MAXIMAL ACCUMULATED OXYGEN DEFICIT (MAOD) OF PHYSICALLY ACTIVE FEMALES DURING MID-FOLLICULAR AND MID-LUTEAL PHASES OF OVARIAN CYCLE

BY

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MAOD	Maximal accumulated oxygen deficit
MF	Mid-follicular phase of ovarian cycle
ML	Mid-luteal phase of ovarian cycle
VCO_2	Volume of carbon dioxide per minute
VE	Expired ventilation per minute
VO_2	Volume of oxygen consumed per minute
VO_{2max}	Maximal oxygen uptake

Maksimal Pengumpulan Defisit Oksigen Bagi Perempuan yang Aktif Semasa Fasa Pertengahan Folikular Dan Fasa Pertengahan Luteal Dalam Kitar Ovari

Abstrak

Kajian ini bertujuan untuk mengkaji kapasiti anarobik semasa pecutan berbasikal berulangan pada fasa-fasa berlainan dalam kitar ovari Dua belas orang perempuan aktif berumur 22.41 ± 1.68 tahun, berat 52.06 ± 7.28 kg, tinggi 158.17 ± 4.17 cm, dengan purata VO_{2max} 34.92 ± 4.85 $ml \cdot kg^{-1} \cdot min^{-1}$ telah mengambil bahagian dalam ujikaji ini. Pengukuran kapasiti anarobik dibuat melalui kaedah maksimal pengumpulan deficit oksigen (Maximal Accumulated Oxygen Deficit [MAOD]) berdasarkan kaedah yang diadaptasikan daripada Medbø et al., (1988). Pada mulanya, VO_{2max} setiap peserta diuji menggunakan mesin basikal mengikuti protokol senaman intensiti meningkat. Kemudian, para peserta telah melakukan senaman berbasikal sub-maksimal selama 10 minit di intensiti 50%, 60%, 70% dan 80% daripada VO_{2max} pada hari yang berlainan. Regrasi sekata antara VO_2 dan bebanan tenaga sewaktu ujian maksimal dan sub-maksimal digunakan untuk menentukan intensiti supra-maksimal (120% daripada VO_{2max}). Selepas itu, para peserta menjalani ujian pecutan berulang pada intensiti 120% daripada VO_{2max} diselangi rehat selama 20 minit antara pecutan pada fasa pertengahan folikuar. Protokol yang sama juga diadakan pada fasa pertengahan luteal bagi setiap peserta. Fasa-fasa kitar haid ini ditentukan melalui pengukuran suhu badan setiap hari dan analisis serum progesteron. Perolehan yang didapati menunjukkan tiada perbezaan dalam maksimal pengumpulan deficit oksigen dan prestasi pecutan antara fasa pertengahan folikular dan pertengahan luteal dalam ujian pecutan berulang. Tiada perbezaan juga didapati dalam kepekatan plasma asid laktat dan plasma ammonia antara fasa pertengahan folikular dan pertengahan luteal dalam ujian pecutan berulang.. Kesimpulannya, kitar haid, bagi perempuan yang teratur kitar haidnya, tidak mempunyai sebarang kesan terhadap kapasiti anaerobik.

Maximal Accumulated Oxygen Deficit (MAOD) Of Physically Active Females During Mid-Follicular (MF) And Mid-Luteal (ML) Phases Of Ovarian Cycle

Abstract

This intervention study was undertaken with an objective to evaluate the anaerobic capacity in repeated sprint cycling bouts during different phases of ovarian cycle. Twelve physically active females aged 22.41 ± 1.68 years, weight 52.06 ± 7.28 kg, height 158.17 ± 4.17 cm, and VO_{2max} of 34.92 ± 4.85 $ml \cdot kg^{-1} \cdot min^{-1}$ contributed in this study. The method of measuring maximal accumulated oxygen deficit (MAOD) was implemented from Medbø et al., (1988). Initially, the VO_{2max} of the participant were measured on cycle ergometer following a graded exercise protocol. Then, the participants did sub-maximal cycling exercise for 10 minutes at 50%, 60%, 70% and 80% of VO_{2max} on separate days. The linear regression determined from the VO_2–power relationship was used to approximate supra-maximal power output at 120% VO_{2max}. Next, the participants performed repeated sprint cycling at 120% of VO_{2max} intensity with 20 minutes rest between consecutive sprints during mid-follicular (MF) and mid-luteal (ML) phases. The menstrual phases were verified through daily basal body measurement and serum progesterone analysis. Results indicated there were no significant difference in maximal accumulated oxygen deficit (MAOD) and sprint performance between mid-follicular (MF) and mid-luteal (ML) phases in repeated sprint cycling. There was also no significant difference in plasma lactate and plasma ammonia concentration between mid-follicular (MF) and mid-luteal (ML) phases in repeated sprint cycling. Hence, it is concluded that the ovarian phases of women with regular menstrual cycle, have no significant effect on anaerobic capacity.

CHAPTER 1

INTRODUCTION

Maximal accumulated oxygen deficit (MAOD) has been used to examine differences in anaerobic capacity among endurance athletes, sprinters, and untrained subjects (Medbø and Burgers, 1990). Anaerobic capacity is defined as the maximal amount of adenosine triphosphate (ATP) that can be produced through anaerobic metabolism during a single supra-maximal exercise bout (Green and Dawson, 1993). Quantification of anaerobic capacity among athletes provides information for applying suitable high intensity training program which is anaerobic in nature and thereby to improve performance (Maxwell and Nimmo, 1996). However, the magnitude of the energy contribution from anaerobic metabolism is difficult to determine (Ward-Smith, 1999). Experimental methodology involves two basic kinds of measurement, which are direct and indirect approach.

In the direct approach, the depletion of ATP and phosphocreatine and the increase in lactate production in the muscles are measured (Ward-Smith, 1999). Direct attempts of anaerobic capacity determination through muscle biopsy had also been done, but the procedure is invasive, expensive and provides information on relative concentrations, and not the exact quantity (Scott et al., 1991). On the other hand, the direct sampling of muscle tissue is not always possible within specific populations (Maxwell and Nimmo, 1996). Since the active muscle mass in any activity is unknown, the anaerobic energy contribution can only be estimated and not measured (Scott et al., 1991). In particular, the results of direct technique cannot readily be related to whole-body energy conversion (Ward-Smith, 1999).

A number of indirect laboratory and field tests have been adopted. In the indirect method, information of anaerobic metabolism is inferred from measurements of oxygen consumption during exercise (Ward-Smith, 1999). The validity of such experiments, depend upon the intensity and duration of the tests at which the energy is released from the anaerobic energy system (Scott et al., 1991). Unfortunately, this work score includes both anaerobic and aerobic energy component. As an example for the Wingate test, which is only 30 seconds in duration, 9% to 19% of energy is released from aerobic sources, depending on mechanical efficiency (Scott et al., 1991).

Then, concept of oxygen deficit was introduced by Krogh and Lindhard (1920), and was used as a measure of anaerobic capacity during late 1960s (Karlsson and Saltin, 1970). As proposed by Medbø, the measurement of maximal accumulated oxygen deficit (MAOD) involves the establishment of a linear relationship between oxygen uptake and exercise intensity from sub-maximal exercise intensities (Buck and McNaughton, 1999). Minimum 10 minutes of the sub-maximal exercise bouts were required to construct the power-VO_2 relationship (Medbø et al., 1988). Using this relationship, the oxygen demand for supra-maximal exercise intensity is extrapolated (Buck and McNaughton, 1999). The accumulated oxygen deficit was then determined as the difference between the calculated oxygen demand and the actual oxygen uptake (Medbø et al., 1988).

Saltin (1990), Medbø and Tabata (1989), Scott (1991) have stated that maximal accumulated oxygen deficit (MAOD) is the only method with the potential to quantify anaerobic capacity, and other researchers have reported that it is a valid measurement (Medbø et al., 1988; Bangsbo et al., 1998; Withers et al., 1993; Medbø and Tabata, 1993).

The past three decades have seen a dramatic increase in the involvement of women in high intensity sports, exercise, and vocational activities (Batterham and Birch, 1996). Females are of particular interest since spectacular improvements in the sports performance in female athletes occur during these years (Giacomoni et al., 2001). This trend has raised essential research questions emphasizing on the nature of observed female physiological cycles, such as ovarian cycle and its effect on sport performances.

During the course of normal ovarian cycle, many hormonal changes occur in a predictable manner (Lebrun, 2000). Gonadotrophin-releasing hormone (GnRH) from the hypothalamus initiates secretion of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) at pituitary level (Lebrun, 2000). Changes in female sex steroids throughout menstrual cycle modulate the endocrine events, leading to ovulation and thickening of endometrium (Lebrun, 2000). During follicular phase, level of estrogen and progesterone are low (Lebrun, 2000). Immediately preceding ovulation, there is a peak in estrogen level (Lebrun, 2000). During luteal phase, secretion from corpus luteum results in elevated concentration of both hormones (Giacomoni et al., 2000). Studies had shown that both 17 ß-estradiol and progesterone, the two major ovarian cycle hormones, can affect energy substrate metabolism, thermoregulation, body water, and electrolyte homeostasis which are crucial during exercise (Redman et al., 2003).

Metabolic actions of estrogen include facilitation of glycogen storage and uptake in liver and muscle (Lebrun, 2000). Elevated level of estrogen also promotes lipolytic activity, thus results of glycogen sparing effect during exercise (Giacomoni et al., 2000). Meanwhile, progesterone causes a shift towards a greater dependence on fat mobilization (Lebrun, 2000). This is evidenced by lower respiratory exchange ratio (RER), lower blood lactate level during sub-maximal exercise (Dombovy et al., 1987) and higher circulating free fatty acids (FFA) (Reinke et al., 1972). Core body temperature is raised by 0.3° - 0.5° C during the luteal phase, as a result of the presence of progesterone (Lebrun, 2000).

Therefore, the different hormonal environments during the follicular and luteal phases of ovarian cycle have the potential effect on both exercise capacity and exercise performance (Redman et al., 2003). The response to exercise is dependent upon the phases of ovarian cycle (Giacomoni et al., 2000).

1.1 Purpose of the study

This study is an attempt to investigate the anaerobic capacity of physically active females during mid-follicular phase and mid-luteal phases of ovarian cycle. The anaerobic capacity is quantified here as maximal accumulated oxygen deficit (MAOD).

1.2 Objectives of the study

The objectives of this study are to investigate:

1. Maximal accumulated oxygen deficit (MAOD) of physically active females during mid-follicular (MF) phase of ovarian cycle.
2. Maximal accumulated oxygen deficit (MAOD) of physically active females during mid-luteal (ML) phase of menstrual cycle.
3. The variations of maximal accumulated oxygen deficit (MAOD) in these two phases, if any.

1.3 Significance of the study

Maximal accumulated oxygen deficit (MAOD) denotes anaerobic component of any individuals. This study will ascertain the variation of anaerobic capacity focusing on mid-follicular (MF) and mid-luteal (ML) phases of menstrual cycle.

1.4 Hypothesis of the study

H_o = There is no difference of maximal accumulated oxygen deficit (MAOD) between mid-luteal (ML) and mid-follicular (MF) phases. Hence, ovarian cycles have no effect on oxygen deficit of female athletes.

H_A = There is a difference in maximal accumulated oxygen deficit (MAOD) between mid-luteal (ML) and mid-follicular (MF) phases. Hence, ovarian cycles have an effect on oxygen deficit of female athletes.

CHAPTER 2

LITERATURE REVIEW

2.1 Anaerobic capacity

There are three discrete yet closely integrated processes that operate together to suit the energy requirements of the muscle (Saltin, 1990). The first process, aerobic energy system or oxidative metabolism, involves the combustion of carbohydrate and fats, and under some circumstances proteins, in the presence of oxygen (Gastin, 2001). Conversely, the anaerobic energy system is divided into alactic and lactic acid components referring to the processes involved (Gastin, 2001). The first process involves the splitting of the high energy phosphagen and phosphocreatine (PCr), which together with the stored ATP in the cell, provides the instant energy in the primary stages of intense exercise. The second process involves the anaerobic breakdown of carbohydrate to pyruvic acid and then lactic acid through glycolysis (Gastin, 2001).

The anaerobic energy system is competent to produce rapid energy and large power output during short-term intense activity (Green, 1994). However, work done during high-intensity exercise depends upon a high rate of ATP re-synthesis via anaerobic metabolism. The anaerobic ATPs are produced through phosphocreatine (Pcr) and glycogen breakdown to lactic acid (Medbø and Sejested, 1985). At supra-maximal intensity of exercise, at which ATP-turnover rate surpass the maximal power of oxygen transport system, body will depend heavily upon the anaerobic capacity (Medbø et al., 1988). Thus, anaerobic capacity is defined as the maximal amount of ATP re-synthesis through anaerobic metabolism, which is significant for high intensity exercise of short duration (Green, 1994).

Intense exercise lasting a few minutes or less is greatly dependant on energy released from both the aerobic and the dominating anaerobic processes (Medbø et al., 1988; Medbø and Tabata, 1989). A high anaerobic capacity is therefore beneficial for this kind of activities. It is a frequent experience that a proper application of anaerobic types of training increases the performance of short burst of high intensity exercise (Green, 1994). Determination of the heritability of anaerobic capacity is useful to predict the improvement that could be gained from training since the greater the genetic component of a given variable, the lesser the possible enhancement by training (Calvo et al., 2002). The heritability index of MAOD was only 0.22, which considered lowest of all the anaerobic variables analyzed (Calvo et al., 2002). This result is in agreement with the finding of many studies which proved that anaerobic capacity is trainable (Nevill et al., 1989; Medbø and Burgers, 1990).

Muscle performance is largely dependent on the effectiveness of both anaerobic and aerobic energy systems (Nevill et al., 1989). These systems are activated to a different relative extent according to the intensity and duration of effort required (Mezzani et al., 2006). Aerobic metabolism relies on the efficiency of several systems such as respiratory, cardiovascular, and muscular. On the other hand, anaerobic metabolism is primarily skeletal muscle-dependent (Mezzani et al., 2006).

It may take two minutes to exhaust the anaerobic capacity (Medbø et al., 1988) and at exhaustion the muscle lactate concentration is around 30 mmol/kg wet weight of the muscle (Saltin, 1990). This corresponds to a mean rate of lactate formation of 0.25 mmol/kg wet weight muscle. However, human muscle may produce lactate at least two to three times faster (Jacobs, et al., 1982; Nevill et al., 1989) and since lactate production is the main element of the anaerobic capacity (Saltin, 1990), the maximum rate of anaerobic energy release cannot be maintained for as long as two minutes.

Typically, endurance athletes have a high oxidative capacity in their muscles (Gollnick et al., 1972), a high potential to recover from exercise (Saltin, 1990) and in general very good maximal oxygen uptake (Rusko et al., 1978). Meanwhile, the sprint athletes have been found to have high glycolytic potential (Gollnick et al., 1972), are more susceptible to fatigue (Thornstensson and Karlsson, 1976) and have very high anaerobic capacity and power (Kindermann and Keul, 1977).

Anaerobic capacity had been investigated and many methods of quantifying it had been adopted, though, the magnitude of the energy contribution from anaerobic metabolism is complicated to determine (Ward-Smith, 1999). In the direct approach, the depletion of ATP and phosphocreatine and the elevation in lactate production in muscle are measured. However, the results of direct technique cannot readily be correlated to whole-body energy conversion (Ward-Smith, 1999). In the indirect approach, information on anaerobic metabolism is inferred from measurements of oxygen consumption during exercise. This approach has been widely used by means of maximal accumulated oxygen deficit (Ward-Smith, 1999). According to Saltin (1990), maximal accumulated oxygen deficit (MAOD) has been widely regarded as the most acceptable method for anaerobic capacity estimation. In a recent study (Mezzani et al., 2006), maximal accumulated oxygen deficit (MAOD) has been proposed as a descriptor of maximal amount of energy obtainable in anaerobic capacity.

2.2 Maximal Accumulated Oxygen Deficit (MAOD)

Medbø et al. (1988) have proposed that the maximal accumulated oxygen deficit (MAOD) quantifies the maximal anaerobic energy release, and this technique is the most acceptable modus operandi available for indirectly assessing anaerobic capacity in human during exhaustive dynamic exercise. Hill (1996) also proposed that maximal accumulated oxygen deficit (MAOD) is a valid and reliable measurement of anaerobic capacity.

The anaerobic capacity varies between various types of exercise (Green, 1994). MAOD has been reported in the recent literature for anaerobic capacity determination in athletic subjects in a number of sports including cycling (Craig et al., 1993), swimming (Ogita et al., 1996), rowing (Pripstein et al., 1999) and track running (Spencer and Gastin, 2001).

The method of measuring MAOD described by Medbø and colleagues (1988) involve the establishment of a linear relationship between oxygen uptake and power output from several sub-maximal exercise intensities. The linear regression determined from the VO_2-power relationship is used to estimate the oxygen demand for supra-maximal exercise intensities which is between 110% and 125% of VO_2 peak. MAOD is then determined as the difference between the calculated oxygen demand and the measured VO_2 during the MAOD test (Weber and Schneider, 2001).

MAOD is calculated from a high intensity performance based on the following assumptions, which explains that if these assumptions are justified, the accumulated oxygen deficit is an accurate measure of the anaerobic energy release during exercise (Medbø et al., 1988):

1. The anaerobic energy release is the total energy released excluding the aerobic energy release which is taken as the accumulated oxygen uptake.
2. The oxygen demand increase linearly with the exercise intensity.
3. The oxygen demand remains constant during exhaustive high intensity exercise.

However, Bangsbo (1996) have questioned the two assumptions used in the determination of maximal accumulated oxygen deficit. The first assumption is that the relationship between oxygen demand and intensity is linear over a large range of exercise intensities (Medbø et al., 1988). For cycle ergometer exercise, a linear relationship is generally assumed (Green et al., 1994) but not always reported (Zoladz et