# ACUTE HEMODYNAMIC CHANGES ASSOCIATED WITH DANCE EXERCISES IN FEMALES OF LUSAKA, ZAMBIA

**By:**

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***A dissertation submitted to the University of Zambia in partial fulfilment of the requirements of the degree of Master of Science in Human Physiology.***

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# ABSTRACT

The research was titled; Acute Hemodynamic Changes Associated with Dance Exercises in Females of Lusaka, Zambia. Dynamic exercises are known to elicit hemodynamic changes in the cardiovascular system. Zumba and ZOCA are part of a fast growing group of dance fitness programmes designed to provide a cardiovascular dynamic workout by moving the large muscle groups rhythmically, repetitively and continuously following choreography in synchrony to music. However, despite their growing popularity, very few studies have been done to provide knowledge regarding the hemodynamic changes associated with these dance exercises. The study was a case study in which 27 female participants took part in 60 minutes of either a Zumba or ZOCA class. Using digital blood pressure monitors, recordings of blood pressure and heart rate were taken at three different points. The first readings were taken before commencement of the exercise (baseline measures), the second measurements were taken 30 minutes after exercise (peak exercise time) and at the end of the class (after the cool down choreography which is performed slowly in order to gradually restore the body back to its resting state before exercise). The results obtained were as follows; Mean baseline blood pressures were 118 ±14 mmHg and 77 ±7 mmHg, systolic and diastolic blood pressure, respectively. After 30 minutes of dancing, mean systolic blood pressure increased to 130 ±19 mmHg ($p< 0.05$) while diastolic blood pressure only rose to an average of 80 ± 8 mmHg ($p> 0.05$). At the end of the class (after the cool down phase) mean systolic blood pressure reduced to 109 ± 13 mmHg ($p<0.05$) while diastolic blood pressure reduced to 74 ± 12 mmHg ($p< 0.05$). Heart rate increased from a baseline value of 83 ± 16 beats/min to 124 ± 25 beats/min after 30 minutes of dance exercise ($p< 0.05$) and reduced to 110 ± 17 beats/min at the end of the class ($p< 0.05$). From the heart rate at 30 minutes, the average percentage of maximum heart rate (% HRmax) was calculated to be 65 ±12%. The researchers concluded that Zumba and ZOCA elicited significant hemodynamic changes that can be attributed to these exercises stimulating the cardiovascular regulatory mechanisms sufficiently and hence resulting in autonomic adjustments that were concurrent with dynamic exercise.

# DECLARATION

I declare that this research is my own work and that it has not been submitted by any other person for the acquisition of another postgraduate degree. All the sources of information that were used have been acknowledged appropriately.

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| **…………………………** | **…………………………** |
| Chanda Grace Chisunka. | Date |

# DEDICATION

To my children, I hope this inspires you to achieve greater things.

# ACKNOWLEDGEMENTS

I give thanks to my God for His sufficient grace.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

During the performance of muscular exercise, the cardiovascular system undergoes important adaptive changes depending on the type of exercise. There are broadly two types of muscular activity; dynamic or isotonic exercise and static or isometric exercise. Exercise in which skeletal muscle contraction causes principally a change in length with little change in tension is termed dynamic or isotonic exercise. It involves repetition of low resistance motion and performance of external work; frequent performance increases endurance. Static exercise on the other hand is muscular activity in which the contraction causes principally a change in tension with little change in length, it involves sustained contraction of skeletal muscles against a fixed resistance and does not involve movement of the joints or axial skeleton and hence no external work is performed; regular performance does not increase endurance (Lavie et al., 2001). Most muscular exercise is neither purely dynamic nor purely static. Activities that are predominantly dynamic include walking, running and cycling while those predominantly static include lifting or pushing heavy weights (Punia et al., 2016).

Acute hemodynamic changes during dynamic exercise include increases in heart rate, stroke volume and cardiac output, with relatively little change in mean arterial pressure because systolic blood pressure tends to increase markedly while diastolic blood pressure does not. Thus dynamic exercise may be thought of as causing primarily a volume load on the heart as opposed to a pressure load caused by static exercise (Weippert et al., 2013). With regular endurance exercise, there can be chronic adaptations in the cardiovascular system that improve cardiovascular health such as increase in left ventricular mass and chamber volume without ventricular wall thickening, a phenomenon known as eccentric cardiac hypertrophy (Joyner and Casey, 2015). These adaptations augment stroke volume and thus maximum cardiac output. During maximum exercise, heart rate increases to values of 200 beats per minute (bpm) while stroke volume may also increase from 70ml per beat at rest to 100ml per beat.

Thus maximum cardiac output may reach a value of 20 liters per minute. This increase in stroke volume is also enhanced by training induced increases in blood volume. Blood volume increases due an increase in both red cell mass and plasma volume (Convertino, 2007).

A fairly new phenomenon in the types of dynamic exercises are aerobic dancing classes such as Zumba (Luettgen et al., 2014) and Zambia's own Carribean and African dance (ZOCA). The typical format of a class begins with a warm up dance of 3 to 5 minutes. The dance starts slowly to music and gradually increases in speed for the next 30 to 45 minutes. Heart rate elevates to the target as one performs the dance based movements. The class ends with a 3 to 4 minutes of slow music in order to gradually restore heart rate to resting levels, this is referred to as the cool down and is then followed by stretches (Wolfe, 2016).

Zumba and ZOCA are aerobic dances which involve moving the large muscle groups (in the arms and legs) rhythmically, repetitively and continuously following choreography in synchrony to music. Zumba uses mainly Latin music while ZOCA uses mainly Zambian and Caribbean music. The aim is to offer fun and a high energy cardiovascular workout. Both offer the social aspects of group fitness and support as well as a certified instructor to lead the class. In this study, acute hemodynamic changes in clients taking part in Zumba and ZOCA were measured following their participation in a session of either one of these dance aerobics in order to generate knowledge about the acute effects of dance exercises on hemodynamic parameters in females of Lusaka, Zambia.

### 1.1.1 Arterial Blood Pressure At Rest And In Response To Exercise

Arterial blood pressure regulation like other cardiovascular functions is controlled by the autonomic nervous system. However, the autonomic nervous system is organized as functional reflexes in which sensory signals from receptors is relayed to integrating centers in the central nervous system, the impulses are then transmitted via efferent pathways to the visceral organs to control their activity (Gordan, Gwathmey and Xie, 2015). Integration of cardiovascular reflexes occurs within specialised groups of neurons in the medulla oblongata collectively known as the vasomotor center (Ganong, 2001). The terminations of the afferent fibers (via the vagus and glossopharyngeal nerves) of the cardiovascular reflex are located in the nucleus tractus solitarii (NTS). From the nucleus solitarii, secondary neurons project directly to groups of neurons which formulate modulatory autonomic signals (Shariff and Hou, 2017). Neurons of the caudal ventrolateral medulla (CVLM) and rostral ventrolateral medulla (RVLM) determine the sympathetic tone. They generate excitatory action potentials to the sympathetic preganglionic neurons (SPN) in the spinal cord. Activation of sympathetic efferent nerves to the heart increases heart contractility, rate of relaxation and conduction velocity. In blood vessels, sympathetic activity constricts arteries and arterioles (resistance vessels) which increases vascular resistance and decreases blood flow. When this occurs, the increased vascular resistance causes an increase in arterial pressure. The nucleus ambiguous (NA) and the dorsal motor nucleus of vagus (DMV) have cell bodies of parasympathetic preganglionic neurons. These mediate the parasympathetic component of the cardiovascular reflexes which is opposite from sympathetic activity (Martins-Pinje, 2011). The parasympathetic nervous system acts to decrease cardiac activity in response to fast increases in blood pressure. At rest, the sympathetic and parasympathetic nervous systems function reciprocally and maintain an average normal blood pressure of 120/80mmHg, but it can range from 90/60 mmHg to 130/80 mmHg (Mallett and Dougherly, 2000).

The most important reflex mechanism that moderates the neural regulation explained above and plays an important role in short term control of blood pressure during pathologic and physiologic conditions such as dynamic exercise is known as the baroreceptor reflex. Mechanoreceptors located in the aorta, carotid sinus, atria, ventricles and pulmonary vessels are sensitive to the stretch of the walls of these structures. When the walls are stretched by increased transmural pressure, receptor firing rate increases and this initiates reflex responses of the autonomic nervous system that alter cardiac output and systemic vascular resistance (Swenne, 2013). Increased pressure in the carotid sinus and aorta stretches the carotid sinus baroreceptors and aortic baroreceptors and raises their firing rate. The increased firing rate leads to excitation of the nucleus ambiguous neurons and inhibition of firing of the rostral ventrolateral neurons. This results in increased parasympathetic neural activity to the heart and resistance vessels causing decreased cardiac output and decreased systemic vascular resistance. Since arterial pressure is the product of systemic vascular resistance and cardiac output, arterial pressure is returned toward the normal level. Conversely, decreases in arterial pressure leads to decreased stretch of the baroreceptors and increased sympathetic neural activity and decreased parasympathetic neural activity resulting in increased heart rate, stroke volume and systemic vascular resistance, this raises blood pressure toward the normal level. The primary purpose of the arterial baroreflex is to provide rapid and efficient stabilization of arterial blood pressure on a short term basis. Impaired baroreflexes leads to increased blood pressure variability (Irigoyen and Krieger, 1998).

During exercise, in order to allow for the increase in heart rate and arterial blood pressure that occur with exercise, the arterial (aortic and carotid) baroreflexes are reset to function at the higher prevailing arterial blood pressure of exercise (Michelini et al., 2015).The central command and the exercise- pressor reflex both play a role in the resetting (Gallagher et al., 2001). Resetting of the operating pressure of the baroreflex to a higher pressure enables the baroreflex control of sympathetic nerve activity to be maintained at the resting level despite an increase in pressure produced by a rise in heart rate and cardiac output (Sheriff, 2006).

Typical maximal values of systolic blood pressure during exercise range from 160 to 220 mmHg. Any further increase in systolic blood pressure during exercise is commonly interpreted as hypertensive response. On the contrary, a failure of systolic blood pressure to increase is a hypotensive response. Clinically, both responses may be associated with underlying risk or presence of cardiovascular disease (Porcari, Bryant and Comana, 2015).

The diastolic blood pressure does not change significantly during exercise in spite of the increase in systolic blood pressure. This is because diastolic blood pressure is a parameter mainly determined by cardiac output and peripheral vascular resistance and as the exercise becomes more intense, systemic vascular resistance normally decreases due to exercise- induced metabolite local vasodilation in the exercising muscles (Kubozono et al., 2005). This local vasodilation necessitates the hyperemia in the muscles in order to increase the blood flow to these exercising muscles.

### 1.1.2 Heart Rate At Rest And In Response To Exercise

Heart rate is normally determined by the sinuatrial node (SA) which exhibits automaticity. This intrinsic automaticity, if left unmodified by neurohumoral factors, exhibits a spontaneous firing rate of 100- 115 beats/min. At rest, there is significant vagal tone on the SA node so that the resting heart rate is between 60 to 100 beats per minute (Klabunde, 2012).

During exercise, there is both a withdrawal of vagal tone and an activation of sympathetic activity innervating the SA node. This reciprocal change in sympathetic and parasympathetic activity permits heart rate to increase during exercise. This neural activity is also modified by other regulatory factors such as mechanical input from the muscles (Klabunde, 2012).

In as much as heart rate increases linearly with workload and oxygen consumption, there is a maximum heart rate that an individual can attain known as the **maximum heart rate** (HRmax). Maximal heart rate is often used in exercise physiology and clinical practice in order to develop exercise prescriptions, estimate aerobic fitness levels and as a criterion for achieving maximal exertion in the determination of maximal aerobic capacity (Sarzynski, 2013).

In the determination of an individuals' maximum heart rate, researchers, clinicians, fitness instructors and exercise practitioners often use age-based prediction equations to calculate HRmax. Although many age- based formulae have been proposed, the most commonly used equation is the age- predicted maximal heart rate calculated by subtracting an individuals' age in years from 220 (Zhang et al., 2016). Or more specifically according to Edwards (2015) 226 - age in years (for women) and 220 – age in years (for men).  In order for an individual to achieve a particular benefit of an aerobic exercise, one needs to exercise within a percentage of the maximum heart rate known as the target heart rate.

**Target heart rate** is a specific age- based pulse rate to be achieved and maintained during aerobic exercise to ensure optimal cardiovascular function and to ensure an exercise intensity that maintains the heart rate at 60 % to 85% of the maximum (Fletcher et al., 1995).

Another physiological measure of work and exercise intensity is the **rate pressure product** (RPP), also known as the double product. RPP is an estimate myocardial work (and the resulting oxygen consumption). It is calculated by multiplying the heart rate (number of the times the heart needs to beat) and the systolic blood pressure (the arterial pressure against which the heart is pumping). This index of relative cardiac work relates closely to directly measured myocardial oxygen consumption and coronary blood flow in healthy subjects over a wide range of exercise intensities. Changes in heart rate and blood pressure contribute equally to changes in RPP. Typical values for RPP range from 6000 at rest (HR=50 beats/min; SBP=120 mmHg) to 40,000 (HR= 200 beats/min; SBP= 200mmHg) or above, depending on intensity and exercise mode. Resistance training and upper body exercise produce substantially higher heart rate and blood pressure responses (hence higher RPPs) than more rhythmic exercise with the lower body. This added myocardial work poses an unnecessary risk for coronary heart disease patients with compromised myocardial oxygen supply. The RPP thus provides an objective measure to evaluate the effects on cardiac performance of various clinical, surgical, or exercise interventions (McArdle et al., 2010).

## 1.2 Statement Of The Problem

Non-communicable diseases (NCDs) such as cardiovascular disease, diabetes mellitus, chronic obstructive pulmonary diseases (COPD) and cancers are among the leading causes of morbidity and mortality in the world, with higher rates in developing countries (Islam et al., 2014). The risk of these diseases is significantly reduced by appropriate lifestyle modifications such as increased physical activity (Golbidi and Laher, 2012).

Aerobic exercises result in autonomic modulation of hemodynamic parameters mainly mediated by parasympathetic withdrawal and sympathetic activation. This results in acute cardiovascular changes such as an increase in heart rate, stroke volume, cardiac output and mean arterial blood pressure (Klabunde, 2012). With regular aerobic training, chronic adaptations in the cardiovascular system take place e.g. eccentric cardiac hypertrophy (Joyner and Casey, 2015). In order to produce noticeable or measurable training effects that then result in these adaptations, principles of exercise entail exposing the organism (human systems) to an exercise load or work stress of sufficient intensity, duration and frequency (Åstrand, 2003). Dance exercises are principally dynamic type of exercises that are performed in synchrony to music. The choreography of Zumba and ZOCA dances utilizes mainly the large muscle groups of the arms and legs rhythmically and repetively for an average of 60 minutes per class (Wolfe, 2016). However, investigations into physiological and fitness components of dance and aerobic exercises has mainly concentrated on classical forms such as ballet dancing (Koutedakis and Jamurtas, 2014). Relatively little has been published in relation to modern dance exercises despite their growing popularity (Luettgen et al., 2014). This study sought to generate knowledge about the hemodynamic changes associated with Zumba and ZOCA dance exercises in females of Lusaka, Zambia.

## 1.3 Study Justification

Exercise is an important factor in the prevention and management of obesity and non-communicable diseases (NCDs). According to the African Health Observatory (2010), there are some interventions that have been identified to reduce the prevalence of NCDs, these include: introducing and strengthening physical activities in all schools, community physical/sporting activities and promotion of healthy diets. This study contributes to awareness about the types of exercises that Zambians are already engaging into even as implementation of the above interventions is undertaken.

The study can be used in the formulation of hypotheses for further research related to dance aerobics and similar dance exercises and contributes to The University of Zambia's information in the section of exercise therapy research.

Understanding the hemodynamic changes that occur during dance exercise provides dance aerobics instructors and their client's information needed for them to be more effective in achieving their desired goals of the exercises.

In addition, as far as the researcher's literature review went, there are no documented studies that have been done in Zambia to either quantify or describe the health benefits of dance.

Dance is well received as is evidenced from how fast it's spreading. The way to credit its contribution as an exercise is through research. This study contributes to this.

## 1.4 Research Question

What are the acute hemodynamic changes associated with dance exercises in females of Lusaka, Zambia?

## 1.5 Objectives

### 1.5.1 Main Objective

To determine the acute hemodynamic changes of female participants during a dance exercise session.

### 1.5.2 Specific Objectives

To assess the blood pressure changes of female participants during a dance exercise session

To assess the heart rate changes of female participants during a dance exercise session

### 1.6 Organisation Of Dissertation

The study is presented under six chapters. Chapter one introduces the study by giving the background of the study, which also elaborates the relevance of the study, the problem identified and the objectives. Chapter two presents a review of some literature that relates to the study. Chapter three presents the methodology used in the study and gives a description of the study population, participant recruitment and the study tools used. Chapter four presents the results obtained during the study as they relate to the main and specific objectives of the study. Chapter five discusses the findings of the study and compares and contrasts them to other studies and relevant literature. Chapter six gives a summary of the study findings or conclusions and recommendations for further research.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Physiology Of Hemodynamic Changes During Exercise

Cardiovascular responses during exercise are due to autonomic modulations that consist of nervous system regulation (parasympathetic withdrawal and sympathetic activation) and of mechanical mechanisms (skeletal and respiratory pumps) (Nobrega et al., 2014).

The neural regulation of cardiovascular response during exercise is due to parasympathetic withdrawal and sympathetic activation. Both of these are a function of exercise intensity and the total muscle mass recruited (Fisher, 2013).

The sympathetic system (thoracolumbar division) consists of nerves that originate from the thoracolumbar division of the spinal cord (T1- T4) and innervate target organs while nerves of the parasympathetic originate within the midbrain, pons and medulla oblongata of the brain stem and part of the spinal sacral region (S2 –S4). This autonomic nervous system in turn receives input from the reflex cardiovascular mechanisms via the neurons of vasomotor center in the medulla oblongata.

The cardiac sympathetic preganglionic nerves originate from the upper thoracic segments (T1-T4). These secrete the neurotransmitter acetylcholine. The postganglionic neurons of the sympathetic nervous system release norepinephrine which attaches to adrenergic receptors in the cardiovascular system. β1 receptors are expressed in the heart (in the sinuatrial (SA) node, atrioventricular (AV) node and on atrial and ventricular cardiomyocytes). Activation of β1 receptors increases heart rate (via increased action potentials from the sinuatrial node), increases cardiac contractility as a result of increased intracellular calcium concentrations and increased calcium release from the sarcoplasmic reticulum and increased AV conduction velocity. In addition, activation of sympathetic β1 receptors induces renin release by the kidneys which activates the renin-angiotensin- aldosterone system for the long term regulation of blood pressure, plasma sodium concentration and blood volume. α1 adrenergic receptors are expressed mainly in vascular smooth muscle proximal to sympathetic nerve terminals. Activation elicits vascoconstriction. Low expression is also present in cardiomyocytes, activation of which increases contractility. α2 receptors are expressed in vascular smooth muscles distal to sympathetic nerve terminals. Activation of these receptors also results in vasoconstriction. In summary, the sympathetic nervous system to the cardiovascular system functions to increase heart rate, increase cardiomyocyte contractility, enhance conduction velocity and vasoconstriction (Gordan, Gwathmey and Xie, 2015).

Cardiac parasympathetic preganglionic neurons are located in the motor nuclei of cranial nerves and sacral nerves. These receive activation from the nucleus ambiguous and dorsal nucleus of vagus in the medulla oblongata. Parasympathetic nerves associated with parts of the head are carried by occulomotor, facial and glossopharyngeal nerves. Fibers that innervate organs of the thorax and abdomen are part of the vagus nerve which carries about 75% of all parasympathetic nerve fibers to the heart, lungs and stomach. Sacral nerves S2 – S4 carry impulses to viscera in the pelvic cavity. Both the preganglionic and postganglionic neurons release acetylcholine which binds to muscarinic receptors. In relation to the cardiovascular system, the parasympathetic nervous system has two kinds of muscarinic receptors, M2 and M3 receptors. M2 receptors are expressed in the heart, abundant in nodal and atrial tissue but sparse in the ventricles. Binding of acetylcholine to M2 receptors slows heart rate back to resting sinus rhythm by slowing the rate of depolarization and reducing conduction velocity through the AV node. Parasympathetic activity also reduces contractility of atrial cardiomyocytes thus reducing cardiac output as a result of reducing cardiomyocyte contractility, reducing stroke volume and slowing heart rate. M3 receptors are mainly expressed in vascular endothelium. M3 receptor activation causes dilation of vessels by stimulating nitric oxide production by vascular endothelial cells (Gordan, Gwathmey and Xie, 2015).

Parasympathetic withdrawal and sympathetic activation during exercise therefore results in an increase in cardiac chronotropy (increased heart rate), increase in cardiac inotropy (increased myocardial contractility) to increase stroke volume, at inducing venoconstriction to improve venous return, at increasing vascular resistance in the abdominal viscera and nonactive skeletal muscles and at preserving most of the available cardiac output for the perfusion of the active muscles where metabolic-mediated vasodilation takes place. This neural regulation is also referred to as central command (Fisher, 2013). However, the heart rate increase accounts for a greater proportion of the increase in cardiac output than does the increase in stroke volume during strenuous exercise. The stroke volume normally reaches its maximum by the time the cardiac output has increased only halfway to its maximum. Any further increase in cardiac output must occur by an increase in heart rate (Guyton and Hall, 2006).

Mechanical mechanisms consist of the contribution of respiratory and skeletal pumps. The skeletal pumps play the most important role. The muscle rhythms of contraction occurring during dynamic exercise create intramuscular oscillations which facilitate blood flow to the heart and enhance cardiac preload, thus increasing stroke volume (SV) and also cardiac output (CO), this is achieved by recruiting The Frank-Starling mechanism. In addition, mechanoreceptors and metaboreceptors within muscle reflexively modulate sympathetic tone on the basis of the mechanic and metabolic conditions of the contracting muscle. This is referred to as the exercise pressor reflex (Nobrega et al., 2014). Hypoxia and metabolites produced within endothelial cells of exercising muscles during dynamic exercise stimulate afferent fibers to the medullary regulatory centers. Metabolites include adenosine, prostaglandins and nitric oxide (Casey and Joyner, 2011). These metabolites also increase blood flow in the exercising muscles by causing vasodilation. This vasodilation lowers peripheral resistance.

In the architecture of skeletal muscle vasculature, the skeletal muscle is perfused by a feed artery branching off a major conduit artery. There are then four or six branch orders before the terminal arterioles give rise to capillaries. When the microcirculation is visualized using imaging and video techniques in contracting skeletal muscle, there is marked dilation in all elements of the arteriolar tree, with the most pronounced elements seen in the smallest arterioles (VanTeeffelen and Segal, 2006). However, vasodilation does not only take place in small arterioles, vasodilation occurs even in feed arteries. Vasodilation that starts in the smallest arterioles closest to capillaries in the contracting muscles can ascend to the largest elements of the arteriolar network including feed arteries. This mechanism is dependent on an intact endothelium and appears to be an active process that includes calcium and electrical signaling along the endothelium and between the smooth muscle cells and endothelial cells. And finally, with muscle contractions, the smallest arterioles that vasodilate most vigorously are relatively resistant to sympathetically mediated vasoconstriction (VanTeeffelen and Segal, 2006). Arterioles' being the major site of vascular resistance, their dilation significantly lowers peripheral resistance and maintains diastolic blood pressure at near resting values during exercise. This is because as mentioned earlier, diastolic blood pressure is determined mainly by cardiac output and peripheral resistance. A marked increase in diastolic blood pressure during exercise could therefore result from an inappropriately high cardiac output or impaired vasodilation of resistance vessels within skeletal musculature (Brett, Chowienczyk and Ritter, 1999).

Thus, the hemodynamic changes/adjustments shown during dynamic exercise are achieved by an integration of several inputs from the motor cortex, arterials and skeletal muscle receptors. The cardiovascular controlling center integrates this information and generates hemodynamic adjustments such as an increase in heart rate, increase in myocardial contractility, increase in blood pressure and constriction of the vascular beds of organs and tissues not involved in exercise. Figure 2-1 illustrates some of the factors that contribute to the cardiovascular adjustments occurring during dynamic exercise.

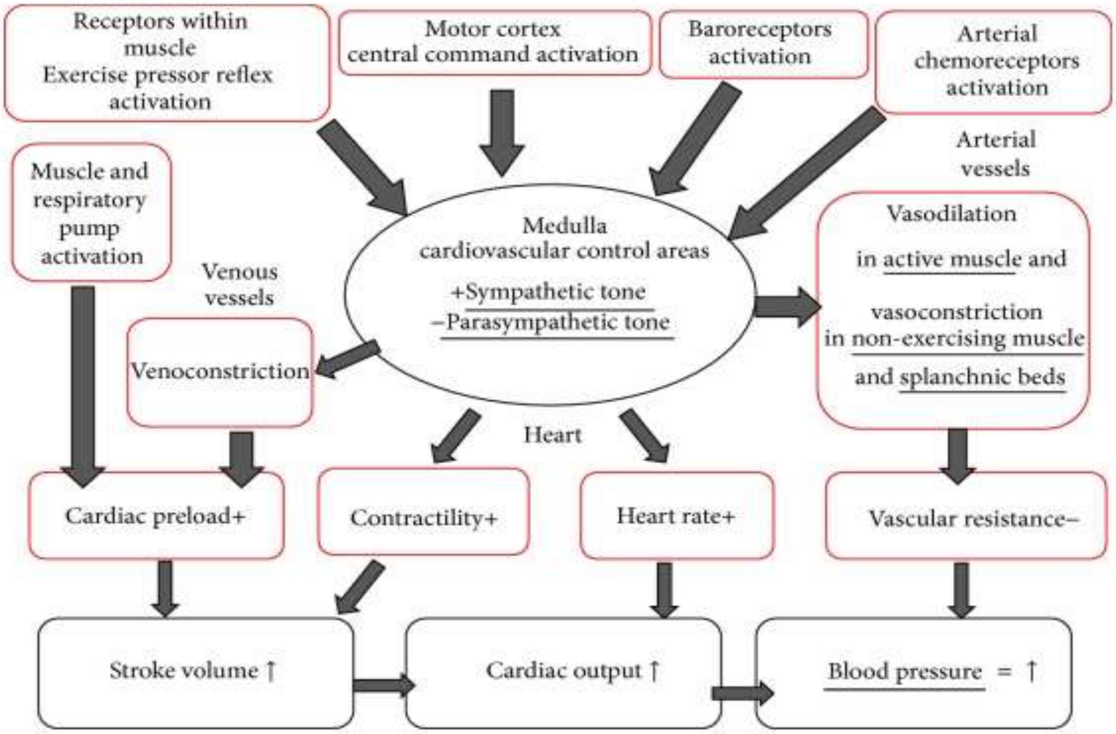

Figure 2:1 Factors that integrate and result in cardiovascular adjustments during dynamic exercise (Nobrega et al., 2014).

## 2.2 Cardiovascular Adaptations To Regular Exercise

Regular dynamic exercise promotes several cardiovascular adjustments, including remodeling of the heart and skeletal muscle circulation, improvement of autonomic control of the heart, and resting bradycardia, a marker of exercise training. Trained individuals exhibit faster ventricular filling, increased myocardial contractility with larger stroke volumes, increased capillary supply, predominance of arteriole vasodilator responses with larger exercise induced muscle blood flow. These cardiac and skeletal muscle adaptations maintain cardiac output with less energy expenditure and thus a lower heart rate (Martins- Pinge, 2011).

Fagard (2003) reported that athlete’s had larger left ventricular diameters, larger left ventricular mass and higher ventricular wall thickness, significant higher posterior wall thickness and interventricular septal thickness. Apart from these structural adaptations, athlete’s also had high stroke volumes which were attributed to them having higher end-diastolic volumes. Therefore, at rest, cardiac output of trained (well exercised) individuals is reached by higher stroke volumes and lower heart rates.

In achieving adaptations due to exercise, the overload principle needs to be applied. Principles of physical training entail exposing the body systems to a training load or work stress of sufficient intensity, duration and frequency in order to produce a noticeable or measurable training effect i.e. an improvement of the function for which one is training. In order to achieve such a training effect, it is necessary to expose the organism to an overload, that is, to a stress which is greater than the one regularly encountered during activities of daily living (Åstrand et al., 2003).This principle is based on the need to train the body at a level beyond that at which it normally performs. Therefore, overload should be a training stimulus, sufficient for chronic adaptations to occur. Exercise frequency, duration and intensity are the variables most often manipulated to provide overload to the systems of the body with specific consideration given to the mode of exercise (Frontera, 2007). These variables are given under the basic recommendations for the quality and quantity of cardiorespiratory exercise for apparently healthy adults as laid down by the American College of Sports Medicine (ACSM) given below;

- Adults should get at least 150 minutes of moderate-intensity exercise per week.
- Exercise recommendations can be met through 30-60 minutes of moderate-intensity exercise (five days per week) or 20-60 minutes of vigorous-intensity exercise (three days per week).
- One continuous session or multiple shorter sessions (of at least 10 minutes) are both acceptable to accumulate desired amount of daily exercise (American College of Sports Medicine [ACSM], 2011).

The American Heart Association (2014) also recommends that emphasis should be on aerobic physical activities at moderate intensity, as part of an active lifestyle, for at least 150 minutes per week in bouts of 10 minutes or more. Or 75 minutes per week of vigorous physical activity, or a combination of the two.

## 2.3 Review Of Current Studies Assessing Effects Of Dance Aerobics On The Cardiovascular System

Dance exercise is principally an isotonic type of exercise that is performed in synchrony to music. In particular, dance exercise classes utilize mainly the large muscle groups in the arms and legs rhythmically and repetitively for an average of 60 minutes. During this time, there are acute hemodynamic changes that occur (such as an increase in heart rate, increase in stroke volume and cardiac output). With regular aerobic training, chronic adaptations in the cardiovascular system take place such as eccentric cardiac hypertrophy (Fernandes and Oliveira, 2011). It is on this basis that exercise programmes are undertaken. However, investigations into physiological and fitness components of dance and dancers has mainly concentrated on classical forms of dance such as ballet (koutedakis and Jamurtas, 2004). Relatively little has been published in relation to modern types of dance such as Zumba and ZOCA. The following are some studies which the researcher reviewed relating to these dance aerobics.

In a study carried out by the American Council on Exercise to determine the average exercise intensity and energy expenditure during a typical Zumba fitness class, researchers found that the average heart rate (HR) of their participants during the class was 154 beats per minute (bpm), which was roughly 80 percent of the average predicted maximum heart rate (HRmax) for the subjects. The researchers reported that this was within the fitness industry guidelines which suggest exercising in the range of 64 percent to 94 percent of HRmax in order to improve cardio endurance. The researchers concluded that Zumba may feel like a party, but that it’s also a highly effective workout (Luettgen et al., 2014).

Donath et al. (2013) carried out a study in which they provided instructed Zumba training to thirty female college students twice per week for eight weeks. They found that clients performed better on a six minutes walk test after the eight weeks of Zumba than they had done prior to it ($p<0.001$). They concluded that Zumba training had resulted in an improvement in cardiovascular endurance. However, in the same study, trunk flexibily and lower extremity strength did not change significantly ($p<0.05$). This was in accordance with the findings of Barene et al. (2014) in which they found that after 9 months of Zumba training (two to three one hour sessions of Zumba per week for the first three months and once a week for another 6 months), no significant intervention effects were revealed in trunk flexibility ($p<0.05$) nor in vertical jump height ($p<0.05$) among the participants.

The health enhancing effects of Zumba are also supported by the work of Domene et al. (2015) in which they evaluated, among other things, the physiological effects of Zumba on cardiovascular risk factors and inflammatory biomarkers in overweight and physically inactive women. Participants were randomly assigned to either engaging in one or two one hour classes of Zumba fitness weekly. Laboratory assessments were conducted pre (week 0) and post- intervention (week 8). In the intervention group, maximal oxygen uptake significantly increased ($p<0.05$), percentage of body fat significantly decreased ($p<0.05$) and interleukin 6 and white blood cell count both significantly decreased ($p<0.05$). They concluded that Zumba fitness was an efficacious health-enhancing activity for adults.

More studies need to be done in order to have comparable results from which conclusions can be made about the physiological and metabolic effects of dance exercises such as Zumba and ZOCA.

# CHAPTER THREE

# METHODOLOGY

## 3.1 Study Design

The research was a case study.

## 3.2 Study Setting

The study was conducted at Chez Nthemba Sports Club, Intercontinental Hotel Gym and Olympia Fitness Centre. Study sites were identified by visiting Gyms/Fitness centres closest to the University of Zambia, Ridgeway Campus and by referral from the instructors at the visited Gyms/Fitness centres. The researcher then paid a visit to the different gyms to find out whether they had a dance class, after which permission to conduct the study was sought from the management at the study sites and from the respective instructors who offered dance exercise classes.

The three selected study sites were found to have dance exercise instructors with either a Zumba Fitness or ZOCA Dance instructor licence.

## 3.3 Study Population

The study population included all members of the selected study sites attending dance exercise classes. These were between the ages of 18 and 56. A preliminary visit to the study sites revealed that only females were taking part in both Zumba Fitness and ZOCA Dance classes.

Therefore, the study population included adult female members of Zumba Fitness or ZOCA dance exercise classes who met the inclusion criterion and gave consent to taking part in the study.

### 3.4 Participant Recruitment

Convenience sampling was the method used in this study. In every session that data were collected, the first two volunteering clients were selected to take part in the study for that day. Data were collected within a period of one month at each study site. During this duration, 27 dance exercise clients were recruited and took part in this study.

### 3.5 Inclusion Criterion

The inclusion criterion was all dance exercise class members above the age of 18 who had normal measures of blood pressure and heart rate at rest, had attended at least one dance exercise class prior to the day of data collection and gave consent to taking part in the study.

Normal blood pressure at rest was taken to be in the range of 90/60 mmHg to 130/80 mmHg (Malett and Dougherly, 2000).

Normal range of heart rate was considered to be 60 to 100 beats per minute (Edward, 2014).

### 3.6 Exclusion Criterion

Dance exercise class members who were below the age of 18 and those who did not have normal measures of blood pressure and heart rate at baseline were excluded from the study.

### 3.7 Data Collection Procedure

All consenting participants were given a table to fill in demographic information before the start of the dance exercise session (appendix I). Demographic information included information such as date of birth, age, gender and how long that client had been taking dance as an exercise.

Blood pressure and heart rate measurements were collected using a Digital Wrist Blood Pressure Monitor (Brand; Citizen Micro HumanTech, Model; CH- 618). Each time measurements were taken, the client was asked to sit down and rest their hand on a table so that their hand was approximately at the level of the heart. The sphygmomanometer was then strapped at the wrist and the measurement taken.  Each session in which data were collected lasted approximately 60 minutes and all participants in a particular session started the exercise at the same time. Dance classes were on average, three times per week. Measurements of blood pressure and heart rate were collected three times for each participant during a single session.

The first measurements were taken before the start of the exercise session. A consenting client was asked to take a five minutes rest on a chair before these baseline measurements were taken. These were also taken in order to exclude participants who might have blood pressures and heart rates outside the normal resting ranges for a normal adult. Such clients were advised to consult with a Physician for medical advice.

The second measurement was taken after 30 minutes of exercise. At this time, it was expected that the client would have exercised for enough time to reach their aerobic target heart rate and exercising blood pressure. The measurements at this time are referred to as the aerobic measurements in this study to indicate that these measurements were taken during the aerobic phase of the dance exercise session. Instructors also gave a one minute break at this time for clients to refresh and it was immediately at the start of this break that measurements were taken.

The third measurement was taken after 60 minutes, that is, at the end of the session, after the cool down choreography. Towards the end of the dance exercise class, for the last approximately 5 minutes, the instructor reduces the tempo of the choreography, this is referred to as the ‘cool down’ phase. This is important because an effective cool down aims to restore the body back to its resting state before exercise. Aside from bringing body temperature and heart rate down, the cool down helps the body to dispose of waste products (such as lactic acid) and toxins produced during exercise which would otherwise contribute to muscle soreness (Weippert et al., 2013).

### 3.8 Data Recording Procedure

Demographic information and measurements of blood pressure and heart rate were recorded in a table (Appendix I). The information was then entered in a Microsoft Excel Spreadsheet in readiness for analysis.

### 3.9 Data Analysis

Continuous variables (such as age, systolic blood pressure, diastolic blood pressure and heart rate) were summarized using means, medians and standard deviations.

Paired t-tests were used to determine statistical significance of the change in the variables between baseline and 30 minutes, between 30 minutes and 60 minutes and between baseline and 60 minutes.

Data analyses were done using STATA version 12.

Data were presented in tables and graphs for clearer display of the results.

### 3.10 Limitations

The hemodynamic parameters were measured only once for each phase of exercise. Taking atleast three measurements and then calculating the average would have minimised possible errors made during the procedure of taking measurements. However, the necessary client preparation was done precisely to minimise errors. This included asking the client to sit with the arm resting at the level of the heart, showing the sphygmomanometer to the client in advance and assuring them that the sensation of tightening on the wrist was safe (to avoid anxiety) and explaining that they were to avoid unnecessary movements and talking while measurements were being taken.

### 3.11 Ethical Considerations

Participation in the study was voluntary and participants were informed that they were not obliged to continue exercising for the purpose of the study in an event that they experienced symptoms such as dizziness, shortness of breath or chest discomfort. It was explained that although it is rare in healthy adult individuals, certain changes may occur during aerobic exercise, including abnormal blood pressure, fainting, abnormal heart rate and other side effects of exercise and that if this happened, it would be advisable for that client to stop the exercise and thereafter, to consult with their doctor.

Measurements were taken using a digital blood pressure monitor both to optimise the accuracy of the change in hemodynamic measurements and also to ensure that the participants were only minimally disturbed during their exercise session.

All sessions in which data were collected were choreographed by a licensed dance instructor to ensure that the session was typical of the dance exercise and to ensure the safety of the clients as the licensed instructors are taught how to monitor their clients.

Participants were not identified by name but using numbers and written consent was obtained for each participant.

Participants were also told that the information obtained would be used by the researcher as partial fulfillment for the obtainment of a Master of Science in Human Physiology Degree, and would also be published for statistical or /and scientific purposes.

Permission to carry out the study was sought from ERES COVERGE and from the Fitness Instructors of the Zumba Fitness and ZOCA at the different study sites.

# CHAPTER FOUR

# RESULTS

## 4.1 Basic Characteristics Of The Study Participants

The total sample consisted of 27 adult females. The age range was 18 to 56 with a mean of 36 years. Of these, 12 (44.4%) had been taking dance exercise for a period of more than one year, 11 (40.7%) for a period of 1-12 months and 4 (14.8%) for less than 4 weeks.

## 4.2 Hemodynamic Parameters

### 4.2.1 Systolic Blood Pressure

Systolic blood pressure was measured at baseline, 30 minutes and also 60 minutes after exercise. Baseline mean systolic blood pressure was 118 ±14 mmHg. After 30 minutes of exercise (during aerobic phase), mean systolic blood pressure increased to 130 ±19 mmHg ($p< 0.05$). 60 minutes after exercise (cool down phase), mean systolic blood pressure reduced to 109 ± 13 mmHg ($p<0.05$).

**Table 4-1:** Systolic Blood Pressure Changes

| **Characteristics** | **Mean** | **Median** | **Range** | **SD** | **P-value** |
|---|---|---|---|---|---|
| Baseline systolic BP, (mmHg) | 118 | 116 | 93-142 | 14 | 0.0052[a] |
| Systolic BP 30min after training (mmHg) | 130 | 132 | 97-165 | 19 | <0.0001[sc] |
| Cool down systolic BP (mmHg) | 109 | 106 | 88-129 | 13 | 0.0005[b] |

SD (standard deviation). SBP (Systolic blood pressure). [a]Paired t-test p-value for baseline mean and 30 minutes after training systolic blood pressures. [sc]Paired t-test p-value for systolic BP 30min after training and cool down systolic BP. [b]Paired t-test p-value for baseline and cool down systolic blood pressures

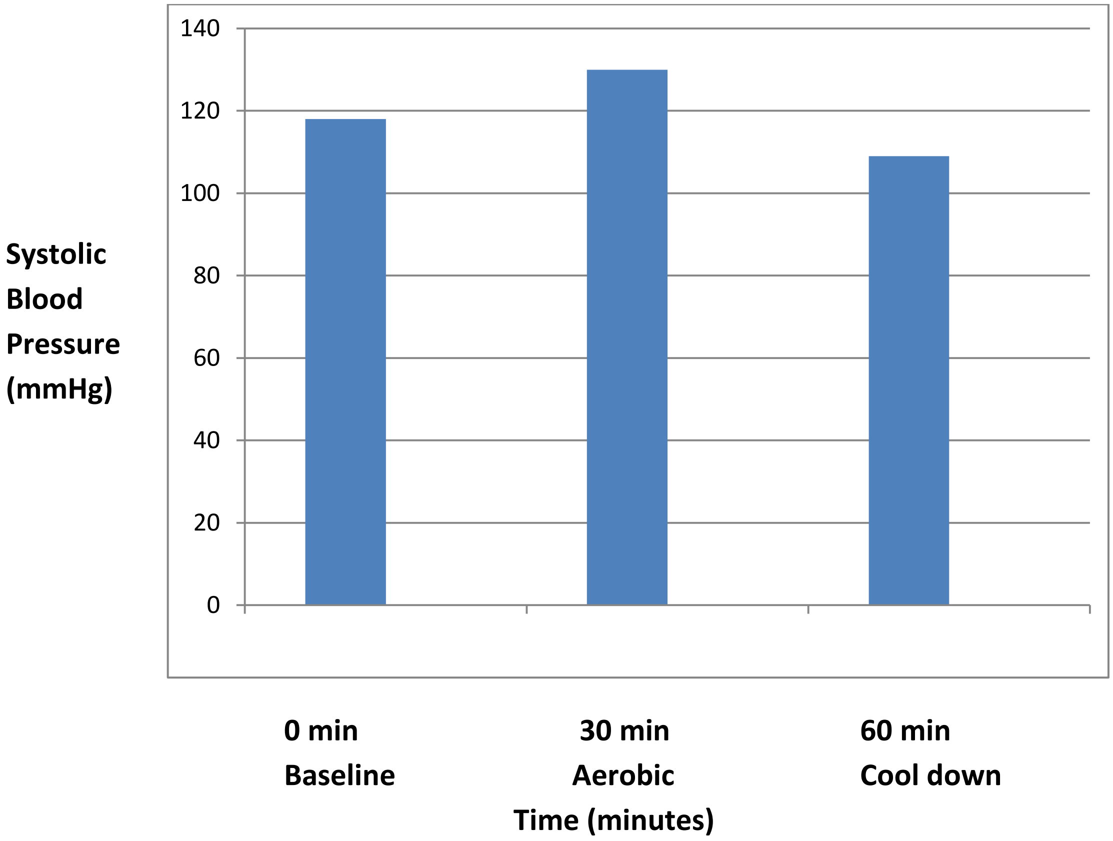

**Figure 4-1:** Mean systolic blood pressures at baseline (0min), during the aerobic (30 min) and cool down phases (60 min) of the dance exercise.

### 4.2.2 Diastolic Blood Pressure

Diastolic blood pressure was measured at baseline, 30 minutes and 60 minutes after exercise. The mean diastolic blood pressure at baseline was 77 ±7 mmHg and showed no significant change after 30 minutes of dance exercise as it only rose to 80 ± 8 mmHg ($p > 0.05$). At the end of the class, diastolic blood pressure reduced to 74 ± 12 mmHg ($p < 0.05$).

**Table 4-2:** Diastolic Blood Pressure Changes

| **Characteristics** | **Mean** | **Median** | **Range** | **SD** | **P-value** |
|---|---|---|---|---|---|
| Baseline diastolic BP (mmHg) | 77 | 79 | 64-86 | 7 | 0.1237$^{c}$ |
| Diastolic BP 30min after training (mmHg) | 80 | 81 | 67-110 | 8 | 0.0012$^{dc}$ |
| Cool down diastolic BP (mmHg) | 74 | 74 | 53-106 | 12 | 0.1123$^{d}$ |

SD (standard deviation). DBP (diastolic blood pressure). $^{c}$Paired t-test p-value for baseline mean DBP and mean DBP 30 minutes after exercise. $^{dc}$Paired t-test for mean DBP 30min after exercise and mean DBP after 60 minutes of exercise. $^{d}$Paired t-test p-value for mean DBP at baseline and mean DBP 60 minutes after exercise.

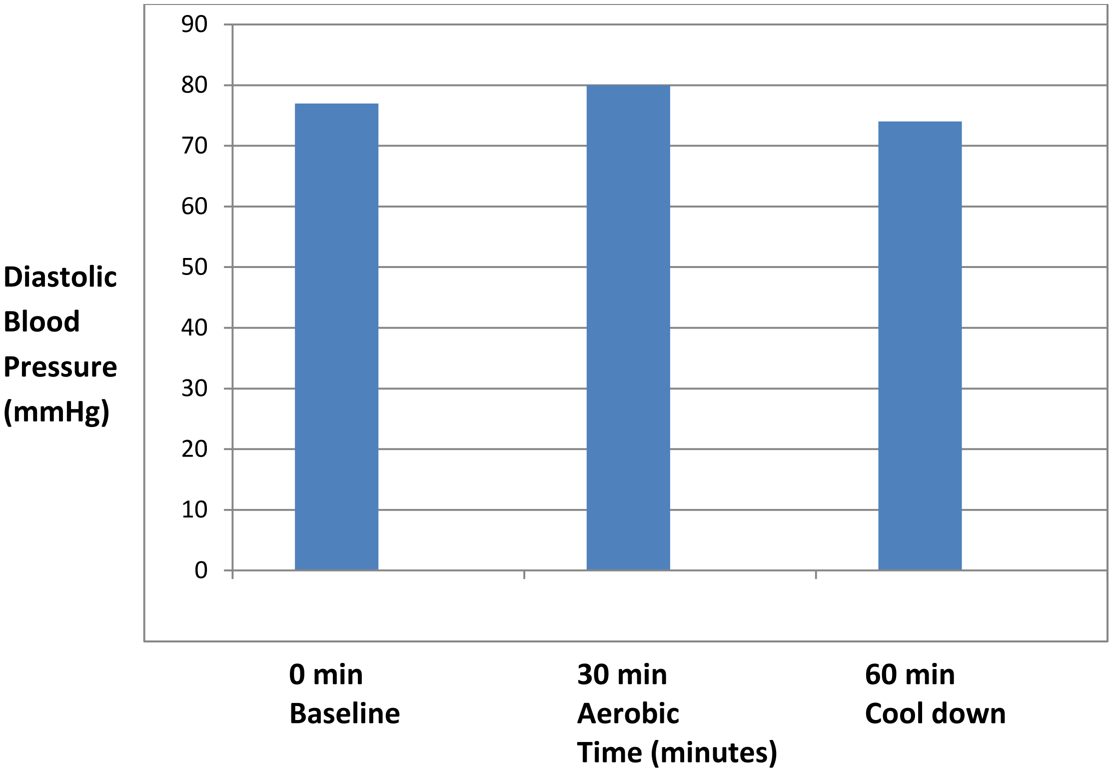

**Figure 4-2:** Mean diastolic blood pressures at baseline (0min), during the aerobic (30 min) and cool down phases (60 min) of the dance exercise.

### 4.2.3 Heart Rate (HR), Maximum Heart Rate (HRmax) And Percentage Of Maximum Heart Rate (%HRmax)

Heart rate was measured three times for each participant, at baseline, 30 minutes after exercise and 60 minutes after exercise. The means for heart rate were 83 ± 16 , 124 ± 25 and 110 ± 17 beats per minute (bpm) respectively. The mean heart rates recorded 30 minutes after exercise and also 60 minutes after exercise were statistically higher than the mean heart rate at baseline ($p<0.05$). Using the age-predicted formula for women (i.e., 226- age), the maximum heart rate was calculated first for each participant and then the mean maximum heart rate for the participants was calculated and found to be 190 bpm. Furthermore, using the heart rates measured at 30 minutes after exercise, and the maximum heart rates of the participants, the percentage of maximum heart rate during the aerobic phase of exercise was calculated for each participant. The average percentage of maximum heart rate was 65% (41-96) in this study. Details of these characteristics are outlined in table 4-3.

**Table 4-3:** Heart rate, maximum heart rate and percentage of maximum heart rate

| **Characteristics** | **Mean** | **Median** | **Range** | **SD** | **P-value** |
|---|---|---|---|---|---|
| Baseline heart rate (bpm) | 83 | 80 | 59-109 | 16 | |
| Heart 30min after exercise (bpm) | 124 | 119 | 80-184 | 25 | <0.0001[e] |
| Cool down heart rate (bpm) | 110 | 110 | 68-139 | 17 | <0.0001[f] |
| Maximum heart rate (HRmax) | 190 | 189 | 68-208 | 10 | |
| Percentage (%) of Maximum heart rate | 65 | 63 | 41-96 | 12 | |

SD (standard deviation). [e]Paired t-test p-value for mean baseline HR and mean HR 30 minutes after exercise. [f]Paired t-test p-value for mean baseline HR and mean HR after 60 minutes.

# CHAPTER FIVE

# DISCUSSION

## 5.1 Assessment Of Blood Pressure Changes

### 5.1.1 Systolic Blood Pressure Changes

In healthy adults, during acute aerobic exercise, systolic blood pressure increases linearly in relation to the exercise intensity (Kokkinos, 2010). The systolic blood pressure of the participants in this study showed a significant increase between baseline and the aerobic phase of exercise ($p<0.05$) and also between the aerobic phase and the cool down phase of the exercise session ($p<0.05$). This significant increase in systolic blood pressure during the aerobic phase of dance exercise demonstrates that the exercise intensity of Zumba and ZOCA was sufficient to elicit cardiovascular reflex activity that influenced the autonomic nervous system to increase cardiovascular activity. This is because the neural regulatory mechanism’s (central command) response of the cardiovascular system to acute exercise is a result of an integration of information from the metaboreflex of the exercising muscles and the arterial baroreflex (Michelini et al., 2015). The neural regulation of the cardiovascular system responds to acute exercise by parasympathetic withdrawal and sympathetic activation. Sympathetic activation results in activation of β1 adrenergic receptors in the sinuatrial node, atrioventricular node, atrial and ventricular cardiomyocytes resulting in increased action potentials from the sinuatrial node, increased atrioventricular conductivity and increased cardiac contractility (Gordan, Gwathmey and Xie, 2015). The resultant effect is increased heart rate, stroke volume and hence cardiac output. Sympathetic activation also results in vasoconstriction via activation of α1 and α2 receptors of vascular smooth muscle. Vasoconstriction then leads to increased venous return and increased vascular resistance. A further increase in venous return is caused by the muscle pumps of exercising muscle groups’, these are muscle rhythms of contraction and relaxation which facilitate blood flow to the heart. An increase in venous return increases end-diastolic volume which increases resting fiber length of cardiomyocytes and results in a further increase in the force of contraction. This increase in the force of contraction results in an increased stroke volume and subsequently an increased cardiac output, a phenomenon explained by The Frank-Starling mechanism (Nobrega et al., 2014). Apart from increasing venous return, vasoconstriction increases vascular resistance in abdominal viscera, this is important so that cardiac output can be preserved for the exercising muscles were local vasodilation occurs due to the effect of local metabolites (such as nitric oxide, prostaglandins and adenosine) produced during muscular activity. The metabolites also activate metaboreceptors in the exercising muscles, these together with mechanoreceptors, send afferent input to the vasomotor center to reflexively increase sympathetic tone (exercise-pressor reflex). Both the increased cardiac output and increased vascular resistance contribute to the increased arterial blood pressure observed during dynamic exercise (Martins-Pinge, 2011). In addition to the contribution of the central command and exercise-pressor reflex, an increase in systolic blood pressure is also possible due to an effective baroreflex resetting. The arterial baroreflex is responsible for maintaining a stable arterial blood pressure on a short term basis and therefore, to allow the physiological increase in arterial blood pressure that occurs with dynamic exercise, this reflex is reset to operate at the prevailing higher arterial blood pressure (Michelini et al., 2015). In this study, an effective increase in systolic blood pressure during the aerobic phase of dance exercise suggests that effective baroreflex resetting occurred in the study participants. In summary, the significant increase in systolic blood pressure from baseline to the aerobic phase of this study suggest that the intensity of the Zumba and ZOCA exercises was sufficient to stimulate the exercise-pressor reflex input to the vasomotor center with resultant neural modulation and baroreflex resetting that facilitated the increase in systolic blood pressure.

In order to promote and integrate scientific research and practical application of sport and exercise science for the maintenance and enhancement of physical performance, fitness, health and quality of life, certain membership organizations formulate guidelines for professionals and individuals to adhere to. The American College of Sports Medicine is one such organization and its guidelines in the field of sport and exercise are considered to be the ‘gold standard’ in the health and exercise industry. According to the American College of Sports Medicine (2011), adults should get at least 150 minutes of moderate-intensity exercise per week for the maintenance and improvement of cardiorespiratory health. In this study, Zumba and ZOCA sessions were routinely offered for 60 minutes per session, three times per week. With the significant increase in mean systolic blood pressure recorded during the aerobic phase of exercise, it can be said that the guidelines of Zumba and ZOCA comply with the guidelines for the duration and intensity of exercise for adults.

### 5.1.2 Diastolic Blood Pressure Changes

In this study, the means of diastolic blood pressure before the dance exercises and during the aerobic phase of exercise were not statistically different ($p>0.05$), showing that diastolic blood pressure did not change significantly during this period of exercise. This finding is in agreement with literature reviewed that states that in healthy individuals, diastolic blood pressure does not change significantly during dynamic exercise in spite of the increase in systolic blood pressure (Kubozono et al., 2005).

The diastolic blood pressure is defined as the minimum pressure experienced in the aorta when the heart is relaxing before ejecting blood into the aorta from the left ventricle, often approximately 80mmHg (Homan and Cichowski, 2018). Together with cardiac output, one of the important determinants of arterial blood pressure is total peripheral resistance. It a reflection of the countervailing force against cardiac blood flow in the microvasculature. Multiple factors affect total peripheral resistance and those directly proportional to it include vessel diameter, total vessel length, blood volume and blood viscosity. An increase in any of these parameters results in an increase in total peripheral resistance and hence an increase in blood pressure and vise versa (Hill et al., 2018). During diastole, the heart is relaxed, not ejecting a stroke volume and hence during this part of the cardiac cycle, the blood pressure is mainly affected by the peripheral resistance.

During dynamic exercise, local metabolites produced in the exercising muscles cause vasodilation which then lowers peripheral resistance. Although the vasomotor center is the nervous control center of vessel diameter, arterioles and precapillary sphincters are affected by accumulation of local vasodilator metabolites such as adenosine, potassium, nitric oxide, prostanoids and adenosine triphosphate (Clifford and Hellsten, 2004). These local effects override the vasomotor center through a process called autoregulation and increase the rate of exchange of materials between tissue cells and the capillaries. In addition to vasodilator metabolites, local mechanisms maintaining vasodilation and hence a high blood flow in exercising muscle include a fall in partial pressure of oxygen, a rise in tissue partial pressure of carbondioxide, a decreased pH and an increased temperature (Ganong, 2001). A marked increase in diastolic blood pressure during dynamic exercise could therefore result from an inappropriately high cardiac output or impaired vasodilation of resistance vessels within skeletal musculature (Brett, Chowienczyk and Ritter, 1999). Apart from the short term vasodilation, sustained postexercise vasodilation (resulting in postexercise reduction in blood pressure) typically lasts in excess of 2 hours following moderate-intensity aerobic exercise (Halliwill et al. (2013). Previous work by McCord and Halliwill (2006) had demonstrated that the sustained postexercise vasodilation is dependent on the activation of histamine H1 and H2 receptors and that combined antagonism of these receptors reduces postexercise vasodilation by 80% and postexercise hypotension by 65% following 60 min of moderate-intensity cycle ergometry in both sedentary and endurance-trained athletes. These findings are important because they prompt further investigations into possible benefits that may result from such responses to aerobic exercise.

## 5.2 Assessment Of Acute Heart Rate Changes

### 5.2.1 Baseline Heart Rate

The heart's electrical activity is initiated by specialized cardiac pacemaker cells residing in the sinoatrial node, often referred to as the SA node (Yanjiv, Tsutsui and Lakatta, 2015). The electrical impulse is then transmitted by perinodal cells to the right atrium and then through the rest of the heart's electrical conduction system, resulting in myocardial contraction (Kashou and Kaushou, 2017). The intrinsic electrical automaticity of the SA node determines the heart rate (Klabunde, 2012). At rest, the SA nodal myocytes depolarize at a regular rate between 60 and 100 impulses/minute which is considered the normal resting heart rate (Kashou and Kashou, 2017). In this study, participants had an average baseline heart rate of 83 beats per minute which was within the physiological limits. It was important that all participants have heart rate within the normal range at baseline so that changes measured during the course of the exercise session could be attributed to the physiological effects of the dance exercises.

The rate and rhythm of spontaneous action potential firing of sinoatrial nodal cells (SANC) are regulated by stochastic mechanisms that determine the level of coupling of chemical to electrical clocks within cardiac pacemaker cells. These rhythmic clocks are the ion channels (and currents) on the surface membrane of the SA node referred to as the membrane clock (M clock) or voltage clock and calcium channels and currents on the sarcoplasmic reticulum referred to as the calcium clock (Ca2+ clock). In spontaneously firing SANC, the M and Ca2+ clocks do not operate in isolation, but work together and are called a coupled clock system. These clocks work together via numerous interactions modulated by membrane voltage, subsarcolemmal Ca2+, protein kinase A (PKA) and Calcium/clamodulin protein kinase II (CaMKII)-dependent protein phosphorylation. Through these interactions the two subsystem clocks become mutually entrained to form a robust, stable, coupled-clock system that drives normal cardiac pacemaker cell automaticity. The coupled- clock system is modulated by autonomic signaling from the brain via neurotransmitter release from the vagus and sympathetic nerves (Yanjiv, Tsutsui and Lakatta, 2015). The influence of the autonomic modulation allows heart rate to vary depending on various environmental and physiological factors. During exercise, there is both a withdrawal of vagal tone and an activation of sympathetic activity innervating the SA node. This reciprocal change in sympathetic and parasympathetic activity permits heart rate to increase during exercise. This neural activity is also modified by other regulatory factors such as mechanical input from the muscles (Klabunde, 2012).

Spontaneous diastolic depolarization (DD) is the essence of cardiac pacemaker cell automaticity. This is the absence of a stable resting potential during diastole, but instead, there is a smooth transition from maximum diastolic (resting) potential (MDP, -70mV) to the threshold (-40mV) for the initiation of a new action potential. The diastolic depolarization is also referred to as the pacemaker phase or phase 4. The contributions of the membrane clock and calcium clocks to cardiac pacemaker cell automaticity are discussed in the following paragraphs.

Voltage clock. The voltage clock is mainly governed by the 'funny current', which is an inward influx of sodium and potassium. The hyperpolarisation- activated cyclic-nucleotide gated (HCN) channel is responsible for the funny current. This pump is activated by hyperpolarization which occurs during the last phase of the SA node action potential. This current provides an inward depolarizing current that contributes to diastolic depolarization. At the same time, there is a reduction in outward K+ currents that occurs during hyperpolarisation. Additionally, the delayed rectifier K+ currents which are responsible for repolarisation of the SA node action potential decay following repolarisaton, allowing the funny currents and other inward currents to depolarize the cell. SA node myocytes express both L-type and T-type Ca2+ channels. During the last phase of diastolic depolarization, the T-type Ca2+ channels are activated and this inward Ca2+ current contributes to the final phase of diastolic depolarization (Bartos, Grandi and Ripplinger, 2015).

Calcium clock. During late diastolic depolarisation (DD), there is occurrence of subsarcolemmal local Ca2+ releases (LCR's). SANC have vast sarcoplasmic reticulum calcium (SERCA) 2 pumps in the cytoplasm and ryanodine receptors (RyR) in the subsarcolemmal space. Local calcium releases emanate from sarcoplasmic reticulum via RyRs following the dissipation of a prior action potential and peak during the late DD, as they merge with the cytosolic Ca2+ transient triggered by the next AP. This means local calcium releases induce late diastolic Ca2+ elevations (LDCAE). This Ca2+ elevation results in activation of soldium-calcium exchange channels (NCX). Sodium is transported into the cell as calcium is transported out of the cell.. Due to this calcium going out while sodium comes in, the activation threshold of L-type calcium channels is reached at -50mV to -40mV. Activation of L-type Ca2+ channels during the late DD results in the generation of the AP rapid upstroke, which then triggers a global SR CA2+ release. This coupled system of intracellelular Ca2+ clocks and surface membrane voltage clocks controls the timekeeping mechanism of the hearts pacemaker (Lakatta, Maltsey and Vinogradova, 2010).

### 5.2.2 Heart Rate During The Aerobic Phase Of Exercise

The mean heart rate of the study participants during the aerobic phase of the exercise (at 30 min) was significantly higher than the baseline (0 min) value ($P<0.05$). During aerobic exercise, heart rate increases primarily due to reduced cardiac parasympathetic neural activity (cPNA), i.e. parasympathetic withdrawal. Central command and rapid feedback from muscle mechanoreceptors contributes to initial parasympathetic withdrawal, while loading of the cardiopulmonary baroreceptors (due to an increase in venous return secondary to muscle pump action) likely also elicits parasympathetic withdrawal as well cardiac sympathetic neural activation (cSNA). Both parasympathetic and sympathetic neural activity regulate heart rate throughout the entire exercise continuum with the relative balance shifting from predominantly parasympathetic control at rest and low intensities to mainly sympathetic control at higher intensities (Michael, Graham and Davis, 2017). The sinuatrial node has both sympathetic and parasympathetic innervations. Sympathetic β1 adrenergic receptors of the SA node, when activated by norepinephrine, increase its action potential firing rate and thus results in an increase in heart rate. Activation of β1 receptors also increases contractility as a result of increased intracellular calcium concentrations and increased calcium release by the sarcoplasmic reticulum and increased atrioventricular node conduction velocity. The sinus node also has parasympathetic muscarinic (M2) receptors, the binding of acetylcholine to M2 receptors serves to slow heart rate till it reaches normal sinus rhythm (Gordan, Gwathmey and Xie, 2015). As exercise intensity increases further, progressive baroreceptor resetting as well as afferent feedback from muscle metaboreceptors trigger further cardiac parasympathetic withdrawal and sympathetic activation, the latter of which is increasingly augmented from moderate to maximal intensity by systemic-adrenal activation. This is because as intensity increases, the augmented activity of the adrenergic neurons stimulates increased adrenal gland release of epinephrine (and to a lesser extent norepinephrine) into the bloodstream. These adrenal hormones perpetuate and broaden the sympathetic response to exercise by increasing energy mobilization, energy redistribution and cardiovascular responsivity. Catecholamines do so rapidly by activating glycogenolysis and gluconeogenesis. Epinephrine also augments the supply of free fatty acids to the heart and to the muscles.

Adrenal hormones also raise blood pressure and cardiac output (Berne et al., 2007). The above review emphasizes the knowledge that the muscle activity is the trigger of the reflex response to exercise, a significant increase in heart rate during Zumba and ZOCA suggest that the intensity of the dance participants was adequate to elicit the above mentioned mechanisms of aerobic exercise.

A further extrapolation of the heart rate during the aerobic phase of exercise is the analysis of the maximum heart rate during this phase of exercise. Zakynthinaki (2015) explains that if the heart is viewed as a simple pumping machine, it would be expected to have a minimum and maximum pumping capacity. These would depend on factors such as its size, shape and its intrinsic mechanical characteristics which defer among individuals. As long as there is life, the minimum is never zero but operates at a minimum to sustain bodily functions in the absence of movement. This can be referred to as the mimimum heart rate or resting heart rate. The maximum heart rate (HRmax) on the other hand is the highest value that can be achieved in an all-out effort to the point of exhaustion. It is a highly reliable value that remains constant for a particular subject and changes only slightly with age (a slight but steady decrease of about one beat/min per year, beginning at 10 to 15 years of age has been observed). Based on this explanation, for a person who starts moving from rest (HRmin), the temporal change in heart rate depends on the intensity of the exercise, as well as on a number of other factors, such as temperature, heat, fatigue, age, over-training, nutrition and hydration, altitude, medication, infectious disease or even mental activity. In this study, it was assumed that all other factors remained constant between the time the baseline measurement of heart rate and the subsequent readings measured during the 60 minutes that the participant took part in either a Zumba or ZOCA class and therefore suggests that the changes in heart rate observed were as a result of the dance exercise choreography and intensity. Any kind of movement of a particular intensity imposes a circulatory demand on the body which the heart is called to meet and is rarely equal to HRmax but a fraction of it. This is referred to as the percentage of heart rate maximum (% HRmax) or target heart rate of the physical activity. Percentage of heart rate maximum can thus be used as a measure of exercise intensity and also in developing exercise prescriptions. The American College of Sports Medicine (2011) recommends that individuals should exercise between 64 and 94% of the HRmax to improve cardiovascular fitness. The average percentage of maximum heart rate during the aerobic phase (at 30 minutes) of the study participants was 65 ± 12%, therefore, the intensity of the Zumba and ZOCA dance classes undertaken by these female participants was sufficient to meet the guidelines of the ACSM regarding the intensity of aerobic exercise that should be engaged in by healthy adults for improvement of cardiovascular health. The findings of this study were comparable with those of Luettgen et al. (2014) in which they found that the average percentage of heart rate maximum of their study subjects was 79±7.0%. This was also within the stipulated guidelines.

### 5.2.3 Heart Rate After The Cool Down Choreography

Upon cessation of exercise, the removal of central command together with abolished feedback from muscle mechanoreceptors resets the arterial baroreflex to a lower level and causes an initial heart rate decrease. The heart rate decrease is also caused by increase in cardiac parasympathetic neural activity (cPNA). Hence, this ‘fast phase’ (i.e., initial minute) of HR recovery has often been attributed to parasympathetic reactivation. As recovery continues, a more gradual ‘slow phase’ of cardio-deceleration is observed, likely mediated by both progressive parasympathetic reactivation and sympathetic withdrawal. These slower autonomic adjustments are believed to be elicited primarily by an intensity-dependent combination of gradual metabolite clearance (i.e., reduced metaboreflex input) and a reduction in circulating catecholamines, while thermoregulatory factors (direct thermoreceptor afferents and/or blood flow redistribution) may also be involved (Michael, Graham and Davis, 2017). Weippert et al., 2013 states that cooling down before complete cessation of exercise is important in order to gradually lower body temperature and heart rate, and to ensure disposal of waste products (such as lactic acid) and toxins produced during exercise which would otherwise contribute to muscle soreness. Lactic acid is produced in biochemical processes which involve the breakdown of energy substrates such as glucose and glycogen for the production of energy. As exercise intensity increases, the concentration of lactate in the muscles and arterial blood increases from a basal value of about 1 mM to about 12mM during strenuous exercise (Zakynthinaki, 2015). Upon cessation of exercise, the lactic acid is cleared out of the muscles and blood by two processes; about 20 percent of lactate produced during exercise is reoxidised to pyruvate and then dissimilated to carbondioxide and water, and the remaining lactate is taken up by the liver and forms glucose, which can be converted into glycogen or be delivered to the blood. A review of studies done by Astrand et al. (2003) demonstrated that this removal of lactate, accumulated in the body after exhausting exercise, is enhanced if, during recovery, the subject continues to exercise, but at a lower intensity which normally does not produce any lactate. This lower intensity exercise is what is termed as the cool down phase of exercise. During this study, the last measurement of heart rate was taken upon cessation of exercise but the choreography of the dance exercises in the last five minutes was of a slow tempo and reduced intensity, directed to offer the ‘cool down’ and gradually return the body to rest. The mean heart rate after the 60 minutes was lower than the mean heart rate during the aerobic phase of the exercise, that is to say mean heart rate reduced after the cool down choreography ($p<0.05$). Therefore, the cool down choreography of Zumba and ZOCA effectively lowered the heart rate in the participants of this study.

# CHAPTER SIX

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1 CONCLUSIONS

Hemodynamic changes occurred during dance exercises; Zumba and ZOCA. This can be attributed to these exercises stimulating the cardiovascular regulatory mechanisms significantly resulting in autonomic adjustments that were concurrent with dynamic exercise. The reflexes known to bring about the cardiovascular adjustments during dynamic exercise are central command, exercise-pressor reflex and baroreflex. Each reflex in turn activates neurons within the cardiovascular center of the medulla and modulates the sympathetic and parasympathetic outflow to the cardiovascular system. This autonomic modulation is mainly parasympathetic withdrawal and sympathetic activation to the heart and blood vessels. In this study, this was reflected by significant increases in systolic blood pressure and heart rate between baseline and peak exercise. The increase in systolic blood pressure also indicated that the participants exhibited baroreflex resetting to sustain the increase in systolic blood pressure due to sympathetic activation. There was no significant change in diastolic blood pressure during exercise from which it can be concluded that the vasodilators produced during Zumba and ZOCA counteracted the vasoconstriction due to sympathetic activation and therefore the total vascular resistance could have been maintained or reduced. In addition, because the change in hemodynamic parameters from rest and during aerobic exercise are directly proportional to the exercise intensity, the percentage of heart rate maximum, systolic blood pressure and heart rate change measured during the aerobic phase demonstrate that the exercise intensity of the Zumba and ZOCA classes that these female participants engaged in was sufficient to meet the guidelines for aerobic exercise for the improvement of cardiovascular health in healthy adults.

## 6.2 Recommendations

The hemodynamic responses to Zumba and ZOCA were measured only during one session of exercise for each client. Longitudinal studies should be done to determine the presence or absence of adaptation after regular sessions of dance aerobics. This would generate even more knowledge about the hemodynamic changes and their possible benefits.

There is need for a regulatory body to formulate national initiatives to promote aerobic exercise in Zambia as well as to spear head local research and formulation of guidelines that promote safe but effective aerobic exercises that are tailored to local Zambian needs, resources and interests. Most of the regulations and guidelines used for reference are from international bodies.

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# APPENDICES

## APPENDIX I: Table Of Personal Information And Measurements Of Blood Pressure And Heart Rate

| | |
|---|---|
| Study Site | Date |

| | | | |
|---|---|---|---|
| Date of Birth | Age | Gender | Signature |

| | |
|---|---|
| For how long have you been taking dance classes as an exercise? | < 4 Weeks |
| | 1-12 Months |
| | > 1 Year |

| Participant | Baseline | 30 minutes | | 60 minutes | | |
|---|---|---|---|---|---|---|
| Number | BP | HR | BP | HR | BP | HR |

## APPENDIX II: Information Sheet

My names are Chanda Chisunka Grace. I am a Physiotherapist currently pursuing a Master of Science in Human Physiology Degree at The University of Zambia.

As part of the programme am studying, I am required to carry out a research. The title of my study is ‘Determination of the Acute Hemodynamic Changes Associated with Dance Exercises in Lusaka, Zambia.

In carrying out this study, I will be measuring Blood Pressure and Heart rate three times during one of your Zumba sessions. All these measurements will be taken using a wrist blood pressure monitor which is able to measure both blood pressure and heart rate at the same time at the wrist.

Before participating in this study, your blood pressure and heart rate will be taken while you are relaxed in order to determine whether or not your values are within healthy ranges. If they are found not to be, you should consult your medical doctor as you may have a health condition that would be causing you to have abnormal blood pressure and heart rate at rest.

During the study, if you experience symptoms such as shortness of breath or chest discomfort, do not feel obliged to continue exercising for the purpose of the study. You should stop and consult a doctor. Participation is voluntary and you are free to with draw from the study at any point.

Although it is rare in healthy adult individuals, certain changes may occur during the exercise, including abnormal blood pressure, fainting, abnormal heart rate (too rapid, too low, or ineffective), and other side effects of exercise.

Should you decide to take part in this study, be informed that your name will not be documented. Your readings will be treated as confidential by the researcher who will only use serial numbers when recording the measurements to be taken.

The information obtained will be used by the researcher as partial fulfillment for the obtainment of a Master of Science in Human Physiology Degree, and will also be published for statistical or /and scientific purposes.

If you need further clarification about this study, please contact any of the addresses below:

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## APPENDIX III: Informed Consent Form

I voluntarily agree to participate in the study which is designed to determine my hemodynamic response to Zumba. The information obtained will be used by the researcher as partial fulfillment for obtainment of a Master of Science in Human Physiology Degree.

I have been told that before I participate in the Zumba session, my blood pressure and heart rate will be measured in an attempt to determine whether or not I have normal values at rest and that I should not take part in this study but consult my doctor if my blood pressure and heart rate are found to be outside the normal ranges at rest as this may be an indication of a health condition.

I am told that the Zumba session I will undergo will be performed for 30minutes during which my blood pressure and heart rate will be measured seven times. I have also been told that if I experience symptoms such as shortness of breath, chest discomfort or extreme fatigue, I am not obliged to continue exercising for the purpose of the study but that I should stop and consult a Doctor.

I have been told that although it is rare in healthy individuals, certain changes may occur during the exercise, including abnormal blood pressure, fainting, abnormal heart rate (too rapid, too low, or ineffective), and other side effects of exercise.

I agree that the information obtained may be used and published for statistical or scientific purposes.

I have read the above and understand it, and my questions have been answered to my satisfaction.

Subject ……………………………………………………………

Witness …………………………………………………………...

Date ……………………………………………………………….