serial No.	Variables	Mean±SD
1.	Age (years)	16.19 ± 1.53
2.	Height (cm)	160.97 ± 3.59
3.	Weight (kg)	55.96 ± 5.13

Table-3, gives the descriptive value of hormonal profile of female swimmers in three phases of the training i.e. preparatory phase, pre-competitive phase and competitive phase.

The mean ± standard deviation of testosterone and T/C ratio are high in the pre-competitive phase when compared to preparatory and competitive phase, cortisol level is high in the competitive phase than the other two phases. One way ANOVA result of testosterone and T/C ratio reveals a significant difference while compared among the three different phases. Post-hoc multiple comparison of testosterone is found significant between preparatory and competitive phase; pre-competitive and competitive phase ($p<0.001$) while T/C ratio found significant between pre-competitive and competitive phase ($p<0.01$).

No significant difference in the value of cortisol in any of the phase. However, the mean ± standard deviation value of cortisol is higher in competitive phase while compared to other two phases (Table 4).

Table-5, demonstrates the paired t-test result for speed (m/sec) taken by the swimmers to complete their destination, which is compared between preparatory and competitive phase shows a significant difference ($p<0.001$).

DISCUSSION

Performance of athletes depends on their physiological, technical and psychological abilities. Athletes become elite with well designed planning program and the close monitoring of physical capacities, hormones during the entire training period. It is very essential to find out the effect of the training program and determine if the recovery is sufficient [33].

Research has repeatedly shown that the rate of physiological adaptation occurs primarily in response to the intensity of effort rather than the amount of effort [18]. There has been a growing interest in identifying the physiological and hormonal markers of training responses in competitive swimmers across training cycles. The objective of our research is to determine the response of hormonal markers during training cycles on Indian female swimmers and

TABLE 3. INDIVIDUAL LEVEL OF HORMONES AND SPEED DURING THE TRAINING PHASES IN INDIAN FEMALE SWIMMERS

Subject	Testosterone (nmol/L)			Cortisol (nmol/L)			T/C Ratio (*1000)			Speed (m/sec) % of difference (I & III)
	I	II	III	I	II	III	I	II	III	
1.	0.406	0.132	0.032	266.42	134.78	425.51	1.524	0.979	0.075	2.5%
2.	0.247	0.307	0.032	152.65	232.21	455.13	1.618	1.322	0.070	2.0%
3.	0.225	0.341	0.044	196.68	329.7	416.02	1.144	1.034	0.106	2.6%
4.	0.321	0.261	0.017	258.56	169.07	320.79	1.241	1.544	0.053	0.7%
5.	0.358	0.287	0.033	437.09	202.68	694.98	0.819	1.416	0.047	1.7%
6.	0.128	0.258	0.048	152.38	175.73	286.36	0.84	1.468	0.168	1.4%
7.	0.138	0.257	0.052	254.9	179.96	37.76	0.541	1.428	1.377	7.2%
8.	0.437	0.216	0.031	313.12	233.17	306.13	1.396	0.926	0.101	1.6%
9.	0.327	0.137	0.049	304.1	218.90	340.56	1.075	0.626	0.144	0.6%
10.	0.336	0.347	0.038	304.62	49.17	380.13	1.103	7.057	0.100	2.9%
11.	0.138	0.182	0.037	253.72	155.10	481.22	0.544	1.173	0.077	1.6%
12.	0.171	0.220	0.063	309.62	1160.91	636.79	0.552	0.19	0.099	4.1%
13.	0.194	0.138	0.041	181.25	283.69	356.73	1.07	0.486	0.115	2.1%
14.	0.086	0.068	0.031	288.97	696.88	651.20	0.298	0.098	0.048	2.5%
15.	0.070	0.087	0.025	271.15	691.63	308.66	0.258	0.126	0.081	3.1%
16.	0.229	0.131	0.070	100.05	593.84	733.26	2.289	0.221	0.095	4.3%
17.	0.324	0.135	0.040	501.66	482.57	575.19	0.646	0.28	0.07	2.1%

I - Preparatory phase, II - Precompetitive phase, III - Competitive phase

TABLE 4. HORMONAL PROFILE OF INDIAN FEMALE SWIMMERS DURING THREE PHASES OF THE TRAINING

Variables	Preparatory phase (I)	Precompetitive phase (II)	Competitive phase (III)	One way ANOVA		Post hoc Test (Scheffe)	
				F Ratio	Sig.	Phases	Sig.
Testosterone (nmol/L)	0.243±0.113	0.206±0.088	0.040±0.013	28.96	0.000***	I vs III & II vs III	0.000***
Cortisol (nmol/L)	267.5±99.4	352.4±286.1	435.7±178.6	2.92	0.064	ns	ns
T/C ratio (*1000)	0.998±0.526	1.198±1.597	0.166±0.314	5.22	0.009**	II vs III	0.015**

TABLE 5. PAIRED T-TEST FOR SPEED ($m \cdot sec^{-1}$) BETWEEN PREPARATORY AND COMPETITIVE PHASE

Phases	Mean±SD	T- Value	Level of significance
Preparatory phase	0.841±0.38	6.03	0.000***
Competitive phase	0.820±0.370		

* P<0.05, **P<0.01, ***P<0.001, ns-not significant

the performance records. In the present study, from the total population of 17 female swimmers, 71% are middle distance group, 24% are distance group and 5% are sprinters.

Exercise represents a potent physiological stimulus upon the hypothalamo-pituitary-adrenal axis [20]. Increased activity of the pituitary-thyroid axis as well as the adrenal cortex plays a major role in adaptations to physical exercise. It has been demonstrated that changes in their secretory activity in response to exercise are closely correlated with muscular work intensity [9, 14].

The hormone testosterone has been viewed as anabolic indicator as it can stimulate glycogen storage and muscular protein synthesis [16, 17]. The lack of physical activity and excessive physical activity will result in decreased levels of testosterone. Exercise has effect on testosterone directly by stimulating the pituitary gland and the testes and it probably also rises levels by slowing down the normal breakdown of testosterone [30]. Our result reveals that the level of testosterone decreases significantly from preparatory phase to competitive phase in all the female swimmers (p<0.001). 53% of players show decrease in the level of testosterone during pre-competitive phase whereas 100% shows decrement during competitive phase. As swimmers approaches the pre-competitive phase, the testosterone level increases which leads to muscle tissue development and during competitive phase, testosterone level decreases due to higher intensity and duration of repeats/workout during training. During the course of the training program, the base aerobic volume and anaerobic threshold decrease, the maximum aerobic power and lactate tolerance were improved subsequently (Table 1). Therefore, as the intensity has increased subsequent periodized cycle leads to decrease in testosterone level.

Testosterone level increases most with short intense burst, while it decreases with prolonged activity especially that of frequent endurance training. Because during endurance training or prolonged training period testosterone is needed to maintain muscular function but frequent extended training doesn't allow for repair and recovery. In support of our research, scientists showed that testosterone rise in response to exercise and the levels are higher in well trained individuals [2] but the intense and prolonged training reduces the testosterone level [1, 22]. It is also assumed that, a transient suppressive effect on testicular luteinising hormone receptors as a result of the exercise induced increase in cortisol is the reason that the testosterone level is decreased by endurance training or during overtraining [31].

Cortisol has been used as an indicator of catabolic state for its role in gluconeogenesis via the proteolytic pathway [23]. Cortisol helps to mobilize glycogen and free fatty acid and rises after hard exercise as part of the stress hormone response [8]. Psychological stress also raises, particularly before competition .Table 4 shows that the level of cortisol increases significantly from preparatory phase to the competitive phase. The increase in the level of cortisol during competitive phase is reported in 88% of the swimmers whereas only 53% shows increase during pre-competitive phase but there is no significant difference in cortisol level during 11 weeks of training. Increase in the intensity in subsequent periodised cycle leads to the increase of cortisol level in overreaching condition. 17% and 11% of the players exceeded the limit during the pre-competitive and competitive phase of the training. Hence, hormones testosterone and cortisol acts as an alarm for the coach to reduce the training load for optimizing the training goal. In some cases of female swimmers as they are moving from preparatory phase to competitive phase, their cortisol level increases and the testosterone level decreases, this is certainly a concern for the coaches to diagnose as overtraining.

An equilibrium between anabolic and catabolic states in athletes is often represented by the ratio of the hormones testosterone and cortisol i.e. T/C ratio [3, 7, 29]. T/C ratio has been suggested as a potential marker for insufficient recovery and overtraining syndrome in athletes as it was decreased after intensive endurance exercise [19] and chronic high volumes of endurance training [28, 29]. Our research has shown that the level of T/C ratio decreases significantly from preparatory phase to the competitive phase in the female swimmers. The decrease in the level of T/C ratio during pre-competitive phase is seen in 65% of swimmers whereas 100% shown decrease during the competitive phase. This decrease in T/C ratio is described as "indicator of an insufficient regeneration" and the decrement in T/C ratio was due to the increase in cortisol level and decrease in testosterone level of the players.

In addition to the above information, subject 7 (Table 3) has the highest percentage difference of performance record with lowest cortisol level, higher testosterone level and the highest T/C ratio. From this, we can say that the performance will enhance with low cortisol level and high testosterone, T/C ratio level. Hence it is very essential to monitor these hormones during the different phases of the training to avoid overtraining and to enhance performance.

CONCLUSIONS

Our study concludes that the hormone concentration fluctuates with the intensity and duration of exercise i.e. when the intensity and duration of exercise is increased, the testosterone level decreases, cortisol level increases and T/C ratio decreases. Prevention is the best treatment for the overtraining state and so monitoring of hormones especially for swimmers during the training period is needed to avoid overtraining and to enhance the performance. Hence hormonal markers provide relevant information for an accurate and a trustworthy overtraining diagnosis.

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