OPTIMIZING PHYSIOLOGICAL, PSYCHOLOGICAL AND PERFORMANCE OUTCOMES USING TAPERING TECHNIQUES AMONG JUNIOR CYCLISTS

by

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BRUMS	Brunel Mood Scale
CVR	Content Validity Ratio
CV	Coefficient of variation
CK	Creatine Kinase
EDTA	Ethylenediamine tetra-acetic acid
GXT	Graded Exercise Test
HR_{max}	Heart Rate Maximum
Hg	Hemoglobin
Hct	Hematocrit
KM	Kilometre
Lac	Lactate
LDH	Lactate Dehydrogenase
MET	Modified Exponential Taper
NET	Normal Exponential Taper
RH	Relative Humidity
RPE	Rating of Perceive Exertion
RPM	Revolution Per Minutes
VO_{2max}	Maximum Oxygen Consumption
W_{com}	Workload complete
W_{max}	Maximum Power Output

MENGOPTIMUMKAN HASIL FISILOGIKAL, PSIKOLOGIKAL DAN PRESTASI DENGAN MENGGUNAKAN TEKNIK TAPER DIKALANGAN PELUMBA BERBASIKAL REMAJA

ABSTRAK

Tujuan kajian ini dijalankan adalah untuk mengkaji kesan peningkatan beban latihan dalam tiga hari terakhir fasa taper menggunakan protokol taper eksponen ke atas pemboleh ubah fisiologi, psikologi dan ujian masa 20KM dalam kalangan pelumba basikal remaja. Kajian ini melibatkan kumpulan kawalan dan dua kumpulan eksperimental iaitu kumpulan taper eksponen yang telah diubah suai dan kumpulan taper eksponen biasa. Dua puluh satu pelumba basikal remaja lelaki terlibat dalam kajian ini dan sembilan belas (19) peserta (purata umur = 16.95 $\pm$ 0.8 tahun) menamatkan kajian sehingga ke peringkat akhir. Peserta dipadankan berdasarkan nilai pengambilan oksigen maksimum (VO_{2max}) dari pengukuran awal dan dibahagikan kepada tiga kumpulan; taper eksponen biasa (NET), taper eksponen yang telah diubah suai (MET) dan kumpulan kawalan (CON). Kedua-dua kumpulan eksperimental menjalani latihan kecergasan berbentuk progresif selama tiga bulan diikuti dengan dua minggu latihan taper. Kumpulan kawalan meneruskan latihan kecergasan sehingga ke akhir tempoh kajian. Kesemua parameter diukur pada pengukuran awal, pra-taper dan pasca-taper. Hasil analisis variance *(ANOVA)* menunjukkan terdapat interaksi yang signifikan antara kumpulan eksperimental dengan kumpulan kawalan merentasi masa pengukuran untuk pemboleh ubah VO_{2max}, keluaran kuasa maksimum (W_{max}), kadar denyutan jantung maksimum (HR_{max}), *rating perceive of exertion* (RPE), hemoglobin (Hg), hematokrit (Hct), laktat (Lac), kreatina kinase (CK), laktat dehidrogenase (LDH), kortisol, kelesuan and semangat. Keputusan analisis post-hoc menunjukkan kedua-dua kumpulan eksperimental (NET

dan MET) menunjukkan nilai VO_{2max}, W_{max}, skor RPE, kepekatan Hg, Hct, Lac dan vigor yang tinggi berbanding kumpulan kawalan. Sebagai tambahan, keputusan ujian post-hoc menunjukkan kumpulan eksperimen (NET dan MET) mempunyai nilai HR_{max}, CK, LDH, dan kepekatan kortisol and skor kelesuan yang signifikan rendah berbanding kumpulan kawalan. Keputusan kajian pasca taper menunjukkan kumpulan eksperimental mempunyai masa yang lebih pantas dalam ujian masa 20 km berbanding kumpulan kawalan. Walau bagaimanapun, tiada perbezaan yang signifikan ditunjukkan di antara kumpulan MET dan NET dalam kesemua parameter yang diukur. Sebagai kesimpulan, kedua –dua jenis taper (MET dan NET) mempunyai kesan yang sama untuk mengoptimumkan hasil prestasi, fisiologi dan psikologi dalam kalangan pelumba basikal remaja.

OPTIMIZING PHYSIOLOGICAL, PSYCHOLOGICAL AND PERFORMANCE OUTCOMES USING TAPERING TECHNIQUES AMONG JUNIOR CYCLISTS

ABSTRACT

The aim of this study was to investigate the effects of increased training loads during the final three days of taper using modified exponential taper on physiological, psychological and performance outcomes among junior cyclists. This study involved a pre- and post- experimental design with a control group and two experimental groups (modified exponential taper and normal exponential taper). Twenty one junior male cyclists were recruited and 19 subjects (Mean age = 16.95± 0.8years) completed the whole study protocol. Participants were matched according to a baseline VO_{2max} value and they were assigned into either normal exponential taper (NET), modified exponential taper (MET) and control groups (CON). Both experimental groups underwent three months of progressive endurance training followed by two weeks of taper, while the control group continued their endurance training until the end of the study period. All parameters were measured at baseline, pre-taper and post taper. The results of the Mixed Factorial Analysis of Variance (ANOVA) revealed significant interactions between experimental groups across the measurement sessions for maximum oxygen consumption (VO_{2max}), maximum power output (W_{max}), maximum heart rate (HR_{max}), rating perceive of exertion (RPE), hemoglobin (Hg), hematocrit (Hct), lactate (Lac), creatine kinase (CK), lactate dehydrogenase (LDH), cortisol, fatigue and vigor. No significant interactions were observed for ferritin concentration value, anger, tension, depression and confusion scores. The results of post–hoc analysis revealed that both experimental groups (NET

and MET) showed significantly higher values in VO_{2max}, W_{max}, RPE scores, Hg concentration values, Hct concentration value and Lac concentration value and vigor scores compared to the control group. Furthermore, the results of post-hoc analysis showed that the experimental groups (NET and MET) had significantly lower HR_{max}, CK, LDH, cortisol concentration values and fatigue scores compared to the control group. The result also revealed that the experimental groups had significantly faster time in the 20 km time trial compared to control group at post taper. However, no significant differences were observed between the MET and NET groups. It is concluded that the MET and NET are equally effective in optimizing the physiological, psychological and performance outcomes among junior cyclists.

CHAPTER 1

INTRODUCTION

1.1 Background and Scope of the study

Improved competitive performance can be achieved through a well-plan programme following appropriate training principles. A training load combining the elements of intensity, volume, duration and frequency (Smith, 2003; Mujika, Padilla, Pyne, & Busso, 2004) are crucial to elicit training-induced adaptations (Bompa & Haff, 2009).

Practically, increasing and decreasing training loads (i.e., intensity and volume) are fundamental training elements to develop the athlete abilities and physiological capacity. This can be implemented following progressive overload principles through sequential plan in the macro-cycle and micro-cycle training plan (Plisk & Stone, 2003). According to Bompa (1999), the concept of periodized training involves alternating periods of sequential increase and decrease of training loads, interspersed with recovery to avoid excessive fatigue. The training loads increased gradually in a progressive manner with recovery or regenerative techniques used throughout the training program (Pyne, 1996).

A growing number of researches have suggested that training regime should be intense enough to evoke physiological capacity at maximum level. The most important part to be considered during competitive phase is to eliminate physical stress (fatigue). This may be achieved by using strategies of increasing or maintaining high intensity training followed by reduced training volumes (Bompa & Haff, 2009; Mujika, 2009; Haff, 2014). This specific strategy is called taper.

Taper is recognized as one of the recovery strategies which can be implemented immediately prior to competition to enhance performance (Mujika & Padilla, 2003; Pyne, Mujika & Reilly, 2009). Mujika and Padilla (2003) define taper as a progressive nonlinear reduction of the training load during the period of training in an attempt to reduce the physiological and psychological stress of daily training. It has been well documented that training adaptation occurs during recovery phases after dissipation of fatigue (Smith, 2003).

Tapering techniques has been found as an effective recovery technique from intense training and it has been accepted as an integral part of optimal preparation for competition (Gibala, MacDougall, & Sale, 1994). In sport science literature, taper has been found to elicit a number of benefits among others are improving or retaining athletes physiological status (Neary, Bhambani, & McKenzie, 2003a; Mujika et al, 2004), enhance psychological states (Morgan, Brown, O'Conner, & Ellickson, 1987; Berger et al, 1999), regulate metabolic (Neary, Martin, Reid, & Quinney, 1992) and biochemical parameters (Mujika, Chatard, Padilla, Guezennec, & Geyssant, 1996; Coutts, Reaburn, & Piva, 2007a), enhance physical strength and power (Martin et al, 1994; Trappe, Costill, & Thomas 2000), and fostering sports performances.

Given its potential benefits, taper has been used in many sports such as swimming (Bonifazi, Sardella, & Luppo, 2000; Trappe et al, 2000; Trinity, Pahnke, Reese, & Coyle, 2006; Papoti, Martins, Cunha, Zagatto, & Gobatto, 2007), running (Shepley, MacDougall, Cipriano, Sutton, Tronopolsky, & Coates, 1992; Houmard & Johns, 1994; Child, Wilkinson, & Fallowfield, 2000; Mujika, Goya, Ruiz, Grijalba, Santisteban, & Padilla, 2002), triathlon (Bannister, Carter, & Zakardas, 1999; Margaritis, Palazzeti, Rousseau, Richard, & Favier, 2003; Vollaard, Cooper, &

Shearman, 2006; Coutts, Wallace, & Slattery, 2007b), kayak (Garcia-Pallares, Sanchez-Medina, Perez, Izquierdo-Gabarren, & Izquierdo, 2010), rowing (Steinacker, Lormes, Kellmann, Liu, Reibnacker, Baller, Gunther, Petersen, Kallus, Lehmann, & Altenburg, 2000; Smith, 2000; Meastu, Jurimae, & Jurimae, 2003) and also cycling (Martin & Anderson, 2000; Rietjens, Keizer, Kuipers, & Saris, 2001; Dressendorfer, Petersen, Lovshin, Hannon, Lee, & Bell, 2002; Neary et al, 2003a).

A central focus of taper is reducing physiological and psychological stress and removing residual fatigue with the aim to optimize performance (Mujika, 1998; Smith, 2003). The basic principle of taper is a manipulation of magnitude of reduction of the training volume, intensity, frequency and duration (Hickson & Rosenkoetter, 1981; Shepley et al, 1992; Mujika, 1998; Bannister et al, 1999; Mujika & Padilla, 2003; Bosquet et al, 2007; Wilson & Wilson, 2008; Neary et al, 2012).

Mujika and Padilla (2003) propose that the magnitude of taper effects are largely dependent on its specific types, the interaction between taper and pre-taper physical conditions and the types of sports involved (Pyne et al, 2009). It is well accepted that training intensity is one of the key element to maintain training induced adaptations (Hickson, Foster, Pollock, Galassi, & Rich, 1985; Bosquet, Leger, & Legros, 2002; Mujika & Padilla, 2003). Intensity during taper is closely related to the ability to maintain training induced performance adaptations.

It was observed that when higher intensity at 90% of HR_{max} is included in the tapering program, it tends to increase performance. Conversely, if training intensity is reduced, some of the training induced adaptation may be lost and leads to sub-optimal competition performance (Mujika, 2009). Intensity at or below than 70% of HR_{max} during taper period tend to decrease of endurance performance.

Successful taper also depends on other variables of training load, especially training volume. The relationship between training intensity and volume is important in order to provide the best strategy in taper (Mujika, 2010). Reduction of the training volume has been gaining attention from many taper related studies (e.g., Mujika, 1998; Smith, 2003). Several ranges of training volume reduction during taper have been documented in many sports. For instance, reduction of training volume between range 50% to 90% have been reported in several studies on swimming, running, cycling and triathlon. It has been recommend that the optimal rate of training reduction is 40% - 70% of training volume, but this is dependent on the method of reduction (Thomas, Mujika, & Busso, 2008).

The challenging part in designing a taper program is to determine the optimal duration of taper. This is because the relationship between intensity and volume of training has been shown to be influenced by the duration of time to recovery (Kubukeli, Noakes, & Dennis, 2002). In taper literature, the duration of taper has been proposed to range from four days (Neary et al, 1992) to four weeks (McConnell et al, 1993).

Kenitzer, (1998) study involving a group of female swimmers indicated that a taper of approximately two weeks represented the limit of recovery and compensation time before detraining occurs. Indeed, it has been suggested that athletes who underwent an intense prior to taper require approximately two weeks for full recovery, in which taper may provide the benefit of avoiding loss of fitness level.

Reducing training frequency is another method to reduce the training loads during taper. The reduction of the training frequency between two to four days has been reported in taper literature (Mujika, 2009). Bosquet et al. (2007) indicated that training frequency alone do not have any effect on performance but, it interacts with other training variables, particularly training volume and intensity in order to induce changes in post-taper performance.

Another critical element in designing tapering for competitive athlete's is type of taper employed (Thomas et al, 2008). Different types of taper have demonstrated differential outcomes. Taper can be categorized into non-progressive and progressive taper (Bosquet et al, 2007; Mujika, 2009). A Progressive taper refers to a systematic reduction in training load in a gradual fashion, whereas non-progressive taper refers to a standardized reduction with same amount in training load (Mujika & Padilla, 2003).

In progressive taper, training load can be reduced in either linear or an exponential fashion. A Linear taper involves decreasing volume in a stepwise fashion (e.g., 5% reduction from initial values in every workout) (Wilson & Wilson, 2008). On the other hand, exponential taper involves a decrease in training volume at a rate proportionate to its current value in a nonlinear fashion (Wilson & Wilson, 2008). Conversely, in non-progressive taper, training load reduction follows a constant decrease in training volume until the end of taper and this design is labelled as step taper (e.g., 50% reduction in every workout until the end taper) (Whyte, 2006).

One of the sub-types of progressive taper, the exponential taper, refers to reduction method in curve wave undulating pattern. By undulating, the reduction of training is either involves slow decay or fast decay (Mujika, 2009). The slow exponential taper involves the slow rate of decay whereas the fast exponential taper involves a faster decay of training volume.

Zakardas, Carter and Banister. (1995) conducted a study to investigate the optimal type of taper in eleven-ironman triathletes. The volume of training was reduced in step and exponential pattern in 10 days. The results showed a significant improvement in 5 km criterion run time and a 5% increase in maximal ramp power output for exponential taper group. However, no significant different was found in step taper group on the same parameters.

In a study by Banister et al. (1999) comparing between step and exponential taper, it was shown that the exponential taper group exhibited greater improvement in cycle ergometer and 5 km run performance compared to the step taper. Pyne et al. (2009) suggested that reduced training load followed by a subsequent increased training load in led up to the competition has the potential to contribute to performance gain. However, the number of days in which training load to be increased, remain speculative.

Thomas, Mujika and Busso (2009) conducted a computer simulation study to assess performance benefits by imposing an increased in training load during the final three days of taper period. Data from 13 swimmers were used to run the computer simulation modelling. Their finding showed that the tapering strategy with method of increasing training load during the final three days of taper significantly ($p<.01$) improved compared to traditional taper method (linear). They concluded a short increment in training load provide additional positive training adaptations.

Thus, according to Bosquet et al. (2007) and Mujika (2010), tapering involving a planned increase of training load during the final three days prior to competition may be particularly beneficial for athletes too improve performance. However, this suggestion has been based solely on theoretical predictions. Thus, there is a crucial need to confirm or reject this speculation on the basis of an experimental study. To date, no data exist regarding to effects of two weeks of modified exponential taper on physiological, psychological and performance.

Therefore, the primary aim of this study is to investigate the effects increase in training load during final three days of taper using modified exponential taper on physiological, psychological and performance outcomes among junior cyclists.

1.2 Conceptual Definitions

In this study, the following terminologies are operationalised as follows:

(a) Taper

Taper is a technique of reducing training loads in progressive nonlinear in an attempt to reduce physiological and psychological stress of daily training and optimized sports performance (Mujika & Padilla, 2003).

(b) Exponential Taper

Exponential taper is method training volume reduction in a curve wave undulating pattern (Wilson & Wilson, 2008).

(c) Modified exponential taper

Modified exponential taper involves training volume reduction in curve wave undulating pattern followed by an increase in training load during the final three days of taper (Thomas, et al, 2009).

(d) Training load

Training load is the products of intensity, volume, duration and frequency of training (Bompa & Haff, 2009).

(e) Mood

Mood is a set of feeling, ephemeral in nature, varying in intensity and duration and usually involving more than one emotion. Mood was measured using

BRUMS which is consisting assess of six dimensions of mood including, anger, confusion, depression, tension, fatigue and vigor (Terry et al, 1999).

(f) Recovery

Recovery refers to restoration process after intense training to dissipate accumulated fatigue (Halson & Argus, 2012).

(g) Intensity

Intensity training is qualitative component work of an athlete performs, it refers to how hard they do the exercise (Bompa & Haff, 2009).

(h) Volume

Volume training is defined as a product the sum of work performed during training session, weekly or annually years (Bompa & Haff, 2009).

(i) Junior cyclists

Junior cyclists refers to riders the under 19 age category set by Union Cycliste Internationale (UCI) (Menaspa et al, 2010).

1.3 Objective of the study

The objective of the study was divided into general and specific with following aims:

(a) General objective

The general objective of this study is to investigate the effects of increase in training load during final three days of taper using modified exponential taper on physiological, psychological and performance outcomes among junior cyclists.

(b) Specific objective

The specific objectives of this study are:

(1) To investigate the effects of modified exponential taper with increase load during the final three days of taper on physiological outcomes (VO_{2max}, W_{max}, Maximal heart rate, and RPE) and blood profile (hemoglobin, hematocrit, blood lactate, creatine kinase, lactate dehydrogenase, cortisol and ferritin).

(2) To investigate the effects of modified exponential taper with increase load during the final three days of taper on psychological outcomes (tension, anger, depression, confusion, fatigue and vigor).

(3) To investigate the effects of modified exponential taper with increase load during the final three days of taper on performance outcomes (20 km time trial).

1.4 Research Hypotheses

To achieve the study objectives the following hypotheses are formulated:

Hypothesis 1:

Null Hypothesis (H_{1O}): No significant differences are expected in the physiological outcomes using modified exponential taper with increase load during the final three days taper across the experimental groups.

Alternative Hypothesis (H_{1A}): Significant changes are expected in the physiological outcomes using modified exponential taper with increase load during the final three days taper across the experimental groups.

Hypothesis 2:

Null Hypothesis (H_{2O}): No significant differences are expected in the psychological outcomes using modified exponential taper with increase load during the final three days taper across the experimental groups.

Alternative Hypothesis (H_{2A}): There are significant effects of psychological outcomes using modified exponential taper with increase load during the final three days taper across the experimental groups.

Hypothesis 3:

Null Hypothesis (H_{3O}): No differences are expected in the performance outcomes using modified exponential taper with increase load during the final three days taper across the experimental groups.

Alternative Hypothesis (H_{3A}): Significant changes are expected in the performance outcomes using modified exponential taper with increase load during the final three days taper across the experimental groups.

1.5 Significance of the study

This study provides at least three significant contributions to taper research and practical application. First, it provides guidelines on using exponential tapering techniques to oprimize athletes physiological, psychological and cycling performance. Second, it provides evidence on the effectivenss of modified exponential taper with increase load during the final three days among junior cyclists. Third, it provide a data that can be used to choose tapering strategies for youth cycling program to an optimize performance.

CHAPTER 2

LITERATURE REVIEW

2.1. The role of Endurance in cycling performance

Endurance is a fundamental component for peak performance in many sports. In predominantly endurance sports, it is an important aspect for successes in training and competition (Kubukeli, Noakes & Denis, 2002). Endurance can be defined as the ability to sustain prolonged exercise (Whyte, 2006). Jones and Carter (2000) define endurance as the capacity to sustain a given velocity or power output at the longest possible time without fatigue.

Endurance can be divided into two categories; (1) aerobic endurance, and (2) anaerobic endurance. Aerobic endurance refers to the ability of the body to perform exercises with the presence of oxygen at prolonged time. Whereas, anaerobic endurance refers to the capacity to perform exercise without oxygen at relatively short bust of time (Bosquet, Leger & Lagros, 2002).

In anaerobic endurance exercises, the main energy source utilization during exercise is anaerobic phosphagen and anaerobic glycolysis (Faria, 1984; Maclaren & Morton, 2012). Anaerobic phosphagen pathway produces adenosine triphosphate (ATP-PC) as an energy system. The synthesis of ATP from creatine phosphate (CP) and adenosine diphosphate for these reactions is catalyzed by Creatine Kinase. This energy system is related to short burst exercises of approximately one to ten seconds such as sprinting and power exercises (Maclaren & Morton, 2012).

Furthermore, anaerobic glycolysis is the breakdown of glucose to lactate without the presence of oxygen. It produces pyruvate at the end of glycolysis and is further converted to the lactate. The formation of lactate from pyruvate is catalyzed by enzyme lactate dehydrogenase. Sport events lasting from 10 to 60 second such as swimming, track and field, canoeing and track cycling are predominantly anaerobic (Mathew & Fox, 1988).

In aerobic endurance, the breakdown of carbohydrate and fat to carbon dioxide and water necessitates oxygen and takes place in the mitochondria of the cells (Maclaren & Morton, 2012). Therefore, the adaptive response of skeletal muscle to endurance exercise is an augmentation of the respiratory capacity with increased abilities to oxidise glycogen and fatty acid. Consequently, aerobic endurance requires adequate delivery of oxygen capacity to cytochrome oxidase in the mitochondrial electron transport chain and the supply of fuels in the form of carbohydrate and lipids (Leger, Mercier & Gauvin, 1986).

Factors that can contribute to endurance capacity include neuromuscular function, metabolic capacity, cardiorespiratory function as well as skeletal muscle (Joyner, 1991; Smith, 2003). The neuromuscular function involves the central nervous system, which is linked by a system of nerves ensuring the passage of information between skeletal muscles. It ensures that the skeletal muscle produces the power output necessary to induce movement and displacement, based on the command from brain (Hausswirth & Meur, 2012). Moreover, during endurance activities, this system is linked to the body’s metabolic energy system to ensure energy resynthesis of ATP to supply into skeletal muscle. Oxygen is required to oxidise these substrate and delivery to the active muscle through cardiorespiratory system (Jones & Carter, 2002; Hausswirth & Meur, 2012).

The goal of endurance training is to improve endurance capacity and performance. Endurance performance requires the ability to perform and sustain the specific power output at sub-maximal or maximal intensity over an extended duration. It has been reported that endurance performance can range from 5 minutes to 4 hours duration at 65 to 100% of VO_{2max} (Jones & Carter, 2000; Whyte, 2006).

Numerous studies have documented that physiological characteristics related to endurance performance include VO_{2max}, power output, lactate, movement economy, heart rate and perceive of exertion, (Coyle, 1999; Mujika, 2009; Pyne & Saunders, 2012; Hausswirth & Meur, 2012). It has also been shown that VO_{2max} is the best predictor of endurance performance. A larger improvement in movement economy is also required to achieve the same performance gains, while, improvement in lactate associated with improvement in movement economy (Pyne & Saunders, 2012).

Even though the physiological parameters are crucial in the success of endurance performance, psychological aspects also contribute to performance success. The psychological factors that have been proposed to play a role in endurance training and performance include motivation, mental toughness and mood states (Berger et al, 1999; Smith, 2003; Simon, 2012). Prolonged activities in endurance training are very intense and therefore demand greater efforts to complete the tasks. The accumulated of fatigue from prolonged exposure to intense activities can increase pain and impair of effort. Thus, successful performance in endurance events are generally related to desirable psychological traits and healthier mood states (Raglin, 2007).

2.1.1 Physiology of cycling

Typically, cycling is classified as a cyclic skill with motor reaction in repetitive movements (Bompa & Haff, 2009). It has become one of the world's popular activities, whether for transportation, recreational or competitive activities (Faria, Parker & Faria, 2005). In competitive settings, cycling can be divided into two categories; (1) track, and (2) road. In track cycling, it can be further divided into two broad categories; (1) sprints event, and (2) endurance races (Faria, et al, 2005). Sprint events consist of 200m sprint, keirin, team sprint and track time trial. On the other hand, endurance races involve individual and team pursuit, scratch, madison and omnium (Craig & Norton, 2001; Faria et al, 2005). For road cycling, the duration of the competition is approximately one to five hours involving multi stages or multiple consecutive days of racing such as Tour de France, Giro d'Italia and Le Tour de Langkawi (Mujika & Padilla, 2001).

Different physiological demands are associated with different cycling events. Therefore, development of event-specific characteristics through systematic training is crucial to ensure that cyclists are able to meet the competition demands. Factors contributing to cycling performance are multidimensional including physiological and psychological factors, appropriate techniques and tactics (Hawley, 2002; Lucia, Hoyos, & Chicharro, 2001). Numerous researchers have documented the physiological factors affecting performance in cycling include maximal oxygen consumption (VO_{2max}), maximal power output, heart rate, muscle fibre type, cycling efficiency or economy, lactate threshold (Colye, 1999; Faria, 1984; Mujika & Padilla, 2001) and anthropometric measures (Mujika & Padilla, 2001).

VO_{2max} can be described as the maximal amount of oxygen that can be utilised at the cellular level for the entire body (McArdle, Katch, & Katch, 2001). In fact, it represents the body's ability to absorb and utilise oxygen for maximal power output and energy production. VO_{2max} can be expressed in millilitres of oxygen per kilogram of body weight per minute ($ml.kg.min^{-1}$) At a given exercise intensity, VO_2

does not increase despite increasing exercise intensity, indicating that the individual has reached the maximal oxygen uptake (Mujika, 2009). VO_{2max} is considered as the best measure of cardiovascular system function and also as one of the best determinants of success in endurance athletes' performance (Brooks, Fahey, White, & Baldwin, 2000), specifically in cycling (Coyle, 1999; Hawley, 2002). Generally, it is accepted as a prerequisite criterion for athletes performing in endurance events.

It has been well documented that competitive cyclists requires high VO_{2max} value (Craig & Norton, 2001; Lucia et al., 2001; Mujika & Padilla, 2001). For instance, Faria (1984) reported that the average values of VO_{2max} of elite cyclist range from 68.1 to 76.0 $ml.kg.min^{-1}$. Coyle et al. (1991) reported that the average VO_{2max} of 15 male elite cyclists was between 64.4 to 73.9 $ml.kg.min^{-1}$. Furthermore, in comparison between male and female elite cyclists, Faria et al. (1989) reported VO_{2max} value approximately 68.0 to 75.7 $ml.kg.min^{-1}$ for male cyclists, while VO_{2max} of 68.0 $ml.kg.min^{-1}$ has been reported in female elite cyclists by Wilber et al. (1997).

Several ranges of VO_{2max} values have been reported in studies involving junior cyclists. In the study by Bunc et al. (1996), the value of VO_{2max} among top Czech junior cyclists was 65.5 $mL.kg.min^{-1}$. However, a study by Menaspa et al. (2010) among Italian junior cyclists showed that the highest value of VO_{2max} were approximately 74 $ml.kg.min^{-1}$. A study by Yuan and Chan (2004), reported that the average value of VO_{2max} in the Hong Kong junior cyclists was 65.9 of $mL.kg.min^{-1}$ after 18 months training.

The variety in the characteristics of aerobic capacity among the junior cyclists is a reflection of the training experience such as hours of training, years of training, level of performance, anthropometric and level of competition (Faria et al, 2005; Mujika & Padilla, 2001; Menaspa et al, 2012).

VO_{2max} alone is not an accurate predictor of success in cycling performance (Coyle, 1995; Basset & Howley, 2000). Instead, it should be accompanied by high maximal power output (W_{max}) (Hawley & Noakes, 1992). Hawley and Noakes (1992), reported that the W_{max} and VO_{2max} have a high significant correlation during graded exercise test (r = 0.97, p < 0.01). The results from the same study also indicated a high correlation between W_{max} and 20km time trial (r = 0.91, p < 0.01) among 19 male well-trained cyclists. Bentley et al. (1998) also reported significant positive correlation between Peak Power Output (PPO) and cycling time trial in 20 km and 40 km.

Maximal power output can be defined at the highest workload maintained for a complete exercise period (Faria, et al, 2005). The W_{max} can be achieved by producing the maximum wattage during the incremental test protocols in the laboratory (Bentley et al, 1998). For competition, high W_{max} play important role to win the race, especially during the starting phase, breakaway, and finishing line sprint (Faria et al, 2005).

Mujika and Padilla (2001) and Lucia et al. (2001) reported that the values of W_{max} range between 349 to 525 watts for pro-cyclists. As mentioned earlier, the maximum value of W_{max} value for professional cyclists ranges between 349 and 525 watt (Padilla et al, 1999; Padilla et al, 2000). In contrast, Perez-Landaluce et al. (2002) reported that the average value of W_{max} in 26 elite junior male cyclists was 350 watt. On the other hand, Menaspa et al. (2012) observed the W_{max} in junior male cyclists exhibited 422 watt. Consequently, Menaspa et al. (2012) investigated the W_{max} distribution in different specialities (uphill, flat, sprinter and all terrain) of male junior cyclists. The results showed that W_{max} in all terrain was significantly higher than the uphill ($p < 0.01$). Meanwhile, the difference between flat terrain and sprinter (398±46 and 391±35, respectively) was not significantly different.

Generally, lactate threshold can be defined as the critical work rates before lactic acid begin to accumulate in the blood (Reaburn & Dascombe, 2008). It is an important predictor of endurance performance (include cycling) because it determines performance velocity (Coyle, 1995). During light to moderate exercise, blood lactate levels tend to be the same due to the equal rate of lactate removal compared to the lactate production (Davis, 1985).

A study by Craig et al. (1993) observed a high correlation between lactate threshold and 4000m individual time pursuit in 18 male elite track cyclists ($r = 0.86$). Coyle et al. (1991) documented that average blood lactate in elite endurance cyclist range approximately from 6.3 to 10.1 mmol/L. Mujika and Padilla (2001) on the other hand reported the range of lactate between 6.9 to 13.7 mmol/L in pro-cyclists.

Exercising at light to moderate intensity and even during rest, hydrogen is produced during glycolysis (next to lactate) and carried by Nicotinamide Adenine Dinucleotide Hydrogen (NADH) into the mitochondria to become oxidized in the aerobic ß-oxidation (respiratory chain) (McArdle et al, 2001). During increased energy demands at high intensity exercise, hydrogen ion (H^+) production increases and blood pH drops. Consequently, the respiratory chain is unable to keep up with the hydrogen production (Davis, 1985; Myers & Ashley, 1997) resulting in non - oxidized hydrogen that causes metabolic acidosis (Myers & Ashley, 1997).

The metabolic acidosis is a condition in which lactic acid production exceeds from the normal rate, causing by release of a proton (H+) at the final product in glycolysis (Robergs, Ghiasvand & Parkers, 2004). The production of lactic acid is fundamental for muscle to produce and support continued regeneration of ATP from glycolysis process. Robergs et al. (2004) indicate that the process in which catalysis of pyruvate to lactate produces proton (H+) as a buffer to prevent accumulation of acidosis in muscle and blood. In this regard, lactic acid is considered not to be negative, but rather helping to delay the onset of metabolic acidosis, thereby improving endurance performance (Robergs et al, 2004; Faria et al, 2005).

Cycling economy is advantageous to endurance performance because it results in lower oxygen utilisation during a given exercise intensity. Cycling economy can be defined as the sub maximal VO_2 per unit of body weight required to perform a given time task (Coyle, Sidossis & Horowittz, 1992). Accordingly, enhanced cycling economy is reflected by a decrease in the percentage of VO_{2max} required for sustaining a given mechanical work (Lucia et al, 2002). It also refers to amount of energy that is required to maintain a constant velocity or power output (Moseley & Jeukendrup, 2001).

Cycling economy is crucial during prolonged or endurance exercise, where performance depends on the aerobic capacity and the ability to maintain a low as possible VO_2 (McArdle et al, 2001). Coyle et al. (1992) indicated that cycling economy probably related to muscle factors, in which type muscle fibre could be influenced by contractile efficiency. Therefore, improvement of the cycling economy is associated with the strength training of cyclists (Loveless, Weber, Haseler & Schneider, 2005).

Many studies have been conducted to observed the effects of endurance training on heart rate (Kubukeli et al, 2000; Zavorsky, 2000). Maximal heart rate (HR_{max}) is defined as the highest heart rate obtained during incremental exercise performed to a maximal effort (Mahon, Marjerrison, Lee, Woodruff & Hanna, 2010). Most importantly, heart rate sets the upper limit of cardiovascular function and can be used as a basis for prescribing appropriate intensity of exercise (American College of Sport Medicine, 2006). Usually, alteration in heart rate during exercise occur, where the autonomic nervous system regulates both the initial increase in heart rate after the start of an exercise and the decrease immediately after exercise ends (Daanen, Lamberts, Kallen, Jin & Meeteren, 2012).

In summary, endurance is a fundamental component in many sports including cycling. Highly developed factors related to endurance such as VO_{2max}, W_{max}, lactate, heart rate and movement economy are primary contributing factors to successes in cycling competition. Therefore, it is essential that the physiological and psychological capacity be addressed in developing junior cyclists in order to improve their performance. Furthermore, systematic training program needs to be developed for the preparation for competition to allow the physiological and psychological development.

2.2 Variables of training process

Athletes always strive to improve their physical, technical and tactical abilities through training process at the highest possible level of performance. Training process can defined as a systematic process of repetitive and progressive exercise to improve the ability of an athlete to achieve optimal performance (Bompa, 1995).

For competition, in order to enhancement skill and performance, the physiological potential of an athlete’s is to be developed in order to improve body functions and optimize performance (Bompa, 1999; Smith, 2003). If the appropriate levels of physiological adaptation are not reached during the training, it could affect the efficiency of technical and tactical abilities and increase the risk of poor performance.

Meanwhile, technical preparation is important to improve sports skill. Technique embodies all the movement pattern and skill that are necessary to perform the sport (Bompa & Haff, 2009). Thus, athletes must continually strive to establish perfect techniques to create the most efficient movement patterns. Therefore, technical ability is based on the physiological adaptation to support the efficiency of the mechanical movement. In most sport, the efficiency and effectiveness of technical aspect is related to tactical development.

Tactics refers to the organization of the training and competition game plans. Bompa and Haff (2009) indicated that the basis of any successful tactical plan during training and competition depends on the level of athletes' technical proficiency. The main objective of tactical preparation is to assist the athletes in developing tactical knowledge required for the specific sport event (Dick, 2002).

The psychological aspect must also be integrated into every elements of competitive preparation. Psychological skills training minimizes the effects of negative mental influence and at the same time positively enhance athletes' psychological states in order to attain high sport efficiency. However, the preparation of athlete for competition is multifacets (Smith, 2003; McNeely & Sandler, 2007). Therefore, the training should integrate all the performance contributing variables to enhance performance.

In conclusion, integration of all aspects in preparatory is necessary to achieved optimal performance. Additionally, improves in physical training it can be affected to others components for increases the abilities to excel in sport performance. During training, training load and recovery play important role to ensure an athlete can develops the potential in appropriates training stimulus for adaptations.

2.2.1. Training Model

General Adaptations Syndrome (GAS) and Fitness-Fatigue model have been proposed in order to understand the mechanism of the relationship between training loads and recovery in the adaptation process (Chiu & Barnes, 2003; Moxnes & Hausken, 2008; Bompa & Haff, 2009; Turner, 2011).

GAS model has been proposed by Han Selye in 1956 to describe the body's physiological response to stress (Chiu & Barnes, 2003; Turner, 2011). In response to stress, training load create stimulus to fatigue (Chiu & Barnes, 2003; Turner, 2011). A recovery strategy can then be applied to reduce the stressor. If the body is able to cope with the stressor, training adaptation would occur to a new level in haemostasis, which is called supercompensation (Moxnes & Hausken, 2008; Bompa & Haff, 2009).

Another model explaining the relationship between training load, fatigue, recovery and training adaptation is the fitness-fatigue model. The fitness – fatigue model is proposed by Banister and colleague in 1975 to describe the relationship between fatigue and adaptation responses (Chiu & Barnes, 2003). Busso et al. (1997) concluded that this model was useful for investigating the underlying mechanisms of adaptation and fatigue.

This model reflects the relationship between performance and fatigue curve cause by training load. According to Chiu and Barnes (2003), performance curve will decline due to the body's accumulated stress (fatigue) from intense training. Consequently, this would lead to an incline in fatigue levels. This model postulates that given sufficient time for recovery, fatigue would be dissipated (Taha & Thomas, 2003; Chiu & Barnes, 2003). Reduction in training load is one of the strategies during recovery process that can contribute to minimizing fatigue and allows for the process of training adaptation to occur (Zatsiorsky & Kreamer, 2006).

Consequently, it is predicted that fitness level would increase and performance curve is predicted to incline (Taha & Thomas, 2003; Chiu & Barnes, 2003). Bishop, Jones and Woods (2008) indicated that most of training induced adaptation process takes place during the recovery process.

Therefore, the interaction between variables of the fitness and fatigue can be maximized by manipulating the training loads (Mujika, 2009). It has been suggested that reduced training load can facilitate the recovery process. Finally, by achieving an appropriate balance between training stress and recovery, the athlete performance can be maximized.

2.2.2 Load and recovery variables

In training process, adaptation occurs when the training loads and recovery are balanced. The relationship between training load and recovery are fundamental elements in training process. Training loads are usually determined from the products of intensity, volume, duration and frequency of training (Mujika, 1998), and the dynamics of training depend on the manipulation of these variables (Smith, 2003). Meur et al. (2013) concluded that the magnitude of performance adaptation is influenced by the training loads.

Endurance performance requires an athlete to sustain high intensity of sub-maximal exercise, and it is recognized that relatively high VO_{2max} uptake is necessary for superior performance. Training for endurance, especially in cycling generally involves a participation in long duration of low to moderate intensity exercise during a preparatory training phase of the season, and inclusion of shorter duration of high intensity efforts as the competition phase approaches (Laursen & Jenkins, 2002; Paton & Hopkins, 2001). Therefore, manipulation of training loads is crucial to maximize adaptation throughout the training process to ensure balance between training stress and recovery. Further, increases in training load must be implemented in a progressive and systematic fashion (Bompa & Haff, 2009).

Intensity training is a qualitative work component of an athlete to perform. Intensity in relation to training refers to power output or velocity of progression (Bompa & Haff, 2009). Several researchers have proposed that the intensity in endurance training can be quantified using percentage of maximal heart rate (HR_{max}), or percentage of maximal oxygen uptake (VO_{2max}) or rating of perceived exertion (RPE) or blood lactate concentrations (Jeukendrup & Diemen, 1998; Hawley, 2002).

Training intensity is the major parameter that influences the effects of endurance training on cardiorespiratory system (Wenger & Bell, 1986; Mujika, 1998). In cycling, Hawley (2002) and Smith (2003) suggested that the percentage of HR_{max} and VO_{2max} can be used as an indicator of intensity. High intensity training has been reported to produce improvements in VO_{2max} (Tabata et al, 1996; Norris & Petersen, 1998) and, increased blood volume in endurance training (Costill & Wilmore, 1988).

Seiler (2010) has proposed intensity guidelines for training prescription in endurance sports. The intensity distribution has five intensity zones, which are presented in the following table:

Intensity zone	VO_2 (% max)	Heart Rate (% max)	Lactate ($mmol.L^{-1}$)	Accumulated duration within zone
1	50 - 65	60 - 72	0.8 - 1.5	1 – 6 hours
2	66 - 80	73 - 82	1.5 -2.5	1-3 hours
3	81 - 87	83 - 87	2.5 - 4.0	50-90 minutes
4	88 - 93	88 - 92	4.0 - 6.0	30-60 minutes
5	94 - 100	93 - 100	6.0 - 10.0	15-30 minutes

Table 2.1 A five-zone intensity scale to prescribe and monitor training of endurance athletes. Adapted from International Journal of Sports Physiology and Performance (p.277), by Seiler, S, 2010, Human Kinetics. Inc.

Furthermore, Hawley (2002) recommended that training program for cycling should involve a different level of intensity to provoke multiple adaptations and bases on the distinct phase. Training intensity approximately at 65 to 90% of HR_{max} can be beneficial to improve VO_{2max}, increase in oxidative enzyme, power output, lactate tolerance and endurance capacity (Hawley, 2002; Seiler, 2010).

The effects of intensity training on aerobic capacity and performance have been reported in several studies. For instance, Tabata et al. (1996) reported that the training intensity at 70% of VO_{2max} has been shown to elicit an increase in the VO_{2max} from 53±5 $ml.kg.^{-1}.min^{-1}$ to 58±3 $ml.kg^{-1}.min^{-1}$ after 6 weeks endurance training program. They indicated that moderate intensity training for 60 $min.d^{-1}$ with 5 $d.wk^{-1}$ was sufficient to stimulate the cardiovascular responses.

Another study by Westgarth-Taylor et al. (1997) demonstrated that the time in 40 km time trial and W_{peak} were significantly improved from 57.2 minutes to 55.8 minutes and 404 watt to 424 watt, respectively, after 6 weeks of high intensity