STUDY OF CARDIAC AUTONOMIC CONTROL AND PHYSICAL FITNESS IN MARTIAL ARTISTS

A Dissertation submitted in partial fulfillment of the requirement for the Degree of Doctor of Medicine in Physiology (Branch – V) Of the Tamilnadu Dr. M.G.R Medical University, to be held in April 2013

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By

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CERTIFICATE

This is to certify that the thesis entitled "**Study of Cardiac Autonomic Control and Physical Fitness in Martial Artists**" is a bonafide; original work carried out by Dr. Aneesh Joseph, in partial fulfillment of the rules and regulations for the M.D – Branch V Physiology examination of the Tamilnadu Dr. M.G.R. Medical University, Chennai to be held in April- 2013.

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DECLARATION

I hereby declare that the investigations that form the subject matter for the thesis entitled "**Study of Cardiac Autonomic Control and Physical Fitness in Martial Artists**" were carried out by me during my term as a post graduate student in the Department of Physiology, Christian Medical College, Vellore. This thesis has not been submitted in part or full to any other university.

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ABSTRACT

TITLE OF THE ABSTRACT : Study of cardiac autonomic control and physical fitness in martial artists.

DEPARTMENT : Physiology

NAME OF THE CANDIDATE : Dr. Aneesh Joseph

DEGREE AND SUBJECT : MD Physiology

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OBJECTIVES

To study the effect of Kungfu training on cardiac autonomic status and physical fitness by comparing Kungfu trained subjects with control subjects matched for age, BMI and physical activity level.

MATERIALS AND METHODS

Twenty Kungfu trained subjects and twenty matched control subjects were rested in supine position for twenty minutes. ECG and respiration data was acquired for five minutes after this, to obtain short-term heart rate variability parameters and other resting parameters. Standard cardiac autonomic tests were done. A maximal treadmill test was done and exercise duration, heart rate at maximal intensity and heart rate during recovery was measured and further analyzed to obtain recovery heart rates and time constants of recovery. All parameters were correlated with duration of Kungfu training. Analysis was done using SPSS software and suitable statistical tests were done.

RESULTS:

Subjects with Kungfu training had greater total heart rate variability as denoted by greater SDNN and greater cardiac vagal modulations as denoted by greater RMSSD than control subjects with

similar physical activity levels. This augmented cardiac autonomic control observed in Kungfu subjects may be attributable to the regular practice of ‘breath out maneuvers’, which form an intrinsic part of the exercise protocol of Kungfu training. Kungfu training allowed the subject to do similar quantum of work at a lower heart rate than controls, as evidenced by the lower heart rate in the Kungfu group at similar maximal work intensities reached by both groups. With increased duration of Kungfu training there was significant decrease in the maximal heart rate achieved with maximal exercise and the absolute heart rate at thirty seconds after stopping maximal exercise, in the martial artists. This finding may simply be a reflection of the positive effect of longer duration of training on the work capacity and $\dot{V}O2$ max of martial artists.

Key Words

Kungfu, cardiac autonomic control, physical fitness, martial arts, heart rate variability, maximal treadmill test, breathing exercise, meditation, Time constant, Recovery heart rate, maximal heart rate, breath out maneuver

INTRODUCTION

INTRODUCTION

Charles Darwin used the phrase “survival of the fittest”, introduced by British polymath, Herbert Spencer, to describe survival of species that are better adapted for their environment. (1) Fitness makes the organism better able to survive in its environment. Man is a sentient being that can modify itself and its environment, in the constant struggle for survival. Scientists have been pursuing and defining physical fitness for years. The definition of physical fitness in physiology is different from an evolutionary or popular one. Physical fitness has been defined by the American college of sports medicine (ACSM) as “A multidimensional concept that has been defined as a set of attributes that people possess or achieve that relates to the ability to perform physical activity”. (2,3) Higher physical fitness prolongs life. (4–6) Physical activity is any movement associated with significant energy expenditure above resting level. (2) To attain, maintain and improve physical fitness, one mode of physical activity used is exercise. Exercise consists of planned repetitive bodily movements targeted at achieving and maintaining fitness. (2)

Martial arts are methods of combat that have been altered into exercises. (7) Kungfu is a Cantonese term used for Chinese martial arts. (8) Kungfu incorporates a mixed anaerobic and aerobic exercise regimen which is combined with breathing exercises and meditation. (8–11) The order of performing these exercises are warm up aerobic running, stretching exercises and intermittent high intensity anaerobic exercises followed by a cool down exercises. This format of a Kungfu class unintentionally obeys the general format for an exercise session recommended by ACSM guidelines. The classes start and end with a short period of meditation. The anaerobic exercises are interspersed with frequent breathing exercises. Kungfu is comparable to a moderate to high intensity form of aerobic exercise and has been shown to improve cardiovascular fitness.

(12,13) No studies have been done on the effect of Kungfu training on cardiac autonomic function.

Aerobic and anaerobic exercise improves different components of fitness. Combined endurance and strength training is better than any of those components alone as multiple components of physical fitness can be improved. (14) The cardiac autonomic effects of endurance and strength training have been studied separately. (15) Moderate to high aerobic exercise training has been shown to increase aerobic capacity, decrease resting heart rate, improve heart rate recovery and generally increase cardiac autonomic modulations. (15–20) Further, breathing exercises and meditation have been shown to affect cardiac autonomic status by lowering heart rate and modifying heart rate variability. (21,22) Kungfu involves aerobic and anaerobic training, along with meditation and breathing exercises. Kungfu has been shown to improve sub-maximal cardiovascular fitness. (12) There are no studies reporting the effect of Kungfu training on cardiac autonomic control. This lack of research on martial arts limits its use as an exercise prescription for keeping fit and as a form of physical therapy. Does this unique exercise training regimen provide any added advantage over other physical activity? This study attempts to answer this question.

Twenty martial artists, who have trained in Kungfu, for over a year were recruited and compared with twenty subjects of similar age, BMI and physical activity. Cardiac autonomic status and fitness level was compared between these groups.

The cardiac autonomic function tests administered were heart rate variability analysis, deep breathing test, orthostatic challenge test, Valsalva maneuver and maximal hand grip test. The tests were conducted as per standardized published protocols. Standard indices were calculated from these tests and compared. The resting heart rate was also obtained as an index of cardiac autonomic control. (23) These tests were followed by a treadmill test.

A maximal exercise test was used to estimate $\dot{V}O_{2\ max}$ indirectly. A fixed ramp protocol was used in a motor driven treadmill to administer a maximal test. Immediately after exercise, the subject rested in the supine position, during the period of recovery. The maximal heart rate achieved with maximal exercise (HRmax) and absolute heart rates at different points of recovery was obtained. The heart rate recovery (HRR) at a given point of time was computed by subtracting the absolute heart rate at that point of time from the HRmax. HRR is an index of physical fitness and a predictor of $\dot{V}O_{2\ max}$. (24) The ratio of HRmax to resting heart rate and total exercise duration was also used as predictors of $\dot{V}O_{2\ max}$. (25) The work intensity at maximal exercise was also calculated and compared. (26)

The recovery heart rate decay was analyzed and it fitted well with a double exponential fit. Two time constants were derived. The lower time constant was arbitrarily selected to be the parasympathetic reactivation time constant and the higher one was selected to be the sympathetic withdrawal time constant. These time constants were compared between the two groups. The effect of duration of kungfu training on the various autonomic parameters was analyzed.

Tests revealed significantly increased SDNN and RMSSD parameters of short-term heart rate variability in Kungfu trained subjects showing improved overall autonomic modulations and vagal modulations when compared to controls,. The maximal heart rate reached with maximal exercise was significantly less in Kungfu group. Other parameters were not significantly different.

Kungfu is a unique form of exercise training which incorporates aerobic exercises, anaerobic exercises, breathing exercises and meditation. Kungfu training improved overall heart rate variability and vagal modulations and allowed subjects to do same quantum of work as the controls at lower heart rate, as indexed by the lower heart rate at similar maximal work intensity in Kungfu group compared to group.

AIMS AND OBJECTIVES

Aim:

To study the effect of Kungfu training on cardiac autonomic status and physical fitness.

Objectives:

To compare the following parameters, in martial artists and in control subjects matched for age, BMI and physical activity level:

1. Resting heart rate
2. Resting respiratory rate
3. Mean arterial pressure
4. Rate pressure product
5. Short term heart rate variability indices
6. Standard cardiac autonomic function test parameters
7. Maximal heart rate reached with exercise
8. Ratio of maximal heart rate (reached with maximal exercise) to resting heart rate
9. Treadmill exercise time
10. Work done at maximal treadmill exercise
11. Absolute heart rates at various times of recovery
12. Recovery heart rate
13. Time constant of recovery heart rate decay for parasympathetic reactivation
14. Time constant of recovery heart rate decay for sympathetic withdrawal

To correlate duration of Kungfu training with the following parameters in martial artists:

1. Resting heart rate
2. Mean arterial pressure
3. Rate pressure product
4. Time domain heart rate variability indices
5. Frequency domain heart rate variability indices
6. Standard cardiac autonomic function test parameters
7. Maximal heart rate reached with exercise
8. Ratio of maximal heart rate (reached with maximal exercise) to resting heart rate
9. Treadmill exercise time
10. Work done at maximal treadmill exercise
11. Absolute heart rates at various times of recovery
12. Recovery heart rate
13. Time constant of recovery heart rate decay for parasympathetic reactivation
14. Time constant of recovery heart rate decay for sympathetic withdrawal

The objective of the above correlation was to better understand the physiological basis of heart rate decay in all the subjects and to evolve out physiologically relevant indices for studying parasympathetic and sympathetic action.

LITERATURE REVIEW

LITERATURE REVIEW

The American college of sports medicine defines physical fitness as “a set of attributes that people possess or achieve that relates to the ability to perform physical activity”. (2) Some examples of the various components of physical fitness include speed, strength, endurance, power, flexibility and body composition. (2) People with higher physical fitness live longer, when compared to less fit controls, even after matching for smoking habit, BP and cholesterol levels, and family history of coronary heart disease. (4) Unfit men who actively improved physical fitness levels were less likely to die earlier than unfit men who chose not to improve their fitness level even while other risk factors were the same. (5,6) Higher physical fitness seems to prolong life and seems a parameter modifiable by increasing physical activity. (5,6) Physical activity is any movement caused by the contraction of skeletal muscle which involves energy expenditure above resting level. (2) Among Indians, especially for those who live in urban areas, there is a strong correlation between decreased physical activity and risk of coronary heart disease. (27) Exercise is protective against coronary heart disease and stroke. (15,28) Similarly, there is a rising burden of diabetes in India, due to decreased physical activity. (29) ACSM recommends at least 30 minutes of physical activity on most, and if possible, all days of the week. (30) Even adolescents are recommended to spend more than an hour a day participating in vigorous physical activity. (31,32) If decreasing physical activity and obesity, on the rise in Indian adolescents, is not curtailed it may add on to the disease burden in the future. (33)

To attain, maintain and improve physical fitness, one mode of physical activity used is exercise. Exercise consists of planned repetitive bodily movements targeted at achieving and maintaining fitness. (2) Exercise training is effectively available to everyone to improve and maintain the various parameters of physical fitness. (6) An ideal exercise regimen should address as many of the different components of fitness as possible. Besides improving and maintaining fitness parameters, exercise training also provides other benefits such as increased high-density lipoprotein levels, improved blood pressure levels, decreased fibrinogen levels, decreased incidence of colon cancer, reduced cardiovascular stress response and decreased incidence of depression and anxiety disorders. (34–38) The most common modes of exercise training used are aerobic (or endurance) training and resistance (or strength) training. Aerobic and anaerobic exercise training improve different components of fitness. Combined endurance and strength training is better than endurance or strength training alone. (14) One limiting factor in doing the aerobic exercise or strength training, which has been studied by various groups, is the need for special exercise equipment and training in the use of this equipment. (12)

Martial arts are methods of combat that have been altered into exercises. (7) Kungfu is a term used for a group of Chinese martial arts. (8) Kung Fu is a Cantonese phrase which means "hard work," or even "skill" depending on usage. (8) Kungfu incorporates a mixed anaerobic and aerobic exercise regimen combined with breathing exercises, meditation, punching, kicking and sparring. (8–11) In the Indian setting, Kungfu classes have duration of nearly two hours or more, and are conducted at least once a week. Each Kungfu class consists of several forms of exercise. The order of performing these exercises are aerobic running, meditation, stretching of all joints, anaerobic exercises , stance and footwork exercises, sparring (rule-based, unrehearsed fighting), forms (choreographed patterns of movements) and limb strikes like punching and kicking (with or without impact). (9–12,39,40) These are practiced repetitively with intermittent breathing exercises. (12) Classes end with cool down and meditation. This format of a Kungfu class unintentionally obeys the general format for an exercise session as recommended by the ACSM. (2) The meditation followed in Kungfu is similar to zazen meditation, student is asked to sit in a particular posture, without any other instruction. (41)

Kungfu training improves sub-maximal cardiovascular fitness measures. (12) Kungfu training also improves other components of physical fitness, like lower body muscle endurance, upper body strength, upper body muscle velocity, muscle power, leg muscle strength, auditory reaction time, body composition, flexibility, lumbar isometric strength, arm anaerobic power and synchronization of motor units. (9–12,39,42–47) Kungfu is comparable to a moderate to high intensity form of aerobic exercise as it achieves up to nearly 90% of maximal heart rate and hence may confer benefits similar to moderate to high intensity aerobic training modalities. (11–13,48) But unlike other moderate intensity aerobic modalities Kungfu lessons are intermittent in nature, often interrupted by technique corrections, but still provide similar benefits. (12)

Aerobic and anaerobic exercise improves different components of fitness. (14) Combined endurance and strength training is better than any of these components alone. (14) The cardiac autonomic effects of endurance and strength training have been studied separately. (15) Moderate to high intensity aerobic exercise training increases aerobic capacity, lowers resting heart rate, improves heart rate recovery and generally increases cardiac autonomic modulations. (15–20) Resistance training shows a mild improvement of aerobic capacity, increases endurance, does not affect resting heart rate and has a variable effect on cardiac autonomic modulations. (15,20,49,50) There are no studies on the effect of combined aerobic and anaerobic training programs on cardiac autonomic control. Such combined programs are used for rehabilitation and strengthening by medical professionals, therefore the lack of studies on effect of combined training on the cardiac autonomic function is a lacuna in scientific knowledge. Further, breathing exercises and meditation affect cardiac autonomic status by lowering heart rate and modifying heart rate variability. (21,22) Kung Fu is a unique form of exercise training which combines aerobic and anaerobic training, along with meditation and breathing exercises. There are no studies reporting the effect of Kungfu training on cardiac autonomic control. This lack of research on martial arts limits its use as an exercise prescription for keeping fit and as a form of physical therapy.

The autonomic nervous system is responsible for maintaining internal homeostasis and helps in adapting to changes in external environment. The autonomic nervous system has three divisions' sympathetic, parasympathetic and enteric nervous system. (51) The sympathetic and parasympathetic nervous systems act in synergistic and complementary fashion to maintain homeostasis. The sympathetic system is mainly concerned with "fight flight fright" responses of internal organs while parasympathetic is concerned mainly with rest and digest. The tests that assess the autonomic nervous system mainly evaluate cardiovascular reflexes triggered by performing specific maneuvers. Due to the complex nature of the autonomic nervous system no single test precisely reflects its function, hence a battery of tests are done to assess it. (52) One such commonly used battery assesses resting heart rate, short term heart rate variability, and cardiovascular response to deep breathing, orthostatic challenge, Valsalva maneuver and isometric hand grip. (53,54)

Mean Heart Rate

The Sino atrial node (SA node), the pacemaker of the entire heart, is supplied by both sympathetic and parasympathetic branches of the autonomic nervous system. Heart rate (HR) is antagonistically controlled by sympathetic and parasympathetic activity. While parasympathetic supply decreases the rate of SA nodal discharge, sympathetic supply increases it. Mean heart rate or RR interval is an indicator of sympathovagal balance. (23) At rest the high vagal tone keeps heart rate lower than the intrinsic firing rate of the SA node.

Short Term heart rate variability indices

The duration of any given beat is dependent upon the sympathetic and parasympathetic activity at the instant of initiation of the impulse from the SA node. Sympathetic and parasympathetic activity fluctuates continuously due to fluctuations of various inputs that modulate them, such as respiration and baroreceptor inputs. (52) The instantaneous RR interval therefore varies from beat to beat, in milliseconds, and this variability is known as heart rate variability (HRV).(55) This variability provides information about cardiac autonomic modulation. (56) At rest, vagal mediated sinus arrhythmia is the most prominent variability and is mainly responsible for heart rate variability. The influence of changes in parasympathetic activation is quicker and transient due to fast acetylcholine degradation, shortness of the unmyelinated post ganglionic axon and less number of synapses in the parasympathetic pathway when compared with the sympathetic pathway. (51,52) the effect of variations in sympathetic stimulation develops more slowly. Thus, an analysis of heart rate variability gives an indirect evaluation of the cardiac autonomic modulations, by their effect on Sinus node cells. (52) So beats that originate from below the SA node, such as ectopics, lead to error in estimation of cardiac autonomic modulations and hence such segments of ECG are excluded from analysis.

Heart rate variability can be analyzed by computing the RR intervals from the recorded ECG, each RR interval denoting the duration of a cardiac cycle. Different software and algorithms are used to analyze the RR intervals for a standard period of time to derive standard time domain and frequency domain parameters of HRV as per published guidelines. Standard duration of a short term Heart rate variability test is recommended to be 5-minutes. (57)

Heart rate variability is assessed based on time and frequency-domain analysis.

Time Domain Analysis

Time domain analysis uses the RR intervals also called Normal to normal intervals (NN) i.e. without ectopics, and analyzing their relationship using statistical tests. Parameters of time-domain analysis include:

1) **SDNN** which is the Standard deviation of normal-to-normal intervals and describes the overall Heart rate variability.

2) **RMSDD** is the square root of mean squared differences of successive normal-to-normal intervals. It describes fast changes and hence reflects parasympathetic activity

3) **pNN50** is the proportion of differences in consecutive normal-to-normal intervals that are longer than 50 milliseconds. Similar to RMSSD, it reflects parasympathetic activity. (52,57)

Frequency Doman Analysis

Frequency domain analysis expresses the varying heart rate as a function of frequency. The cyclical nature hidden in the varying RR intervals are analyzed using mathematical algorithms like fast Fourier transform. The RR interval wave plotted against time, called the RR interval tachogram (See figure 1), is split into its component waves using the fast fourier transform and the power density for separate frequency ranges are calculated (See Figure 2).

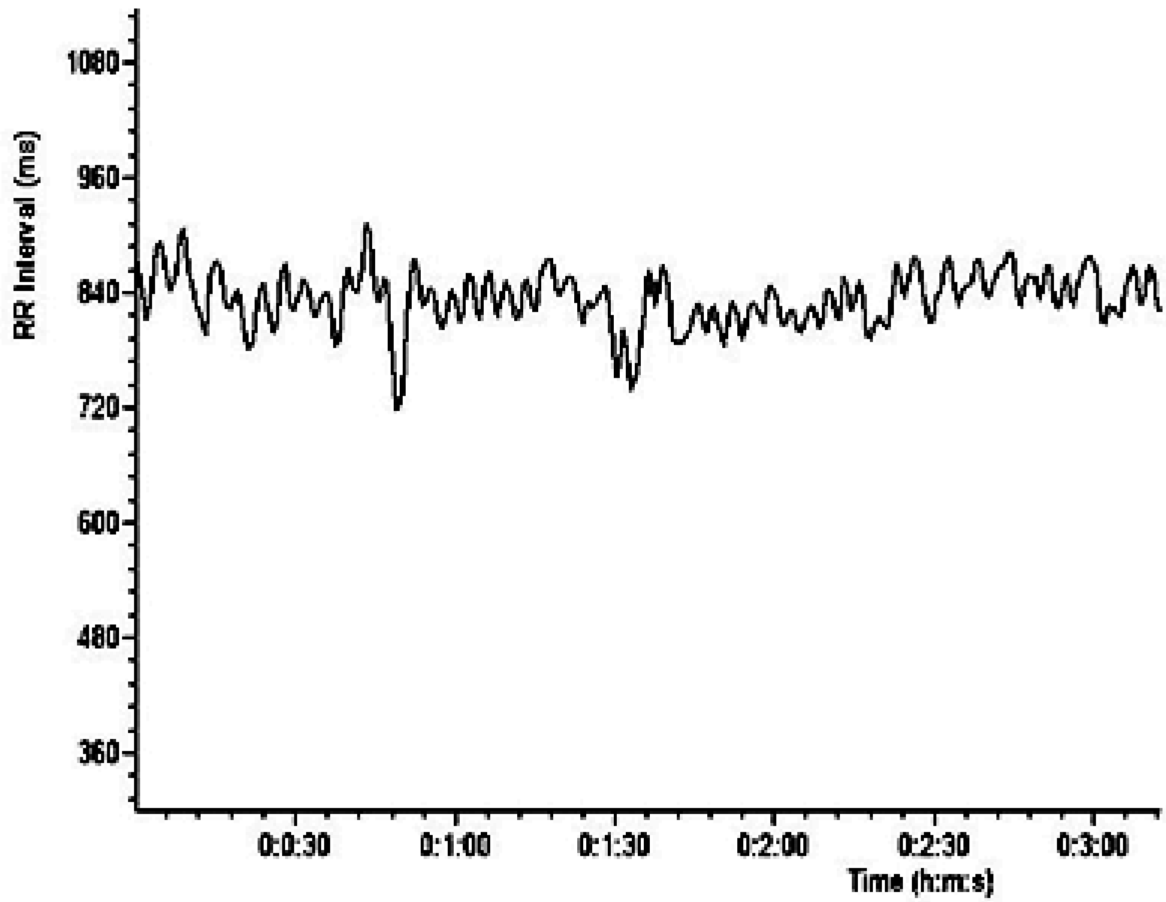


Figure 1: An RR interval Tachogram with time on the x axis and RR interval duration on the Y axis

The frequency ranges can be grouped into three bands: High-frequency (HF) band, at 0.15-0.4 Hz, is parasympathetically mediated as it is blocked by atropine (See figure 2), the low-frequency (LF) band at 0.04-0.15 Hz is modulated by both sympathetic and parasympathetic activity and is suppressed by total autonomic blockade, and very-low frequency (VLF) band, at 0.0033-0.04 Hz whose relevance is unclear. (52,56–58)

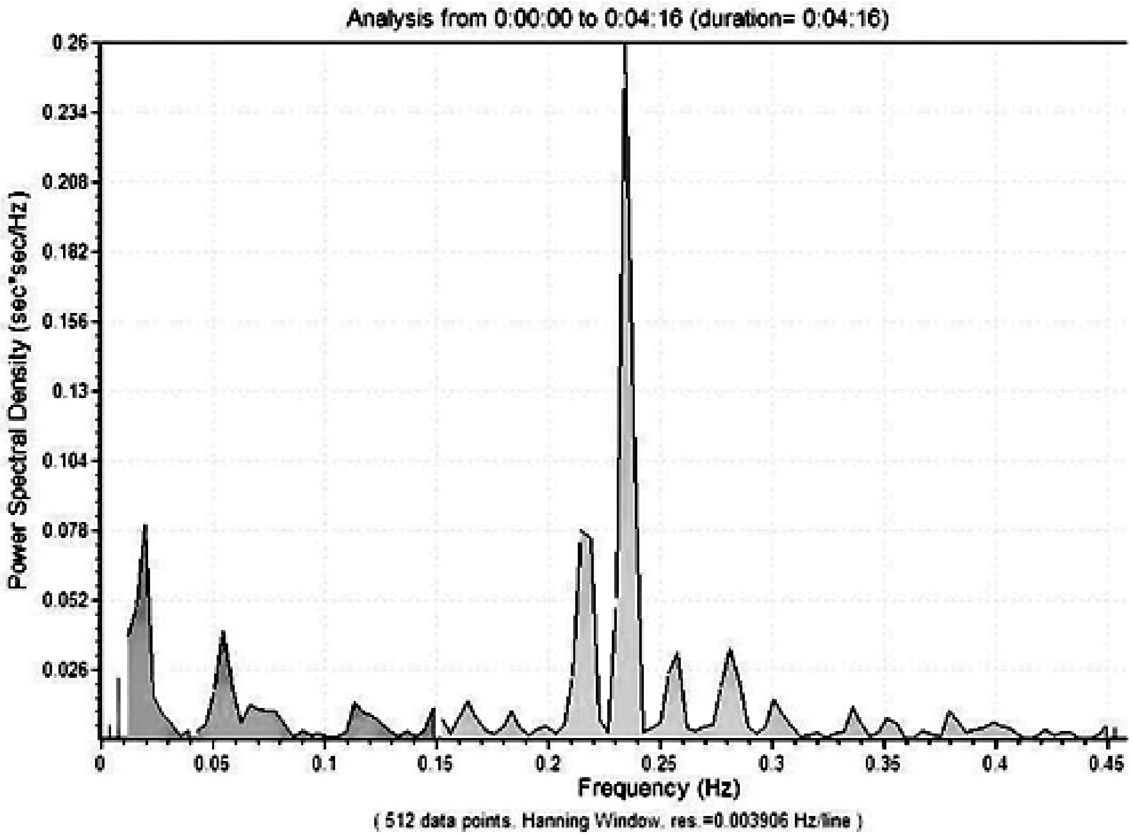


Figure 2: Wave distribution after a power spectral analysis of a tachogram using fast fourier transform X axis = Frequency Y axis = Power spectral density. Not the peak between 0.15 to 0.4 hertz showing an increased High frequency power in the subject

The main frequency domain variables used are:

1) LF power denoting both sympathetic and parasympathetic modulations.

2) HF power denoting parasympathetic modulations.

3) LF/HF ratio reflects the interactions of both sympathetic and parasympathetic modulations. (52)

4) LF nu (normalized unit) is Ratio of LF power to sum of LF and HF power and HF nu is ratio of HF power to sum of LF and HF power. Expression in normalized units decreases the effect of

total power on these ratios and also shows the balanced nature of both branches of the autonomic nervous system. (57)

5) Total power: Sum of LF and HF power. Denoting total variability in sympathetic and parasympathetic systems

Many investigators have studied the impact of aerobic exercise on HRV showing a lower resting heart rate while HRV parameters were either improved or did not change. (16,18,19) Meta-analysis of multiple studies reveals that aerobic exercise training results in significant increases in RR interval and HF power. (60) There are only a few studies on the impact of anaerobic exercise training on HRV showing varied results. Anaerobic exercise training has been shown to have no change or even increased HF and total power. (50,59)

Deep breathing Test

Respiratory sinus arrhythmia is the normal phenomenon by which the heart rate increases with inspiration and decreases with expiration. This variability in heart rate is more when taking slow deep breaths at six breaths per minute. The difference between the accelerations and decelerations are an index of parasympathetic modulation. (52)

Orthostatic challenge test

When a subject stands up from supine position, blood is redistributed to lower limb blood vessels resulting in a reflex compensatory reaction consisting of activation of the sympathetic system. Initially there is an acceleration of heart rate in the first 30 seconds. The heart rates in the initial phase of standing are analyzed. (52)

Valsalva maneuver

Heart rate response to Valsalva maneuver evaluates parasympathetic function. Valsalva maneuver is the voluntary forced expiration by a subject against resistance. The increase in intrathoracic pressure leads to increase in BP followed by a decrease, leading to compensatory tachycardia. When the expiration is stopped, an overshoot of blood pressure leads to a reflex fall in heart rate. This test gives an idea about parasympathetic function, by evaluating the changes in heart rate that occur during the different phases of the maneuver. (52)

Maximal handgrip test

The acute increase in heart rate in response to gripping a force dynamometer denotes a decrease in the parasympathetic activity. (52)

Rate-Pressure Product (RPP):

Myocardial oxygen uptake is strongly related to coronary blood flow. Myocardial oxygen uptake can be estimated indirectly by using the product of heart rate and systolic blood pressure, called the rate pressure product (RPP). (2,61,62) Myocardial oxygen uptake is determined by intra myocardial wall stress, contractility, heart rate, external work done by the heart, activation energy and basal metabolism of myocardium. (62) Lesser heart rate and Blood pressure at rest would suggest a more economical working of the heart.

Parameters of Physical fitness:

Maximal oxygen uptake ($\dot{V}O_2$ max) is the amount of Oxygen used by unit weight of body tissues in unit time during a maximal aerobic exercise and is the best measure of cardiorespiratory fitness and exercise capacity. (2,62) When direct measurement is not possible an indirect method can be used to predict $\dot{V}O_{2\,max}$. A maximal exercise test can be used for this purpose. (2) Treadmill ergometer is a tool which can be used for maximal testing.

Treadmill ergometer:

The term ‘ergometer’ is made up of the Greek words ‘ergon’ (work) and ‘metron’ (measure). Therefore, ergometer means "work measurer". An Ergometer is a device used for measuring amount of work done while exercising. (26,63) Broadly ergometers can be broadly divided into Weight machines and Endless path machines. Endless-path machines have some inbuilt rotational devices allowing continuous use without any movement of the machine-user unit in any direction.

Treadmill ergometer is an example of an endless path machine. The first exercise treadmill was designed in the University of Washington, by Dr. Robert Bruce and Wayne Quinton in 1952.

A treadmill ergometer is a device for measuring work output while subject walks or runs on a moving platform with a conveyor belt (see figure 3) driven by an electric motor. The belt moves requiring the subject to walk or run at a speed that matches the belt. The belt moving rate determines the speed of running or walking. The speed at which the subject walks or runs can be controlled by changing the speed of the belt. The running deck has damping elements that act as shock absorbers.

The entire frame including the running deck is raised by a lifting element to create an uphill grade to increase power output. The treadmill has handrails (see figure 3) but gripping is not allowed during testing in young healthy subjects as it reduces the accuracy of estimated exercise capacity. An emergency stop button (see figure 3) is available in case of any adverse event for the examiner to stop the treadmill. Motor driven treadmills can be used for submaximal and maximal testing. Maximal exercise testing provides a better estimate of $\dot{V}O_{2\ max}$ than submaximal testing. (2) Various treadmill protocols can be used in a treadmill to help a Subject achieve maximal exercise intensity, at which point the subject would have reached his or her individual maximal heart rate (HRmax).

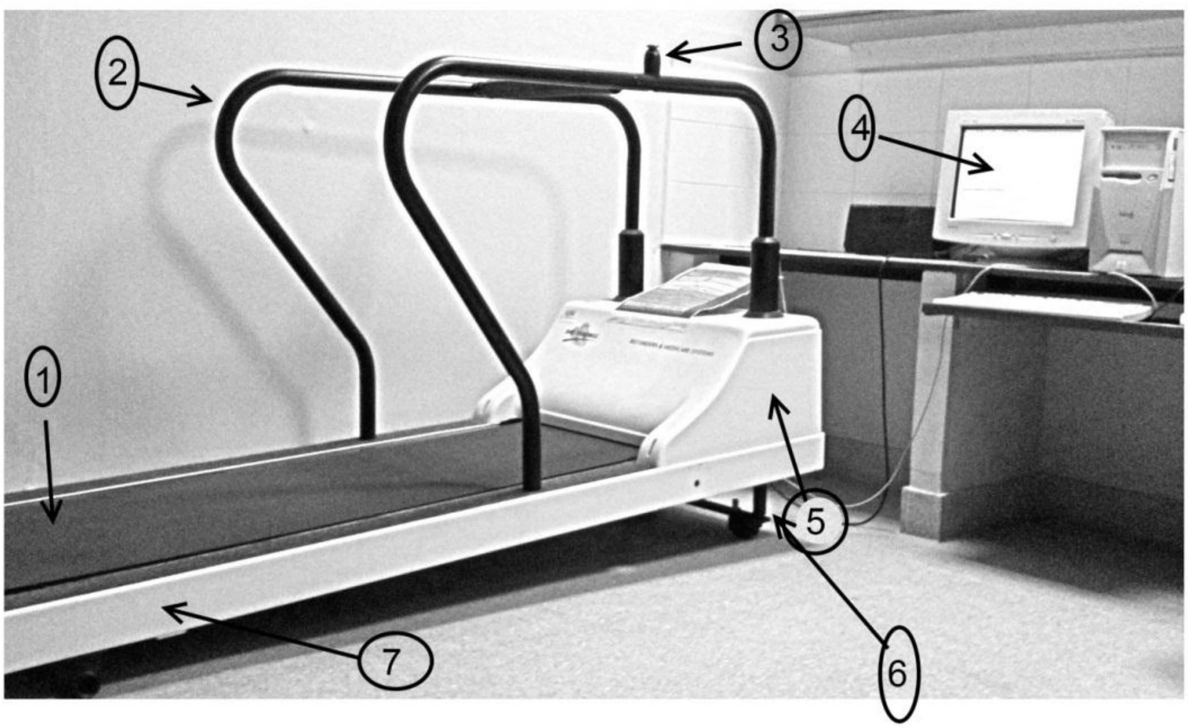


Figure 3. Parts of the Treadmill. 1 - Treadmill conveyor belt. 2 - Hand rail. 3 - Emergency stop button 4. Personal Computer controlling the treadmill. 5- Assembly containing electric motor 6. Support of lifting element. 7. Running deck containing rollers

Treadmill testing provides a common physiologic stress, walking and running, so subjects are more likely to attain a slightly higher oxygen consumption and peak heart rate. The protocol used to do a treadmill test depends on the purpose, outcomes desired, and the group tested. Some common exercise protocols are Bruce, Ellestad, Naughton and Balke-Ware. The Bruce treadmill test is the most commonly used, but it employs relatively large increments of work rate every three minutes resulting in less uniform changes in physiologic responses, resulting in overestimation of exercise capacity. Protocols with smaller increments of work rate will give better results.

The ramp protocol is a protocol in which work rate increases in a constant and continuous manner. Both individualized and fixed ramp tests have been used for testing. In the fixed or standardized ramp test all subjects run on the same protocol in which work rate increases in ramp fashion while in individualized ramp protocol the rate of increase in intensity is based on the subject. The advantages of using the ramp protocol include:

1. It helps avoid large uneven rise in workload
2. The physiological response is more uniform
3. It is more accurate.

A fixed ramp protocol starts with the subject walking. The speed is gradually increased to running speeds so that subject achieves a good stride. (62) After the subject reaches this point, the ramp angle of incline (the grade) is progressively increased at fixed intervals starting at 0. The grade increases at this fixed rate until the point where the subject reaches maximal exertion and the test is terminated.

When undergoing a maximal exercise test to assess $\dot{V}O_{2\ max}$, the protocol is selected so that test duration is between six and twelve minutes and the end point is volitional fatigue. (2,62) With a fixed ramp protocol exercise can undershoot or overshoot the optimum test duration depending on subject exercise capacity. The protocol can be programmed into a personal computer and a motor driven treadmill can be driven according to it.

The endpoint of a maximal exercise test may be

1. Volitional fatigue
2. Subject achieves more than 85% of age predicted maximal heart rate
3. Near maximal perceived exertion using a scale for rate of perceived exertion like the modified Borg CR 10 scale.
4. Heart rate does not increase with increased exercise intensity
5. Physical signs of severe fatigue
6. Other reasons to terminate a maximal test include onset of pathological signs like angina, dyspnea, wheezing, claudication, altered sensorium, pallor and cyanosis, subject requesting to stop before maximal exertion and failure of any testing equipment. (2)

Maximal Heart rate

Many formulas have been applied to estimate the maximal heart rate that an individual can attain at maximal exercise intensity. The more accurate ones are as follows:

1. HRmax = 205.8 - (0.685 x Age) (64)
2. HRmax = 208 - (0.7 X Age) (65)

In both these formulas the error percentage is too high, so no acceptable formula exists. (64–66) Also HRmax varies with training. Due to variation among individuals, subjects may reach maximal effort when exercising at 85% of the estimated HRmax. (2) Hence acceptable end points of a maximal exercise test include >85% of estimated HRmax. (2)

Modified Borg CR10 scale for rate of perceived exertion

The subjective level of exertion as perceived by the subject is a strong indicator of fatigue. The rate of perceived exertion is strongly related with heart rate, lactate levels and other parameters of exercise intensity. (67,68) An example of a scale used to assess this rate of perceived exertion is the Borg scale. When compared to other scales the Borg scale is specifically sensitive in assessing general fatigue. (68) The Borg Scale is a simple method of rating perceived exertion (RPE). Gunnar Borg initially introduced his first scale to measure perceived exertion with numbers ranging from six to twenty. The numbers were six to twenty so that multiplying with ten gave an idea about the heart rate at that level of perceived exertion. Later he modified this scale to range between 0-10 to create a simple category scale with ratio properties. (69) The modified Borg CR10 scale has twelve points, nine of which have verbal descriptors (see figure 4). Above nine in the modified Borg CR10 scale is taken as point of volitional fatigue.

Rating	Verbal descriptor
0	Nothing at all
0.5	Very, very weak (just noticeable)
1	Very weak
2	Weak (light)
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very Strong
8	
9	
10	Very very strong (Maximal)

Figure 4: **Ratings and Verbal Descriptors of modified Borg CR10 Scale**

Indirect Estimation of $\dot{V}O_{2\,max}$

There are three parameters that can be used as an indirect index of $\dot{V}O_{2\,max}$ from a maximal exercise test. The parameters are the ratio of maximal to resting heart rate, total treadmill time and recovery heart rate. (24,25,70)

Based on the relationship between $\dot{V}O_{2\,max}$, and resting heart rate (RHR) and HRmax, Uth-Sørensen-Overgaard-Pedersen formula was derived from Fick's principle. (64)

Ventilation at rest ($\dot{V}O_{2r}$) is the amount of blood oxygen used by tissues at rest. By applying Fick's law we get the formula

Ventilation at rest $\dot{V}O_{2r}$ is equal to cardiac output (CO) multiplied by arteriovenous oxygen difference at rest [(a-v)r]

$\dot{V}O_{2r} = CO * (a\text{-}v)_r$

Putting in the formula Cardiac output is equal to Stroke Volume (SV) multiplied by heart rate (HR)

Ventilation at rest ($\dot{V}O_{2r}$) is equal to Stroke Volume at rest (SV_r) multiplied by resting heart rate (RHR) and arteriovenous oxygen difference at rest [$(a\text{-}v)_r$]

$\dot{V}O_{2r} = SV_r * RHR * (a\text{-}v)_r$

So Ventilation at maximal oxygen consumption ($\dot{V}O_{2\,max}$) will be the product of stroke volume at maximal exercise multiplied by heart rate at maximal exercise (HRmax) and arteriovenous oxygen difference at maximal exercise [$(a\text{-}v)_m$].

$\dot{V}O_{2\,max} = SV_m * HRmax\,(a\text{-}v)_m$

Dividing the maximal $\dot{V}O_2$ by $\dot{V}O_2$ at rest.

So $\dot{V}O_{2\,max}/\dot{V}O_{2r} = SV_m/SV_r * HRmax/RHR * (a\text{-}v)_m/\,(a\text{-}v)_r$

$\dot{V}O_{2\,max} = \dot{V}O_{2r} * SV_m * (a\text{-}v)_m/SV_r * (a\text{-}v)_r * HRmax/RHR$

For getting the $\dot{V}O_{2\ max}$ per unit mass of tissue we will divide by Body Mass (BM)

Proportionality Factor (PF) is $\dot{V}O_{2r}/BM * SV_m/SV_r * (a\text{-}v)_m/(a\text{-}v)_r$. It is dependent on training of the individual.

So $\dot{V}O_{2\ max}$ per unit weight =PF * HRmax/RHR

Uth-Sørensen-Overgaard-Pedersen formula states that mass specific $\dot{V}O_{2\ max}$ = PF x HRmax/RHR where PF is the Proportionality Factor, 15.3 ± 0.7 ml/min/kg in trained western males. (64) As this proportionality factor is not based on Indian data a similar Indian constant needs to be derived. But until standard Indian values of proportionality factor has been derived, the ratio of HRmax/RHR can be taken as an index of $\dot{V}O_{2\ max}$ while comparing subjects of similar physical activity levels.

Total treadmill time

$\dot{V}O_{2\ max}$ is proportional to treadmill running time in a fixed protocol, but this method gives only a gross estimation and hence is less accurate. (70,72).

Heart rate Recovery

Parasympathetic tone dominates the resting state keeping the heart rate low, while exercise causes sympathetic activation accompanied with withdrawal of vagal tone. After termination of exercise, heart rate recovers to normal level by parasympathetic reactivation along with sympathetic withdrawal. (73–75) Heart rate recovery (HRR) is defined as heart rate at specified time after exercise subtracted from the maximal heart rate achieved during the exercise. (74,75) Heart rate recovery after exercise, therefore is an index of vagal reactivation. (73,74,76)

Therefore, a delayed heart rate recovery after exercise implies a dysfunction of vagal reactivation. Heart rate recovery is an independent predictor of all cause and cardiovascular mortality in both healthy individuals and in patients with heart disease.(77) HRR is associated with fitness parameters like $\dot{V}O_{2\ max}$,endurance capacity and resting heart rate.(77)

Physical fitness and $\dot{V}O_{2\ max}$ is strongly related with heart rate recovery values. (24,74,76) A higher heart rate recovery is associated with a higher $\dot{V}O_{2\ max}$. This relationship is higher during the earlier periods of recovery (15 – 30 seconds) but the relationship continues even during the later periods of recovery (> 60 seconds) but the magnitude of this relationship decreases with time. An earlier study has derived equations to predict $\dot{V}O_{2\ max}$ from recovery heart rate among Indian sportsmen using a submaximal exercise test. (24) There is a linear relationship between $\dot{V}O_{2\ max}$ and recovery heart rate. A subject with a higher $\dot{V}O_{2\ max}$ will have a higher recovery heart rate. (24) The absolute heart rate after the exercise may be a better comparator than the recovery heart rate, to draw conclusions about the $\dot{V}O_2$ max. (75) Heart rate recovery is also an important prognostic marker and decreased rate of heart rate recovery is a predictor of mortality. (2,73,74,76)

Heart rate Recovery Time Constants

After a maximal exercise the heart rate recovers through the actions of both wings of the autonomic nervous system. At maximal heart rate the action of the parasympathetic nervous system is nearly nonexistent as shown by the lack of effect of both presence or absence of atropine on the maximal heart rate.(78) But recovery occurs through parasympathetic reactivation as well as sympathetic withdrawal. Both processes act through receptors and hence depend on receptor kinetics and hence follow exponential kinetics.(79) The parasympathetic activity exponentially increases while the sympathetic activity exponentially decreases. Both these systems acting together lead to the exponential decay of heart rate from the maximal heart rate achieved during exercise to resting levels during the recovery period. The inherent nature of the circulatory system can also cause the exponential decrease in heart rate in recovery period when both wings of the autonomic nervous system are chemically blocked. (80) Previous studies have described the heart rate decay using polynomial, first order and second order modeling. (79–83) Due to the dependence on two exponential functions, a double exponential fit has a better physiological basis of application in studying parasympathetic reactivation and sympathetic withdrawal. Since the parasympathetic nervous system acts faster on the SA Node due to its shorter unmyelinated postganglionic neuron and fast destruction of acetyl choline at the Sino atrial node due to the high concentration of acetyl cholinesterase and due to the faster action of acetyl choline (51), parasympathetic aspect of heart rate decay should theoretically be faster.

A linear relationship can be represented by the formula '$y= ax + c$ ' where 'a' and 'c' are constants. In an exponential function the dependent variable 'y' depends on e^x where 'e' is the base of natural logarithm having a value of nearly 2.718. An example of a simple exponential relationship $y = e^x$ is shown in figure 5

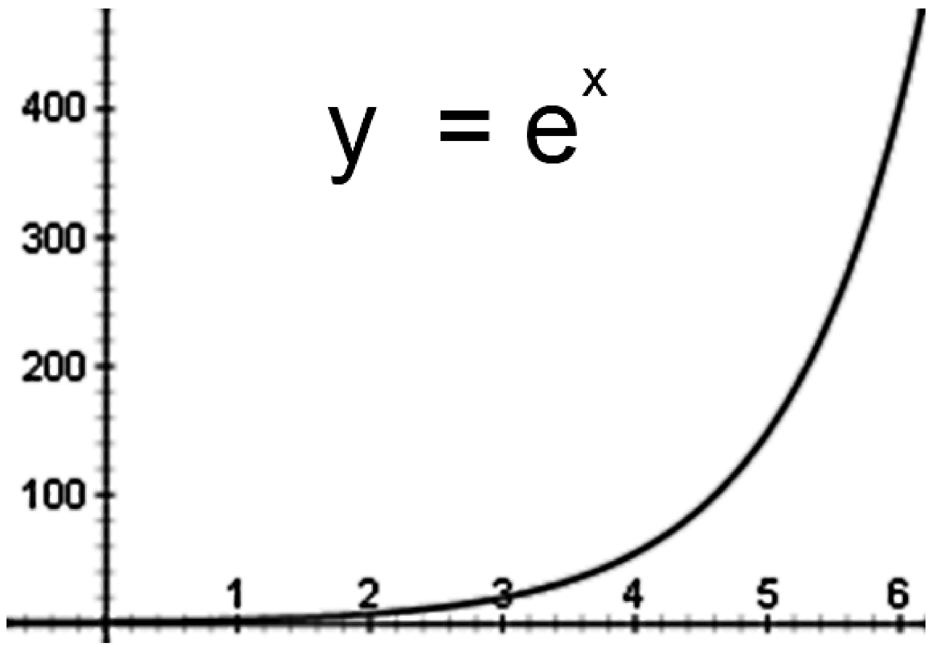


Figure 5 : Graphical represntation of the function y = e^x.. where e is the base of the natural logarithm with a value of approximately 2.71828

With a single exponential relationship it is called first order exponential relation. An important characteristic of a first order system is the **time constant**. Time constant is represented by the Greek letter **tau** '**τ**'. It represents the mean life of an exponentially decaying system. In our current example if we take the decaying heart rate as a first order exponential relationship and the maximal heart rate as 100%, then time constant is the time taken for nearly 63% of heart rate to decrease leaving behind only 37% of the maximal heart rate.

The time constant can be used to show how fast a given system decays. For example, with duration of one time constant the effect becomes 36.8% of initial value and with the passage of second time constant 63.2% of that dissipates leaving only 13.54%. Hence a system with a small time constant dissipates faster.

An exponentially decaying first order function is given in figure 6.

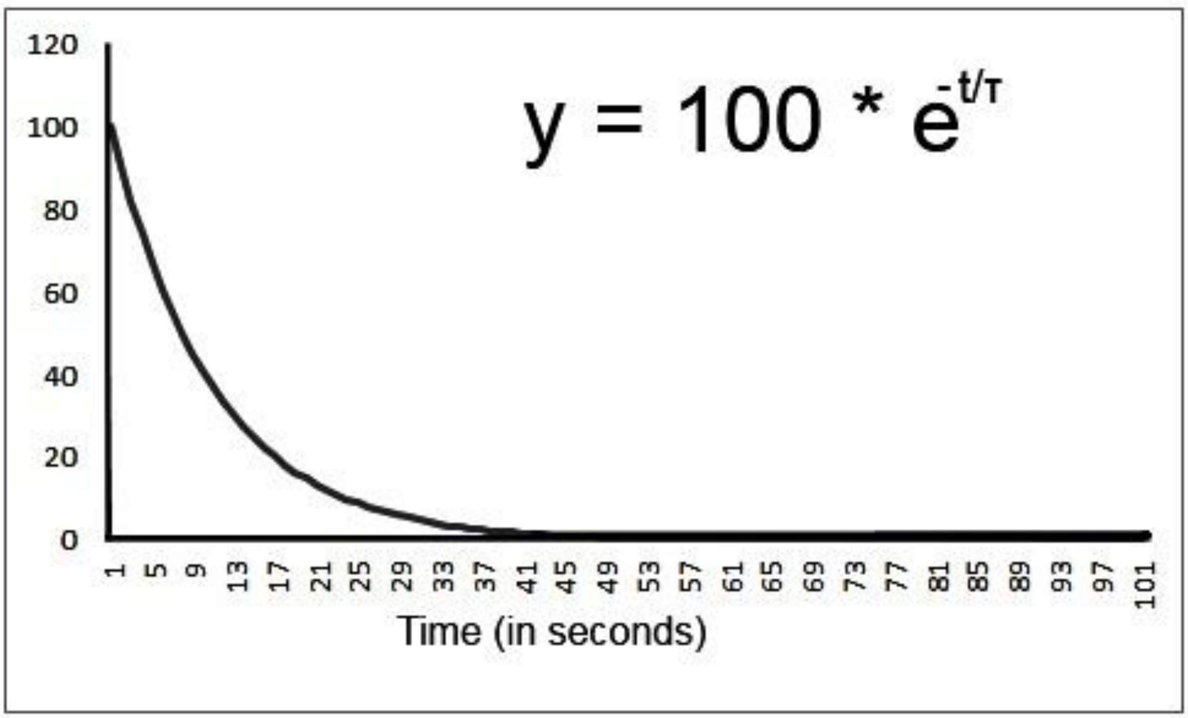


Figure 6: Graphical representation of the function $y = 100 * e^{-t/\tau}$ where t is the time in seconds and τ is the time constant. this graph has been drawn with a τ value of 10

The current example shows a curve that starts from 100 and decays with a time constant of 10 seconds. If the time constant is smaller it will decay faster.

Many authors have attempted to study recovery heart rate decay using first order kinetics. (79–81,83) Pierpont and Voth has written separate empirically derived exponential functions for Parasympathetic and Sympathetic function and studied their interactions during the recovery period. (79)The functions are theoretical and denote arbitrary units for parasympathetic and sympathetic activity.

Parasympathetic activity (**P**) at any point of time during recovery was calculated by adding Parasympathetic activity at onset of recovery (**Po**) with its difference from Parasympathetic activity at rest (**Pr**) multiplied by one minus the exponential to the base of the natural logarithm of negative of time divided by the time constant for parasympathetic system (**Tp**). (79)

$$\mathbf{P = Po + (Pr - Po) \times (1 - e^{-t/Tp})}$$

Sympathetic activity at any point of time during recovery (**S**) was calculated by adding Sympathetic activity at rest (**Sr**) to its difference from Sympathetic activity at onset of recovery (**So**) multiplied by exponential to the base of the natural logarithm of negative of time divided by the time constant for sympathetic system (**Ts**). (79)

$$\mathbf{S = Sr + (So - Sr) \times e^{-t/Ts}}$$

Pierpont and Voth studied heart rate decay as a sum of both these arbitrary exponential decays and attempted to fit the heart rate decay to the sum of these two first order kinetics at the same time derived **P** as a function of **S** to demonstrate central integration and interdependence of the parasympathetic and sympathetic nervous system. (79) The fundamental hypothesis was that the onset of action of sympathetic withdrawal and parasympathetic activation was different. The time constant of parasympathetic was generally observed by them to be lower than the time constant for sympathetic system.(79) This is consistent with the fact that action of the parasympathetic nervous system on the heart is faster than the action of the sympathetic nervous system. Wang et al have shown that the first order time constant is significantly different between physically fit and unfit individuals doing a submaximal exercise and proposed the first order time constant as an index of physical fitness.(84) But Pierpont, Stolpman and Gornick have shown that first order exponential function cannot generate an adequate model to explain heart rate decay after a maximal exercise. (83)

Broman and Wigertz have studied heart rate change with submaximal exercise and rest and found best fit with second order models. (82) A double exponential fit is better as the heart rate decay after a maximal exercise is due to the synergistic action of both sympathetic and parasympathetic nervous systems , both of which act through receptor kinetics , hence both follow first order exponential relationship with different time constants and different profiles but ultimately leading to the decrease of a single component , namely heart rate, from maximal to resting levels.(79) The combined action of both these first order systems may result in heart rate decay being a double exponential decay affected by the time constants of both the sympathetic and parasympathetic nervous system. A double exponential function will have two time constants. The time constant for parasympathetic (**TauP**) will theoretically be lower due to its fast action on the SA node due to shorter unmyelinated postganglionic neuron, faster action of acetyl choline and fast destruction of acetyl choline at the Sino atrial node due to the high concentration of acetyl cholinesterase. The second time constant which is larger will represent the time constant for sympathetic withdrawal (**TauS**), which is a slower process. The shorter time constant **TauP** can be a quantifiable index of speed of parasympathetic reactivation while the longer time constant **TauS** can be an be a quantifiable index of speed of sympathetic withdrawal after exercise. Both time constants indirectly quantifying the health of the two wings of the autonomic nervous system. A person with a lower **TauP** will have a faster vagal reactivation.

Power output or work done at maximal treadmill exercise

Treadmill is an ergometer that quantifies the amount of work done and the power output.

Work (W) represents the application of force (F) through a distance (D).

W = F * D

Power (P) represents the work done in unit time. (T)

P = F * D/ T

The treadmill has a moving conveyor belt with varying angles of inclination and speed.

Work performed equals the product of the weight (Wt.) of the person (F) and the vertical distance achieved while running up the incline. (26,63)

W = Wt. * Vertical distance

The vertical distance equals the sine of the treadmill angle theta (θ) multiplied by the distance travelled along the incline.

W = Wt. * sine θ * Distance

The distance travelled while running is the product of speed and time.

(Distance = treadmill speed * time)

W = Wt. * Sine θ * speed * time

Sine θ = vertical rise divided by the hypotenuse of the triangle formed by the rising conveyor belt. (As seen in Figure 7)

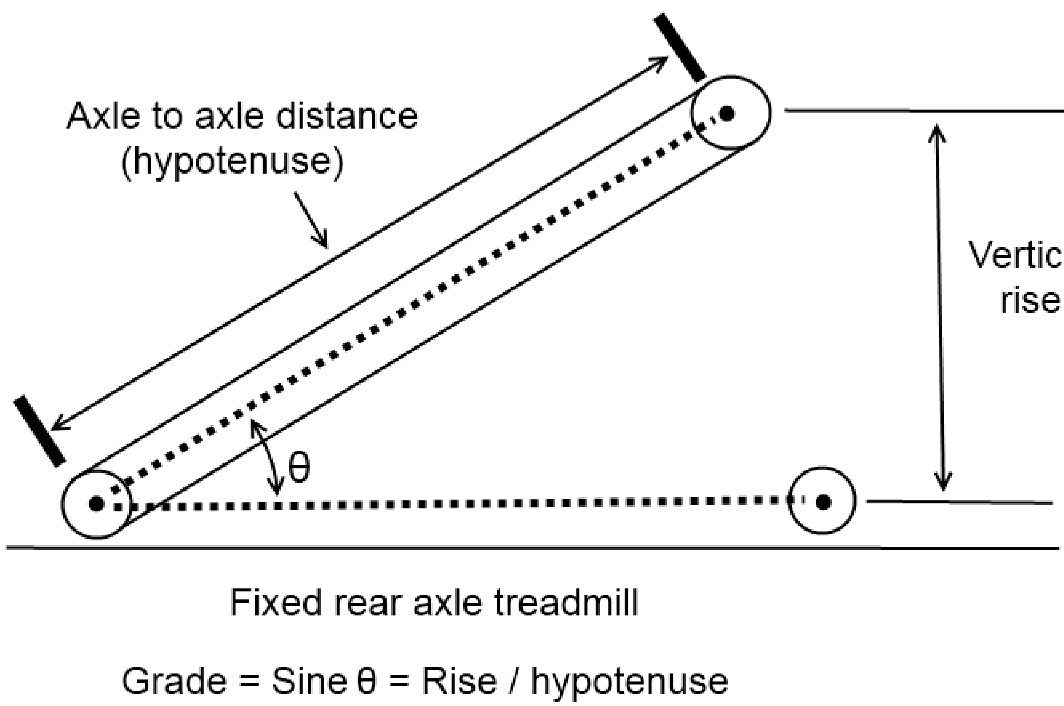


Figure 7: Treadmill forms a triangle with an angle theta (θ) as it rises with each grade

Sine θ = Rise of treadmill divided by the hypotenuse = Grade of the treadmill

Sine θ is the grade of the treadmill. (26,63)

W = Wt. * Grade * speed * Time

So the power output at a given time is

W/t = Wt. * Grade * speed

Power output or work done at maximal treadmill exercise is the product of the weight of the person by the grade of the treadmill and the speed of the treadmill.

The work intensity at maximal exercise will give an idea of the maximal power output possible by an individual.

MATERIALS AND METHODS

MATERIALS & METHODS

Study was approved by the ethics committee and the Institutional review board.

SUBJECTS

Martial artists who have been undergoing Kungfu training for more than a year, atleast once a week, were recruited from multiple Kungfu classes from surrounding areas. Subjects were recruited from Kungfu classes by personal meetings and phone interviews.

Controls of similar age, BMI and physical activity level were recruited from people participating in tennis, cricket, basketball, running and swimming. Physical activity levels were assessed using the International Physical Activity Questionnaire (IPAQ). (85)

IPAQ is an instrument used to obtain estimates of physical activity. The long version of the questionnaire was used for this study. IPAQ assesses physical activity in the four domains of leisure time activity, domestic activities, work-related physical activity and transport-related physical activity. METs (metabolic equivalents) are multiples of resting metabolic rate or resting oxygen consumption. One MET is equal to 3.5ml of O_2 per min per kg body weight. Multiples of METs are used to express the energy consumption during physical activities. Thus, a physical activity of two METS requires double the resting energy consumption. A MET-minute is computed by multiplying the MET score of an activity by the number of minutes it is performed. Average MET scores have been derived for each activity. For example, walking is 3.3 METs so total walking MET-minutes in a week will be the product of 3.3 and the minutes spent walking in a week. Adding the MET-minutes scores from different domains of physical activity, the total Physical activity level was calculated for each subject. Based on these values, subjects were divided into three levels of physical activity based on the MET-minutes of activity done per week. Subjects accumulating more than 1500 MET-minutes of activity a week were categorized as highly active while those between 600 and 1500 MET-minutes were categorized as moderately active while those below 600 MET-minutes were categorized as sedentary.

Table 1. Physical activity levels of kungfu and control group subjects

Physical activity level	Kungfu	Control
Heavily active	11	11
Moderatively active	9	9

Subjects in both groups were male and over 18 years of age.

Exclusion Criteria: Diabetics, hypertensive, those with chronic respiratory diseases, heart diseases, those who are on any long term medications and those who practice some other form of martial arts, meditation or breathing exercises were excluded from the study.

Tests were done after obtaining written informed consent from the subjects.

Twenty martial artists of mean age 26.2 ± 5.2 years, mean BMI of 22.98 ± 2.1 kg/m² and moderate to heavy physical activity levels were compared with controls of mean age 25.3 ± 5.2 years, mean BMI of 22.6 ± 2.7 kg/m² and with moderate to heavy physical activity levels. There was no statistical difference in age (p>0.05), BMI (p>0.05) or Physical activity levels (p>0.05).

PRE-TEST INSTRUCTIONS

Prior to the test subjects were given instructions to

A. Avoid smoking and drinking alcohol or caffeinated beverages for 12 hours prior to test

B. Avoid strenuous activity one day prior to testing

C. To have at least seven hours of sleep in the previous night.

D. On the morning of the test to come fasting or to have only a light breakfast atleast two hours before test.

EXPERIMENTAL SETUP

Tests were conducted in Clinical physiology lab of the Department of Physiology in Christian Medical College, Vellore. All tests were done between 5:00 AM and 12:30 PM. The subjects were all tested by the same examiner. Compliance with pretest instructions was checked. Height and weight was measured and BMI computed.

Physical activity readiness was assessed by Physical Activity Readiness Questionnaire (PAR-Q). (86)

EXPERIMENTAL PROTOCOL

The experiments were done in this order after a twenty minute supine rest period:

1) Recording of 5-min ECG and respiration for short-term HRV analysis
2) Cardiac autonomic function tests
3) Treadmill test

Environmental settings like room temperature, lighting were standardized. The room was quiet. Each Subject was asked to lie supine on the bed and instrumentation was done. ECG leads were placed in lead II configuration after scrubbing skin with cotton soaked in spirit and a respiratory belt was placed to record respiratory movements. Blood pressure was measured by manual sphygmomanometry. The ECG and respiration was amplified and converted into digital signals using MP150 (BIOPAC Systems, Inc., CA 93117, USA) accessed using AcqKnowledge software version 3.9.1 and stored in a personal computer.

While the subjects were resting in supine position, repeated measurements of blood pressure (BP) were made by manual sphygmomanometry. The mean arterial pressure (MAP) was computed from the stable BP recording made after 15 min of supine rest. After 20 minutes of supine rest a five minute recording of ECG and respiration was done for short term heart rate variability analysis. The resting respiratory rate was calculated from this recording.

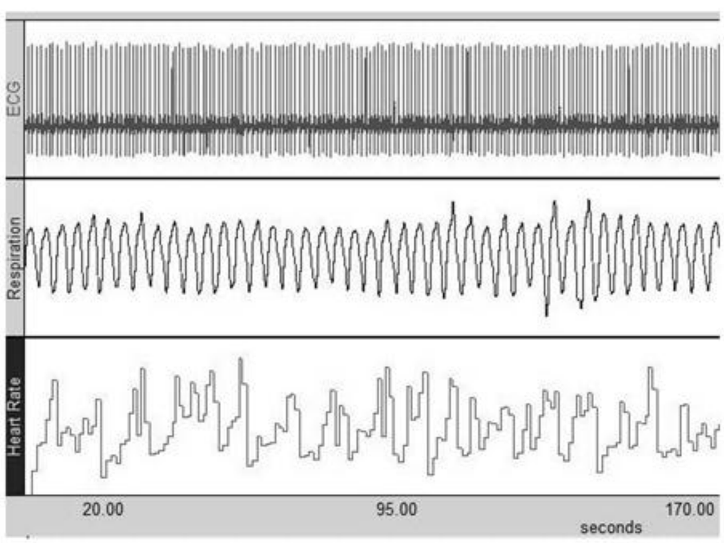


Figure **8** : A segment of the five minute minute recording taken for heart rate variability analysis. Top row shows ECG, Midle row shows respiratory movements and third row shws instantaneous heart rate calculated from ECG

Short term heart rate variability Analysis

The 5minute ECG (Figure 8) was scrutinized to ensure that there were no ectopic beats and no artifacts and noise. The 5-min ECG was then analyzed using Nevrokard aHRV analysis software and time and frequency domain parameters of HRV were computed. The time domain parameters computed were SDNN, RMSSD and pNN50. The frequency domain parameters computed were LF power, HF power, LF/HF ratio, LF power in normalized units, HF power in normalized units and total power.

Resting heart rate

The resting heart rate also calculated from the five minute ECG data. (Figure 8)

Resting respiratory rate

Resting respiratory rate was calculated from the five minute data by taking an average of five minutes of respiratory data. (Figure 8)

Rate Pressure Product

Rate pressure product was obtained by multiplying the resting heart rate with systolic blood pressure obtained with rest in the supine position.

Mean arterial pressure

The resting mean arterial pressure (RMAP) was calculated from the resting BP.

Cardiac autonomic tests:

After the five minutes of recording for short term heart rate variability the rest of the cardiac autonomic tests were done with a rest period of 2 minutes between each test. The tests were deep breathing test, orthostatic challenge test, Valsalva maneuver and maximal handgrip test. The ECG was recorded during all the tests. Respiration was recorded only in deep breathing test.

Deep breathing test

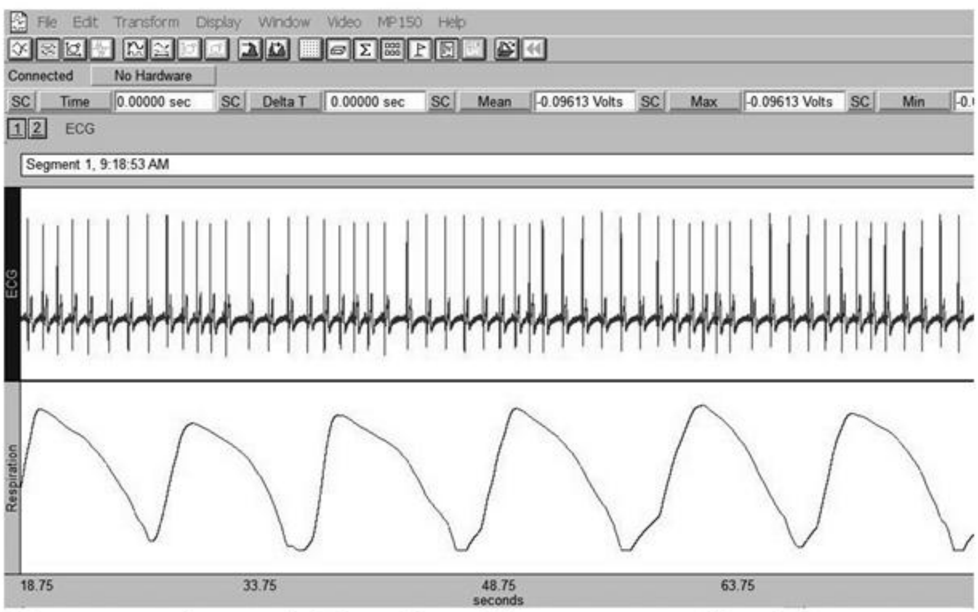


Figure 9 : A sample Deep Breathing test recording. The top row is ECG recoording while bottom row is respiration recording. Subject is taking deep breaths at a rate of 6 breaths per minute

Deep breathing evaluates changes in heart rate that is caused by "deep" breathing at 6 breaths/min. (Figure 9) Still in the supine position, the subject was instructed to inhale and exhale for 5 seconds each, by verbal and visual cues provided by the examiner. This 10 second respiratory cycle was repeated 6 times. Breathing was instructed to be slow, continuous and regular. The maximum heart rate during each deep inspiration and minimum heart rate during each deep expiration was calculated. The differences in these heart rates were averaged to get the I-E indices. The six values obtained were averaged to get the I-E index. The maximum RR interval in each deep expiration and minimum RR interval in each deep inspiration was calculated and divided to get E/I ratios. (52,54). The values obtained were averaged to get the E/I ratio.

Orthostatic Challenge Test

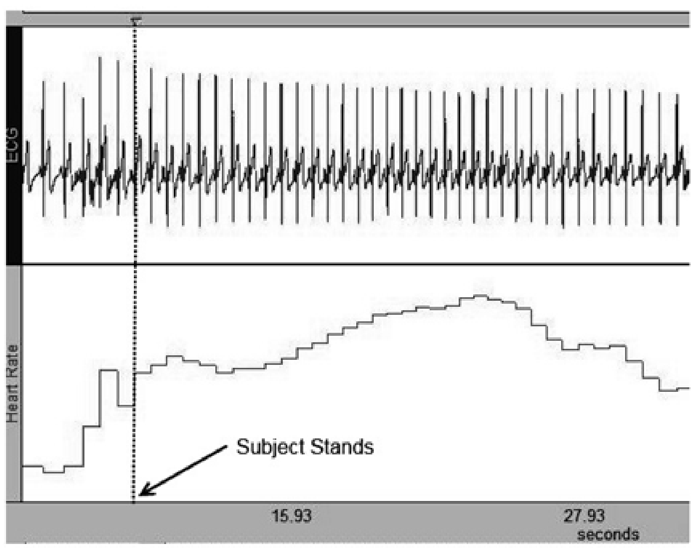


Figure 10 : Responce of ECG (Top row) and Instantaneous heart rate (Bottom row) to standing - Orthostatic Challenge

After taking the supine BP, subjects were asked to stand erect from the supine position as quickly as possible (within 3 seconds) and with minimal effort. Immediately on standing a BP recording was taken. If systolic BP did not fall more than 10mmHg compared to the supine, the subject was asked to sit down. Normally an increase in heart rate occurs on standing that is maximal at about the 15th beat, followed by a relative bradycardia, maximal around the 30th beat after standing (Figure 10). The RR interval of the longest beat around the 30^{th} beat was divided by the shortest RR interval around the 15^{th} beat to compute the 30:15 ratios. (52,54)

Valsalva maneuver

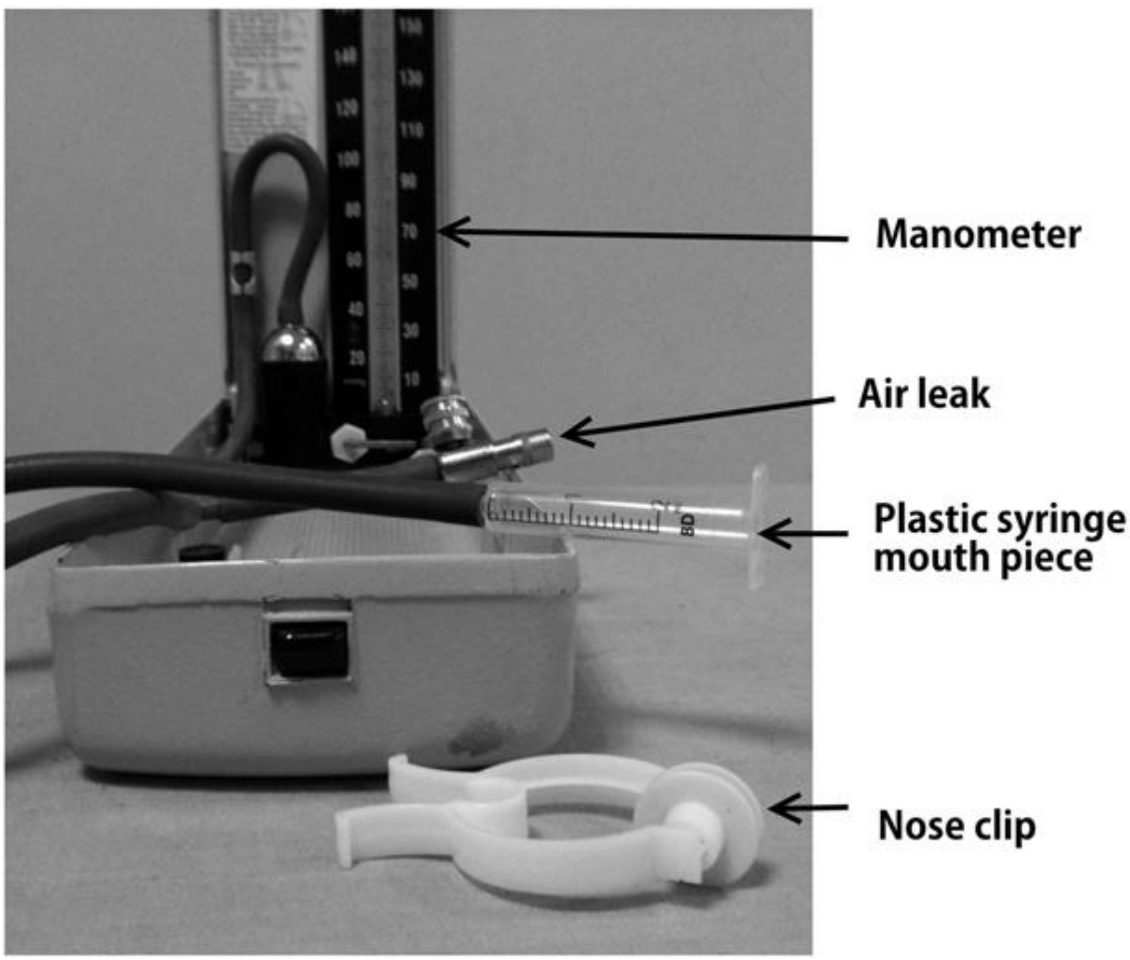


Figure11.Parts of the Valsalva Apparatus

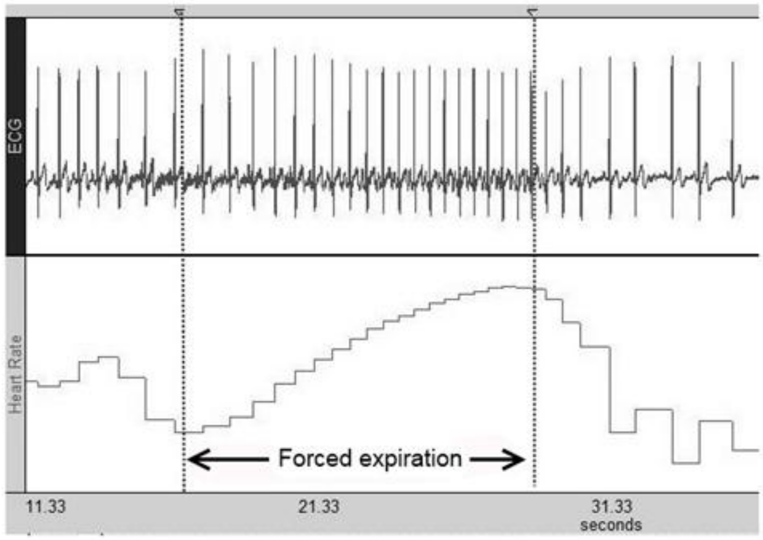


Figure 12 : Response of ECG (Top row) and Instantaneous heart rate (Bottom Row) to forced expiration - Valsalava maneuver

Valsalva apparatus was made by connecting the pressure gauge of a sphygmomanometer to a 5 ml plastic syringe. An air leak is also made in the tubing to prevent closing of the glottis while blowing into the plastic syringe (figure 11). (87) The subject was made to sit comfortably and nostril was clamped. Then the subjects were instructed to take a deep breath and blow forcibly into the plastic syringe which served as the mouth piece of the apparatus, till the mercury in the manometer reached a reading of 40 mm Hg. Subjects were asked to continue to blow out to maintain the same pressure till instructed. (Figure 12) The pressure was maintained for more than 10 seconds up to 40 seconds. The test was done twice with a rest period of 2 minutes in between. Valsalva ratio was calculated by dividing the maximum heart rate during the maneuver by the lowest heart rate obtained within 30 seconds after the peak heart rate, after stopping the maneuver.

Maximal handgrip test

Subject was asked to relax with arms resting and a baseline ECG was recorded, after which subjects were instructed to grip a hand dynamometer with maximal power for three seconds. The test was repeated after 2 minutes. The mean heart rate before procedure was subtracted from maximum heart rate achieved during procedure to obtain MHG ratio. The highest value was taken for analysis.

Treadmill test

After the cardiac autonomic function tests, the treadmill test was administered. The treadmill (RMS TMT MK II, Recorders & Medicare systems) was programmed using RMS CARDIO software in a Personal computer to run the fixed ramp protocol. Polar wireless heart rate monitor belt (RS800Cx, Polar Electro, Finland) was applied to the chest of the subject. (Figure 13)

The treadmill protocol was explained to the subject. The protocol started at a low treadmill speed and speed increased slowly and angle of incline of the ramp also increased at a fixed intervals starting from zero grade hence the work rate increased at a constant rate [see table 2]. (62) A fixed ramp protocol was used. The speed increased in two steps to the running speed of 10km/hr. After two minutes were run at this speed the grade was increased by 2% every minute till test was stopped at volitional fatigue. Subjects were instructed to assess rate of perceived exertion by referring to a Borg's CR10 visual analogue scale affixed to the treadmill.

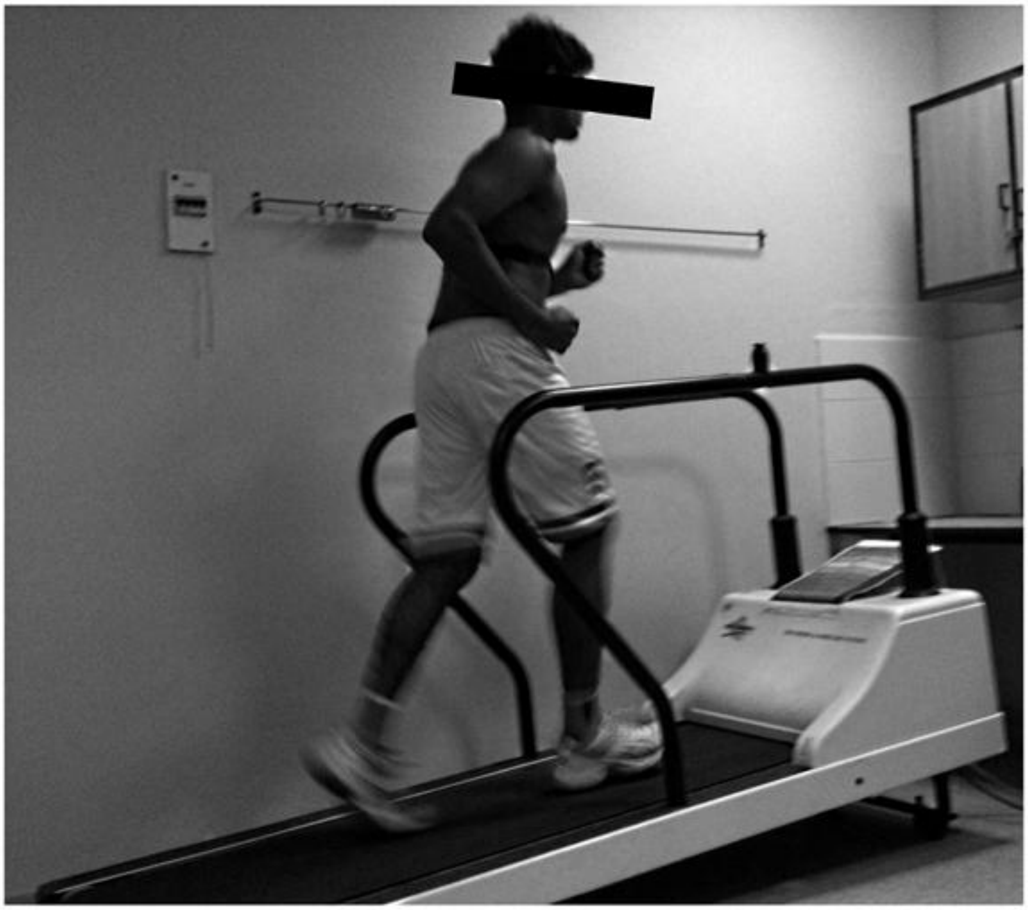


Figure 13. Subject running on the treadmill wearing the polar heart rate monitor belt at a speed of 10 km/hr and a grade of 4

At volitional fatigue treadmill was stopped and subject was placed in supine position as soon as possible (less than 5 seconds). Subjects were instructed to lie still for a further six minutes. The various parameters assessed were maximal heart rate reached during exercise, ratio of maximal to resting heart rate, total treadmill time, Work intensity and heart rate recovery at various periods of recovery.

Time (in mins)	Speed (in km/hr)	Grade (in %)
12	10	16
11	10	14
10	10	12
9	10	10
8	10	8
7	10	6
6	10	4
5	10	2
4	10	0
3	10	0
2	6.4	0
1	3.5	0

TABLE 2 : RAMP PROTOCOL USED

Maximal Heart rate

The polar heart rate monitor measured the heart rate of the subject by taking an average of five beats. The maximal heart rate was obtained from this data after being transferred to a personal computer.

Ratio of maximal to resting heart rate

The ratio was calculated for each subject by dividing the maximal heart rate with resting heart rate.

Total treadmill time:

The total duration was calculated from the recordings for each subject.

Work Intensity

Work Intensity (WI) was obtained by multiplying the weight of the subject with the grade of the treadmill at maximal intensity and the speed of the treadmill.

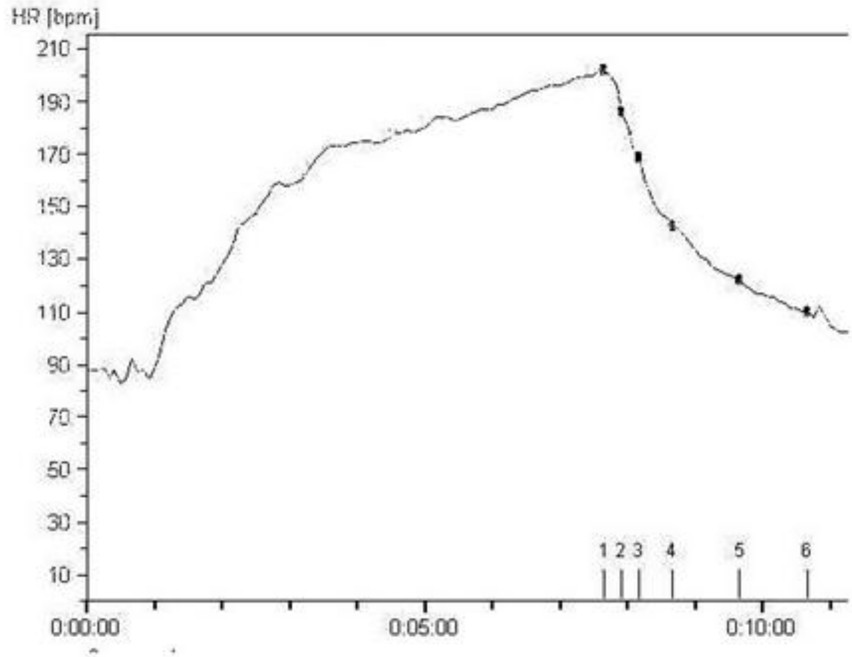


Figure14 Polar Heart rate monitor data of a maximal treadmill test X axis - time, Y axis - heart rate.

Recovery heart rate:

Absolute heart rates at 15, 30, 60, 120, 180. 240 and 300 seconds were obtained from the Polar data. The recovery Heart rates at these time periods were calculated by subtracting from the maximal heart rate.

Heart rate Recovery Time Constants

The recovery heart rates were plotted from the absolute heart rates used earlier and curve fitting was done with double exponential offset fit using Igor Pro version 5 (WaveMetrics, USA). Double exponential of two Kungfu subjects and two control subjects are seen in figure 15.

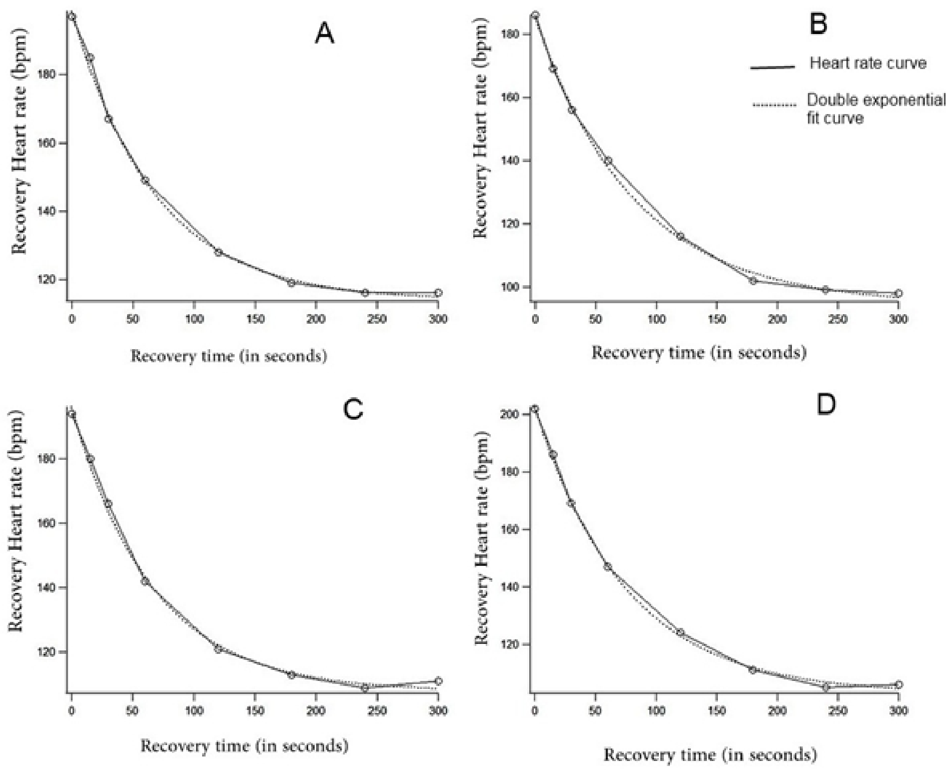


Figure 15 . Double exponential curve fitting of the recovery heart rates of two kungfu subjects A &B and 2 control subjects C & D. Solid line is heart rate curve while dotted line is fitted curve

The time constants were named **Tau1** and **Tau2** as given by the program. **Tau1** and **Tau2** of all the subjects were compared to see if they were significantly different. The lowest time constant was designated as **TauP** and larger time constant as **TauS** and compared across the whole group. **TauP** and **TauS** of all the subjects were compared. The **Tau1, Tau2, TauP and TauS** of Kungfu subjects were compared with control subjects

Duration of Kungfu Training

Duration of Kungfu training was enquired from each subject and correlated with resting heart rate, mean arterial pressure, rate pressure product, Time domain heart rate variability indices, Frequency domain heart rate variability indices, Standard cardiac autonomic function test parameters, maximal heart rate reached with exercise, ratio of maximal heart rate (reached with maximal exercise) to resting heart rate, treadmill exercise time, work Intensity, absolute heart rates at various times of recovery , Recovery heart rates and the recovery time constants.

Breath Out Maneuver

Breathing exercise called 'breath out maneuver' is done multiple times during a Kungfu class, whenever the subjects are out of breath. During the latter half of class as students are more tired, 'breath out' maneuver is done once every couple of minutes. To understand the physiological effect of 'breath out' maneuver two subjects were asked to do the breath out maneuver and the heart rate and respiration changes were examined and analyzed.

Potential confounders

Potential confounders were mental or emotional stress of subject on the day of recording.

Statistical analysis

Statistical analysis was done using SPSS. Variance was assessed using Levene's test. An independent sample t- test was done. A p-value of less than 0.05 was considered significant.

Student's t test was done to compare the time constants within and between the groups. Linear regression was done to correlate duration of Kungfu training with the parameters.

RESULTS

RESULTS

All results are expressed as mean ± standard deviation

Short term heart rate variability Analysis

Time domain parameters:

SDNN value of 106.66 ± 78.57 ms in Kungfu subjects was found to be significantly greater than the control value of 83.4 ± 27.16 ms ($p < 0.05$)

RMSSD value of 105.47 ± 83.59 ms in Kungfu subjects was found to be significantly greater than that of controls with a value of 77.2 ± 33.36 ms ($p < 0.05$)

pNN50 in Kungfu and control groups were not statistically different.

Frequency domain parameters:

LF power in Kungfu was 3281.2 ± 5209.1 ms^2 and in controls it was 2848.2 ± 899.9 ms^2 while HF power in Kungfu was 3330.9 ± 5047.1 ms^2 and in controls it was 2801.6 ± 2221.1 ms^2. The total power in Kungfu subjects were found to be 6612.1± 10030.6 ms^2 while in controls it was 5649.9 ± 4359.4 ms^2. LF/HF ratio in Kungfu was 1.5 ± 1.2 while in controls it was 1.4 ± 1.3. LFnu in Kungfu was 0.5 ± 0.2 nu (normalized units) while in controls it was 0.5 ± 0.2 nu and HFnu in Kungfu was 0.5 ± 0.2 nu while in controls it was 0.5 ± 0.2 nu. None of the frequency domain parameters were found to be significantly different. All frequency domain parameters were comparable in both groups.

Table 3 Comparison of the short-term heart rate variability parameters in Kungfu (n = 20) and control groups (n= 20)

HRV Indices	Kungfu	Control	p value
SDNN , ms	106.66 ± 78.57	83.4 ± 27.16	0.019*
RMSSD, ms	105.47 ± 83.59	77.2 ± 33.36	0.03*
pNN50, %	38.87 ± 22.64	43.39 ± 21.62	0.522
LF Power, ms²	3281.2 ± 5209.05	2848.2 ± 2899.87	0.213
HF Power, ms²	3330.9 ± 5047.08	2801.6 ± 2221.12	0.107
LF/HF Ratio	1.5 ± 1.21	1.37 ± 1.3	0.545
LFnu, nu	0.52 ± 0.2	0.5 ± 0.18	0.478
Hfnu, nu	0.49 ± 0.2	0.50 ± 0.18	0.478
Total Power, ms²	6612.14 ± 10030.6	5649.85 ± 4359.37	0.697

All values are mean ± SD. * $p < 0.05$ considered significant (unpaired ttest)
SDNN - Standard deviation of the normal-to-normal RR intervals, RMSSD - Root mean square of successive differences between adjacent RR intervals, pNN50 - percentage of number of RR intervals with differences >50 ms, LF - low frequency, HF - high frequency, nu - normalized units

Resting parameters

Resting heart rate in Kungfu was 60.92 ± 6.72 bpm while in controls it was 62.14 ± 7.94 bpm. The resting mean arterial pressure in Kungfu was found to be 81.47 ± 5.04 mmHg while in controls it was 85.03 ±5.00 mmHg. The Resting respiratory rate in Kungfu was 16.6±2.19 breaths/ min while in controls it was 15.75 ± 2.12 breaths/min. The Rate Pressure Product in Kungfu subjects were 6567.3 ± 907.66 bpm mmHg while in controls it was 6929 ± 856.20 bpm mmHg. None of the parameters were significantly different.

TABLE 4 Comparison of resting parameters in kungfu (n = 20) and control groups (n = 20)

Parameters	Kungfu	controls	p value
RHR, bpm	60.92 ± 6.72	62.14 ±7.94	0.501
RMAP, mmHg	81.47 ± 5.04	85.03 ±5.00	0.828
RR, breaths/min	16.6 ± 2.19	15.75 ± 2.12	0.536
RPP, mmHg bpm	6567.3 ± 907.66	6929 ± 856.20	0.628

All values are mean ± SD, * p<0.05 considered significant.. RHR - Resting heart rate, RMAP - Resting mean arterial pressure, RR - Resting respiratiory rate, RPP - Resting rate pressure product

Other cardiac autonomic function test parameters

I-E index of the deep breathing test in Kungfu group was 29.56 ± 7.66 bpm while in controls it was 26.32 ± 6.86 bpm while the E/I ratio of the deep breathing test in Kungfu was 1.62 ± 0.21 and in controls it was 1.53 ± 0.18. The 30:15 ratio obtained by performing orthostatic challenge test in Kungfu group was 1.54 ± 0.26 while in controls it was 1.59 ± 0.27. The Valsalva ratio in Kungfu group was 2 ± 0.4 while in controls it was 1.92 ± 0.32 and the maximal handgrip ratio in Kungfu was 25.5 ± 8.4 bpm while in controls it was 24.6 ± 9.08 bpm. None of the cardiac autonomic function test parameters were significantly different in the two groups.

Table 5 Comparison of cardiac autonomic function test parameters in kungfu (n = 20) and control groups (n = 20)

Parameters	Kungfu	controls	p value
DBT I-E index , bpm	29.56 ± 7.66	26.32 ± 6.86	0.894
DBT E/I ratio	1.62 ± 0.21	1.53 ± 0.18	0.797
OCT 30:15 ratio	1.54 ± 0.26	1.59 ± 0.27	0.659
Valsalva ratio	2 ± 0.4	1.92 ± 0.32	0.097
MHG ratio, bpm	25.5 ± 8.4	24.6 ± 9.08	0.745

All values are mean ± SD. * $p<0.05$ considered significant. DBT - Deep breathing test, OCT - Orthostatic challenge test, MHG - Maximal hand grip test, bpm - beats per minute

Treadmill test Parameters

Maximal heart rate reached with maximal exercise in Kungfu group (182.8 ± 7.80 bpm) was significantly lower ($p<0.05$) than that in controls (185.55 ± 12.37 bpm).

The Ratio of maximal to resting heart rate was 3.04 ± 0.38 in Kungfu and 3.03 ± 0.39 in controls. The total exercise duration was 405.25 ± 86.21 seconds in Kungfu group while it was 388 ± 80.38 seconds in controls. The mean maximal power output in Kungfu group was 119.7 ± 54.5 Kg m/s and in control group it was 111.9 ± 50.2 Kg m/s. These parameters were not statistically different between the groups.

Table 6 Comparison of treadmill test parameters in kungfu (n = 20) and control groups (n = 20)

Parameters	Kungfu	controls	p
HRmax, bpm	182.8 ± 7.80	185.55 ± 12.37	0.038*
HRmax/RHR ratio	3.04 ± 0.38	3.03 ± 0.39	0.682
Exercise Duration, seconds	405.25 ± 86.21	388 ± 80.38	0.685
Power Output , Kg m/s	119.7 ± 54.5	111.9 ± 50.2	0.64

All values are mean ± SD. * p<0.05 considered significant. HRmax - Maximum heart rate reached with maximal exercise, RHR - Resting heart rate

Recovery period parameters

Table 7 Comparison of Absolute and recovery heart rates at different points during recovery in kungfu (n = 20) and control group (n = 20)

	Kung Fu	Control	p			Kung Fu	Control	p
HR15 , bpm	172.55 ± 9.3	174.35 ± 12.6	0.204		HRR15 , bpm	10.25 ± 4.3	11.2 ± 3.7	0.877
HR30 , bpm	153.2 ± 9.9	156.6 ± 13.2	0.198		HRR30 , bpm	29.6± 6.7	28.95 ± 4.9	0.199
HR60 , bpm	132.6 ± 8.8	137.55 ± 12	0.389		HRR60 , bpm	50.2 ± 5.6	48 ± 6.2	0.567
HR120 , bpm	113.05 ± 9.2	115.9 ± 9.4	0.831		HRR120 , bpm	69.75 ± 5.7	69.65 ± 7.2	0.107
HR180 , bpm	103.65 ± 10.1	107.3 ± 10.6	0.658		HRR180 , bpm	79.15 ± 7.8	78.25 ± 7.8	0.955
HR240 , bpm	100.35 ± 8.7	105.95 ± 10.1	0.785		HRR240 , bpm	82.45 ± 7.9	79.6 ± 9.1	0.498
HR300 , bpm	98.85 ± 7.8	102.75 ± 10.2	0.471		HRR300 , bpm	83.95 ± 7.4	82.8 ± 8.4	0.487

All values are mean ± SD. * p<0.05 considered significant. HRn - Absolute heart rate at n instant of recovery , HRRn - Recovery heart rate at n instant of recovery

The absolute heart rates at 15, 30, 60, 120, 180, 240 and 300 seconds were 172.6 ± 9.3 bpm, 153.2 ± 9.9 bpm, 132.6 ± 8.8 bpm, 113 ± 9.2 bpm, 103.7 ± 10.1 bpm, 100.4 ± 8.7 bpm and 98.9 ± 7.8 bpm in Kungfu group while in controls it was 174.4 ± 12.6 bpm, 156.6 ± 13.2 bpm, 137.6 ± 12 bpm, 115.9 ± 9.4 bpm, 107.3 ± 10.6 bpm, 106 ± 10.1 bpm and 102.8 ± 10.2 bpm respectively. While the recovery heart rates at the same intervals were 10.3 ± 4.3 bpm, 29.5 ± 6.7 bpm, 50.2 ± 5.6 bpm, 69.8 ± 5.7 bpm, 79.2 ± 7.8 bpm, 82.5 ± 7.9 bpm and 84 ± 7.4 bpm in the Kungfu group while in the control group it was 11.2 ± 3.7 bpm, 29 ± 4.9 v, 48 ± 6.2 bpm, 69.7 ± 7.2 bpm, 78.3 ± 7.1 bpm, 79.6 ± 9.8 bpm and 82.8 ± 8.4 bpm. All the variables were similar in both groups as there was no statistically significant difference.

Heart rate Recovery Time Constants

Mean **Tau1** for both groups combined was 67.6 ± 33.81 seconds and mean **Tau2** was found to be 123.92 ± 122.82 seconds and these values were significantly different with a p Value of 0.0065. Mean TauP for both groups combined was 62.45 ± 18.55 seconds and mean **TauS** was 129.07 ± 123.43 seconds. Mean **TauP** was significantly different from mean **TauS** with a p value of 0.0012. Mean **Tau1** for the Kungfu group 61.73 ± 21.53 was not significantly different from the mean **Tau1** of the control group value of 73.47 ± 42.54 seconds. Mean **Tau2** for the Kungfu group 160.07 ± 161.53 seconds was not significantly different from the mean **Tau2** of the control group value of 87.77 ± 46.08 seconds with a p value of 0.06. Mean **TauP** for the Kungfu group 60.44 ± 20.72 seconds was not significantly different from the mean **TauP** of the control group value of 64.47 ± 16.4 seconds. Mean **TauS** for the Kungfu group 161.36 ± 160.8 seconds was not significantly different from the mean **TauS** of the control group value of 96.77 ± 56.77 seconds with a p value of 0.1.

Table 8: Comparison of mean Tau values in Kungfu and control group

	Kungfu	Control	p value
Tau1,s	61.73 ± 21.53	73.47 ± 42.54	0.28
Tau2,s	160.07 ± 161.53	87.77 ± 46.08	0.06
TauP,s	60.44 ± 20.72	64.47 ± 16.4	0.5
TauS,s	161.36 ± 160.8	96.77 ± 56.77	0.1

All values in mean± SD. $p<0.05$ considered significant. **Tau1**- First time constant of recovery heart rate decay, **Tau2** – Second time constant of recovery heart rate decay, **TauP** - Time constant of recovery heart rate decay for parasympathetic reactivation, **TauS** - Time constant of recovery heart rate decay for sympathetic withdrawal

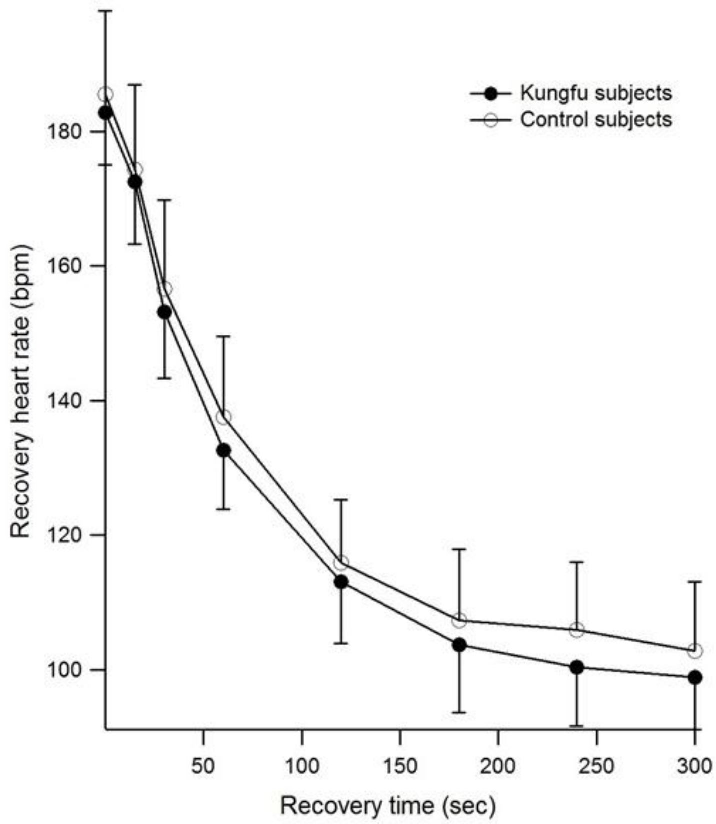


Figure 16 Recovery Heart rate plots of kungfu and control subjects represented as mean and SD

Breath Out Maneuver

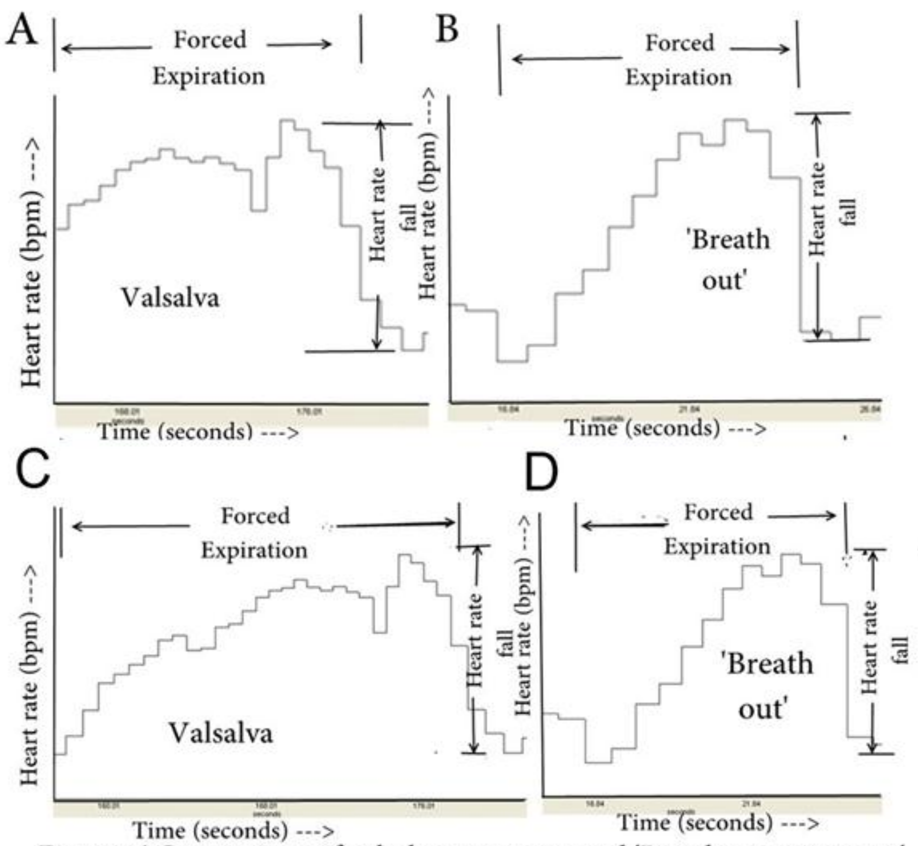


Figure 17 Comparison of valsalva maneuver and 'Breath out maneuver' of two subjects. A & C are heart rate responses to Valsalva maneuver B & D are Heart rate responses to “Breath out' maneuver X axis - time (seconds) Y axis Heart rate (bpm)

Figure 17 shows the heart rate change with breath out maneuver and valsalva maneuver in two Kungfu subjects.

Linear Regression Analysis

Table 9 Linear regression analysis with Kungfu training duration (n=20)				
Parameter	pValue		Parameter	pValue
Resting heart rate, bpm	0.978		HRmax, bpm	0.033*
Resting MAP, mmHg	0.344		HRmax/RHR ratio	0.504
Rate Pressure Product mmHg bpm	0.859		HR15 , bpm	0.062
Respiratory rate breaths/min	0.191		HR30 , bpm	0.19*
DBT I-E, bpm	0.06		HR60 , bpm	0.444
DBT E/I ratio	0.028*		HR120 , bpm	0.597
OCT 30:15 ratio	0.239		HR180 , bpm	0.667
MHG ratio, bpm	0.251		HR300 , bpm	0.851
Valsalva ratio	0.852		HR300	0.823
SDNN , ms	0.124		HRR15 , bpm	0.847
RMSSD, ms	0.158		HRR30 , bpm	0.657
pNN50, %	0.512		HRR60 , bpm	0.102
LF Power, ms²	0.309		HRR120 , bpm	0.048*
HF Power, ms²	0.491		HRR180 , bpm	0.135
LF/HF Ratio	0.692		HRR240 , bpm	0.064
LFnu, nu	0.776		HRR300 , bpm	0.049*
HFnu, nu	0.776		**Tau1,** s	0.816
Total Power, ms²	0.382		**Tau2**, s	0.578
Exercise Duration, s	0.649		**TauP**, s	0.837
Power Output, Kg m/s	0.509		**TauS**, s	0.573
*p<0.05 considered significant. MAP – Mean arterial pressre, DBT – dep breathing test, MHG – Maximal hand grip, SDNN – Standard deviation of normal - to - normal RR intervals, RMSSD – Root mean square of successive differences between adjacent RR intervals, pNN50 – percentage of RR intervals with difference > 50 milliseconds, LF – Low frequency, HF – High frequency, nu – normalized units, HRmax – maximal heart rate achieved with maximal exercise, HRn – Absolute heart rate at nth second of recovery, HRRn – heart rate recovery at nth second of recovery, **Tau1-** First time constant of recovery heart rate decay, **Tau2** – Second time constant of recovery heart rate decay, **TauP -** Time constant of recovery heart rate decay for parasympathetic reactivation, **TauS -** Time constant of recovery heart rate decay for sympathetic withdrawal				

With dependent variable as duration of Kungfu training the various parameters were analyzed using linear regression. The Deep breathing test E/I ratio was significantly affected by Kungfu training ($p<0.05$) while the I – E was not significant with a p Value of 0.06. The Deep breathing test E/I ratio significantly decreased with progressively increasing training duration.

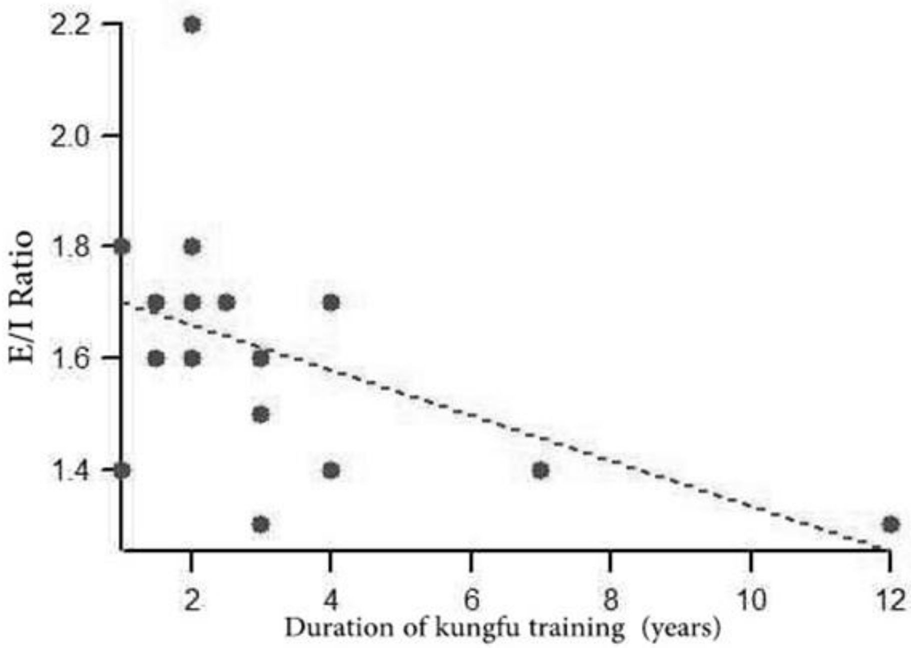


Figure 18 . E/I from deep breathing test in kungfu subjects is plotted against duration of kungfu training. Dots show individual values. dotted line shows a fitted line

The maximal heart rate achieved (HRmax) was significantly related to duration of Kungfu training ($p<0.05$) and decreased with progressive Kungfu training.

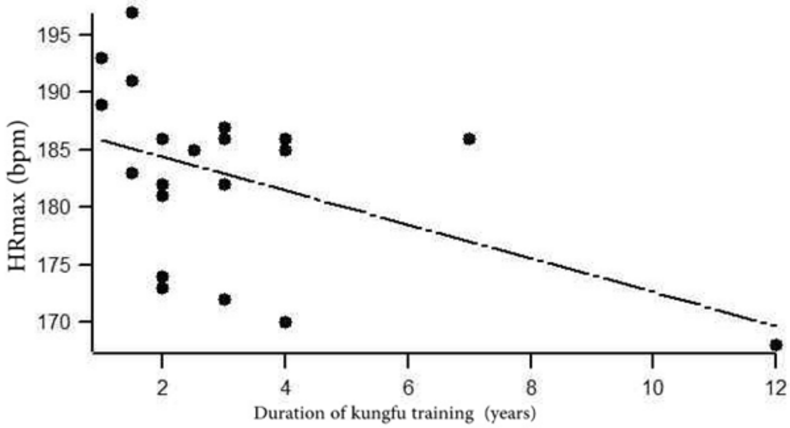


Figure 19 . Maximal heart rate achieved with maximal exercise in kungfu subjects plotted against duration of kungfu training. Dots show individual values. Broken line is a linear equation fit

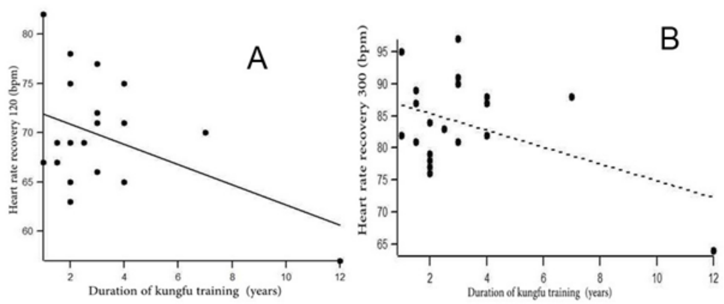
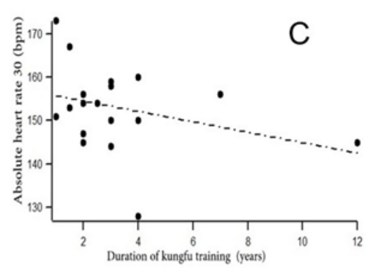


Figure 20 . Relation of heart rate and heart rate recovery with duration of kungfu training with lines fitted.
A -HRR at 120 seconds
B- HRR at 300 seconds
C- HR at 30th sec



The absolute heart rate at the 15th second in the recovery period was not significantly related to duration of Kungfu training p = 0.062.

The absolute heart rate at the 30^{th} second in the recovery period was significantly decreased by longer duration of Kungfu training while other values were not significant. Recovery Heart rate by the 120^{th} and 300^{th} second were significantly ($p<0.05$) decreased by duration of Kungfu training. Recovery heart rate by the 240^{th} second was not significant with a p value of 0.064. Other recovery heart rates were not significantly affected by duration of Kungfu training.

DISCUSSION

DISCUSSION

Exercise is a specific type of planned structure physical activity done to improve or maintain physical fitness.(2) Physical fitness is comprised of multiple attributes related to the ability to perform physical activity. Some of the attributes include as varied parameters as cardiorespiratory fitness, regional body fat distribution, body mass index, muscular strength, muscular endurance, flexibility, power, reaction time, speed, blood sugar levels and blood lipid levels.(2) Various exercise training regimens have been studied to see their effect on the various components of fitness. $\dot{V}O_{2\ max}$ is the best indicator of cardiorespiratory fitness.(62) Aerobic training has been shown to improve cardiorespiratory fitness. Rather than have multiple exercise regimens targeted at improving each attribute of physical fitness, a better strategy would be to do a combination exercise that will improve as many attributes of fitness as possible. Also the types of training that have been studied extensively, often requires specialized equipment that may not be available to the general population. Martial arts are a unique exercise regimen that is generally available and does not require any specialized equipment.

Many studies have been conducted that look at the effect of Kungfu training on different components of physical fitness. This is the first study comparing cardiac autonomic parameters and physical fitness measures in Kungfu practitioners and controls of similar physical activity level that do not practice any other form of martial art. Previous studies that specifically looked at cardiorespiratory fitness have compared Kungfu subjects with controls who practiced an alternate martial art. (12,48)

Both Tsang et al and Schneider et al have compared Kungfu training with tai chi training. Tai chi is a soft martial art which incorporates breathing exercises and meditation with less emphasis on power. (44) This may act as a confounder. The intensity of Kungfu sessions are higher with an oxygen consumption of 52.4% of $\dot{V}O_{2\ max}$ and achieving a heart rate of 70.5 – 89 % of HRmax, while tai chi practice reaches 36.4% of $\dot{V}O_{2\ max}$ and 59.8% of HRmax.(13,48). Elderly subjects who have been trained in tai chi for a year have been found to have significantly better aerobic capacity than sedentary controls while having similar aerobic capacity as brisk walking controls.

In the current study, all alternate martial artists, those performing other types of breathing exercise and meditation were excluded.

Tsang et al compared the effect of six months training in Kungfu in obese adolescents in a randomized control setting comparing with tai chi training assuming it to be a sham exercise.(12)

Both Kungfu and tai chi groups showed significant improvement in absolute upper and lower body strength, and upper body muscle endurance, without any difference between groups. Because of the low baseline levels in obese sedentary subjects any form of exercise may show a significant improvement. Selection of sedentary controls can be a selection bias as sedentary obese subjects will have a low baseline fitness level. To avoid this selection bias the current study compared subjects of similar physical activity levels.

Tsang et al showed significant improvement in submaximal fitness in Kungfu group while the peak aerobic fitness was same in Kungfu and tai chi group which is consistent with the results of the current study which shows no significant difference in physical fitness parameters between Kungfu group and controls of similar physical activity level. The peak fitness did not alter with six months martial arts training in both groups.

Tsang et al showed that the Kungfu group had significantly greater lower body muscle endurance and upper body muscle velocity than tai chi group. Also the upper body peak velocity significantly declined over six months in the tai chi group. This may be due to the focus of Kungfu on power and speed while tai chi focuses on slow meditative movements.

Schneider and Leung also studied the effect of Kungfu training on cardiorespiratory fitness by using a tai chi group as a control. There was no significant difference in $\dot{V}O_{2\ max}$ and HRmax between the groups. The current study has shown that HRmax is lower in Kungfu subjects (K = 182.8) when compared to control subjects (C = 185.6). The lack of difference in HRmax between Kungfu and tai chi subjects in study by Schneider and Leung suggest the possibility that the decrease in HRmax may be due to the components of martial arts training which will be present in both the Kungfu trained and the tai chi trained martial artist who are being compared.

Various studies have shown that both anaerobic and aerobic exercise training can decrease maximal heart rate achieved in maximal exercise testing. (88–90) Zavorsky has shown that aerobic training and detraining can vary the HRmax by 3 – 7%.(90) The reason for this decreased HRmax is not clear but some of the proposed mechanisms are plasma volume expansion, enhanced baroreflex function, alteration of SA nodal activity and change in sympathetic receptor profile produced by regular exercise. (90)

Was the significant decrease of HRmax in Kungfu due to any underperformance by Kungfu subjects? The question is answered by the fact that the work intensity at maximal level was the same in both groups ($p>0.05$). The Kungfu group has reached the same work intensity with a lower HRmax, showing better work capacity for the same level of workload. This lower heart rate for a work load may have been the reason for significantly higher submaximal fitness shown by Tsang et al in Kungfu group.

Effect of Kungfu training on the other parameters of fitness has been studied by other groups. Six month Kungfu training when compared to tai chi training in obese adolescents was found to have no significant difference in body composition parameters, bone mineral density, blood lipids, blood glucose and HbA1c between the martial arts groups. (42,43) Kungfu trained subjects had significantly better total auditory reaction times, movement time, hand speed, effective mass, leg muscle strength than sedentary controls while there was no significant difference in trunk muscle strength.(44,91) Jones and Unnithan compared experts in Kungfu to novices and found that while doing forms and punching experts, worked at a significantly lower percentage of $\dot{V}O_{2\ max}$ showing a better aerobic economy. The exercise intensity elicited by Kungfu protocols were found to be in the cardiovascular training zone.

No other group has studied the effect of Kungfu training on cardiac autonomic control. The significant increase in SDNN in Kungfu subjects (K = 106.7) over controls (C = 83.4) reflects an increase in total Heart rate variability in Kungfu trained subjects when compared to subjects with same physical activity level.

RMSSD which is an index of vagal activity was significantly higher in Kungfu subjects (K = 105.5) than in controls (C = 77.2). This indicates higher parasympathetic modulations in Kungfu trained subjects. While pNN50 and HFnu both are alternate indices of parasympathetic activity, they were not significantly different between the groups. This seems contradictory but RMSSD is reported to be a better parameter than pNN50 as it is not influenced by heart rate trends and is independent of mean heart rate and has overall better statistical properties.(57,92) so the significant RMSSD change should be considered to be more valid.

Which component of Kungfu training is responsible for this significant increase in cardiac autonomic modulations?

Kungfu is a combination of aerobic and anaerobic exercise interspersed with frequent breathing exercises with a short period of meditation at the beginning and end. Meditation and breathing maneuvers have been shown to improve cardiac autonomic modulations. (22) But there is only a short period of meditation. Breathing exercise called ‘breath out maneuver’ is done multiple times during a Kungfu class, whenever the subjects are out of breath. During the latter half of class as students are more tired, ‘breath out’ maneuver is done once every couple of minutes.

To understand the physiological effect of ‘breath out’ maneuver two subjects were asked to do the breath out maneuver and the heart rate and respiration changes were examined and analyzed. ‘Breath out’ maneuver consists of a slow forced expiration in the standing position with abdominal muscles contracted. The arms move forward while air is slowly blown out forcibly against a partially closed glottis. During the expiration phase of the maneuver the heart rate was found to rise slowly. After cessation of maneuver there was a sudden bradycardia. Valsalva maneuver is forced expiration against resistance. In Valsalva maneuver also a similar reflex bradycardia is observed. The heart rate responses to ‘breath out’ and valsalva maneuvers are compared in figure 17.

The breath out maneuver may be a modified form of Valsalva maneuver. Does this use of modified Valsalva maneuver have any positive or detrimental effect on cardiac autonomic status? This question is answered by our study. Let us look at the Valsalva maneuver.

Valsalva maneuver was originally described by Antonio Valsalva in 1704 in his Latin treatise ‘De aure humana tractatus’.(93) Valsalva maneuver is defined as forceful expiration against a closed glottis or with an open glottis against an expiratory pressure.(94–96) Valsalva maneuver may lead to medical complications like Valsalva retinopathy and surgical emphysema.(93) Valsalva maneuvers are performed often, both voluntarily and involuntarily during daily life when coughing, straining and lifting weights. So it is essential to understand the underlying physiology.

Valsalva maneuver has four physiological phases:

Phase I - Onset of blowing. In this phase forced expiration raises intrathoracic pressure pressing on aorta leading to raised MAP. (94–96)

Phase II - Continued expiration. Due to continually raised intrathoracic pressure there is a fall in venous return and consecutively there is decreased atrial filling leading to decreased cardiac output and BP falls. Fall in BP causes unloading of the baroreceptors located in the carotid sinus and aortic arch caused decreased impulses in glossopharyngeal and vagal afferents to the nucleus of the tractus solitarius. Sympathetic outflow is stimulated via centers in the medulla leading to peripheral vasoconstriction and increase in cardiac output and hence BP. Vagal neurons of the nucleus ambiguus are inhibited leading to a rise in heart rate. (94–96)

Phase III - Release of strain. After release of expiratory pressure Intrathoracic pressure becomes negative leading to release of pressure on the arterial tree causing drop in BP and entry of blood into the pulmonary vasculature. (94–96)

Phase IV - Recovery. As cardiac output becomes normal, the persistently increased sympathetic tone and systemic vascular resistance leads to overshoot of BP. A reflex bradycardia results due to stimulation of arterial baroreceptors, and later both BP and heart rate return to baseline values. (94–96)

The tachycardia in phase II and the bradycardia in phase IV are used as indexes of cardiovagal integrity. The hypertensive response in phase IV and BP recovery in phase II and are used as indexes of baroreceptor mediated sympathetic integrity .Valsalva maneuver can be used to noninvasively assess baroreceptor sensitivity. (94–96)

What is the consequence of this repeated stimulation of baroreflex in Kungfu subjects? The breath out maneuver is done in the standing position. In standing position there is increased total peripheral resistance, heart rate and while doing valsalva there is an increased fall of BP in phase II and overshoot in phase IV.(96) Baroreflex gain is found to be reduced in standing valsalva when compared to supine position but even with lower gain the repeated 'breath out' maneuvers may increase the baroreceptor sensitivity by repeated stimulation of the baroreflex. Tai Chi training has been shown to significantly improve baroreflex sensitivity. (97) Aerobic training also increases baroreflex sensitivity.(98)

This improvement in cardiac autonomic modulations and specifically vagal modulations and the lowering of HRmax caused by Kungfu training may be due to this increased baroreceptor sensitivity.

Tai chi training, similarly, has been shown to significantly increase overall cardiac autonomic modulations and specifically increase vagal tone and modulations by decreasing heart rate, increasing total variability, increasing SDNN and increasing HFnu. (99–101)

Whether modified Valsalva maneuver should be included in other fitness regimens needs more research.

Heart rate recovery after exercise occurs through the synergistic action of both wings of the autonomic nervous and also through other intrinsic processes in the circulatory system. As both wings of the autonomic nervous system act through receptors and hence acts through first order kinetics, various scientists have attempted to explain the heart rate decay after exercise through first order kinetics.(79,83) But these attempts have not borne fruit as first order exponential function is not a good model to explain recovery after a maximal exercise.(83) Pierpont et al has shown that in spite of this inability to fully model maximal exercise recovery satisfactorily, first order kinetics can provide a reasonable model for submaximal exercise recovery(83) and Wang et al has shown that the first order time constant is a useful measure of fitness.(84)

In the present study it is proposed that since two exponential functions namely parasympathetic reactivation and sympathetic withdrawal are involved in the heart rate recovery from maximal exercise a double exponential function will explain the heart rate decay better. And such a double exponential function will provide two time constants, each showing the speed of action of the underlying processes, namely parasympathetic reactivation and sympathetic withdrawal. Since action of parasympathetic nervous system is faster, the lower time constant could be the time constant that describes the activity of the parasympathetic system. Fitting of the recovery heart rate curves resulted in two time constants which were significantly different from each other ($p < 0.05$), showing the existence of two systems at work that cause the decay of heart rate post exercise. Mean **Tau1** for both groups combined was 67.6 ± 33.81 seconds and mean **Tau2** was found to be 123.92 ± 122.82 seconds showing the existence of two systems with different speed of actions. The lower Time constant was assumed to be due to the parasympathetic nervous system and the time constants named as **TauP**, with a mean value of 62.45 ± 18.55 seconds and the larger Time constant was assumed to be due to activity of sympathetic nervous system and named as **TauS**, with a mean value of 129.07 ± 123.43 seconds. **TauP** and **TauS** was also found to be significantly different from each other. ($p < 0.05$). There was no significant difference between the time constants of Kungfu and control groups. Mean value of **Tau2** was 160.07 ± 161.53 seconds in Kungfu subjects and 87.77 ± 46.08 seconds in control subjects and mean **TauS** value was 161.36 ± 160.8 seconds in Kungfu subjects and 96.77 ± 56.77 seconds in control subjects.

Double exponential modeling of heart rate recovery is a useful tool, which can help us study the underlying physiological processes that occur during recovery, and **TauP** and **TauS** can be important indices of health of the parasympathetic and sympathetic nervous systems and should be further studied.

The duration of Kungfu training affected the various autonomic and fitness parameters in different ways. The resting parameters, heart rate variability parameters, recovery time constants, exercise duration and intensity were not affected by duration of Kungfu training. Autonomic function tests other than deep breathing indices were not influenced by training duration.

E/I ratio was negatively influenced by Kungfu training ($p < 0.05$) as shown in figure 18. However the I – E index did not show a significant correlation with duration of Kungfu training. The E/I ratio and the I-E index are indices reflecting the same branch of autonomic nervous system, namely cardiac parasympathetic activity. Hence the finding of a significant correlation between only E/I ratio and duration of Kungfu training may be a trivial finding without any implication. Breath out maneuver and other breathing exercises may modify the effect of breathing on the autonomic control of heart rate. There may not be a significant effect on the parasympathetic tone itself as the resting heart rate is comparable between the Kungfu and the control group pointing to similar parasympathetic tone.

The maximal heart rate achieved with maximal exercise showed significant linear decrease with duration of Kungfu training as shown in figure 19. This decrease of HRmax with progressive Kungfu training may show the training effect of significantly lower HRmax seen.

During recovery period the absolute heart rate decrease with Kungfu training was significant in the 30th second ($p < 0.05$) as shown in figure 24. As absolute heart rate values in recovery period is directly related to $\dot{V}O_{2\ max}$, this indirectly shows increased $\dot{V}O_{2\ max}$ associated with Kungfu training.(24)

But the Recovery Heart rate by the 120th and 300th second were significantly lowered ($p<0.05$) by duration of Kungfu training (figure 20). But absolute heart rate is a better parameter as it is more reliable than recovery heart rate as HRR is more heterogenous and correlation between recovery heart rate and $\dot{V}O_{2\ max}$ is highest in the initial 15-30 seconds of recovery as shown by Verma et al. (24,75) Therefore the correlation between HRR at 120th and 300th sec and Kungfu training duration may not be of much importance, while the correlation between absolute heart rate 30 sec after stopping exercise and the duration of training may be noteworthy reflecting greater $\dot{V}O2$ max in longer trained martial artists.

In conclusion, subjects with Kungfu training had greater total heart rate variability as denoted by greater SDNN and greater cardiac vagal modulations as denoted by greater RMSSD than control subjects with similar physical activity levels. This augmented cardiac autonomic control observed in Kungfu subjects may be attributable to the regular practice of ‘breath out maneuvers’, which form an intrinsic part of the exercise protocol of Kungfu training. With increased duration of Kungfu training there was significant decrease in the maximal heart rate achieved with maximal exercise and the absolute heart rate thirty seconds after stopping maximal exercise, in the martial artists. This finding may simply be a reflection of the positive effect of longer duration of training on the work capacity and $\dot{V}O2$ max of martial artists.

LIMITATIONS

LIMITATIONS

Direct Assessment of $\dot{V}O_{2\ max}$ was not possible due to unavailability of breath analyzing equipment. Suitable indirect methods were used to assess it. If such equipment is available, an individualized ramp protocol targeted at 9 minutes to reach exercise time could have been used. A fixed ramp protocol was used as the treadmill time duration itself was a parameter for indirectly assessing $\dot{V}O_{2\ max}$.

SUMMARY AND CONCLUSIONS

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Higher physical fitness appears to prolong life. (4–6) To attain, maintain and improve fitness, one mode of physical activity used is exercise. Exercise consists of planned, structured, and repetitive bodily movement. (2) Martial arts are methods of combat that have been altered into exercises. (7) Kung Fu is a generic term used for Chinese martial arts. (8) Kungfu is a unique which incorporates a mixed anaerobic and aerobic exercise regimen which is combined with breathing exercises and meditation. (8–11) No studies have been done on the effect of Kung Fu training on cardiac autonomic function. This study looked at the effect of Kungfu training on cardiac autonomic status and physical fitness.

The cardiac autonomic effects of endurance and strength training have been studied separately and documented. (15) But there are no studies on combined aerobic and anaerobic training programs on cardiac autonomic status. Further, breathing exercises and meditation have been shown to affect cardiac autonomic status by lowering heart rate, modifying heart rate variability and decreasing blood pressure. (21,22) Kung Fu involves aerobic and anaerobic training, along with meditation and breathing exercises. There are no studies reporting the combined effects of all these maneuvers on physical fitness and cardiac autonomic control.

Twenty Martial artists who have practiced Kungfu for over a year were recruited and compared with twenty normal subjects of similar age, BMI and physical activity. Cardiac autonomic status and fitness level was compared between these groups.

The cardiac autonomic function tests administered were heart rate variability analysis, deep breathing test, orthostatic challenge test, Valsalva maneuver and maximal hand grip test. The tests were conducted as per standardized published protocols. Standard indices were calculated from these tests and compared. The resting heart rate, resting blood pressure and rate pressure product were also obtained. This was followed by a maximal treadmill test.

A maximal exercise test was used to estimate $\dot{V}O_{2\ max}$ indirectly. A fixed ramp protocol was used in a motor driven treadmill to administer a maximal test. Immediately after exercise, the subject rested in the supine position, during the period of recovery. The maximal heart rate achieved with maximal exercise (HRmax) and absolute heart rates at different points of recovery was obtained. The heart rate recovery (HRR) at a given point of time was computed by subtracting the absolute heart rate at that point of time from the HRmax. HRR is an index of physical fitness and a predictor of $\dot{V}O_{2\ max}$. (24) The ratio of HRmax to resting heart rate and total exercise duration was also used as predictors of $\dot{V}O_{2\ max}$. (25) The work intensity at maximal exercise was also calculated and compared. (26)

The recovery heart rate decay was analyzed and it fitted well with double exponential functions. Two time constants were derived. The lower time constant was arbitrarily selected to be the parasympathetic reactivation time constant and the higher one was selected to be the sympathetic withdrawal time constant. These time constants were compared between the two groups. The effect of duration of Kungfu training on the various autonomic parameters was analyzed.

Tests revealed significantly increased SDNN and RMSSD parameters of short-term heart rate variability in Kungfu trained subjects showing improved overall autonomic modulations and vagal modulations when compared to controls,. The maximal heart rate reached with maximal exercise was significantly less in Kungfu group. With increased duration of Kungfu training there was significant decrease in the maximal heart rate achieved with maximal exercise and the absolute heart rate thirty seconds after stopping maximal exercise, in the martial artists. This finding may simply be a reflection of the positive effect of longer duration of training on the work capacity and $\dot{V}O_2$ max of martial artists.

Kungfu is a unique form of exercise training which incorporates aerobic exercises, anaerobic exercises, breathing exercises and meditation. Kungfu training improved overall heart rate variability and vagal modulations and allowed the subject to do similar quantum of work at a lower heart rate than controls, as evidenced by the lower heart rate in the Kungfu group at similar maximal work intensities reached by both groups.

FUTURE COURSE

FUTURE COURSE

The breath out maneuver needs to be studied more to understand its physiological effects.

And to determine whether it needs to be added to existing sports and fitness regimens.

Effect of breathing exercise and meditation can be studied separately in a RCT setting to quantify the benefits when isolated from other forms of exercise.

The effect of combined aerobic and anaerobic exercise training on cardiac autonomic control can be studied in a randomized crossover trial setting.

REFERENCES

REFERENCES

1. Paul DB. The selection of the “Survival of the Fittest.”Journal of the History of Biology. 1988;21(3):411–24.

2. Thompson WR, Gordon NF. ACSM’s Guidelines for Exercise Testing and Prescription. Lippincott Williams & Wilkins; 2009.

3. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. 1985;100(2):126–31.

4. Blair SN, Kohl HW, Paffenbarger RS, Clark DG, Cooper KH, Gibbons LW. Physical Fitness and All-Cause Mortality: A Prospective Study of Healthy Men and Women. JAMA: The Journal of the American Medical Association. 1989 Nov 3;262(17):2395–401.

5. Blair SN, Kohl HW, Barlow CE, Paffenbarger RS, Gibbons LW, Macera CA. Changes in Physical Fitness and All-Cause Mortality: A Prospective Study of Healthy and Unhealthy Men. JAMA: The Journal of the American Medical Association. 1995 Apr 12;273(14):1093–8.

6. Erikssen G, Liestøl K, Bjørnholt J, Thaulow E, Sandvik L, Erikssen J. Changes in physical fitness and changes in mortality. The Lancet. 1998 Sep 5;352(9130):759–62.

7. Bu B, Haijun H, Yong L, Chaohui Z, Xiaoyuan Y, Singh MF. Effects of martial arts on health status: a systematic review. J Evid Based Med. 2010 Nov;3(4):205–19.

8. Green TA, editor. Martial Arts of the World: An Encyclopedia. 2 Vol. Set. ABC-CLIO; 2001.

9. Neto OP, Magini M, Pacheco MTT. Electromyographic study of a sequence ofYau-Man Kung Fu palm strikes with and without impact. JSSM. 2007 Oct 1;6(CSSI-2):23–7.

10. Bolander RP, Neto OP, Bir CA. The effects of height and distance on theforce production and acceleration in martial arts strikes. JSSM. 2009 Jan 1;8(CSSI 3):47–52.

11. Artioli GG, Gualano B, Franchini E, Batista RN, Polacow VO, Lancha AH Jr. Physiological, performance, and nutritional profile of the Brazilian Olympic Wushu (kung-fu) team. J Strength Cond Res. 2009 Jan;23(1):20–5.

12. Tsang TW, Kohn MR, Chow CM, Fiatarone Singh MA. Kung Fu Training Improves Physical Fitness Measures in Overweight/Obese Adolescents: The “Martial Fitness” Study. Journal of Obesity. 2010;2010:1–10.

13. Ribeiro JL, Castro BOSD de, Rosa CS, Baptista RR, Oliveira AR. Heart rate and blood lactate responses to Changquan and daoshu forms of modern Wushu. Journal of Sports Science and Medicine. 2006 Jul 1;2006(CSSI 1):1–4.

14. Chtara M, Chamari K, Chaouachi M, Chaouachi A, Koubaa D, Feki Y, et al. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. Br J Sports Med. 2005 Aug;39(8):555–60.

15. Sloan RP, Shapiro PA, DeMeersman RE, Bagiella E, Brondolo EN, McKinley PS, et al. The Effect of Aerobic Training and Cardiac Autonomic Regulation in Young Adults. Am J Public Health. 2009 May;99(5):921–8.

16. Loimaala A, Huikuri H, Oja P, Pasanen M, Vuori I. Controlled 5-mo aerobic training improves heart rate but not heart rate variability or baroreflex sensitivity. J. Appl. Physiol. 2000 Nov;89(5):1825–9.

17. Hautala AJ, Mäkikallio TH, Kiviniemi A, Laukkanen RT, Nissilä S, Huikuri HV, et al. Cardiovascular autonomic function correlates with the response to aerobic training in healthy sedentary subjects. Am. J. Physiol. Heart Circ. Physiol. 2003 Oct;285(4):H1747–1752.

18. Shin K, Minamitani H, Onishi S, Yamazaki H, Lee M. Assessment of training-induced autonomic adaptations in athletes with spectral analysis of cardiovascular variability signals. Jpn. J. Physiol. 1995;45(6):1053–69.

19. Tulppo MP, Hautala AJ, Mäkikallio TH, Laukkanen RT, Nissilä S, Hughson RL, et al. Effects of aerobic training on heart rate dynamics in sedentary subjects. J Appl Physiol. 2003 Jul 1;95(1):364–72.

20. Chaudhary S, Kang MK, Sandhu JS. The effects of aerobic versus resistance training on cardiovascular fitness in obese sedentary females. Asian J Sports Med. 2010 Dec;1(4):177–84.

21. Manikonda JP, Störk S, Tögel S, Lobmüller A, Grünberg I, Bedel S, et al. Contemplative meditation reduces ambulatory blood pressure and stress-induced hypertension: a randomized pilot trial. J Hum Hypertens. 2008 Feb;22(2):138–40.

22. Lehrer P, Sasaki Y, Saito Y. Zazen and cardiac variability. Psychosom Med. 1999 Dec;61(6):812–21.

23. Goldberger JJ. Sympathovagal balance: how should we measure it? Am J Physiol Heart Circ Physiol. 1999 Apr 1;276(4):H1273–H1280.

24. Verma SK, Sidhu LS, Kansal DK. A study of maximum oxygen uptake and heart rate during work and recovery as measured on cycle ergometer on national Indian sportsmen. Br J Sports Med. 1979 Apr;13(1):24–8.

25. Uth N. Gender difference in the proportionality factor between the mass specific VO2max and the ratio between HR(max) and HR(rest). Int J Sports Med. 2005 Nov;26(9):763–7.

26. McArdle WD, Katch FI, Katch VL. Exercise Physiology: Nutrition, Energy, and Human Performance. Lippincott Williams & Wilkins; 2009.

27. Rastogi T, Vaz M, Spiegelman D, Reddy KS, Bharathi AV, Stampfer MJ, et al. Physical activity and risk of coronary heart disease in India. Int J Epidemiol. 2004 Aug;33(4):759–67.

28. Reimers CD, Knapp G, Reimers AK. Exercise as stroke prophylaxis. Dtsch Arztebl Int. 2009 Oct;106(44):715–21.

29. Ramachandran A, Snehalatha C, Kapur A, Vijay V, Mohan V, Das AK, et al. High prevalence of diabetes and impaired glucose tolerance in India: National Urban Diabetes Survey. Diabetologia. 2001;44(9):1094–101.

30. Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA. 1995 Feb 1;273(5):402–7.

31. Strong WB, Malina RM, Blimkie CJR, Daniels SR, Dishman RK, Gutin B, et al. Evidence based physical activity for school-age youth. J. Pediatr. 2005 Jun;146(6):732–7.

32. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010;7:40.

33. Jeemon P, Prabhakaran D, Mohan V, Thankappan KR, Joshi PP, Ahmed F, et al. Double burden of underweight and overweight among children (10-19 years of age) of employees working in Indian industrial units. Natl Med J India. 2009 Aug;22(4):172–6.

34. Barbeau P, Johnson MH, Howe CA, Allison J, Davis CL, Gutin B, et al. Ten Months of Exercise Improves General and Visceral Adiposity, Bone, and Fitness in Black Girls*. Obesity. 2007;15(8):2077–85.

35. Hagberg JM, Ferrell RE, Dengel DR, Wilund KR. Exercise Training-Induced Blood Pressure and Plasma Lipid Improvements in Hypertensives May Be Genotype Dependent. Hypertension. 1999 Jul 1;34(1):18–23.

36. Ernst E. Regular exercise reduces fibrinogen levels: a review of longitudinal studies. Br J Sports Med. 1993 Sep;27(3):175–6.

37. Giovannucci E, Ascherio A, Rimm EB, Colditz GA, Stampfer MJ, Willett WC. Physical activity, obesity, and risk for colon cancer and adenoma in men. Ann. Intern. Med. 1995 Mar 1;122(5):327–34.

38. Georgiades A, Sherwood A, Gullette ECD, Babyak MA, Hinderliter A, Waugh R, et al. Effects of Exercise and Weight Loss on Mental Stress–Induced Cardiovascular Responses in Individuals With High Blood Pressure. Hypertension. 2000 Aug 1;36(2):171–6.

39. Woodward TW. A review of the effects of martial arts practice on health. WMJ. 2009 Feb;108(1):40–3.

40. Terry CM. The Martial Arts. Physical Medicine and Rehabilitation Clinics of North America. 2006 Aug;17(3):645–76.

41. Sekida K. Zen Training: Methods and Philosophy. Shambhala Publications; 2005.

42. Tsang TW, Kohn M, Chow CM, Singh M F. A Randomised Placebo-Exercise Controlled trial of Kung Fu training for improvements in Body composition in overweight/Obese adolescents: The “Martial Fitness” Study. JSSM. 2009 Mar 1;2009(8):97–106.

43. Tsang TW, Kohn M, Chow CM, Singh MF. A randomized controlled trial of Kung Fu training for metabolic health in overweight/obese adolescents: the “martial fitness” study. J. Pediatr. Endocrinol. Metab. 2009 Jul;22(7):595–607.

44. O’Donovan O, Cheung J, Catley M, McGregor AH, Strutton PH. An investigation of leg and trunk strength and reaction times of hard- style martial arts. JSSM. 2006 Jul 1;2006(CSSI):5–12.

45. Neto OP, Magini M, Saba MMF, Pacheco MTT. Comparison of force, power, and striking efficiency for a Kung Fu strike performed by novice and experienced practitioners: preliminary analysis. Percept Mot Skills. 2008 Feb;106(1):188–96.

46. Bu B, Haijun H, Yong L, Chaohui Z, Xiaoyuan Y, Singh MF. Effects of martial arts on health status: a systematic review. J Evid Based Med. 2010 Nov;3(4):205–19.

47. Tsang TWM, Kohn M, Chow CM, Singh MF. Health benefits of Kung Fu: A systematic review. Journal of Sports Sciences. 2008;26(12):1249–67.

48. Schneider D, Leung R. Metabolic and cardiorespiratory responses to the performance of Wing Chun and T’ai Chi Chuan exercise. Int J Sports Med. 1991 Jun;12(3):319–23.

49. Pollock ML, Franklin BA, Balady GJ, Chaitman BL, Fleg JL, Fletcher B, et al. Resistance Exercise in Individuals With and Without Cardiovascular Disease Benefits, Rationale, Safety, and Prescription An Advisory From the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association. Circulation. 2000 Feb 22;101(7):828–33.

50. Figueroa A, Kingsley JD, McMillan V, Panton LB. Resistance exercise training improves heart rate variability in women with fibromyalgia. Clinical Physiology and Functional Imaging. 2008;28(1):49–54.

51. Boron W, Boulpaep EL. Textbook of Medical Physiology. 1st ed. Saunders; 2002.

52. Zygmunt A, Stanczyk J. Methods of evaluation of autonomic nervous system function. Archives of Medical Science. 2010;1:11–8.

53. Thiyagarajan R, Subramanian SK, Sampath N, Madanmohan Trakroo, Pal P, Bobby Z, et al. Association between Cardiac Autonomic Function, Oxidative Stress and Inflammatory Response in Impaired Fasting Glucose Subjects: Cross-Sectional Study. PLoS ONE. 2012 Jul 31;7(7):e41889.

54. O'Brien IA, O'Hare P, Corrall RJ. Heart rate variability in healthy subjects: effect of age and the derivation of normal ranges for tests of autonomic function. Br Heart J. 1986 Apr;55(4):348–54.

55. Tharion E, Parthasarathy S, Neelakantan N. Short-term heart rate variability measures in students during examinations. Natl Med J India. 2009 Apr;22(2):63–6.

56. Stein PK, Kleiger RE. Insights from the study of heart rate variability. Annu. Rev. Med. 1999;50:249–61.

57. Electrophysiology TF of the ES of C the NAS of P. Heart Rate Variability Standards of Measurement, Physiological Interpretation, and Clinical Use. Circulation. 1996 Mar 1;93(5):1043–65.

58. Malliani A, Lombardi F, Pagani M. Power spectrum analysis of heart rate variability: a tool to explore neural regulatory mechanisms. Br Heart J. 1994 Jan;71(1):1–2.

59. Heffernan KS, Fahs CA, Shinsako KK, Jae SY, Fernhall B. Heart rate recovery and heart rate complexity following resistance exercise training and detraining in young men. Am. J. Physiol. Heart Circ. Physiol. 2007 Nov;293(5):H3180–3186.

60. Sandercock GRH, Bromley PD, Brodie DA. Effects of exercise on heart rate variability: inferences from meta-analysis. Med Sci Sports Exerc. 2005 Mar;37(3):433–9.

61. Figueroa MA, DeMeersman RE, Manning J. The Autonomic and Rate Pressure Product Responses of Tai Chi Practitioners. N Am J Med Sci. 2012 Jun;4(6):270–5.

62. Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, et al. Exercise Standards for Testing and Training A Statement for Healthcare Professionals From the American Heart Association. Circulation. 2001 Oct 2;104(14):1694–740.

63. McArdle WD, Katch FI, Katch VL. Essentials of Exercise Physiology. Lippincott Williams & Wilkins; 2005.

64. Robergs RA, Landwehr R. The surprising history of the "HRmax = 220- age" equation. Journal of Exercise Physiology. 2002 May 2;5(2):1–10.

65. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. Journal of the American College of Cardiology. 2001 Jan;37(1):153–6.

66. Gellish RL, Goslin BR, Olson RE, McDonald A, Russi GD, Moudgil VK. Longitudinal modeling of the relationship between age and maximal heart rate. Med Sci Sports Exerc. 2007 May;39(5):822–9.

67. Noble BJ, Borg GA, Jacobs I, Ceci R, Kaiser P. A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. Med Sci Sports Exerc. 1983;15(6):523–8.

68. Grant S. A Comparison of the Reproducibility and the Sensitivity to Change of Visual Analogue Scales, Borg Scales, and Likert Scales in Normal Subjects During Submaximal Exercise. Chest. 1999 Nov 1;116(5):1208–17.

69. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377–81.

70. Froelicher VF Jr, Thompson AJ Jr, Davis G, Stewart AJ, Triebwasser JH. Prediction of maximal oxygen consumption. Comparison of the Bruce and Balke treadmill protocols. Chest. 1975 Sep;68(3):331–6.

72. Froelicher VF, Brammell H, Davis G, Noguera I, Stewart A, Lancaster MC. A Comparison of the Reproducibility and Physiologic Response to Three Maximal Treadmill Exercise Protocols. Chest. 1974 May 1;65(5):512–7.

73. Sung J, Choi Y-H, Park JB. Metabolic syndrome is associated with delayed heart rate recovery after exercise. J. Korean Med. Sci. 2006 Aug;21(4):621–6.

74. Shetler K, Marcus R, Froelicher VF, Vora S, Kalisetti D, Prakash M, et al. Heart rate recovery: validation and methodologic issues. J. Am. Coll. Cardiol. 2001 Dec;38(7):1980–7.

75. Bosquet L, Gamelin F-X, Berthoin S. Reliability of postexercise heart rate recovery. Int J Sports Med. 2008 Mar;29(3):238–43.

76. Cole CR, Blackstone EH, Pashkow FJ, Snader CE, Lauer MS. Heart-rate recovery immediately after exercise as a predictor of mortality. N. Engl. J. Med. 1999 Oct 28;341(18):1351–7.

77. Dimkpa U. Post-exercise heart rate recovery: an index of cardiovascular fitness. Journal of Exercise Physiology online. 2009 Dec 1;12(No 1):19–22.

78. ROBINSON S, PEARCY M, BRUECKMAN FR, NICHOLAS JR, MILLER DI. Effects of atropine on heart rate and oxygen intake in working man. J Appl Physiol. 1953 Mar;5(9):508–12.

79. Pierpont GL, Voth EJ. Assessing autonomic function by analysis of heart rate recovery from exercise in healthy subjects. Am. J. Cardiol. 2004 Jul 1;94(1):64–8.

80. Savin WM, Davidson DM, Haskell WL. Autonomic contribution to heart rate recovery from exercise in humans. J Appl Physiol. 1982 Dec;53(6):1572–5.

81. Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, et al. Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. J. Am. Coll. Cardiol. 1994 Nov 15;24(6):1529–35.

82. Broman S, Wigertz O. Transient Dynamics of Ventilation and Heart Rate with Step Changes in Work Load from Different Load Levels. Acta Physiologica Scandinavica. 1971;81(1):54–74.

83. Pierpont GL, Stolpman DR, Gornick CC. Heart rate recovery post-exercise as an index of parasympathetic activity. J. Auton. Nerv. Syst. 2000 May 12;80(3):169–74.

84. Wang L, Su SW, Celler BG. Time constant of heart rate recovery after low level exercise as a useful measure of cardiovascular fitness. Conf Proc IEEE Eng Med Biol Soc. 2006;1:1799–802.

85. Hagströmer M, Oja P, Sjöström M. The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. Public Health Nutr. 2006 Sep;9(6):755–62.

86. Thomas S, Reading J, Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Sciences. 1992;17(4):338–45.

87. Novak P. Quantitative Autonomic Testing. J Vis Exp [Internet]. 2011 Jul 19 [cited 2012 Aug 12];(53). Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3196175/

88. Whyte GP, George K, Shave R, Middleton N, Nevill AM. Training induced changes in maximum heart rate. Int J Sports Med. 2008 Feb;29(2):129–33.

89. Lester M, Sheffield LT, Trammell P, Reeves TJ. The effect of age and athletic training on the maximal heart rate during muscular exercise. American Heart Journal. 1968 Sep;76(3):370–6.

90. Zavorsky G.S. Evidence and Possible Mechanisms of Altered Maximum Heart Rate With Endurance Training and Tapering. Sports Medicine. 2000;29(1):13–26.

91. Neto OP, Magini M, Saba MMF. The role of effective mass and hand speed in the performance of kung fu athletes compared with nonpractitioners. J Appl Biomech. 2007 May;23(2):139–48.

92. Hilz MJ, Dütsch M. Quantitative studies of autonomic function. Muscle Nerve. 2006 Jan;33(1):6–20.

93. Jellinek EH. The Valsalva manoeuvre and Antonio Valsalva (1666-1723). JRSM. 2006 Sep 1;99(9):448–51.

94. Yale SH. Antonio Maria Valsalva (1666 – 1723). Clin Med Res. 2005 Feb;3(1):35–8.

95. Zhang R, Crandall CG, Levine BD. Cerebral hemodynamics during the Valsalva maneuver: insights from ganglionic blockade. Stroke. 2004 Apr;35(4):843–7.

96. Singer W, OpferGgehrking TL, McPhee BR, Hilz MJ, Low PA. Influence of posture on the Valsalva manoeuvre. Clin. Sci. 2001 Apr;100(4):433–40.

97. Sato S, Makita S, Uchida R, Ishihara S, Masuda M. Effect of Tai Chi training on baroreflex sensitivity and heart rate variability in patients with coronary heart disease. Int Heart J. 2010 Jul;51(4):238–41.

98. Somers VK, Conway J, Johnston J, Sleight P. Effects of endurance training on baroreflex sensitivity and blood pressure in borderline hypertension. The Lancet. 1991 Jun 8;337(8754):1365–8.

99. Field T. Tai Chi research review. Complementary Therapies in Clinical Practice. 2011 Aug;17(3):141–6.

100. Audette JF, Jin YS, Newcomer R, Stein L, Duncan G, Frontera WR. Tai Chi versus brisk walking in elderly women. Age Ageing. 2006 Jul;35(4):388–93.

101. Väänänen J, Xusheng S, Wang S, Laitinen T, Pekkarinen H, Länsimies E. Taichiquan acutely increases heart rate variability. Clin Physiol Funct Imaging. 2002 Jan;22(1):2–3.

ANNEXURES

ANNEXURE I

PRE-TEST QUESTIONNAIRE

Date:

Name: Gender: **M/F**

Date of birth: Occupation:

Do you smoke, chew tobacco or sniff tobacco?
If yes, for how long and how much per day?

Are you in the habit of consuming alcohol?
If so, for how long and how much do you consume?

Are you in the habit of performing any regular physical exercise, martial arts, breathing exercises or meditation?
If so, for how long and what is the exercise and what is the routine?

Are you a diabetic?
Do you have a family history of diabetes?
If yes, please specify:

Are you a hypertensive?
Do you have a family history of hypertension?
If yes, please specify:

Do you have any chronic respiratory ailments like asthma or bronchitis?
If yes, please specify the type and duration:

Do you have any heart problems or heart diseases?
If yes, please specify:

Do you have any cough, breathlessness or palpitations?

Do you get attacks of fainting?

Are you on any medications?
If yes, please mention the name and duration of intake:

Did you have a considerable weight loss or weight gain in the past 3 months?
If yes, please specify:

ANNEXURE II

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (October 2002)

LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ
The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ
Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation
Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ
International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information
More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective.* Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

   ☐ Yes

   ☐ No ➡ ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

   _____ **days per week**

   ☐ No vigorous job-related physical activity ➡ ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

   _____ **hours per day**
   _____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

   _____ **days per week**

   ☐ No moderate job-related physical activity ➡ ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place ➡ ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard ➡ ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard ➡ ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**
_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ **hours per day**
_____ **minutes per day**

This is the end of the questionnaire, thank you for participating.

ANNEXURE III

PAR-Q

Physical Activity Readiness Questionnaire

The following list of questions should be completed by anyone who is looking to start an exercise program, to increase their current activity level, or partake in a fitness testing assessment. The questionnaire helps to determine how safe it is for you.

The questionnaire is suitable for those aged between 15 and 69. If you are over 69 years of age, and you are not used to being very active, check with your doctor. Read the questions carefully and answer each one honestly.

Yes	No	
☐	☐	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	Do you feel pain in your chest when you do physical activity?
☐	☐	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	Do you know of any other reason why you should not do physical activity?

If you answered YES

If you answered "yes" to one or more questions, talk with your doctor before you start becoming much more active or before you have a fitness test. Tell you doctor about the PAR-Q and which questions you answered "yes".

If you answered NO

If you answered "no" honestly to all of the questions, you can be reasonably sure that you can start becoming much more physically active or take part in a physical fitness appraisal – begin slowly and build up gradually. This is the safest and easiest way to go.

ANNEXURE IV

INFORMED CONSENT
Christian Medical College, Vellore
Department of Physiology

Study Title
Study of Cardiac autonomic control and physical fitness in Martial Artists

Information sheet

You are being requested to participate in a study which aims to investigate the nervous control of heart and fitness, in those who train in martial arts as compared to those who do not. You will be recruited into this study either as a test subject (of Martial arts study group) or as a control subject (who does not train in Martial arts).

If you take part what will you have to do?

If you agree to participate in this study, you will be asked to avoid heavy physical activity for a day and to avoid smoking cigarettes, drinking alcoholic or caffeinated beverages for twelve hours prior to testing. You will come to physiology department on a convenient date after a good nights sleep and a light breakfast. You will be asked to lie down comfortably and ECG electrodes, and a belt to measure breathing , will be placed on your chest. You will lie down for about half an hour and then you will be asked to do simple things like hand gripping, breathing deeply into a tube, standing, followed by running on a treadmill for about 15 minutes or till you tire.

Can you withdraw from this study after it starts?

Your participation in this study is entirely voluntary and you are also free to decide to withdraw from this study at any time.

What will happen if you develop any study related injury?

We do not expect any injury to happen to you.

Will you have to pay for the tests?

The testing is free. We will also reimburse you the money that you spent on travel to come for testing (please keep your bus or train tickets) for the visit that you make for this study.

Will your personal details be kept confidential?

The results of this study will be published in a medical journal but you will not be identified by name in any publication or presentation of results. However, the data collected from you may be reviewed by people associated with the study, without your additional permission, should you decide to participate in this study.

CONSENT FORM

Study Title:
Study of Cardiac autonomic control and physical fitness in Martial Artists

Participant's name:
Date of Birth / Age (in years):

I____
___________, son/daughter of ___________________________________

(Please tick boxes)
I Declare that I have read the information sheet provided to me regarding this study and I have clarified any doubts that I had. [ ]
I also understand that my participation in this study is entirely voluntary and that I am free to withdraw permission to continue to participate at any time [ ]
I understand that the study staff and institutional ethics committee members will not need my permission to look at my data even if I withdraw from the study. I agree to this access [ ]
I understand that my identity will not be revealed in any information released to third parties or published [ ]
I voluntarily agree to take part in this study [ ]

Name:
Signature:
Date:

Name of witness:
Signature:
Date:

தகவல் மற்றும் ஒப்புதல் படிவம்

கிருத்துவ மருத்துவ கல்லூரி, வேலூர், பிசியாலஜி துறை.

வீர விளையாட்டு வீரர்களிலுள்ள, உடலுறுதி மற்றும் இருதய நரம்பு மண்டலத்தின் நிலை பற்றிய ஆராய்ச்சி.

தகவல் படிவம்

மேற்கண்ட ஆராய்ச்சியில் பங்கேற்க, தங்களை அழைக்கிறோம்.

உடற்பயிற்சி செய்வோர்களில் உடலுறுதி மற்றும் இருதய நரம்பு மண்டலத்தின் நிலை சீராக இருப்பதை ஆராய்ச்சிகள் நிருபித்துள்ளன.

நாங்கள் வீர விளையாட்டு வீரர்களின் உடலுறுதி மற்றும் இருதய நரம்பு மண்டலத்தின் நிலை பற்றி ஆராய்ச்சி செய்ய உள்ளோம். ஆராய்ச்சியில் பங்குகொள்வோர்களை இரண்டு குழுவாக பிரிக்க உள்ளோம். வீர விளையாட்டு வீரர்களை ஒரு குழுவாகவும், வீர விளையாட்டு பயிலாத மக்களை மற்றொரு குழுவாகவும் பிரிக்க உள்ளோம். தாங்கள் எந்த குழுலை சேர்ந்தவராக இருந்தாலும், சோதனை முறை ஒன்றே ஆகும்.

1. தாங்கள் இவ்வாராய்ச்சியில் பங்கேற்க செய்ய வேண்டியவை.

- ஆராய்ச்சி கூடத்திற்கு வருவதற்கு 24 மணி நேரங்களுக்கு முன் எந்த விதமான கடும் வேலைகளில் ஈடுபட கூடாது.
- இங்கு வருவதற்கு முன் சுமார் 7 மணி நேரமாகவது தூங்கியிருக்க வேண்டும்.
- இங்கு வரும் நாளன்று டீ, காபி, காலை உணவு சாப்பிட வேண்டாம். மது அருந்தியிருக்கக்கூடாது.
- ஆராய்ச்சி சோதனை நடைபெறும் நாளன்று, தாங்கள், பிசியாலஜி துறை, கிருத்துவ மருத்துவ கல்லூரிக்கு வர வேண்டும்.

தங்களிடம் இருந்து சுருள் படம், மற்றும் மூச்சு வேகம் பற்றிய தகவல்கள் கனிணி மூலம் சேகரிக்கப்படும்.

தங்கள் சுமார் ½ மணி நேரம் படுத்த நிலையில் இருக்க வேண்டும். பிறகு ஒரு சிறிய இயந்திரத்தை கையினால் கவ்வி பிடிக்க வேண்டும். அதன் பிறகு ஓர் ஆழ்ந்த மூச்சு ஓர்

நீண்ட குழாயின் மூலம் விட வேண்டும். அதன் பிறகு எழுந்து நிற்க வேண்டும். பிறகு ஓர் இயந்திரத்தின் மீது 15 நிமிடம் ஓட வேண்டும்.

2. இந்த ஆராய்ச்சியிலிருந்து தாங்கள் பின் வாங்க முடியுமா?

   தாங்கள் ஆராய்ச்சியில் பங்கேற்பது தங்களின் சொந்த முடிவு, ஆகையால் தாங்கள் எப்பொழுது வேண்டுமானாலும் பின் வாங்கலாம்.

3. இந்த ஆராய்ச்சி மூலம் ஏதேனும் உடல் சார்ந்த கேடு ஏற்படுமா?

   இந்த ஆராய்ச்சியில் எந்த விதமான கேடும் ஏற்படாது என்று எதிர்பார்க்கப்படுகின்றது.

4. இச்சோதனைகளுக்கு ஏதேனும் கட்டணம் வசூலிக்கப்படுமா?

   இச்சோதனை முழுதும் இலவசமானது. தங்களின் போக்குவரத்து செலவு உங்களுக்கு தரப்படும். (பேருந்து மற்றும் ரயில் பயணச்சீட்டுகளை கொண்டு வரவும்).

5. தங்களது ஆள்சார் தகவல்கள் ரகசியமாக வைக்கப்படுமா?

   இந்த ஆராய்ச்சியிலிருந்து வரும் விவரங்கள், மருத்துவ பத்திரிக்கைகளில் வெளியிடப்படும். ஆனாலும் உங்களது மருத்துவ விவரங்கள் இந்த ஆராய்ச்சியில் பங்கு பெறும் ஆராய்ச்சியாளர் மட்டும் காண முடியும். இவர்கள் இத்தகவல்களை உங்களது கூடுதல் அனுமதியின்றி காணலாம்.

ஒப்புதல் படிவம்

ஆராய்ச்சி தலைப்பு: வீர விளையாட்டு வீரர்களிலுள்ள, உடலுறுதி மற்றும் இருதய நரம்பு மண்டலத்தின் நிலை பற்றிய ஆராய்ச்சி.

பங்கு பெறுவோரின் பெயர்:

பிறந்த தேதி:

வயது:

நான்______________________________S/o__________________________.

[ ] இடங்களில் குறியிடவும்

1. எனக்கு கொடுத்த தகவல் படிவத்தை படித்து புரிந்து கொண்டேன் [ ]
2. நான் இந்த ஆராய்ச்சியில் பங்கு கொள்வது எனது சொந்த முடிவு என்றும், இதிலிருந்து எப்பொழுது வேண்டுமானாலும் விலகி கொள்ளலாம் என்றும், அறிவேன். [ ]
3. என்னுடைய ஆள்சார் தகவல்களை நான் ஆராய்ச்சியிலிருந்து விலகிக் கொண்டாலும், என்னுடைய கூடுதல் அனுமதியின்றி ஆராய்ச்சியாளர்கள் எப்பொழுது வேண்டுமானாலும் பார்க்கலாம் என்றும் நான் அறிவேன். [ ]
4. என்னுடைய ஆள்சார் தகவல்கள் வெளியிடப்படாது என்று நான் அறிவேன். [ ]
5. இந்த ஆராய்ச்சியில் நான் பங்கு கொள்வது சொந்த முடிவாகும். [ ]

பெயர்:

கையொப்பம்:

தேதி:

சாட்சி பெயர்:

கையொப்பம்:

தேதி:

ANNEXURE V

KUNGFU DATA TABLE 1

I-E	I/E	OCT	MHG	VR	Hrmax	HR15	HR30	HR60	HR120	HR180	HR240	HR300	RHR	MAP	RPP	RR	Mean	SDNN	RMSSD
31	1.5	1.2	37	1.6	186	174	159	140	114	97	93	89	55.65	79.33	5899.38	14	1078.08	67.569	86.96
32.3	1.6	1.7	28	1.7	181	172	154	122	106	104	102	103	75.75	88	8787.55	14	792.03	124.63	121.76
34.8	1.7	1.7	27	2.8	185	174	154	134	116	103	100	102	53.89	71.33	5281.17	18	1113.39	112.83	104.81
32.5	1.7	1.4	40	2.4	183	179	167	141	116	107	97	94	57.49	80	6209.28	12	1043.6	78.338	56.193
29.7	1.6	1.3	33	2.8	197	185	167	149	128	119	116	116	64.65	88.67	7111.76	15	928.04	66.034	49.016
15.4	1.3	1.4	11	1.6	172	165	150	121	101	94	94	91	69.54	86	7649.51	18	862.8	41.07	28.614
27.1	1.7	1.4	15	1.6	173	162	147	131	108	100	101	96	55	83.33	6050.44	15	1090.83	55.347	54.571
24.8	1.8	1.3	29	1.9	174	163	145	125	96	91	91	98	67.8	73.33	6779.58	19	885.01	49.097	47.61
19.4	1.5	1.6	24	1.8	187	182	158	132	110	100	96	96	53.01	87.33	5830.65	18	1131.95	105.47	108.64
38.2	1.7	1.1	23	1.8	182	171	147	130	113	105	100	98	65.81	82.67	7370.76	17	911.71	95.061	92.989
29.5	1.6	1.3	32	1.7	182	175	144	129	116	103	104	92	61.42	76	6141.94	14	976.89	129.42	93.169
31.7	1.7	1.8	28	2.2	186	176	160	138	121	114	110	104	48.7	83.33	5356.97	17	1232.04	134.46	156.55
34.7	1.8	1.3	18	1.7	189	180	151	127	107	101	97	94	65.42	83.33	7196.68	19	917.09	360.59	353.76
49	2.2	2	42	2.3	186	177	156	138	123	118	111	107	57.67	77.33	5766.57	16	1040.48	190.5	184.08
22.5	1.3	1.8	17	1.8	168	163	145	127	111	108	106	104	66.77	87.33	7344.35	19	898.65	36.762	26.453
34.3	1.7	2	24	2.4	191	182	153	136	124	109	103	104	55.39	74.67	5538.79	19	1083.27	229.51	272.34
32	1.4	1.5	18	1.6	193	184	173	146	126	120	114	111	66.73	84.67	7606.68	17	899.21	50.963	42.551
31.5	1.7	1.8	25	2.3	185	171	150	133	114	101	95	97	60.69	82	6675.77	14	988.65	107.41	122.2
19.5	1.4	1.7	17	1.9	170	147	128	113	95	77	78	83	58.2	78.67	6285.77	18	1030.9	43.657	43.25
21.2	1.4	1.5	22	2.3	186	169	156	140	116	102	99	98	58.75	82	6462.35	19	1021.3	54.476	63.927

KUNGFU DATA TABLE 2

pNN50	fft LF	fft HF	fft LF	Lfnu	Hfnu	HRR15	HRR30	HRR60	HRR120	HRR180	HRR240	HRR300	HRm/RHR	DUR	speed	grade	wt	work int	Total pov
50.18	831.79	3987.5	0.2	0.17	0.83	12	27	46	72	89	93	97	3.342048	405	10	6	54.9	91.5732	4819.3
4.8	526	344.65	1.5	0.6	0.4	9	27	59	75	77	79	78	2.389291	385	10	6	71	118.428	870.65
55.26	3936.7	2223	1.8	0.64	0.36	11	31	51	69	82	85	83	3.432953	425	10	8	56	124.544	6159.7
28.17	2463.9	682.84	3.6	0.78	0.22	4	16	42	67	76	86	89	3.18298	360	10	4	67	74.504	3146.8
28.75	2391.3	556.08	4.3	0.81	0.19	12	30	48	69	78	81	81	3.047065	430	10	8	74	164.576	2947.4
4.638	323.66	308.42	1	0.51	0.49	7	22	51	71	78	78	81	2.47336	320	10	4	62	68.944	632.08
39.56	518.26	632.07	0.8	0.45	0.55	11	26	42	65	73	72	77	3.145227	480	10	8	72	160.128	1150.3
17.61	1012.3	567.91	1.8	0.64	0.36	11	29	49	78	83	83	76	2.566529	475	10	8	74	164.576	1580.2
53.44	4879.3	2133.9	2.3	0.7	0.3	5	29	55	77	87	91	91	3.527911	640	10	14	65	252.98	7013.2
61.04	1524.9	3199.3	0.5	0.32	0.68	11	35	52	69	77	82	84	2.76552	365	10	6	68	113.424	4724.3
35.2	3717.8	2831.3	1.3	0.57	0.43	7	38	53	66	79	78	90	2.963233	385	10	6	72	120.096	6549.1
68.88	2247.4	4986.5	0.5	0.31	0.69	10	26	48	65	72	76	82	3.819324	505	10	10	80	222.4	7233.9
20.74	2406.4	1036.8	2.3	0.7	0.3	9	38	62	82	88	92	95	2.888834	350	10	4	68	75.616	3443.2
66.32	12400	10252	1.2	0.55	0.45	9	30	48	63	68	75	79	3.225488	470	10	8	70	155.68	22651
3.636	740.76	201.46	3.7	0.79	0.21	5	23	41	57	60	62	64	2.51622	330	10	4	60	66.72	942.22
67.15	22184	21581	1	0.51	0.49	9	38	55	67	82	88	87	3.44841	355	10	4	65	72.28	43765
22.66	1350	1123.7	1.2	0.55	0.45	9	20	47	67	73	79	82	2.892459	385	10	6	64	106.752	2473.7
72	1313.1	7689.9	0.2	0.15	0.85	14	35	52	71	84	90	88	3.048338	315	10	4	72	80.064	9003
27.78	216.07	542.6	0.4	0.28	0.72	23	42	57	75	93	92	87	2.920883	250	10	2	65	36.14	758.67
49.48	640.69	1738.2	0.4	0.27	0.73	17	30	46	70	84	87	88	3.16603	475	10	8	56	124.544	2378.9

CONTROL DATA TABLE 1

I-E	I/E	OCT	MHG	VR	Hrmax	HR15	HR30	HR60	HR120	HR180	HR240	HR300	RHR	MAP	RPP	RR	Mean	SDNN	RMSSD
38.2	1.8	1.59	20	2.6	196	187	160	137	119	114	115	113	64.67	87.33	7114.1	12	927.73	127.6	114.3
11.3	1.15	1.17	12	1.4	189	180	162	144	127	121	117	118	79.59	83.33	8436.1	12	753.9	27.22	18.23
29.3	1.5	1.23	37	1.7	196	184	158	139	116	106	103	108	73.66	82	7808.5	16	814.5	49.67	21.88
16	1.4	1.99	27	1.8	198	186	169	145	118	106	109	99	53.23	89.33	6387.5	17	1127.2	78.21	67.67
28.5	1.7	1.75	43	1.7	180	172	152	133	110	103	101	99	54.35	80	5435.4	18	1103.9	88.59	98.17
31.5	1.6	1.6	22	1.8	181	165	150	136	121	113	106	103	55.12	98.67	6614.1	16	1088.6	114.3	110.5
32	1.7	1.81	18	2.3	174	159	146	135	113	108	103	104	63.1	83.33	6940.9	18	950.88	72.4	71.65
19.5	1.3	1.51	12	1.7	174	170	144	129	111	99	104	99	67.01	92.67	7907	16	895.41	69.25	53.12
36.8	1.8	1.33	43	1.8	202	186	169	147	124	111	105	106	55.05	83.33	6055.3	15	1090	114.5	125.3
28.7	1.5	1.55	32	1.9	199	190	173	155	126	122	115	110	67.11	78	7382.6	19	893.99	75.15	71.42
29.8	1.6	1.5	19	1.9	193	179	158	133	112	105	105	99	60.54	82	6659	17	991.14	103.3	121.7
21.7	1.4	1.6	22	2	180	175	162	137	108	100	101	101	58.59	80	7030.4	13	1024.1	67.49	54.5
18.2	1.3	1.2	21	1.8	177	164	148	128	106	98	117	92	66.07	84.67	7267.7	17	908.13	91.51	86.03
26.5	1.5	1.6	21	1.7	192	183	166	151	123	113	110	102	68.68	87.33	7279.7	16	873.66	66.25	56.4
31.2	1.7	2	21	2	191	174	168	147	118	110	105	109	57.61	88.67	7259.1	18	1041.5	57.51	70.22
29.3	1.6	1.7	36	2.4	194	180	166	142	121	113	109	111	53.73	87.33	5910.7	12	1116.6	135.2	134.7
24.7	1.5	1.5	21	1.8	186	176	157	143	124	116	115	109	60.53	88	7264.1	17	991.17	60.75	60.51
23.7	1.5	1.4	26	1.8	157	146	127	107	92	85	86	87	61.25	84	6615.1	16	979.58	90.52	72.69
20.3	1.3	2.2	17	2.6	191	184	170	150	128	120	116	113	73.57	79.33	8092.4	16	815.58	74.88	37.66
29.2	1.7	1.6	22	1.6	161	147	127	113	101	83	77	73	49.24	81.33	5120.8	14	1218.6	103.7	97.27

CONTROL DATA TABLE 2

pNN50	fft LF	fft HF	LF/HF	Lfnu	Hfnu	HRR15	HRR30	HRR60	HRR120	HRR180	HRR240	HRR300	HRm/RHR	DUR	speed	grade	Wt	work int	Total pov
60.31	12863	4489.1	2.87	0.74	0.26	9	36	59	77	82	81	83	3.03058	385	2.78	6	55	91.073	17352.2
0.508	217.32	109.56	1.98	0.66	0.34	9	27	45	62	68	72	71	2.37479	305	2.78	4	78	86.736	326.879
2.192	302.65	235.62	1.28	0.56	0.44	12	38	57	80	90	93	88	2.6607	515	2.78	10	69	191.54	538.262
52.47	1796.5	1470.8	1.22	0.55	0.45	12	29	53	80	92	89	99	3.71976	500	2.78	10	70	194.6	3267.26
64.31	2086.8	2978.1	0.7	0.41	0.59	8	28	47	70	77	79	81	3.31161	355	2.78	4	70	77.84	5064.84
66.3	1552.7	4643.3	0.33	0.25	0.75	16	31	45	60	68	75	78	3.28391	305	2.78	4	81	90.072	6195.98
33.65	2265	1167.9	1.94	0.66	0.34	15	28	39	61	66	71	70	2.75755	350	2.78	4	70	77.84	3432.85
36.75	1777.2	1441.7	1.23	0.55	0.45	4	30	45	63	75	70	75	2.59669	410	2.78	6	55	91.74	3218.93
62.87	7969.1	5662.5	1.41	0.58	0.42	16	33	55	78	91	97	96	3.6695	385	2.78	6	57	95.076	13631.6
29.82	3146.2	2982	1.06	0.51	0.49	9	26	44	73	77	84	89	2.96507	370	2.78	6	57	95.076	6128.12
74.33	2379.3	5723.4	0.42	0.29	0.71	14	35	60	81	88	88	94	3.18817	365	2.78	6	72	120.1	8102.69
42.41	231.41	1786	0.13	0.11	0.89	5	18	43	72	80	79	79	3.07239	435	2.78	8	83	184.59	2017.41
44.95	3090.2	2375.4	1.3	0.57	0.43	13	29	49	71	79	60	85	2.67898	360	2.78	4	56	61.716	5465.53
35	1771	1930.8	0.92	0.48	0.52	9	26	41	69	79	82	90	2.79571	350	2.78	4	71	78.952	3701.73
48.07	727.76	1703.6	0.43	0.3	0.7	17	23	44	73	81	86	82	3.31528	335	2.78	4	90	100.08	2431.4
69.55	2937.5	9090.9	0.32	0.24	0.76	14	28	52	73	81	85	83	3.61037	575	2.78	12	57	190.15	12028.4
42.81	1924.1	1455.6	1.32	0.57	0.43	10	29	43	62	70	71	77	3.07263	410	2.78	6	76	126.77	3379.75
28.71	3390.3	2863.4	1.18	0.54	0.46	11	30	50	65	72	71	70	2.56323	370	2.78	6	79	131.77	6253.7
11.26	2711.4	440.23	6.16	0.86	0.14	7	21	41	63	71	75	78	2.59626	460	2.78	8	68	151.23	3151.67
61.48	3824.7	3483	1.1	0.52	0.48	14	34	48	60	78	84	88	3.26978	220	2.78	0	72	0	7307.69

ANNEXURE VI

INSTITUTIONAL REVIEW BOARD (IRB)
CHRISTIAN MEDICAL COLLEGE
VELLORE 632 002, INDIA

Dr.B.J.Prashantham, M.A.,M.A.,Dr.Min(Clinical)
Director, Christian Counseling Centre
Editor, Indian Journal of Psychological Counseling
Chairperson, Ethics Committee, IRB

Dr.George Mathew, MS, MD, FCAMS
Chairperson, Research Committee &
Principal

Dr.Gagandeep Kang, MD, Ph.D, FRCPath
Secretary, Research Committee, IRB
Additional Vice Principal(Research)

August 10, 2011

Dr. Aneesh Joseph
PG Demonstrator
Department of Physiology
Christian Medical College
Vellore 632 004

Sub: **FLUID Research grant Project NEW PROPOSAL:**
Study of Cardiac autonomic control and physical fitness in Martial Artists
Dr. Aneesh Joseph, PG Demonstrator, Physiology, Dr. Elizabeth Tharion, Physiology, Mr. Saravana Kumar, Biostatistics.

Ref: IRB Min. No. 7527 dated 5.07.2011

Dear Dr. Joseph,

The Institutional Review Board (Blue, Research and Ethics Committee) of the Christian Medical College, Vellore, reviewed and discussed your project titled "Study of Cardiac autonomic control and physical fitness in Martial Artists" on July 5, 2011.

The Committees reviewed the following documents:

1. Format for application to IRB submission
2. Information Sheet and Informed Consent Form
3. Questionnaires
4. Cvs of Drs. Aneesh Joseph, Elizabeth Tharion, Mr. Saravana Kumar

The following Institutional Review Board (Ethics Committee) members were present at the meeting held on July 5, 2011 in the CREST/SACN Conference Room, Christian Medical College, Bagayam, Vellore- 632002.

Name	Qualification	Designation	Other Affiliations
Dr. B.J.Prashantham	MA(Counseling),MA (Theology), Dr Min (Clinical)	Chairperson(IRB)& Director, Christian Counselling Centre	Non-CMC
Mr. Harikrishnan	BL	Lawyer	Non-CMC

TEL : 0416 - 2284294, 2284202 FAX : 0416 - 2262788, 2284481 E-mail : research@cmcvellore.ac.in

INSTITUTIONAL REVIEW BOARD (IRB)
CHRISTIAN MEDICAL COLLEGE
VELLORE 632 002, INDIA

Dr.B.J.Prasantham, M.A.,M.A.,Dr.Min(Clinical)
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Editor, Indian Journal of Psychological Counseling
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Dr.George Mathew, MS, MD, FCAMS
Chairperson, Research Committee &
Principal

Dr.Gagandeep Kang, MD, Ph.D, FRCPath
Secretary, Research Committee, IRB
Additional Vice Principal(Research)

Mrs. S. Pattabiraman	BSc, DSSA	Social Worker, Vellore	Non-CMC
Dr. Jayaprakash Muliyil	BSC, MBBS, MD, MPH, Dr PH(Epid), DMHC	Academic Officer, CMC	CMC
Mr. Samson Varghese	BSc, BD, MA, DCPC	Chaplain, CMC	CMC

We approve the project to be conducted as presented.

The Institutional Ethics Committee expects to be informed about the progress of the project, any serious adverse events occurring in the course of the project, any changes in the protocol and the patient information/informed consent and requires a copy of the final report.

A sum of ₹ 39,500/- (Rupees Thirty nine thousand five hundred only) is sanctioned for 1 year.

Yours sincerely,

George Mathew

Dr. George Mathew
Principal& Chairman (Research Committee)
Institutional Review Board

Dr. George Mathew, MS., MD., FCAMS
Chairperson (Research Committee) &
Principal
Christian Medical College
Vellore - 632 002, Tamil Nadu, India

ANNEXURE VII : Plagiarism Check Screenshot