THE EFFECT OF MODERATE EXERCISE ON SERUM IMMUNOGLOBULIN LEVELS AMONG SECONDARY SCHOOL CHILDREN

By

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DEDICATION

To all the students of Sek. Men. Sains Tengku Muhamad Faris Petra who participated as subjects;

You are the most priceless assets of this study.

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KESAN SENAMAN SEDERHANA KE ATAS ARAS IMUNOGLOBULIN DI KALANGAN PELAJAR SEKOLAH MENENGAH

ABSTRAK

Kajian terkini melaporkan bahawa senaman sederhana dapat meningkatkan aktiviti sel pembunuh semulajadi, aras leukosit dan limfosit darah, serta aras immunoglobulin serum. Walau bagaimanapun, tidak banyak kajian telah dijalankan mengenai kesan senaman ke atas sistem imun humoral di kalangan remaja. Maka dengan itu, kajian ini adalah bertujuan untuk mengkaji kesan senaman sederhana ke atas aras imunoglobulin serum di kalangan remaja.

Kajian ini melibatkan 35 orang pelajar lelaki berusia 16 tahun, yang tidak aktif secara fizikal dan dipadankan dengan ukuran BMI serta tahap kecergasan fizikal. Latihan senaman jogging diberikan sekerap tiga kali seminggu, selama 45 minit setiap satu pada intensiti 60% hingga 75% kadar nadi simpanan. Sebanyak 10 ml darah diambil sebelum dan selepas lapan minggu latihan bagi tujuan analisis darah. Perbandingan keputusan menggunakan ujian t-berpasangan menunjukkan terdapat peningkatan signifikan ($p<0.001$) pada aras min IgG (13.79 ± 0.27 g/l) dan IgM (1.34 ± 0.02 g/l) setelah lapan minggu latihan berbanding nilai sebelumnya.

Aras sel darah merah, hemoglobin, dan hematokrit juga meningkat secara signifikan ($p<0.05$) tetapi tiada perbezaan yang dilihat pada aras IgA, leukosit dan platelet. Tekanan darah dan kadar nadi rehat didapati menurun secara signifikan ($p<0.001$) setelah lapan minggu latihan diikuti dengan peningkatan prestasi ujian larian 1-batu ($p<0.001$). Secara

kesimpulan, latihan senaman sederhana selama lapan minggu dikaitkan dengan peningkatan aras IgG dan IgM, serta komponen darah lain pada remaja yang tidak aktif secara fizikal.

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ABSTRACT

Recent studies have reported that enhancement in immunity occur following a moderate exercise bout, acommpanied by an increase in neutrophils, lymphocytes, augmented NK cells activity, and an increase in serum immunoglobulins levels. However, limited empirical evidence exists on the influence of moderate exercise training on humoral immunity, particularly among the youth. Therefore, the aim of the present study was to investigate the relationship between moderate exercise training and changes in serum immunoglobulin levels in adolescents.

Thirty-five (n=35), physically inactive male residential school-going students aged 16 years, matched for BMI and fitness level were recruited and subjected to three 45-minute jogging sessions per week at 60% to 75% of heart rate reserve. A 10-ml blood sample was collected from each subject prior to and after the implementation of exercise programme for the determination of serum immunoglobulins using single radial immunodiffusion technique. Results were analyzed using Student's paired-t test.

Serum IgG and IgM levels were found to be significantly ($p<0.001$) increased (13.79 ± 0.27 g/l and 1.34 ± 0.02 g/l respectively) after eight weeks of exercise training relatively to baseline values. A significant ($p<0.05$) increases in erythrocyte, hemoglobin, and haematocrit levels were also observed. No differences were observed in IgA levels, leukocyte, and platelet counts. The eight weeks of moderate exercise training also resulted

in a significant ($p<0.001$) decrease in resting heart rate and improved 1-Mile run performance.

This study indicates that eight weeks of moderate exercise training produced significant increases in serum IgG and IgM levels as well as other hematological parameters in previously physically inactive adolescents.

CHAPTER I

INTRODUCTION

1.0 Preface

The impact of exercise on the immune system has recently been recognized in the area of exercise physiology. Interest in the immune response to exercise has arisen due to the need to keep athletes healthy during training and competitions. Illnesses affect the athlete's ability to train and compete, and continued training during illness may be detrimental to the athlete's health. Recently, a number of investigators have reported on the clinical implications of exercise to immunology in aging, cerebrovascular diseases, cancers, and even AIDS. Exercise is also prescribed to counteract the physically debilitating effects of the diseases and to improve the patient's psychological state (MacKinnon, 1992).

The focus on exercise and immunity has been shaped by community interest in health promotion. Investigative evidence available suggests that regular moderate exercise appears to improve host protection and immunosurveillance while heavy training is associated with immune system disturbances (Shephard *et al.*, 1994). In addition, moderate amounts of exercise may actually decrease one's risk of upper respiratory tract infections through favourable changes in the immune function without the negative effects of stress hormones (Hofman-Goetz & Pedersen, 1994). Experimental animal models also

suggest that moderate exercise training prior to induced viral or bacterial infection enhances the host's resistance to infection (MacKinnon, 1992).

Although it is commonly believed that moderate exercise stimulates immune function, yet there is very limited supporting empirical evidence at present, especially with regards to exercise-induced changes on serum immunoglobulin levels. Furthermore, studies available suggest that moderate exercise training exert little effect on the humoral immune function in healthy adult populations (Nieman & Nehlsen-Cannarella, 1991; Eliakim *et al.*, 1997). It is possible, however, that moderate exercise training beneficially influences the immune function in other age groups. Since the metabolic and hormonal responses to exercise may be different between adolescents and adults, it is also possible that the immune response may differ. No studies evaluating the exercise-induced changes in immune system among school children have been done. Therefore, the aim of this study is to assess the changes in immune system particularly the serum immunoglobulin levels in response to moderate exercise training among physically inactive adolescents in secondary school.

1.1 General Objectives of Study

To determine the effects of moderate exercise on the immune system in secondary school children who do not participate actively in sports activities.

1.2 Specific Objectives of Study

To determine the levels of serum IgG, IgM, and IgA in secondary school children before and after the implementation of an exercise programme.

1.3 Research Hypotheses

Non-Directional Hypothesis :

There is a statistically significant difference between serum IgG, IgM, and IgA among secondary school children prior to and after the implementation of the exercise training programme.

Null Hypothesis :

There is no statistically significant difference between serum IgG, IgM, and IgA among secondary school children prior to and after the implementation of the exercise training programme.

Directional Hypothesis :

The serum IgG, IgM, and IgA among secondary school children after the implementation of the exercise training program is statistically significantly greater than prior to the implementation of the exercise programme.

CHAPTER II

LITERATURE REVIEW

2.1 The Immune System

The field of immunology has been established since the late 1960s, when successful transplantation of the human kidney was achieved. Public interest in immunology was intensified by the potential application of the immune response to the detection and management of cancer and later for the alarming spread of acquired immune deficiency syndrome (AIDS). Of great impact to humanity was the success of immunology in the prevention and effective elimination of many infectious diseases. Since then, vaccination against infectious diseases has been an effective form of prophylaxis. Immunoprophylaxis against the polio virus that causes poliomyelitis has reduced the spread of this disease in many parts of the world. Similarly, the prevalence of smallpox has been eliminated completely. Recent developments in immunology hold the promise of immunoprophylaxis against zoonotic diseases while vaccination against various substances that play a role in the reproductive process also offers the possibility of a long-term contraception in humans (Benjamini & Leskowitz, 1991).

The main functional role of the immune system is to ensure the survival of an individual through prevention and recovery from infectious diseases (Burtis & Ashwood, 1999). The various responses of this system include destruction and elimination of invading

microorganisms as well as any toxic molecules produced by them. The destructive nature of these responses make it imperative that they be made only to cells and molecules that are foreign to the host and not to those of the host itself. This ability to distinguish self and non-self is a fundamental feature of the immune system (Guyton, 1986).

The term immunity refers to all mechanisms used by the body as a protection against environmental agents that are foreign to the body. There are two levels of body defence against invasion by external agents. There are: innate immunity and adaptive immunity. The principal differences between the two levels relate to the specificity and immunologic memory, which are the properties of the acquired immunity only (Goodman, 1991).

2.1.1 Innate Immunity

Innate immunity is the body's initial defence mechanisms against invading microorganisms. It is present form birth and includes numerous nonspecific elements. These elements include the body surfaces such as the skin, mucous membranes, as well as chemical components such as pH of the skin and secreted fatty acids which act as effective barriers to microorganisms (Benjamini & Leskowitz, 1991).

Numerous internal elements are also features of innate immunity. Such elements are interferon, chemotactic substances released by leukocytes such as complements, histamine, and bradykinin as well as a variety of serum proteins. All these elements either affect pathogenic invaders directly or enhance the effectiveness of host reactions to them. Other internal elements of innate immunity include the phagocytic cells, such as the granulocytes and macrophages which participate in the destruction and elimination of

foreign agents or antigens that have penetrated the physical and chemical barriers (Benjamini & Leskowitz, 1991).

2.1.2 Adaptive Immunity

Adaptive immunity is referred to as specific immunity because it relies upon the ability to recognize antigens. The adaptive immune response comes into play when the innate defence system fails to prevent the entry of antigens into the system. In the adaptive immune response, the antigen triggers a chain of events that lead to the activation of lymphocytes and the synthesis of antibodies with specific reactivity against the specific antigens (Goodman, 1991).

There are three major of types of cells that play a part in adaptive immunity. These are mainly the B lymphocytes, T lymphocytes, and macrophages. B and T lymphocytes are responsible for the specificity exhibited by the immune response. Adaptive immunity that is mediated by T lymphocytes and macrophages is termed as cellular immunity while the humoral immunity is mediated by the B lymphocytes (Benjamini & Leskowitz, 1991).

2.1.3 Cellular Immunity

Cell-mediated immunity following antigenic challenge results in the formation of activated T lymphocytes. There are several subpopulations of T lymphocytes, each of which may have the same specificity for an antigenic determinant, even though each subpopulations may perform different functions (Benjamini & Leskowitz, 1991). The

three important subtypes of T lymphocytes are the cytotoxic T cells, helper T cells (CD4+), and suppressor T cells (CD8+).

The cytotoxic T cells recognize and kill cells of the body which may be abnormal antigenically or infected with bacteria or viruses. They also lyse tumour cells which have recognizable antigenic changes on their surfaces. The T helper cells facilitate the functioning of the immune response. This is accomplished by producing and releasing lymphokines such as interleukins, which appear to increase the activity of other T cells including the T lymphocyte memory cells. The T lymphocyte memory cells can be reactivated at any subsequent exposure to a given antigen. Suppressor T cells are downregulating cells and function to suppress the activity of cytotoxic T cells and T helper cells. It also regulates the activity of other immune cells to prevent undue damage to the body (Goodman, 1991).

Apart from T lymphocytes, there are macrophages or also known as antigen presenting cells. Macrophages are large, phagocytic cells and do not exhibit specificity against foreign substances but they play an important role in processing and presenting antigens to T lymphocytes. Upon activation, macrophages can also secrete interleukins, which play a prime role in activating the T lymphocytes (Keast *et al.*, 1988).

2.1.4 Humoral Immunity

The major function of humoral immunity is to produce soluble proteins that circulate freely in the system and exhibit properties that contribute specifically to immunity and protection against foreign material (Benjamini & Leskowitz, 1991).

B lymphocytes, which originate from the bone marrow, are the major components in humoral immunity. When exposed to a specific antigen, they replicate and subsequently mature into plasma cells. Upon activation by some specific interleukins, plasma cells secrete glycoprotein molecules called immunoglobulins. These immunoglobulins are specifically reactive to the initiating antigen and react with the antigen to form an antigen-antibody complex. These reactions effectively kill and assist in the removal of the invading microorganisms or virally-infected cells from the body (Guyton, 1986).

2.1.5 Immunoglobulins

Immunoglobulins (Ig), or previously known as antibodies, are soluble glycoproteins that belong to the class of proteins called globulins due to their globular structure. All immunoglobulin molecules are heterodimers and are composed of four polypeptide chains, two identical large or heavy (H) chains of about 50 to 60 kDa and two small or light (L) chains of about 23 kDa, linked by interchain disulfide bridges. They also contain two or more carbohydrate chains, usually linked to the heavy chains. Some membrane form of immunoglobulins are associated noncovalently with two accessory peptides forming the B lymphocyte antigen receptor complex (Nezlin, 1998).

The structure of immunoglobulins incorporates several features essential for their participation in the immune response. The two most important features are specificity and biologic activity. Specificity restricts the immunoglobulins to combine only with those substances that contain one particular antigenic structure. Thus, immunoglobulins collectively exhibit great diversity, in terms of types of molecular structure which they are capable of reacting with individually. They exhibit a high degree of specificity where each immunoglobulin is able to react with only one particular antigenic structure. Apart from

demonstrating specificity, another part of the immunoglobulin molecule is adapted to allow the immunoglobulin molecule to perform biological activities, such as complement fixation, activation of mast cells, and opsonisation among others (Benjamini & Leskowitz, 1991).

In humans, there are five classes or isotypes of immunoglobulins, which differ in their primary structure, carbohydrate content and antigenic properties of their heavy chains. Only three classes of immunoglobulins will be discussed in this chapter as they are most widely reviewed in exercise physiology.

2.1.5.1 Immunoglobulin G (IgG)

IgG is the major class of immunoglobulins that is predominant in blood, lymph fluid, cerebrospinal fluid, and peritoneal fluid. It represents about 15 percent of total protein in serum of human adults and is distributed equally between the intravascular and extravascular spaces (Benjamini & Leskowitz, 1991). IgG forms about 75 percent of total immunoglobulins and is most commonly found in the lower respiratory tract. After a secondary exposure to an antigen, B lymphocytes secrete predominantly IgG molecules and unlike other immunoglobulins, IgG can penetrate the placenta barrier, thus enabling the mother to transfer her immunity to the foetus and protect the neonate for the first three months of postnatal life. In terms of biological properties, IgG plays a major functional role in the humoral immune response compared to other immunoglobulins (Keast *et al.*, 1988). The versatility in functions of the IgG makes it a very important immunoglobulin in the human immune system.

IgG molecules are able to react with receptors present on the surfaces of macrophages to initiate various effector reactions and particularly facilitate the destruction of antigens. It can also activate the complement system via the classical pathway that results in the release of several important biologically active molecules leading to lysis of the targeted cell or antigen (Nezlin, 1998).

IgG is also an efficient virus-neutralizing antibody. It inhibits viral penetration or shredding of viral coat required for the release of viral DNA or RNA that is needed to induce infection. Besides neutralizing and killing, IgG is capable of immobilizing various motile bacteria. Reactions of IgG that is specific for the flagella and cilia of certain microorganisms causes them to clump, thereby arresting their movement and consequently preventing their ability to spread or invade tissue (Benjamini & Leskowitz, 1991).

2.1.5.2 Immunoglobulin M (IgM)

IgM is a high molecular weight protein or macroglobulin consisting of five IgM monomers. In adult serum, it is the third most abundant immunoglobulin, accounting for about 10 percent of the total circulating immunoglobulins and it is the first immunoglobulin molecule produced during the early phases of immune responses (Nezlin, 1998). It is also the only immunoglobulin that a neonate normally synthesizes and does not cross the placenta.

IgM are very efficient activators of the classical complement pathway. A single IgM molecule can activate complement component C1, whereas several IgG molecules are needed for the same reaction. Upon binding to antigens, IgM will initiate the complement-

mediated lysis of microorganisms and other infected cells. Due to its pentameric form and multiple valency, IgM is competent in agglutinating antigens that contain repeated patterns of the same antigenic determinant. (Benjamini & Leskowitz, 1991).

These abilities, taken together with the role of IgM as the first class of antibodies generated after an infection or immunization, makes IgM very important as a provider of the early line of immunological defences against bacterial infections (Goodman, 1991).

2.1.5.3 Immunoglobulin A (IgA)

IgA accounts for 15 to 20 percent of serum immunoglobulin pool and it plays the most important role in mucosal immunity. IgA molecules are present in serum, gastrointestinal tract, and in exocrine secretions such as saliva, colostrums, breast milk, and tears. The IgA present in mucous secretions exist as a dimer and has an attached protein S which is the secretory component. The IgA present in serum is predominantly monomeric (Benjamini & Leskowitz, 1991). Low serum IgA is often associated with viral infections (Keast *et al.*, 1988).

IgA molecules are synthesized mainly in gastrointestinal lymphoid tissue. The gastrointestinal tract and other mucosal surfaces are the main sources of pathogen invasion, apart from the skin. On mucosal surfaces, IgA molecules inhibit the binding of microorganisms that try to penetrate through the mucosa, thus preventing their invasion into the system. IgA also has been shown to possess bactericidal activity against gram negative microorganisms in the presence of lysozyme (Nezlin, 1998).

2.2 Growth and the Immune System

2.2.1 Adolescence

According to World Health Organisation, adolescence begins with the onset of physiologically normal puberty and corresponds to the period between the ages of 10 and 19 years. For others, adolescence is also defined by the accomplishment of three specific tasks: emancipation of childhood dependence on parents; identity formation on the sexual, intellectual, and moral realms of self concept; and functional role in determining such matters as vocational and career goals, personal lifestyle and family formation (Hofman & Greydanus, 1997).

2.2.1.1 Puberty

Puberty is characterised by sexual maturation and statural growth. Both result from a complex process in which gonadal hormones rapidly rise to a point sufficient to stimulate maturation of the reproductive hormones and musculoskeletal systems. The first visible signs of puberty are the development of secondary sexual characteristics (Johnson, 1983).

Assessment of adequacy of pubertal maturation is accomplished by judging configuration of pubic hair and genitalia, a system known as Tanner Staging. The staging is reflected in a 5-point scale, with stage 1 being prepubertal, stage 2 evidencing the earliest signs of puberty, stage 5 being fully mature, with stages 3 and 4 in between. Staging is further subdivided into the genital stage for males reflecting changes in penis and scrotum; breast stage for girls reflecting changes in breast size and contour; and pubic hair in both genders

(Johnson, 1983). Puberty in females can begin at any time between 8 and 14 years, but once initiated, it is usually completed within 3 years. Puberty starts 1½ to 2 years later in males and takes nearly twice as long to be completed as compared to the females (Hofman & Greydanus, 1997).

2.2.2 Stages of Adolescence

As with puberty, adolescence can be divided into three stages which are early, middle, and late adolescence.

2.2.2.1 Early Adolescence

Early adolescents are in the phase of accelerated puberty growth and narcissistically focus attention on their bodies in integrating the rapidly increasing height, changing shape, and growing physical competence into body image and proprioceptive body space. During this phase, secondary sexual characteristics begin to appear. Early adolescence occurs between ages of 11 and 13 and merges with middle adolescence (Hofman & Greydanus, 1997).

2.2.2.2 Middle Adolescence

Middle adolescent is generally considered as the archetypal teenager. Ninety to ninety-five percent of physical growth is now complete and a new body image concept incorporating an adult size, shape, and function are being consolidated. This phase begins around 14 to 15 years of age and blends into late adolescence (Hofman & Greydanus, 1997).

2.2.2.3 Late Adolescence

Late adolescents are physically fully mature with statural and reproductive organs virtually completed. They have also achieved integrating pubertal changes into their body image and are comfortable in their essentially adult size and function. This phase commences at approximately 16 to 21 years of age, where the upper age limit is particularly dependent on cultural, economic, and educational factors (Hofman & Greydanus, 1997).

2.2.3 Age and the Immune System

The immune organs appear early in embryogenesis and by birth they have reached their morphological maturation. The immune system organs develop especially quickly after birth during the first years of the postnatal ontogenesis. The peak in the development of the organs of immunogenesis, amount and size of the lymphoid noduli, occurs during childhood and adolescent age. Each immune organ has its peculiarities that are determined by their place in the organism, value and intensity of antigenic effect. Beginning from adolescence and youth, the amount of lymphoid tissue and noduli in the organs decrease as the connective and adipose tissue grows out (Sapin, 1989).

Normal immune functions can begin to decline as early as when an individual reaches sexual maturity or puberty. The decline is due to changes in immune cells and their milieu. Cell loss, shift in the proportion of subpopulations and qualitative cellular changes have all been detected to cause this decline (Makinodan & Kay, 1980).

The first hint that normal immune cell functions may decline with age came from the findings of classical morphologists. They showed that the thymic lymphatic mass decreases with age, primarily as a result of atrophy of the cortex. The onset of this decrease coincided with the attainment of sexual maturity. This has been documented in laboratory animals and humans (Denckla, 1978).

2.2.3.1 Age-Related Changes in Cellular Immunity

The most visible cellular target of aging appears to be the T lymphocytes, which shows prominent changes in the regulatory subpopulations. In humans, the number of circulating T lymphocytes has been reported either to decrease progressively or remain the same (Sapin, 1989). The possible changes that could cause a decline with age in T lymphocyte functions are a loss in cell number, qualitative changes, and a shift in subpopulations (Makinodan & Kay, 1980).

The absolute number of colony-forming, circulating T lymphocytes in humans decreases with age (55 to 82 years) to a level that is about 15 percent of that of young adults (21 to 35 years) (Nieman *et al.*, 1993). Intracellular changes at both morphologic and functional level as well as emergence of new receptors at the membrane level have also been detected. In animal studies, T suppressor and T helper cells also decline with age (Makinodan & Kay, 1980).

2.2.3.2 Age-Related Changes in Humoral Immunity

Qualitative changes in the B lymphocytes appear to occur with age. For example, responsiveness of B lymphocytes to stimulation with certain T cell-dependent antigens decreases strikingly with age (Callard & Basten, 1978). The alteration may be at the membrane surface level and the decline in B lymphocytes regulation with age is in part intrinsic to the receptor-mediated signaling mechanisms (Makinodan & Kay, 1980).

The number of B lymphocytes in human and mice however, does not change appreciably with age. Although the total number of B cells remain relatively stable, the number of colony-forming B lymphocytes in the peripheral blood decreases with age. The size of certain subpopulations of B cells also tend to change with age, as reflected in the levels of individual serum immunoglobulin classes (Makinodan & Kay, 1980).

2.2.3.3 Age-Related Changes in Serum Immunoglobulins

Well documented changes in serum immunoglobulin concentrations occur during human developmental years (Chandra & Ghai, 1972; Cejka *et al.*, 1974). It has generally been assumed that changes beyond early adult life are small and of trivial consequence in comparison to those observed during the developmental years. Changes in serum immunoglobulin concentrations occur throughout life and the largest source of biologic variations observed is related to age (Buckley & Dorsey, 1970).

Synthesis of human immunoglobulins starts during postnatal life. Contact of neonates with the environmental antigens causes B lymphocytes to begin to multiply into plasma cells

and consequently IgG, IgM, and IgA levels start to rise (Burtis & Ashwood, 1999). IgG is the only immunoglobulin that is transferred across the placenta to the neonate and the level rises during the last three months of pregnancy. Following birth, there is a progressive decline in IgG concentration, which is attributable to the decay of maternally-derived IgG. The synthesis in the infant begins at three to four weeks of age and the minimum IgG concentration occurs at about four months of age (Chandra & Ghai, 1972). The most marked increase in IgG occurs between four months and six years of age, after which the rate of increase is reduced. Adult values for IgG is attained at about nine years of age (Cejka *et al.*, 1974). However, other findings indicated that adult concentration of IgG is normally reached and maintained after the ages of six and seven years (Smith, 1966; Buckley & Dorsey, 1970). IgG reaches maximum variation and concentration between second and fourth decades of life (Buckley & Dorsey, 1970).

At birth, the human infant has a serum level of IgM that is about one-twentieth the adult value, most of this appears to be of fetal origin. This level rises rapidly over the first two to three months of age (Smith, 1966). Half of the adult value is reached at some point between six and twelve months of age and after about two years of age, IgM increases much slower but continues to increase over the period of adulthood (Cejka *et al.*, 1974). IgM levels are said to reach adult values in early childhood at the age of one month (Buckley *et al.*, 1978); two years (Chandra & Ghai, 1972); and 16 years (Cejka *et al.*, 1974). IgM reaches its maximum concentration at the beginning of the second decade and reaches maximum variance by the fifth decade of life (Buckley & Dorsey, 1970).

IgA is not produced by the normal human infant prenatally, nor does it pass the placenta. It first appears at about one month of age and increases gradually during infancy, reaching

50 percent of adult value at about four to five years of age (Smith, 1966). A slower increase is observed after the age of five years and it reaches adult levels throughout the adolescence period (Cejka *et al.*, 1974). IgA continues to increase slowly through the third decade of life (Buckley & Dorsey, 1970).

In addition to the well documented increases in serum immunoglobulins during the first two decades of life, most age-related changes occur after maturity. IgM concentrations in older individuals decrease to those in early life beyond the fifth decade of life. IgG decreases from the third through the sixth decade of life. Age-related changes in IgA in adults are small in comparison to changes in IgG and IgM (Buckley & Dorsey, 1970).

2.3 Health and Wellness

Health is a general well being of the individual and it comprises of several dimensions: physical health, mental health, social health, emotional health, and spiritual health. Over the years, health has been defined as the absence of disease. Today, however, health is defined in terms of the achievement of an optimal state of being or wellness (Wuest & Bucher, 1999).

On the other hand, Ardell (1984) defined wellness as a "conscious and deliberate approach to an advanced state of physical and psychological health". It stresses the importance of the individual taking an active role in achieving a healthy lifestyle. Attainment of a high degree of wellness is accomplished through proper nutrition, adequate rest, effective stress management and most important of all, performing regular and appropriate physical activity.

2.3.1 Physical Activity, Exercise, And Physical Fitness

Physical activity is defined as any bodily movement produced by the contraction of skeletal muscles that increases energy expenditure above the basal rate level. This includes both static and dynamic skeletal muscular contractions as well as aerobic and anaerobic metabolism (Hofman-Goetz, 1998). Physiologically, physical activity is a component of total energy expenditure and from a behavioural perspective, it can be viewed and measured in terms of recreational, occupational, developmental, rehabilitative, and activities of daily living. Physical activity can vary in intensity, duration, frequency and muscle groups that are used (Baranowski *et al.*, 1992).

Exercise is a term commonly restricted to a subset of physical activity that is planned, structured, and repetitive either with body movements (dynamic exercise) or without body movements (isometric exercise) (Casperson *et al.*, 1985). On the other hand, exercise training involves a systematic use of exercise of specific intensity, duration, and frequency that has its purpose in the improvement and maintenance of physical fitness (Baranowski *et al.*, 1992). Exercise is usually measured in clinical and experimental settings using the dimensions of intensity, duration, measurements of maximal oxygen uptake, heart rate, and time to exhaustion.

Physical fitness on the contrary is a set of attributes that people have or achieve that relates to the ability of the body's system to perform daily tasks including exercise with vigour and alertness without undue fatigue. It reflects the interactions between environment and genetic capacity and is often measured by cardiorespiratory endurance, body composition,

speed, flexibility, muscular strength, power, agility, and reaction time (Hofman-Goetz, 1998).

2.3.1 Exercise and Health

Hippocrates, the father of medicine, routinely prescribed exercise for his patients with a wide variety of ailments. He stated : "*all parts of the body which have a function, if used in moderation, and exercised in labours to which each is accustomed, become thereby healthy and well-developed, and age slowly; but if unused and left idle, they become liable to disease, defective in growth and age quickly. This is especially so with joints and ligaments if one does not use them*".

Exercise have long been identified as one of the most important tool for promoting and maintaining a healthy lifestyle. It contributes to the wellness concept by enhancing or initially establishing a wide variety of positive influences on the individual. These may include improved feeling of well-being, better health, improved appearance, physical prowess and modifications in the aging curves for numerous physical and mental attributes of humans.

Various organisations concerned with the promotion of healthy populations encourage the use of physical activity and exercise to reduce the incidence of important health problems. A major threat to the health and well-being of people today is chronic diseases, many of which can be categorized as hypokinetic diseases. The common hypokinetic diseases are caused by insufficient physical activity, often in conjunction with inappropriate dietary practices. Such diseases are coronary heart diseases, hypertension, osteoporosis, non-

insulin dependent diabetes mellitus, and obesity (Wuest & Bucher, 1999). Sedentary and physically inactive individuals have an increased risk of morbidity and mortality from these diseases. These allegations are based on several well-designed studies which correlate physical inactivity and the prevalence of several hypokinetic diseases such as coronary heart disease, obesity, non-insulin dependent diabetes mellitus, and osteoporosis (Frisch *et al.*, 1986; Powell *et al.*, 1987; Cummings *et al.*, 1985).

Proper amount of exercise has also been shown to be important for the optimal development and health status of children and adolescents (Hofman & Greydanus, 1997). It is not known to many that although the clinical manifestations of the hypokinetic diseases are largely restricted to adults, the risk factors for coronary heart disease, hypertension, non-insulin dependent diabetes mellitus and osteoporosis appear to begin their genesis in childhood and youth (Williams, 1993). For example, as many as 60 percent of children in the United States exhibit at least one modifiable adult risk factor for coronary heart disease by the age of twelve (Baranowski *et al.*, 1992). It is important to acknowledge that youth's risk status for obesity, hypertension, and dyslipidemia may largely track into adulthood, therefore physical activity is a priority concern for the prevention of the risk factors. The promotion of regular exercise in youth also serves as the foundation for a lifetime of regular physical activity and is absolutely indicated on a preventive medicine basis. Consequently, suitable education and intervention programmes need to be planned and instituted in schools to help children and adolescents lead a healthy lifestyle.

Persons of all ages can improve their health by engaging in a moderate amount of physical activity on a regular basis, proportionate to their capacities, needs, and interest. Greater

health benefits can further be achieved by increasing the amount of physical activity through changing the duration, frequency, or intensity of the effort (Pate *et al.*, 1995). The American College of Sports Medicine emphasizes participation in moderate physical activity on most days of the week. Evidence shows that low to moderate-intensity aerobic activities can have some long term health benefits and lower the risk of cardiovascular diseases when performed daily. Moderate physical activity is defined as a physical activity that results in an energy expenditure of 150 calories per day (Wuest & Bucher, 1999) or generally range from 60 to 75 percent of maximal capacity (Pate *et al.*, 1995).

2.3.3 Aerobic Exercise

Aerobic exercise is a moderate activity that utilizes oxygen to supply energy for muscular contractions. This can be sustained for an extended period without building an oxygen debt in the muscles (Sharkey, 1990; Wuest & Bucher, 1999). Examples of these types of exercises are jogging, swimming, aerobic dancing and cycling .

Aerobic metabolism yields 38 molecules of adenosine triphosphate (ATP) via the oxidative pathways and produces less lactic acid. Lactic acid is both an energy carrier and a metabolic by-product of high intensity exercises that produces energy via anaerobic metabolism. High levels of lactic acid are associated with general discomfort, muscle cramps, and fatigue. Based on this, aerobic exercise can therefore be defined as an exercise below the lactate threshold, i.e a point where blood lactic acid level just begins to rise (Sharkey, 1990). Thus, aerobic exercise is relatively pleasant and can be sustained from a few minutes to hours because of the aerobic utilization of fat reserves that produces adequate supply of energy for greater endurance work (McArdle *et al.*, 2000).

2.3.4 Aerobic Training

Regular aerobic exercise improves aerobic fitness and it is associated with health and longevity. Aerobic fitness is defined as the body's ability to transport and utilise oxygen (Latin, 1994). Aerobic fitness is achieved when the metabolic rate and oxygen consumption of muscles are elevated and this elevation is sustained long enough to overload the aerobic enzyme systems (McArdle *et al.*, 2000). There are several factors that influence the outcome of aerobic training. These include training frequency, training duration, and training intensity.

2.3.4.1 Frequency

Three exercise sessions per week are necessary to initiate adaptive changes in the aerobic system, particularly in cardiorespiratory fitness. Majority of studies involving types of training frequency indicate that a training response occurs with exercise performed at least three days weekly for a period of least six weeks. Great improvement is seen if one's initial cardiorespiratory fitness is low. Conversely, if the initial fitness level is high, only little improvement may be seen (McArdle *et al.*, 2000).

2.3.4.2 Duration

It is commonly accepted that for minimal improvement in aerobic fitness, it requires at least 20 to 30 minutes a session of sustained activity of sufficient intensity that is able to maintain the heart rate within its target zone (Wuest & Bucher, 1999). Generally, as the intensity increases, its duration decreases and vice versa. In average adults and children,

longer durations with low-to-moderate intensity is recommended for health-related aerobic fitness. Such programmes achieve better compliance with fewer injuries (McKeag, 1991).

2.3.4.3 Intensity

Exercise intensity is the most critical factor for a successful aerobic training. Intensity reflects the activity's energy requirements per unit time and the specific energy systems activated. By far, the heart rate is the most practical way to assess exercise intensity in the field. During exercise, heart rate changes in proportion to the energy requirements of the task. As the energy requirements increase, there is a corresponding increase in heart rate. Therefore, to achieve training benefits, the intensity of exercise must be regulated so that the heart rate is elevated to a predetermined level and maintained within a certain range. This level is known as the threshold of training and the range is known as the target heart rate zone. In an aerobic exercise of moderate intensity, the lower and upper limits of the target zone are between 60 to 75 percent of maximal heart rate reserve. The range limits of the training zone depend on the individual's age, initial fitness level, and state of training (McArdle *et al.*, 2000).

2.4 Exercise and the Immune System

Human physiological systems are sensitive to psychological or physical stress, hence investigators have begun to study the impact of exercise on the immune system. The theoretical basis for studying the influence of exercise on immune system derives from the work of Walter Cannon and Hans Seyle (Hofman-Goetz & Pedersen, 1994). A number of factors have been postulated to modify the immune system and these include age, genetic,