Training Periodization in Lower Limb Performance and Neuromuscular Controlling in taekwondo athletes

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Background: Taekwondo is a powerful sport in which the maximal performance relies on anaerobic metabolism and explosive power. Aims: to determine the dedication of different strength and power training programs (off-season, pre-season and in-season) to lower limb performance and physiological modulation during a 20-week training period. Methods: Eight male collegiate taekwondo athletes completed 20-week systemic training programs divided into a linear training mesocycle (general conditioning, muscular recruitment, and hypertrophy) from 1 to 12 weeks, and two microcycle (maximum strength , explosive power, agility, speed) from 13 to 20 weeks in periodized fluctuation. Subjects were evaluated biochemical index, forearm total vascular occlusion test and muscular stiffness test six times during Training program: at the beginning (week 0, date1, T1), in the middle (week 2, Date 13, T2; week 8, Date 55, T3; week 14, Date 97, T4; week 18, Date 125, T5) and at the end (week 21, Date 143, T6) of the training program. Squat jump (SJ), countermovement jump (CMJ) and continuous jump bent leg (CJb) were tested before and after the systemic strength training period. Results: There were significantly increasing in the SJ (7.8(2.7)%), CMJ (18.3(4.1)%) and CJb (8.7(4.7)%) after the totally training programs. Training increased creatine kinase levels from T1 to T4 (327.8%) and recovered at T6 (99.4%). Muscle damage and muscular recruitment function recovered at T6 after taper. Conclusion: The conjunction of systemic periodized 20 weeks training programs would increase lower limb performance and strengthen neuromuscular controlling in taekwondo athletes.

[Yen Ke-tien. **Training Periodization in Lower Limb Performance and Neuromuscular Controlling in taekwondo athletes.** *Life Sci J* 2012;9(3):850-857]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 120

Key words: taekwondo, periodization, neuromuscular controlling, muscle mechanical properties

1. Introduction

Taekwondo is a powerful sport in which the maximal performance relies on the specific technical, tactical and physical developments. Taekwondo is a periodic intense sport that demands athletes to compete in sequence of short duration attack (from 1 to 5 s) and waiting for another opportunity of frequent short attack of high intensity exercise, consisted of both moving play and contact play. The anaerobic metabolism and explosive power are needed.

Sports scientists have evaluated joint mobility, muscle conditioning [1], neuromuscular complex [2] and soft tissue characteristics [3]. The muscle mechanical properties have also been used to study training effects on muscle conditioning by recording the damped mechanical oscillations.

Although, most elite athletes consecrate themselves to training programs that force them to the extreme of their exercise performance. Optimal performance is only reachable if athletes can resumeafter optimally balance training stress and energetic recovery. Coaches should organize modifications in training load and compensation in regularly practice. However, when the athlete is not well improved, mild hurts could develop into tissues damages and is characterized by falling performance in spite of an expanded rest period, associated by physiological, biochemical, and psychological stress symptoms.

The assessment and monitoring of stress markers during training programs would assign the individualization of an athlete's training workload [4]. Therefore, the best management to evaluate the training adaptation and to avoid overreaching and overtraining during training programs is the regular monitoring of selected biochemical and physiological markers.

Blood levels of creatine kinase (CK) have been used as an index of training-induced physiological stress. CK is a muscle enzyme that occasionally increases in the blood following strenuous exercise, altering permeability of muscle cell membranes. Factors that influence the degree of CK efflux into the blood include exercise duration and intensity, exercise mode, and fitness level of the individual [5].

The role of peripheral microcirculation including microvascular perfusion, tissue oxygenation and oxygen utilization is the major parts of the physiological mechanisms in different conditioning [6]. Moreover, ensuring tissue oxygenation, evaluating the entirety and adequacy of microvascular to apply tissue needs play important physiological regulatory functions. Since Jobsis (1977) first used Near Infrared Spectroscopy (NIRS) in monitoring cerebral and myocardial oxygen. It has been used to investigate tissue perfusion and oxygenation noninvasively, such as oxygen saturation in athletic muscles [7].

It is noteworthy that NIRS provides an average of saturation of hemoglobin in all vascular compartments (arterioles, capillaries and venules) within the tissue, termed as tissue oxygen saturation (StO_2).

However, different metabolic stress indices should have various time courses in response to the periodization of intense training and following effective recovery. This suggests that training monitoring in athletes should be effected not only in a multi-level approach using estimations of performance but various physiological indices as well.

Thus, to provide a better understanding of the martial art periodization, the aim of the study was to determine the dedication of different strength and power training programs (off-season, pre-season and in-season) to lower limb performance and physiological modulation during a 20-week training period. The training programs divided into a linear training mesocycle from 1 to 12 weeks, and two microcycle from 13 to 20 weeks in periodized fluctuation. Our hypothesis was that the conjunction of systemic periodized 20 weeks training programs from strengthening soft tissue and muscular recruitment in off-season/pre-season, to maximum explosive strength and peaking optimal specific power performance during in-season would increase lower limb performance and strengthen neuromuscular controlling in taekwondo athletes.

2. Methods

2.1. Subjects

Eight male collegiate taekwondo athletes were recruited in this study. The study protocol and aim were explained and informed consent obtained from all subjects before the study. Approval for the study was obtained from the Human Ethics Committee of the Cheng Shiu University. In a pre-study interview, information on routine use of vitamins and other nutritional supplements were obtained from each participant. Subjects were informed to avoid exercise or strenuous physical activity for 3 days prior to the before and after lower limb performance tests. In the twenty-four hour period preceding the study, subjects recorded all food and drink intake and this dietary pattern were duplicated in other parts of monitoring. Squat jump (SJ), countermovement jump (CMJ) and continuous jump bent leg (CJb) were tested before and after the systemic strength training period.

2.2. Experimental design and procedures

Subjects were evaluated six times during Training program (TP) I to IV: at the beginning (week 0, date1, T1), in the middle (week 2, Date 13, T2; week 8, Date 55, T3; week 14, Date 97, T4; week 18, Date 125, T5) and at the end (week 21, Date 143, T6) of the training program. Diets or lifestyles were not controlled during the course of the different seasons (Table 1).

The tests were always performed in the same order in the testing session. On the day of the experimental test, measurements were executed at 6:20 am- 7:20 am before breakfast on Friday morning. Athletes did not perform strenuous physical activities in the 12 hours before recordings. No subject was taking drugs at the time of the recording sessions. Subjects reported to the laboratory following a 10-h overnight fast. Subjects were instructed to consume 240 ml of water to increase hydration when they arrived at the laboratory. The experiments were performed in the room at comfortable ambient temperature (22°C to 24°C) and relative humidity (55-60%).The athletes lay supine for 5 minutes before experiments to relax in the room made noiseless. Firstly, subjects were measured forearm total vascular occlusion test (FTVOT) and muscular stiffness test (MST). Blood samples were collected in a rest position from the earlobe in order to analyze hemoglobin (HB) and creatine kinase (CK).

Table 1. Evaluations during training program (I-IV) of the study

Training period	Before-training		Training program				After-training	
			I	II	III	IV		
Aim	Base line		general conditioning	muscular recruitment	maximum strength	explosive power		
Week			1-6	7-12	13-16	17-20	21	
periodization			Off-season	Pre-season	Pre-season	In-season		
Test	before	T1	T2	T3	T4	T5	T6	after
Testing Date	-7th- -3rd	0	13th	55th	97th	125th	143th	144th-146th
Testing parameters	SJ, CMJ, CJb	HB, CK, NIRS, STIFFNESS						SJ, CMJ, CJb

2.3. Training program

This study was 20 weeks including a total of 1002.2 hours of taekwondo training. The taekwondo training program included of taekwondo related basic physical, tactical and specific technical training, and recreational training (Table 2).

The first 6 weeks of training program I consisting general conditioning and strengthen soft tissue (36 h) (Table 3). The 7th to 12th weeks of training program II including muscular recruitment, strengthen muscle tissue and hypertrophy (44 h) (Table 4). The 13th to 16th weeks of training program III containing maximum strength and strengthen power (24 h) (Table 5). The 17th to 20th weeks of training program IV including explosive power, agility and speed (40 h) (Table 6).

Table 2. Training programs (I-IV) characteristics

Type of Training	Duration of a session (min)	Training programs weekly frequency			
		I	II	III	IV
Recovery	30	6	6	10	7
Endurance	30	12	8	3	3
Specific taekwondo	30	12	18	16	18
Specific speed	40	9	12	9	9
Tactical	30	3	10	13	10
Technical	40	10	12	10	10
Strength training	40	9	11	9	10
Simulated match	40	3	6	6	7
Recreational	30	3	1	2	1

Table 3. Training program I (general conditioning) used between weeks 1 and 6.

AIM: general conditioning, strengthen soft tissue (Monday- Wednesday- Friday)		
Exercises	Sets x repetitions	Intensity
Warm-up	15 min of general activity + stretch	
Abdominal work	1–3 Sets–maximum 50 reps	
Back hyperextension	1Sets–maximum 10 reps	
Side bend with dumbbell	1Sets–maximum 10 reps	
Bar twists	1Sets–maximum 10 reps	
Upper body exercises		
Bench press	3x25-40	45-25% 1RM
Triceps extensions	3x25-40	45-25% 1RM
Wide-grip lat pull-downs	3x25-40	45-25% 1RM
Shoulder dips	1-3x 10reps	
Bicep curls	3x25-40	45-25% 1RM
Lower body exercises		
Body weight squat	3x25-40	45-25% 1RM
Half-squat	3x25-40	45-25% 1RM
Leg press	3x25-40	45-25% 1RM
Hamstring curl	3x25-40	45-25% 1RM

Table 4. Training program II (muscular recruitment) used between weeks 7 and 12

AIM: muscular recruitment, strengthen muscle tissue, hypertrophy (Monday- Wednesday- Friday)		
Exercises	Sets× repetitions	Intensity
Warm-up	15 min of general activity + specific	
Abdominal work	1–3 Sets–maximum 50 reps	
Back hyperextension	1Sets–maximum 10-20 reps	
Side bend with dumbbell	1Sets–maximum 10-15 reps	
Bar twists	1Sets–maximum 10-15 reps	
Upper body exercises		
Incline bench press	3x8-10	75-85% 1RM
Dumbbell lat row	3x8-10	75-85% 1RM
Bicep curls	3x8-10	75-85% 1RM
Low pulley seated lat row	3x8-10	75-85% 1RM
Lower body exercises		
Standing calf (heel) raise	3x8-10	75-85% 1RM
Power clean	3x5-7	20-40% 1RM
Hang clean	3x5-7	25-45% 1RM
Leg press	3x8-10	75-85% 1RM
Hang snatch	3x5-7	20-45% 1RM
Leg extensions	3x8-10	75-85% 1RM
Standing calf (heel) raise	3x8-10	75-85% 1RM
Hamstring curls	3x8-10	75-85% 1RM

Table 5. Training program III (maximum strength) used between weeks 13 and 16

AIM: maximum strength, strengthen power (Monday- Wednesday- Friday)		
Exercises	Sets x repetitions	Intensity
Warm-up	15 min of general activity + specific	
Abdominal work	3–5 Sets–maximum 40 reps	
Back hyperextension	1-2Sets–maximum 10-20 reps	
Side bend with dumbbell	1-2Sets–maximum 10-15 reps	
Bar twists	1-2Sets–maximum 10-15 reps	
Upper body exercises		
Power drops	4x8	Medicine ball (3 kg)
Dumbbell lat row	4x3	90% 1RM
Push press	4x3	90% 1RM
Single arm throw	4x8	Medicine ball (2 kg)
Low pulley seated lat row	4x3	90% 1RM
Lower body exercises		
Standing calf raise	4x3	90% 1RM
Power clean	4x3	45% 1RM
Hang clean	3x5	45% 1RM
Leg press	4x3	90% 1RM
Hang snatch	3x5	40% 1RM
Leg extensions	4x3	90% 1RM
Hamstring curls	4x3	90% 1RM

Table 6. Training program IV (explosive power) used between weeks 17 and 20.

AIM: explosive power, agility, speed (Monday- Wednesday- Friday)		
Exercises	Sets x repetitions	Intensity
Warm-up	15 min of general activity + specific	
Abdominal work	3–5 Sets–maximum 40 reps	
Back hyperextension	2 Sets–maximum 15 reps	
Side bend with dumbbell	2 Sets–maximum 15 reps	
Bar twists	2 Sets–maximum15 reps	
Upper body exercises		
Bench press + medicine ball throws	3x (8 + 8 reps)	80% 1RM
Dumbbell lat row	3x 8	80% 1RM
Push press + medicine ball throws	3x (8 + 8 reps)	80% 1RM
Bicep curls	3x 8	80% 1RM
Low pulley seated lat row	3x 8	80% 1RM
Lower body exercises		
Jump and reach	4x7	90% 1RM
Power clean + (standing triple jump)	3x (5 + 4 reps)	40% 1RM
Lateral box jump + (5-m lateral shuttle)	3x (5 + 4 reps)	90% 1RM
Leg press + (standing long jump)	4x(3+ 2reps)	90% 1RM
Hang snatch + (tuck jumps)	3x (5 + 10 reps)	40% 1RM
Leg extensions + 5-m sprint	4x3	90% 1RM

2.4. *Blood Collection and Analysis*

Earlobe blood samples were collected from each subject for determination of HB and CK. The serum CK concentration was measured immediately with the Ektachem DTSC chemistry analyzer (Johnson and Johnson, Rochester, NY, USA). The hemoglobin was measured with Analyzer (HemoCue® Hb 201+, Ängelholm, Sweden).

2.5 Forearm total vascular occlusion test (FTVOT)

The subject should then be placed sub supine with slight head-of-bed elevation for comfortable resting and to prevent the influence of gravity on blood flow and the accumulation of venous blood. The TSNIR-3 (TSNIR-3, Anheng Inc., Hefeii, China) probe should be placed on the thenar muscle ensuring adequate sealing to prevent ambient light. The dominant thenar muscle with relatively superficial and easy to access characteristics was chosen for FTVOT. During the first 5min, the athletes were in a comfortable supine position [8]. The sleeve-pressing method was used to perform the forearm venous occlusion. The pressure was increase 30-50 mmHg over the systolic pressure to ensure the artery and venous blood flow of the forearm was impeded completely, and this complete occlusion was maintained for 2 min. The pressure was then released and allowed to recover to the normal state. Adequate time should be allowed for the recording of the reactive hyperemia until the return of tissue oxygen saturation (StO_2) to baseline values [9].

After the vascular occlusion measurement, the inflation of the cuff is followed by a rapid pressure decreasing. The StO_2 decrease has been used extensively in the literature as an estimate of oxygen consumption rate (Oxygen consumption rate, %/min) of the muscle tissue[8]. The oxygen consumption rate reflects the basic metabolism of skeletal muscle at rest, but is also influenced by the adequacy of microcirculation to provide necessary oxygen to the tissue. The rate of StO_2 increase after cuff release reflects the resaturation rate of hemoglobin (reperfusion rate, %/min), which relies on integrating function of the vascular endothelium.

2.6. Muscle mechanical properties

The evoked mechanical oscillations are clearly visible. If there is no neural activation, the condition of the muscle is considered to be characterized mainly by the viscoelastic properties [10].MyotonPRO (MyotonPRO, Myoton AS, Tallinn, Estonia) enables us to observe mechanical oscillation of the tissue provoked by mechanical impact with an effort to avoid neurological reactions and non-elastic deformations in the tissue and measures the distortion properties of natural damped oscillations produced following a short (15 ms) mechanical tap to the surface of the skin. Stiffness was created of the underlying muscle, based on equations calculated from the acceleration of the testing probe during oscillations [11]. Rectus femoris (RF) of dominate leg was measured two occasions at the same time. The subjects lay with their knees extended and hips in neutral to rest for 5 min prior to measurements. During this time, room and skin surface temperature were recorded via an electro-thermometer, and the site for measurement on the RF muscle was identified by measuring two-thirds distally from the most anterior aspect of the anterior superior iliac spine to the superior border of the patella, following the direction of muscle fibers. After 5 min, the testing end of MyotonPRO was placed on the skin perpendicular to the surface of the muscle belly over the site located. The contraction of RF muscle was evoked by raising the leg to an angle of 45◦. Stiffness reflects the resistance of the tissue to the force that changes its shape. The higher this value is, the more energy is needed to modify the shape of the tissue. During contraction the stiffness of the muscle increases linearly with the increase in the contraction force [12].

2.7. Lower limb performance

Lower limb performance is a determinant factor for success in many sports. A mixture of explosive force, endurance and coordination is trained and very carefully optimized for each particular sports type. Gymmy Jump provides an objective measurement of force, power and jump height. Gymmy Jump consists of a portable Kistler force plate on which different jump types are performed. The force plate measures the vertical jump force which is analyzed with the computer connected to the system.The Bosco Protocol evaluates 3 different jump types and calculates a variety of parameters: (a) Squat jump (SJ) : Single jump starting from knees bent at 90 degrees; (b) Countermovement jump (CMJ): Single jump starting with straight legs with a natural flexion before takeoff: (c) Continuous jump bent l egs (CJb): Series of 0s to 60s jumping with knees bent.Performance in a squat jump describes jumping ability and explosive (maximal) force production of the lower extremities.

2.8.Statistical analysis

Standard statistical methods were used to calcu-late the mean and standard deviations (SD). The haemocrit level was used to adjust the other parameters for different dehydration. The differences between the Before- and After training program values were statistically examined by paired *t* test. ANOVA with repeated measures was used to determine the differences between tests. When a significant *F* value was achieved, appropriate LSD *post hoc* tests procedures were used to locate the difference between means. The $P<0.05$ criterion was used to establish statistical significance.

3.Results

3.1. Anthropometric characteristics and lower limb performance values

Table 7 shows the variables concerning the anthropometric and metabolic characteristics of the athletes examined before-training and after-training programs period. There were significantly increasing in the SJ, CMJ and CJb after the training programs period.

Table 7 Anthropometric characteristics and lower limb performance of the taekwondo athletes at the before and after the end of the training period

Characteristics	unit	BEFORE-training	AFTER-training	Change (%)
Age	y	22.7(2.3)	22.7(2.3)	
Height	cm	175.4(5.7)	175.4(5.7)	
Weight	kg	76.5(6.3)	77.2(6.8)	0.92(.67)
Hemoglobin	g/dL	13.3(0.5)	13.8(0.7)	3.7(3.5)
Squat jump	cm	37.9(6.0)	40.8(5.1)*	7.8(2.7)
Countermovement jump	cm	41.4(4.2)	42.8(4.9) *	18.3(4.1)
60s Continuous jump bent legs	cm	31.8(5.3)	34.6(5.7)*	8.7(4.7)

Values are expressed as means(SD). *: vs. Before-training period, $P<0.05$.

3.2. Creatine kinase

Training increased creatine kinase levels (Fig. 1) from T1 to T2 (120.5%), T3 (197.7%) and T4 (327.8%). In contrast, CK levels tend to recover at T5 (289.2 %) and incline to baseline significantly ($P<0.05$) at T6 (99.4%) thereafter. Blood levels of CK have been used as an index of training-induced physiological stress.

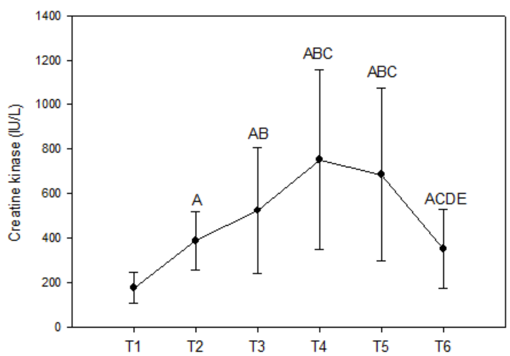

Figure 1. Creatine kinase responses with training. T1, baseline; T2–T5, the four training programs (I-IV); T6, After-training. [A]: vs.T1, $P<0.05$; [B]: vs.T2, $P<0.05$; [C]: vs.T3, $P<0.05$; [D]: vs.T4, $P<0.05$; [E]: vs.T5, $P<0.05$.

3.3. Forearm total vascular occlusion test

Changes in muscle tissue oxygen consumption rate status are represented in Fig. 2. oxygen consumption rate decreased significantly ($P<0.05$) from T4 (53.1 %), in contrast, oxygen consumption rate restored at T5 (53.3 %) and incline to T4 significantly ($P<0.05$) at T6 (86.7 %). The trend of reperfusion rate was the same as oxygen consumption rate. Reperfusion rate significantly decreased ($P<0.05$) at T4 (46.30 %) and elevated at T6 (74.1%). The lower oxygen consumption rate of FTVOT after the training programs was, the less basic metabolism of skeletal muscle performed. FTVOT could been as an index of training-induced metabolic stress.

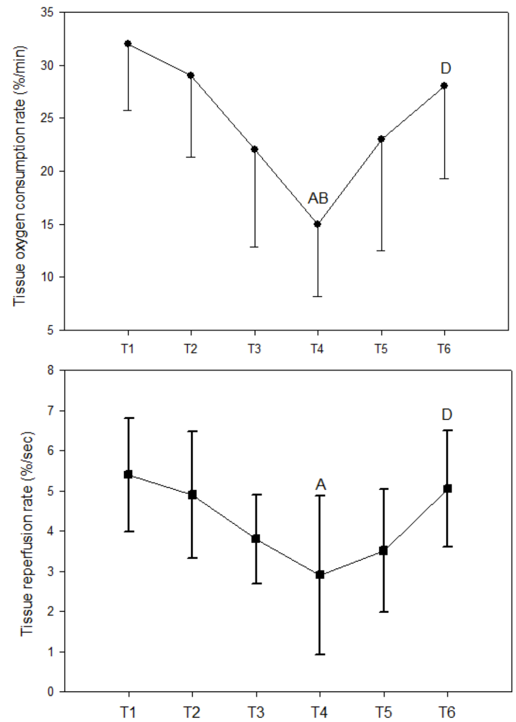

Figure 2. Indices of forearm total vascular occlusion test during training programs. T1, baseline; T2–T5, the four training program periods (I-IV); T6, After-training period. [A]: vs.T1, $P<0.05$; [B]: vs.T2, $P<0.05$; [D]: vs.T4, $P<0.05$.

3.4. Muscle mechanical properties

Fig3 illustrates stiffness changes. There were the same significantly changes trend between contraction and relaxation. Stiffness of contraction were increased from T1 to T4 (T2, 15.0%; T3, 41.8%; T4, 62.1%) and recovered from T4 to T6 (T5, -11.8%; T6, -25.9%). Stiffness of relaxation were increased from T1 to T4 (T2, 22.6%; T3, 44.7%; T4, 53.2%) and recovered from T4 to T6 (T5, -8.5%; T6, -13.0%). Responses of muscle stiffness could be as a quantified index of training load and training intensity.

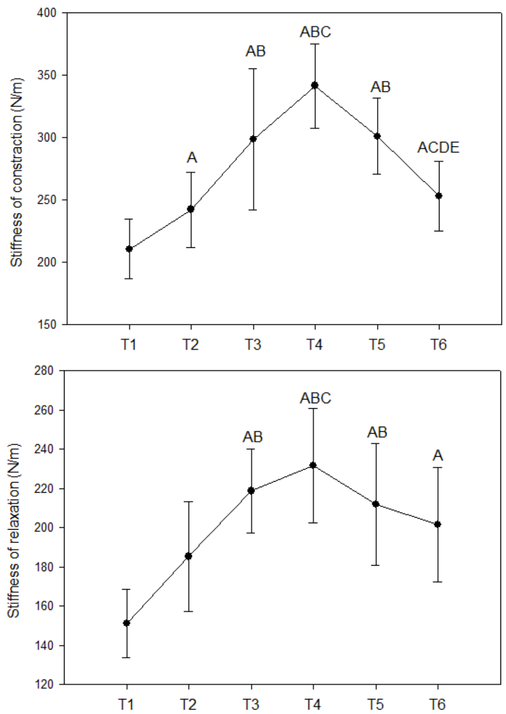

Figure 3. Indices of muscle mechanical properties (stiffness of contraction; stiffness of relaxation reperfusion rate) responses during training. T1, baseline; T2–T5, the four training programs (I-IV); T6, After-training. [A]: vs.T1, $P<0.05$; [B]: vs.T2, $P<0.05$; [C]: vs.T3, $P<0.05$; [D]: vs.T4, $P<0.05$; [E]: vs.T5, $P<0.05$.

Discussion

Taekwondo can be identified as an intermittent exercise alternating dominantly anaerobic metabolism. We believe that athletes must arrange basic and specific muscular fitness to conditioning their performance.

The training load in competitive sport can be characterized as a combination of training intensity, volume, and frequency [13]. This training load is extremely decreased during the taper in an attempt to reduce accumulated fatigue, but reduced training should not be hurtful to training-induced adaptations [14]. During taekwondo high-intensity bouts of activity, athletes are involved in defensive and offensive speeding attacks underlie the anaerobic metabolism contribution that strength, power, agility, and sprint are needed. Therefore, athletes and coaches must judge the content to which the training load can be regulated at the amount of the training variables while reserved or slightly improving adaptations. The study establishes the scientific bases for well monitoring different seasons (TP-I~IV) changed training loads, supporting athletes, coaches, and sports scientists accomplish the optimum training conjugation during the periodization, leading to peak performances at the planned point during the seasons.

The training load is clearly depressed during a taper (TP-IV) after that athletes regain from intensive training (TP-III to TP-IV) and energized before major events (After-training or competition). Research easily displays controlling conditioning (TP-IV) to avoid detraining risks, training intensity should be sustained during the taper, because the organized training periodization is important to reserving performance and explosive power. In addition, high-quality training during the taper can further enhance physiological and performance adaptations (TP-IV). Conversely, if training intensity is diminished, some training-induced adaptations may be lost, leading to suboptimal competition performance.

CK is an important enzyme in muscle energy production that is generally confined to the inside of muscle cells. The presence of elevating values of CK in the blood from TP-I to TP-III suggested that muscle cell membranes had suffered some kind of damage, allowing CK to escape the cells. Following tapering and reducing intensive training, the blood concentration of CK was remarkably decreased, suggesting TP-III increased levels of muscle tissue breakdown.

Thomas and colleagues (2008) present that an overload before the taper is essential to maximize performance but imposes specific requirements during the taper. We prepared to strengthen soft tissue (TP-I), muscular recruitment and hypertrophy (TP-II) firstly. Then, Athletes were potentiated maximum strength applied to explosive power (TP-III) and intensified functional performance (TP-IV). Our study from TP-I to TP-III reflected increasing CK level (327.8%), reducing oxygen consumption rate (-53.1 %) and elevating muscular stiffness responses (62.1%). The study developed a progressive modulation being preferably to taper after prior overload training. Our findings confirm the relevance of the original modeling between TP-I to TP-IV approach in the study of individual responses to training and the optimization of tapering strategies and selected monitoring index.

Neary and colleagues (2005) used near-infrared spectroscopy (NIRS) to examine the effects of a taper on muscle oxygenation during cycling. These authors examined muscle oxygenation of the right vastus medians during a simulated 20 km/cycling time trial before and after a 7-day taper consisting of either a 30%, a 50%, or an 80% reduction in weekly training volume. Mean tissue oxygenation during the cycling test was significantly greater (i.e., increased muscle deoxygenation) following the 50% training volume reduction taper. In addition, there was a moderately high correlation between the change in tissue oxygenation and 20 km time trial performance, which suggests that metabolic changes that occur in the vastus medialis muscle are in part responsible for performance changes at the whole-body level. In other words, the taper induced increased oxygen extraction, which was associated with increased performance [15]. We detected FTVOT responses by monitoring StO_2 changes reacting neuromuscular conditioning during TP-I to TP-IV. Increases in the StO_2 during the taper meight contribute to taper-induced performance gains. A lower oxygen cost of exercise after the taper from TP-I to TP-III could also contribute to improved performances. Any observed change seems to be a reflection of the athletes' adaptation reflecting the resaturation rate of hemoglobin to preceding training rather than to the taper itself.

The extraordinary plasticity of skeletal muscle tissue allows it to adapt to variable levels of functional demands, neuromuscular activity, and biochemical signals and reversibly change its functional characteristics and structural composition[16]. A in-season/precompetition taper presumably reduces the demands placed on the neuromuscular system compared with previous phases of a training program. Increased strength and power as a result of a taper have been a common observation in different athletic activities. Costill and colleagues (1985) were among the first researchers to describe such gains in swimmers. These authors described an 18% improvement in swim bench power and a 25% gain in actual swim power in a group of 17 collegiate swimmers undergoing a 2-week taper. Swim power improvement correlated with a 3.1% competition performance gain (r = .68). In the study, there were recoveries from reducing in CK levels (99.4%), elevating reperfusion rate (74.1%) and decreasing stiffness of contraction (-25.9%) at T6. The reduced training may have allowed for an increase in maximal tension development through changes in the contractile mechanisms or neural controls on fiber recruitment.

In conclusion, the results of this study indicate that systemic periodised strength training programs elevated biological stress increasing CK, oxygen consumption rate and muscular stiffness modulation. According to taper in periodization, there are strong correlations among training load and physiological stress. The conjunction of systemic periodised 20 weeks training programs would increase lower limb performance and strengthen neuromuscular controlling in taekwondo athletes.

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7/12/2012