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EFFECT OF DEEP BREATHING TRAINING ON EXERCISE – INDUCED CHANGES IN ELECTROCARDIOGRAM (ECG) OF THE YOUNG NORMAL VOLUNTEERS

Dissertation submitted in partial fulfillment for the Degree of Bachelor of Science (Health) in Biomedicine

JONG SHUN MEE

School of Health Sciences
Universiti Sains Malaysia
16150 Kubang Kerian, Kelantan
Malaysia

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CERTIFICATE

This is to certify that dissertation entitled

"Effect Of Deep Breathing Training On Exercise – Induced Electrocardiogram (ECG) Changes In Young Normal Volunteers"

is the bonafide record of research work by

Mr. Jong Shun Mee

During the period from **June 2003** to **March 2004**

under my / our supervision

Signature of Supervisor : Prema Sembulingam

Name and Address of Supervisor : P.M. Dr. Prema Sembulingam

: PPSK, Health Campus, USM

16150 Kubang Kerian, Kelantan

Date : 28 March 2004

PROF. MADYA DR. PREMA SEMBULINGAM
Pensyarah
Pusat Pengajian Sains Kesihatan,
Universiti Sains Malaysia,
Cawangan Kelantan.

Signature of Co-Supervisor : K. Sembulingam

Name and Address of Co-Supervisor : P.M. Dr. K. Sembulingam

: PPSK, Health Campus, USM

16150 Kubang Kerian, Kelantan

Date : 28 March 2004

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ABSTRACT

The aim of this study was to investigate the effect of deep breathing training on exercise – induced changes in electrocardiogram (ECG) in normal healthy volunteers. Subjects were divided into two groups – experimental group and control group. The subjects from experimental group were asked to practice deep breathing exercise for 15 minutes twice a day for consecutive 3 week periods with different timing each week; while control group did not do deep breathing exercise. The ECG (lead II) was recorded before and after performance of physical exercise in cycle ergometer with 40 – 50 rpm and 20 Newton resistances for 5 minutes.

The results show that, the amplitude of R wave increased in experimental group and control group before physical exercise ($p < 0.011$) and the R wave amplitude increased further after physical exercise only in experimental group ($p < 0.001$). The amplitude of P wave increased significantly ($p < 0.003$) after physical exercise in both the groups, but there was no difference in the increase between the control and experimental group. The amplitude of T wave was increased significantly after physical exercise in both the groups ($p < 0.001$). The mean values show that the increase in amplitude of T wave is more in control group than in the experimental group. The duration of T wave and RR interval was decreased after physical exercise, and the decrease was similar in both the groups. Other parameters did not show any significant change in both the groups.

The more increase in the amplitude of R wave and less increase in the amplitude of T wave in experimental group indicate that the deep breathing training improves cardiac performance to cope up with the exercise stress.

INTRODUCTION

Breathing is something we don't usually think about. We breathe in and out anywhere from 15 to 25 times per minute without even realizing it. When we exercise our breathing rate goes up, again, without our knowledge. So it is not under our control but the control of autonomic nervous system. Breathing goes on so regularly that we simply take it for granted (Craig C. Freudenrich, 2003).

The breathing cycle has three distinct phases: breathing in, breathing out and then a short pause. It is an act in which we take air from atmosphere into our lungs, absorb the O_2 from it into our blood, and expel the air again into the atmosphere together with CO_2 and water vapour. This act of inhalation and exhalation is repeated every 4 to 5 seconds. An adult normally breathes 8 to 16 times per minutes in resting conditions and a child breathes 20 to 30 times per minute. The mode of breathing in an individual is usually silent under physiological conditions (Jacqueline A., 1999).

Breathing is the most important event in the body. Why is it so? This can be answered, if one understands the functions carried out by breathing. First, it is the only means to supply oxygen to the body, which is vital for the survival of living organisms. Second, it is one of the routes to eliminate waste products and toxins, especially carbon dioxide, from the body. The respiratory system also helps to filter, warm and humidify the air we breathe (M. Beals et al, 2000).

However, in practice, our breathing is too rapid and shallow. This does not allow us to take sufficient oxygen and eliminate the excess carbon dioxide. Quick shallow breathing results in oxygen starvation which leads to reduced vitality, premature ageing, poor immune system and a myriad of other factors. It also results in toxic build-up in the body. Not only that, shallow breathing also does not give enough exercise to the lungs; so their expansibility is reduced, causing a further reduction in vitality (Jacqueline A., 1999).

There are two major unhealthy breathing patterns, which are associated with a sense of breathlessness and/or illness:

1. Thoracic breathing: a shallow breathing marked by breath holding or gasping. It involves the startle reactions with abdominal tightening which results in making the person to inhale into the upper chest. This type of breathing causes increased heart rate and blood pressure, gastro-intestinal distresses, asthmatic symptoms and neck and shoulder tension.

2. Hyperventilation: a rapid, shallow breathing marked by frequent sighs. In this type of breathing, too much of CO_2 is washed out, resulting in increased blood alkalinity. Anxiety, phobia, and dizziness are all associated with hyperventilation (Erik Peper, 2001; Sue Moris, 2003; Phyllis Grannis, 2000).

The first rule for correct breathing is that we should breathe more slowly and deeply through the nose. This may look so obvious, but many people have the habit of breathing through the mouth without even realizing it. Mouth breathing can adversely affect many functions of the body; thyroid gland is affected so much so that it can retard the mental development of children and decrease mental efficiency in adults. It is not difficult to break the habit of breathing through the mouth, and switch over to nostril breathing. Simply by keeping the mouth closed, we can start breathing automatically through the nose (Jacqueline A., 1999; Erik Peper, 2001).

However, the best way of breathing is diaphragmatic or abdominal breathing, which is the natural pattern of breathing. New born babies and young children breathe effortlessly. Where most of the movements associated with their breathing occurs primarily in the lower abdominal area. As they exhale, their abdomens expand outward at the sides. But, as one grows older, he or she looses the habit of breathing in this healthy pattern. Instead, they hold their stomach rigid or slack and use a significant amount of upper body muscular activity to inhale (Erik Peper, 2001; Sue Moris, 2003; Phyllis Grannis, 2000).

The diaphragm, a dome shaped muscle located beneath the ribs and above the stomach plays an essential role in diaphragmatic breathing. During inhalation, the diaphragm tightens and flattens. This activity displaces the liquid contents of the abdomen and creates a larger space in the chest. As this happened, the pressure in the atmosphere exceeds the pressure in the chest and force the air flows in to the body. During inhalation, the diaphragm relaxes and is raised upward. This compresses the air in the chest and allows it to flow out. Thus, inhalation requires the relaxation and expansion of abdominal area; while exhalation requires the contraction and decrease in diameter of abdominal area. The chest and shoulders will stay relaxed throughout the breathing cycle (Erik Peper, 2001; Sue Moris, 2003; Phyllis Grannis, 2000).

Most of the time, the pattern of breathing reflects our emotional as well as physical state. Quiet and slow breathing will soothe our emotions, stabilize the mental processes, and normalize other physiological state. Many performers, including athletes and musicians, use diaphragmatic breathing as an essential part of their training to perform at a peak level (Erik Peper, 2001; Sue Moris, 2003; Phyllis Grannis, 2000; C. Andrew, 1999).

What Is Deep Breathing Exercise?

Deep breathing, or breathing exercise, is more technically known as Pranayama, which is one of the most important parts of yoga practice. But anybody can practice breathing exercise and get benefits out of it, because it is very easy and convenient to practice at any time and at any place. Deep breathing had been shown to have powerful influence on our health. It is important from the standpoint of both physical health and spiritual development. It is believed to increases the vitality and promotes relaxation (K.S. Joshi, 2000; Marilyn M., 2000).

Before accepting the values of deep breathing exercises, one has to experience and understand the role of the chest and diaphragm, as well as the role of the belly, lower ribs, and lower back in the process of breathing. We also need to realize how unnecessary tension in our muscles can impede the breathing (Dennis Lewis, 2002).

When the breathing is deep, it slows down the rate and it involves, not only the respiratory muscles of the chest but also the belly, lower ribcage, and lower back. This slower, deeper breathing, combined with the rhythmical pumping of the diaphragm, abdomen, and belly is shown to help in switching on the parasympathetic nervous system, which is concerned with relaxation and decrease in the heart rate (HR) and blood pressure (BP). It also believed to decrease the sympathetic activity which is responsible for development of stress and tension with increased HR and BP. And this, of course, has a positive impact on the overall health (Dennis Lewis, 2002; A.S. Mahajan and R. Babbar, 2003).

Benefits of Deep Breathing

Lot of information and studies have shown that deep breathing (Pranayama) has positive effects on physical, mental and emotional well being. It is also focused as a factor to encourage spiritual development (Dennis Lewis, 2002; Marilyn M., 2000; A.S. Mahajan and R. Babbar, 2003).

Deep breathing improves the quality of the blood by increasing oxygenation in the lungs, increases the digestion and assimilation of food, improves the health of the nervous system, stimulates rejuvenation of the glands (especially the pituitary and pineal glands) and skin, reduces the work load for the heart and decreases blood pressure, assists in weight control, relaxes the mind and body, reduces tension and excessive anxiety levels, improves sleep, relieves the constipation etc (K.S. Joshi, 2000; Dennis Lewis, 2002; Marilyn M., 2000).

REVIEW OF LITERATURES

In conjunction with this study regarding the effect of the deep breathing exercise on electrocardiogram (ECG), the review on previously published research papers and articles related to this study field was done.

Kim N. C. (1994) found that Dan Jeon breathing method, which is composed of thirty minutes program including Dan Jeon breathing (a kind of abdominal-deep breathing), free gymnastics, mental concentration, physical strength exercise, and suggestion, was an effective behavioral therapy to reduce blood pressure in essential hypertension patients.

Grossman *et al* (2001) have used a new technology of breathing exercise called BIM (Breathing with Interactive Music) in which the hypertensive patients were given active treatment with this device for 10 minutes daily for 8 weeks. The results of this study showed that there was significant decrease in blood pressure and they called it as "effective non-pharmacological treatment".

Qigong is an ancient Chinese breathing exercise with meditation, which is being developed for therapy of chronic illness. It is claimed to cure gastric ulcers, hypertension, anxiety neurosis, otitis media, and cancer and has even been used as a form of anesthesia (Koh T.C., 1982).

Ugalde *et al* (2000) studied the effects of pursed lips breathing, another method of deep breathing exercise, on ventilation, chest wall mechanics, and abdominal muscle recruitment in myotonic muscular dystrophy (MMD). The study showed that this type of breathing increased tidal volume, minute ventilation, and oxygen saturation, reduced respiratory rate, and end expiratory lung volume.

However, dyspnea, slight increased respiratory effort, and fatigue were noticed in this pursed lips breathing.

Cooper *et al* (2003) studied the effects of the Buteyko breathing technique, a device which mimics pranayama (a yoga breathing technique), on bronchial responsiveness in patients with asthma. Subjects practiced the techniques at home twice daily for 6 months and it was found that Buteyko breathing technique reduced the asthmatic symptoms and reduced the bronchodilator usage.

Bhattacharya *et al* (2002) studied the effect of yogic breathing exercises (pranayama) on oxidative stress in 30 young male volunteers. They found that Yogic breathing exercises not only helped in relieving the stresses of life but also improved the antioxidant status of the individual. An improvement in the antioxidant status is helpful in preventing many pathological processes that are known with impaired antioxidant system of body.

In another study, effect of breathing exercise was studied seen with yoga on the health-related aspects of physical fitness, including muscular strength and endurance, flexibility, cardiorespiratory fitness, body composition, and pulmonary function. The study period was for 8 weeks, with minimum of two sessions per week. Each yoga session consisted of 10 minutes of breath-control exercises, 15 minutes of dynamic warm-up exercises, 50 minutes of yoga postures, and 10 minutes of supine relaxation in corpse pose. Finally, it was showed that it improved the general health and physical fitness of all the subjects (Tran M.D *et al*, 2001).

Bernardi *et al* (2001) wanted to see whether slow breathing could modified the sensitivity of the chemoreflex and baroreflex mechanisms in 15 healthy subjects, in which progressive isocapnic hypoxia and progressive hyperoxic hypercapnia were measured during spontaneous breathing and during a breathing rate fixed at 6 and 15 breaths per minute (b.p.m.). The study showed that breathing at 6 b.p.m. depressed both hypoxic and hypercapnic chemoreflex responses, and enhances baroreflex response, compared with spontaneous breathing or 15 b.p.m. controlled breathing. This showed that slow breathing exercise might be beneficial in conditions like chronic heart failure that are associated with inappropriate chemoreflex activation.

In the following year, Bernardi *et al* (2002) investigated the benefits of slow breathing (6 breaths/minute) in 81 patients with stable chronic heart failure (CHF) and in 21 healthy controls. They found that slow breathing induced significant increases in arterial baroreflex sensitivity in both controls and CHF patients. Slow breathing also produced an increase in RR interval and a decrease in the systolic and diastolic blood pressure in CHF patients.

In a study to determine whether 2 months of device-guided slow breathing exercises for 15 minutes daily could safely and effectively reduce high Bood pressure (BP), Laurie Barclay (2003) recruited 17 resistant hypertensive from three clinics. Their mean age was 67 ± 8 years, 59% were men, mean office BP was 155 ± 10 / 89 ± 9 mm Hg and mean home BP was 156 ± 20 / 89 ± 13 mm Hg. It was noticed that slow breathing could reduce both office blood pressure and home blood pressure.

Singh *et al* (1990) studied the effect of breathing exercises on airway reactivity, airway caliber, symptom scores, and medication use in patients with mild asthma. 18 patients practiced slow deep breathing for 15 minutes twice a day for 2-week periods. During the active period, subjects breathed through a

Pink City lung (PCL) exerciser, a device which imposed slowing of breathing and a 1:2 inspiration: expiration duration ratio equivalent to pranayama breathing methods; during the control period, subjects breathed through a matched placebo device. All the subjects showed better improvement with the PCL exerciser than with the placebo device. There was a statistically significant increase in the dose of histamine needed to provoke a 20% reduction in FEV1 (forced expiratory volume in 1 second) during pranayama breathing but not with the placebo device.

Udupa *et al* (2003) studied the effect of deep breathing training on ventricular performance, which was measured by systolic time intervals (STI) and cardiac autonomic function tests (AFT). Study showed that 3 months of pranayam training produced an increase in RR interval variation (RRIV), and modulated ventricular performance by increasing parasympathetic activity and decreasing sympathetic activity.

Vitacca *et al* (1998) investigated the impact of deep diaphragmatic breathing (DB) on blood gases, breathing pattern, pulmonary mechanics and dyspnoea in 25 chronic obstructive pulmonary disease (COPD) patients with chronic hypercapnia. They found that there is a significant increase in partial pressure of oxygen (PO_2) and a significant decrease in partial pressure of carbon dioxide (PCO_2), with a significant increase in tidal volume and a significant reduction in respiratory rate resulting in increased minute ventilation. There also an improvement of blood gases at the expense of a greater inspiratory muscle loading.

Jokerst *et al* (1999) reported that the slow deep breathing, a non-pharmacological procedure known to increase parasympathetic nervous system (PNS) activity, can help to prevent the development of gastric dysrhythmias and symptoms of motion sickness when subjects were exposed to a rotating optokinetic drum.

Mohan *et al* studied the effect of inspiratory and expiratory phases of normal breathing, deep breathing and pranayam type breathing on heart rate and mean ventricular QRS axis in young healthy untrained subjects. Pranayam type breathing produced significant cardio-acceleration and increase in QRS axis during the inspiratory phase as compared to eupnoea. On the other hand, expiratory effort during pranayam type breathing did not produce any significant change in heart rate or QRS axis. The changes in heart rate and QRS axis during the inspiratory and expiratory phases of pranayam type breathing were similar to the changes observed during the corresponding phases of deep breathing.

In a study to compare the effects of deep breathing exercise and ambulation on pattern of breathing in patients after upper abdominal surgery, Orfanos *et al* (1999) found that the deep breathing exercise produced a significant increase in tidal volume (mean change 488.5ml) and a non-significant decrease in respiratory rate (RR); while ambulation produced a non-significant increase in both tidal volume (mean change 163.4ml) and RR.

LACUNAE

Thus the review of literature reveals that many researches on the effect of deep breathing training along with yoga and meditation on respiratory system, cardiovascular system, and biochemical processes had been carried out. However, in cardiovascular system the studies on the effect of deep breathing training on electrocardiogram (ECG) changes were scanty. Most of these studies were done on either hypertensive or asthmatic patients, but the study on young healthy college students is hardly found.

Also, the study regarding the effect of deep breathing training alone on exercise – induced changes in electrocardiogram is very scanty. And this study will be the first of its kind, especially in Malaysian population.

OBJECTIVES

The objectives of the study are as following:

1. To see the effect of physical exercise – induced changes in ECG
2. To see the effect of deep breathing training on normal ECG
3. To see the effect of deep breathing training on exercise – induced changes in ECG

MATERIALS AND METHOD

Subjects

34 normal and healthy young male subjects, who were non-smokers and aged 18 to 30 years, were recruited from the student population of Health Campus, University Sains Malaysia, Kubang Kerian, Kelantan. 17 subjects were asked to be the experimental group (with deep breathing training) and 17 subjects were the control group (without deep breathing training).

Sample Size Determination

Numbers of subjects were determined with the help of Dr Tann Winn, lecturer in Statistics in PPSP (School Of Medical Science), USM, who is also one of the co-supervisor of the study.

Ethical Committee Approval

The Ethical Committee of The University approved the test protocols.

Informed Consent

The protocol was explained in detail to the subjects and written informed consent to participate in the study was obtained from them. The participation in this study was purely voluntary and subjects were given choice of refusing to take part or withdraw from the study at any time.

Sample Size Determination (Example)

$$m = \frac{2\,(f_\alpha + f_\beta)^2\,\delta^2\,(1-\rho)}{n\,s_\chi^2\,d^2}$$

δ^2	= Variance of
ρ	= Error among Repeated Measures?
d	= Detectable Difference
n	= Number of repeated Measures per person
s_X^2	= Subject Variation

FVC1	μ	= 4
	δ	= > 9
	d	= 0.5
	n	= 3
	s_X^2	= 0.67
	p	= ?

$$m = \frac{2\,(1.96 + 0.84)^2\,0.4^2\,(1 - 0.2)}{3 \times 7}$$

PEF	μ	= 520
	δ	= 58
	d	= 10
	n	= 3
	s_X^2	= 5
	p	= 0.2

$$m = \frac{2\,(1.96 + 0.84)^2\,0.4^2\,(1 - 0.2)}{3 \times 4 \times 10^2}$$

S A M P L E S I Z E = 3 4

Inclusion Criteria

All the subjects were normal and healthy without any clinical illness. Dr Paramasivam Arumugam, Medical Officer in Emergency Department, HUSM, who was doctor in charge of this study, certified the subjects for their suitability to participate in the study and supervised the procedures. He is also one of the co-supervisor of the study.

Exclusion Criteria

1. Smokers and drug addicts were not included.
2. Subjects who were treated for any cardiac problems, liver diseases or renal diseases were not included.
3. Regular exercising subjects and athletes were not included.
4. The doctor in charge determined the suitability of the subjects for the test.

ECG Parameters Recorded

1. Amplitude of P wave (AP)
2. Duration of P wave (DP)
3. Amplitude of R wave (AR)
4. Amplitude of T wave (AT)
5. Duration of T wave (DT)
6. Duration of PR interval (DPR)
7. Duration of RR interval (DRR)
8. Duration of QRS complex (DQRS)

Materials

1. Cycle ergometer to perform exercise
2. Cardioline ECG Machine to record ECG
3. Stop watch to time the cycling exercise

Procedures

Subjects were given chance to familiarize with the performance of cycle ergometer, before starting of the actual protocol. Then they were instructed to report in the Physiology laboratory in the morning (8:30 – 11:30 am) on a particular day after having a light breakfast.

Their height, weight and age were noted to calculate BMI at first visit and the last visit to laboratory. Subjects were instructed to take off any metallic materials (e.g. watch, chain, ring, key chain, coins, headphone, and etc) from their bodies, as these materials could disturb ECG recording. Then subject was asked to sit relaxed on a chair for about 10 minutes with the head facing away from the ECG machine. Then the electrodes were fixed and ECG was recorded on Lead II for 30 seconds.

After recording basal ECG, the subject was asked to perform the exercise in the cycle ergometer with 40 – 45 rpm and 20 Newton resistances for 5 minutes. ECG was recorded again immediately after finishing the cycling exercise.

Then the experimental group was taught deep breathing exercise and was asked to practice the deep breathing exercise twice a day for consecutive 3 weeks period.

(Refer Flow Chart 1 and Flow Chart 2)

Flow Chart 1: Protocol for Control Group

Subject report in the laboratory

↓

Height and weight was noted to calculate BMI

↓

Basal ECG parameters were recorded

↓

Cycle ergometry was done

↓

Exercise-induced changes in the ECG parameters were recorded.

ECG Parameters:

1. Amplitude of P Wave (AP)
2. Duration of P Wave (DP)
3. Amplitude of R Wave (AR)
4. Amplitude of T Wave (AT)
5. Duration of T Wave (DT)
6. Duration of PR interval (DPR)
7. Duration of RR Interval (DRR)
8. Duration of QRS Complex (DQRS)

Phase - I

Report in the laboratory on 8th day.

↓

ECG parameters were recorded.

↓

Cycle ergometry was done

↓

ECG parameters were recorded again

Phase - II

Report in the laboratory on 16th day.

↓

ECG parameters were recorded.

↓

Cycle ergometry was done

↓

ECG parameters were recorded again

Phase - III

Report in the laboratory on 24th day.

↓

ECG parameters was recorded.

↓

Cycle ergometry was done

↓

ECG parameters were recorded again

Performing an ECG

The quality of the ECG is dependent on the preparation and the resistance between the skin and the electrode. To ensure a good quality ECG and minimize the skin/electrode resistance, following steps were followed:

1. It was ensured that the patient was warm and relaxed.
2. The electrode area was shaved before cleaning.
3. The area was cleaned thoroughly with alcohol.
4. When applying the electrodes, a layer of gel was applied between the electrode and skin.
5. Then the 4 colour coded limb electrodes (Lead II) were attached with the respective clamps to the arm and foot pick-up sites of the subject (red-right arm, yellow-left arm, black-right leg, and green-left leg).
6. The ECG was recorded for 30 seconds.

Deep Breathing Exercise

The subjects were allowed to practices the deep breathing exercise in standing position. Both arms were placed and rested on the abdomen. Deep breathing exercise was practiced twice a day everyday that is 15 minutes in the morning and 15 minutes in the evening. This breathing exercise was practiced for 3 weeks period with different timing each week as described later.

The subject was instructed to do breathing exercise in standing position.

1. To stand with eye must be closed and concentration should be focused on normal breathing for 2 minutes. After 2 minutes eyes were to be opened and the deep breathing exercise should be started.

2. Air must be exhaled slowly through both nostril and simultaneously the stomach must be pulled inwards: i.e., the abdominal muscles must be contracted to expel air from the lungs. Exhalation should be continued for 3 seconds and at the end of 3 seconds, all the air should have been expelled.
3. Then slowly and deeply inhalation should be done through both nostril. While doing this, the abdominal muscles must be stretched, that is, inhalation must be abdominal of diaphragmatic. This should be done slowly and rhythmically for 3 sec and not fast.
4. At the end of inspiration, there must be a pause for 2 seconds: breath must be held (stopped) with the inhaled air for 2 seconds.
5. Then exhalation must be done through the nostril for 3 seconds as described in steps 1.

So one respiratory cycle must be completed in 8 seconds, i.e. exhalation 3 seconds, inhalation 3 seconds, and pause 2 seconds (3 + 3 + 2 = 8 seconds) with the respiratory rate of 7 – 8 breathes per minute. This is in the first week.

In second week, the subject is instructed to changes the deep breathing pattern, in which exhalation 4 seconds, pause 2 seconds, and inhalation 4 seconds. So the timing was 4 + 4 + 2 = 10 seconds, at the rate of 6 breathes per minute. In the third week, the timing of the deep breathing was increased to 5 + 5 + 5 = 15 seconds, that is inhalation 5 seconds, pause 5 seconds and exhalation 5 seconds, at the rate of 4 breathes per minute (Phulgenda Sinda, 1996).

STATISTICAL ANALYSIS

To determine the differences in electrocardiogram (ECG) components between groups and exercise conditions, a 3-way (Group*Exercise*Time) ANOVA with repeated measures on the second and third factors was used. Groups had 2 levels: experimental and control. Exercise also had 2 levels: before and after exercise. Time had 4 levels: baseline, week 1, week 2, and week 3. Before analyses were carried out, tests were conducted to determine whether the assumptions for (repeated) measures ANOVA were met. Log transformations were calculated if necessary to normalize the data. Simple effects analyses were conducted for 2-way interactions. The level of significance was set at 0.05.

RESULTS

Body Mass Index (BMI)

There was no marked variation in BMI values between the experimental group (mean BMI 22.05 ± 2.85 Kg/M^2) and control group (Mean BMI 22.67 ± 3.02 Kg/M^2).

Amplitude of P Wave (AP)

Table 1 shows the descriptive statistics for the ECG components by group, exercise and time. There were no multivariate and univariate Exercise*Time*Group, Exercise*Time, Time*Group and Exercise*Group interactions ($p > 0.05$ for all). There also were no multivariate and univariate Time and Group main effects ($p > 0.05$ for each). However, there was a multivariate Exercise effect ($p = 0.003$), which was confirmed by the univariate analysis ($p = 0.003$). Collapsed over Time and Group, AP was higher after exercise (0.47 ± 0.15 versus 0.40 ± 0.12).

Amplitude of R Wave (AR)

There were no multivariate and univariate Exercise*Time*Group, Exercise*Time, and Time*Group interactions ($p > 0.05$ for all). However, there was a multivariate ($p = 0.013$) as well as a univariate ($p = 0.013$) Exercise*Group interaction. Table 2 displays the means and standard deviations of AR as a function of exercise and group. Table 3 shows the results of the simple effects analysis of this interaction, indicating the exact location of the differences.

There were no multivariate and univariate Exercise, Time and Group main effects ($p > 0.05$ for each).