

## Monitoring Training Load in Indian Male Swimmers

PRALAY MAJUMDAR‡ and SRI SRIVIDHYA JR.‡

Department of Exercise Physiology; Sports Authority of India; NSSC, Bangalore-560056, India

‡Denotes professional author

---

### ABSTRACT

*Int J Exerc Sci* 3(3): 102-107, 2010. The present study was initiated to monitor the training load with the magnitude of impact on the hormone concentrations such as testosterone, cortisol and T/C (Testosterone/Cortisol) ratio during the three phases of training (i.e. preparatory, pre-competitive, and competitive phases) in Indian male swimmers preparing for the 2010 Commonwealth Games. Blood samples were collected at the end of each training phase and hormone concentration was determined by ELISA. Our results reveal that testosterone concentration and the T/C ratio significantly decreased and the cortisol concentration increased in the subsequent periodized cycle. Change in hormone concentration was associated with the intensity and duration of individual exercise sessions. The greatest performance enhancement was realized with the lowest plasma cortisol, highest testosterone, and a high T/C ratio. Monitoring of these hormones also have implications for identifying and preventing overreaching in swimmers.

KEYWORDS: Testosterone, Cortisol, T/C ratio, Swimmers

### INTRODUCTION

Performance in swimming is governed by the maximal energy output, which is obtained by the well-designed training program (6). The purpose of any training program is to produce metabolic, physiological, and psychological changes, to increase the rate of energy release during exercise and to delay fatigue that allow swimmers to perform better in competition (25). The changes that take place in response to training allow the body system to function more effectively and efficiently during the competition. Significant changes and improvements in some physiological functions can occur in 6-8 weeks of training (16).

Chronic training elicits adaptations in normal physiology, resulting in improved performance. During the actual training, the structural and biochemical constitution

of cells and organs are challenged, leading to an increased catabolism. In the recovery period the disturbed cells or organ systems try to regain homeostasis and anticipate to another disturbance of homeostasis by an over adaptation. Hence, there has to be a proper balance between the disturbed homeostasis and recovery, leading to an increase of individual physical stress tolerance or else the desired adaptations will not occur (18). A loss of previously gained adaptations and overtime of the catabolic process exceeds the ability of tissues to repair themselves. This process is termed as failing adaptation or over training (25). Whenever an excessive and extended training is simultaneously applied with inadequate recovery, several of the positive physiological alterations associated with physical training are reverted to overtraining (2). Hence, there is a subtle limit between an optimum

## TRAINING LOAD IN SWIMMERS

performance and a chronic decrease due to overtraining (10).

Overtraining seems to be associated with changes in neuromuscular, hormonal and immune system functions, which reduce the ability of the athlete to tolerate training. An imbalance between the overall strain experienced during exercise training and the athlete's tolerance of such effort may induce overtraining or overtraining syndrome. Overtraining syndrome is characterised by diminished sport-specific physical performance with accelerated fatigability and subjective symptoms of stress (29). An athlete must maintain the delicate balance between the catabolic and anabolic processes. Hormones regulate the catabolic and anabolic process of the body system. Endogenous hormones are essential for physiological reactions, adaptations during physical work and influence the recovery phase after exercise by modulating anabolic and catabolic processes (11). Hormones play important role in many functions such as providing energy to the muscles, nerves and replacing

that energy, in repairing tissues, in building tissues etc. (25). Increased exercise stress is manifested in physiological, biochemical changes and is often in conjunction with psychological alterations, all of which result from an imbalance in homeostasis (31). Hormone levels are influenced by the physical exercise especially of testosterone and cortisol level (18, 12).

Testosterone is considered as the main anabolic hormone because it stimulates protein synthesis mainly in muscle and skeletal tissues, accounting for more than half of the body's mass (30). Cortisol is the catabolic hormone involves in many functions such as gluconeogenesis via the proteolytic pathway, increases protein breakdown, inhibits glucose uptake and increases lipolysis (20-21, 31). T/C (Testosterone/Cortisol) ratio is used as an indicator of balance between the anabolic and catabolic state of an athlete (5).

The aim of this investigation was to monitor the training load during three phases of training using plasma hormone concentration in Indian male swimmers.

Table 1: Training Program of Indian male Swimmers

Period	Preparatory phase					Pre-competitive phase						Competitive phase									
Mesocycle	I					II						III									
Microcycle	1	2	3	4	5	1		2		3		1		2		3					
Groups	Dist/Mid/Sp Km					Dis t Km	Mid/Sp Km	Dis t Km	Mid/Sp km	Dis t km	Mid/Sp km	Dis t km	Mi d km	Sp km	Dis t km	Mi d km	Sp 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
	VO <sub>2</sub> max	----	----	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), VO<sub>2</sub> max - Aerobic Power (>95% intensity), LT - Lactate Tolerance (>100% intensity), SP - Speed (>100% intensity)

Dist - Distance swimmer, Mid - Middle distance swimmer, Sp - Sprinter

**METHODS**

*Subjects*

Seven national level male swimmers from Sports Authority of India (Bangalore) participated in this study. None of the subjects had history of usage of anabolic steroids. This study was approved by the ethical committee of Sports Authority of India. The physical characteristics of the subjects are presented in Table 1.

*Training*

A well-designed training program for national swimmers was used for 3 months (11 weeks). The periodization involved three phases: preparative, pre-competitive, and competitive phase. Each phase was further subdivided into mesocycles and microcycles as demonstrated in Table 2.

Table 2: Basic characteristics of the players.

Serial No.	Variables	Mean ± SD
1.	Age (yr)	15.52 ± 1.12
2.	Height (cm)	174 ± 4.80
3.	Weight (kg)	60.43 ± 8.60

*Blood Collection*

Venous blood samples (~10 mL) were collected at the beginning of the preparative, pre-competitive, and competitive phases. Blood was drawn from an antecubital arm vein in the morning (0800-0900) following an overnight fast (>12 h).

*Hormone Analysis*

Serum was separated from the whole blood and separate ELISAs were used for the quantitative determination of testosterone (DRG Diagnostics, Germany) and cortisol kit (DIAMETRA, Italy). T/C ratio was calculated by dividing testosterone by cortisol concentration.

*Statistical Analysis*

Statistical analysis was completed using SPSS (Windows release 9.0) and Minitab 14.

One-way analysis of variance (ANOVA) and Scheffe’s post-hoc comparison were used to determine the significant differences among the variables. Data are presented as Mean ± Standard deviation.

**RESULTS**

Table 4: Hormonal profile of Indian male Swimmers during the three phases of the training cycle.

Variables	I	II	III	One way ANOVA		Post-hoc Test (Scheffe)	
				F Ratio	Sig.	Phases	Sig.
Testosterone (ng/ml)	13.29±4.40	13.56±2.95	8.22±3.62	4.615	0.024**	II vs III	0.047*
Cortisol (ng/ml)	93.99±22.44	203.2±88.9	129.02±21.44	7.356	0.005**	I vs II	0.005**
T/C Ratio	0.144±0.046	0.088±0.065	0.064±0.028	4.996	0.019**	I vs III	0.022**

I - Preparatory phase, II - Pre-competitive phase, III - Competitive phase  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001

Testosterone and cortisol concentration were greater during the pre-competitive phase when compared to preparatory and competitive phases. T/C ratio was greater during the preparatory phase than the other two phases. Testosterone, cortisol and T/C ratio varied significantly over all three training phases. Testosterone was significantly different between pre-competitive and competitive phases (P<0.05), cortisol was significantly different between the preparatory and pre-competitive phases (P<0.01), and T/C ratio was significantly different between preparatory and competitive phases (P<0.01).

Table 5: T-test for Speed (m/sec) between preparatory and competitive phase.

Phases	Mean±SD	T-Value	Level of Significance
Preparatory phase	0.644±0.165	3.20	0.019**
Competitive phase	0.620±0.157		

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001

**DISCUSSION**

The aim of this training program was to increase and improve the athlete’s physical performance. Since there is a continuous risk of imbalance among training, competition and recovery, overtraining can be a recurrent problem (18). Overtraining may be defined as an increase in the training volume or intensity that results in

performance decrement (18). Six percent (6%) of long distance runners, twenty one percent (21%) Australian swimmers and more than fifty percent (50%) of Soccer players have been classified with overtraining (28) and it is estimated that seventy percent (70%) of high-level endurance athletes have been in overtraining state during their careers (26).

In the present study, from the total population of seven male swimmers, 57% are from middle distance group, 29% are from distance group and 14% are from sprint group. The objective of our research is to determine the response of hormonal markers during training cycles on Indian male swimmers and the performance responses.

In the present study, testosterone concentration decreased significantly from the preparatory to the competitive phase. The decrement of testosterone concentration during competitive phase was 100% whereas during pre-competitive phase it was 43% when compared to the preparatory phase. During the lead up to the pre-competitive phase, the testosterone concentration increased, which may lead to increased muscular development. This significant change in testosterone concentration appeared to be related to intensity and duration of individual training sessions. During the course of the training program, the base aerobic volume and anaerobic threshold decreased, the maximum aerobic power and lactate tolerance were improved subsequently. Hence, increased intensity in the subsequent periodized cycle lead to decreased testosterone concentration. Our results demonstrate that the duration, intensity and frequency of exercise will determine the circulating testosterone concentration. During endurance training or prolonged training period, testosterone is needed for the maintenance of muscular

function but frequent extended training doesn't allow for repair and recovery. It is also assumed that, a transient suppressive effect on testicular luteinizing hormone receptors as a result of the exercise-induced increase in cortisol is the reason that testosterone concentration was decreased by endurance training or during overtraining (32). Reduced cortisol concentration is ideal for an athlete to achieve tissue growth and positive adaptations to exercise training (21). In the present study, cortisol concentration decreased during competitive phase in 100% case of swimmers whereas only 86% cases reported during pre-competitive phase. This shows that, as the swimmers reached the pre-competitive phase the cortisol increased. This exercise induced cortisol increase depends on the duration and intensity of repeats/workout during training. Therefore, the intensity increased in the subsequent periodized cycle resulted in increased cortisol concentration. In support of our research scientists shown that the endurance training decrease the resting total testosterone (3, 14, 33) and increase the cortisol levels in males (4, 22, 24). These testosterone and cortisol alterations are apparently adaptive responses to the physiological stresses associated with training (13, 15, 23).

Our results show that the T/C ratio decreased significantly from preparatory phase to competitive phase. The T/C ratio decreased during the competitive phase in all subjects, whereas it decreased in only 86% of subjects during pre-competitive phase. Decreased T/C ratio may be an "indicator of an insufficient regeneration". The T/C ratio can decrease up to 0.031 ng/ml without effecting athletic performance. As the normative range of the T/C ratio has not been defined, the above-mentioned value can be used as a frame of reference.

From the results obtained, swimmer performance was enhanced when cortisol concentration was low and testosterone concentration was high. As testosterone and cortisol concentration show considerable individual variation during training, we recommend that testosterone, cortisol, T/C ratio may be used as a potential indices of training volume. Our study concludes that the serum hormone concentration fluctuates with the intensity and duration of exercise.

### REFERENCES

1. Adlercreutz H, Harkonen M, Kuoppasalmi K, et al. Effect of Training on Plasma anabolic and catabolic steroid Hormones and their response during Physical Exercise. *Int J Sports Med* 7: S27-S28, 1986.
2. Armstrong LE, VanHeest JL. The unknown mechanism of the overtraining syndrome: clues from depression and psychoneuroimmunology. *Sports Med* 32(3):185-209, 2002.
3. Ayers JW, Komesu Y, Romani T, et al. Anthropomorphic, hormonal, and psychologic correlates of semen quality in endurance-trained male athletes. *Fertil Steril* 43(6):917-21, 1985.
4. Barron JL, Noakes TD, Wendy Levy, et al. Hypothalamic Dysfunction in Overtrained Athletes. *Journal of Clinical Endocrinology & Metabolism* 60(4):803-806, 1985.
5. Chang CK, Tseng H, Tan H, et al. Responses of saliva testosterone, cortisol, and testosterone-to-cortisol ratio to a triathlon in young and middle-aged males. *Biology of Sport* 22(3): 227-235, 2005.
6. Chatard JC, Collomp C, Maglischo E, et al. Swimming skill and stroking characteristics of front crawl swimmers. *Int J Sports Med* 11(2): 156-61, 1990. Collins KJ and Weiner JS. Endocrinological aspects of exposure to high environmental temperatures. *Physiol Rev* 48:785-839, 1968.
7. Davies CTM and Knibbs AV. The training stimulus: The effects of intensity, duration and frequency of effort on maximum aerobic power output. *European Journal of Applied Physiology* and *Occupational Physiology* 29(4): 299-305, 1971.
8. Duclos M, Guinot M, Bouc YL. Cortisol and GH: Odd and controversial ideas. *Appl Physiol Nutr Metab* 32(5):895-903, 2007.
9. Fry AC, Kraemer WJ. Resistance exercise overtraining and overreaching. *Neuroendocrine responses. Sports Med* 23(2):106-29, 1997.
10. Fry RW, Morton AR, Keast D. Periodisation and the prevention of overtraining. *Can J Sport Sci* 17:241-248, 1992.
11. Galbo H. *Hormonal and Metabolic Adaptation to Exercise*, 1st edition. Stuttgart and New York: Thieme-Stratton Inc. 1-116, 1983.
12. Gwinup G, Johnson B. Clinical testing of the hypothalamic-pituitary-adrenocortical system in states of hypo- and hypercortisolism. *Metabolism* 24(6):777-91, 1975.
13. Hackney AC, Sinning WE, Bruot BC. Reproductive hormonal profiles of endurance-trained and untrained males. *Med Sci Sports Exerc* 20(1): 60-65, 1988.
14. Haynes RC, Larner J. Adrenocorticotrophic hormone, adrenocortical steroids and their synthetic analogs: Inhibitors of adrenocortical steroids biosynthesis. In: *The Pharmacological Basis of Therapeutics*. Goodman LS, Gillman, A (Eds.). 5th Ed. New York, Macmillan Publishing Co. 1472-1506, 1975.
15. Holloszy JO. Biochemical adaptations to Exercise: Aerobic Metabolism. *Exerc Sport Sci Rev* 1:45-71, 1973.
16. Housh TJ, Housh DJ, de Vries HA. *Applied Exercise and sport physiology*. Second edition. 111-112, 2006.
17. Janssen GM, Hoor TF. Marathon running: functional changes in male and female subjects during training and contests. Introduction. *Int J Sports Med* 10(suppl 3): S118-S123, 1989.
18. Johansson C, Tsai L, Hultman E, et al. Restoration of anabolic deficit and muscle glycogen consumption in competitive orienteering. *Int J Sports Med* 11(3): 204-7, 1990.
19. Jurimae J, Jurimae T, Purge P. Plasma testosterone and cortisol responses to prolonged sculling in male competitive rowers. *Journal of Sports Sciences* 19(11): 893-898, 2001.

## TRAINING LOAD IN SWIMMERS

20. Jurimae J, Jurimae T. Responses of blood hormones to the maximal rowing ergometer test in college rowers. *Journal of Sports Medicine And Physical Fitness* 41(1): 73-77, 2001.
21. Kirwan JP, Costill DL, Flynn MG et al. Physiological responses to successive days of intense training in competitive swimmers. *Medicine & Science In Sports & Exercise* 20(3), 2001.
22. Krieger DT, Allen W, Rizzo F, et al. Characterization of the Normal Temporal Pattern of Plasma Corticosteroid Levels. *Journal of Clinical Endocrinology & Metabolism* 32(2): 266-284, 1971.
23. Luger A, Deuster PA, Kyle SB, et al. Acute hypothalamic-pituitary-adrenal responses to the stress of treadmill exercise. Physiologic adaptations to physical training. *The new England journal of medicine* 316(21):1309-1315, 1987.
24. Maglischo EW. Swimming fastest: The essential references on technique, training, and program design 346-670, 2003.
25. Morgan WP, Brown DR, Raglin JS, et al. Psychological monitoring of overtraining and staleness. *British Journal of Sports Medicine* 21:107-114, 1987.
26. Shephard RJ. Intensity, duration and frequency of exercise as determinants of the response to a training regime. *Int Z Angew Physiol* 26(3):272-8, 1987.
27. Smith LL. Cytokine hypothesis of overtraining: a physiological adaptation to excessive stress? *Med Sci Sports Exerc* 32(2): 317-31, 2000.
28. Urhausen A, Gabriel H and Kindermann W. Blood hormones as markers of training stress and overtraining. *Sports Med* 20(4): 251-76, 1995.
29. Viru A and Viru M. Biochemical monitoring of sport training. Human kinetics publishers. 87-104, 2001.
30. Warner SMA, Henderson NMS, Dolan S, et al. What is cortisol? by ERB - Endurance Research Board, Health & Nutrition: 2005.
31. Warren MP, Constantini NW. *Sports endocrinology*. 350-356, 2000.
32. Wheeler GD, Wall SR, Belcastro AN, et al. Reduced serum testosterone and prolactin levels in male distance runners. *JAMA* 252 (4):514-516, 2000.