EFFECT OF AGE AND CARDIOPULMONARY RESUSCITATION (CPR) TECHNIQUES ON CHARACTERISTICS OF MUSCLE FATIGUE IN FEMALES TRAINED IN CPR ADMINISTRATION

by

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ABSTRACT

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Cardio pulmonary resuscitation (CPR) is a widely popular and recommended assessment and intervention technique for life threatening conditions resulting from cardio-pulmonary disorders. As per the American Heart Association® 2005 revised guidelines for CPR administration, the rescuer is required to perform chest compressions and ventilations in the ratio of 30:2 at a rate of 100 compressions per minute with minimal interruption to chest compressions. In the process of CPR administration, the rescuer is likely to experience fatigue over time with continual compressions and ventilations. Fatigue is expected to manifest through variations in the rescuer's muscle activity, changes in joint kinetics and kinematics (angles, acceleration of movement etc.), increases in blood lactate concentration, decrease in depth and rate of chest compressions, increases in ventilation duration and delay in resuming chest compressions after ventilations. Overall, the changes may significantly affect the quality of CPR administered. Twenty subjects, ten females in the age group of 22-35 years and ten females in the age group of 45-60 years, competent in basic life support and currently certified to administer CPR as per American Heart Association® 2005 guidelines were evaluated as they performed CPR with compressions only and CPR with compressions and ventilations (30:2) continuously on a SkillReporter™ Resusci® Anne (Laerdal®, NY) until self-identified fatigue settled in (identified as exertion on Borg's scale) or to a maximum of 10 minutes. The subjects were assessed for fatigue related changes in biomechanical parameters (joint kinematics and kinetics), electrical activity of the muscle or electromyogram (EMG), blood lactate concentration and quality of CPR administered in either case.

TABLE OF CONTENTS

Chapter

Appendix

LIST OF ILLUSTRATIONS

Figure Page

CHAPTER 1

INTRODUCTION

1.1 Background

Cardio pulmonary resuscitation (CPR) can be defined as an emergency technique intended to circulate oxygenated blood through the body of a person when his/her cardiac and/or pulmonary system malfunctions causing a decline in oxygenated blood flow to the vital organs and brain [1]. It involves providing both external respiration support (ventilations) and compressions to the chest to encourage oxygenated blood circulation to the vital organs. Cardiopulmonary collapse can happen anywhere and emergency response times for advanced medical support (paramedics) may take up to 10 minutes. Therefore, individuals trained to administer CPR play a significant role in sustaining the circulation of oxygenated blood to vital organs. The initial 5 minutes after the person collapses are the most critical and proper administration of CPR during this phase can significantly influence the chance of survival and recovery [2]. However, administrating CPR requires strong physical effort and the rescuer may experience fatigue within this time frame which may affect the quality of care.

The American Heart Association® 2005 guidelines require the rescuer to administer chest compressions and ventilations in the ratio 30:2 at a rate of 100 compressions per minute. As fatigue settles overtime, the average compression depth and rate are expected to significantly decrease as the biomechanical neuromuscular and physiological characteristics of the rescuer change. A slower rate of compressions would cause insufficient blood flow and faster rate would lead to inadequate chest recoil and decompression, which would both adversely affects CPR dynamics. Moreover, the compressions delivered earlier in a cycle are deemed to be less effective when compared to the compressions administered later in the cycle because the latter compressions induce increased blood flow to the vital organs, improving chances of survival [1, 2]. Thus, it is essential that the rescuer maintain the quality and rate of CPR administration by compressing the chest as required at an optimal rate. However, any fatigue in the rescuer may cause changes in the rescuer's muscle electrical activity, blood lactate concentration, joint angles, and depth and rate of compressions which may adversely affect the overall quality of CPR administered. The purpose of this study was to determine and to compare the biomechanical, neuromuscular and physiological effects of fatigue on the quality of CPR administered by both young females (22-35 years) and older females (45-60 years), all competent in basic life support with current American Heart Association® certification. These subjects form the ideal sample for the population most likely to administer CPR in both out of hospital and within hospital settings. This study also compares CPR administration with compressions only and CPR administration with compressions and ventilations (30:2) to approximate the effect of the rescuer's pulmonary exertion and the effect of 'hand-off' time on fatigue manifestation and its effect on the quality of CPR administered. This study is expected to be vital in understanding the dynamics of CPR and its effect on the rescuer and to provide with data that would help improve the quality of CPR administered.

1.1.1 Purpose

The purpose of the study was to evaluate ten, young females and ten older females as they performed CPR with compressions only and CPR with compressions and ventilations (30:2) continuously on a SkillReporter™ Resusci® Anne (Laerdal®, NY) until self-identified fatigue settled in (identified as exertion on Borg's scale) or to a maximum of 10 minutes. The subjects were assessed for fatigue related changes in biomechanical parameters (joint kinematics and kinetics), electrical activity of the muscle or electromyogram (EMG), blood lactate concentration and quality of CPR administered in either case.

1.2 Definition of Terms

1) Cardio Pulmonary Resuscitation (CPR): It is an emergency technique intended to circulate oxygenated blood through the body of a person when his/her cardiac and/or pulmonary system malfunctions causing a decline in oxygenated blood flow to the vital organs and brain. CPR involves providing external respiration support (ventilations) to the victim by assessing the airway and compressing the chest to encourage blood circulation if the pulse of the person is not detected or is faint.

2) Surface Electromyogram (SEMG): It is the measurement and recording, using surface sensors, of the electrical activity associated with muscle contraction. A widely employed medical technique, EMG is used to obtain the sum total of the action potentials of all the muscle fibers that are activated within the recording zone of the

sensors. An electromyograph is used to record the muscle electric potential to obtain the EMG signal. The pattern of muscle activation, rate of activation and fatigue of muscles can be determined from the EMG by analyzing its amplitude (root mean square or RMS) and frequency (median frequency or MF).

a) Root Mean Square (RMS): It is a statistical measure of the magnitude of a varying quantity. Computed for a series of discrete values or for a continuously varying function, it is the square root of the mean of the squares of the values. Essentially, it is a power mean with the power of 2.

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} EMG(i)^2}$$

b) Median Frequency (MF): It is the frequency that divides the power spectrum in two regions having the same power or area under the amplitude – frequency curve.

$$\int_{0}^{Fmed} S(f)df = \int_{Fmed}^{\infty} S(f)df$$

3) Kinematics: It is the branch of dynamics concerned with the description of motion. The description of the human movement is accomplished by the use of position, velocity and acceleration. Kinematics is an accurate description of human movement without acknowledging the causes of motion.

4) Kinetics: It is the branch of dynamics concerned with the forces that cause or tend to cause motion. Kinetics is essentially a study of human movement that considers the forces as a cause of movement.

5) Muscle Fatigue: The decrement in the muscle capability of force generation is identified as muscle fatigue. When fatigued, the muscle is required to exert a greater effort in order to maintain the level of force. Muscular fatigue is associated with changes in EMG, joint kinetics and kinematics and blood lactate concentration among other factors.

6) Blood Lactate: With sustained or repeated contraction, lactic acid tends to accumulate in the muscle causing a sensation of pain and fatigue. It is more prominent when the muscle is anaerobically contracting. This accumulation of lactic acid in the muscle causes the level of lactate in the blood to rise which can be monitored over time to indicate the level of fatigue and recovery.

1.3 Delimitations

The delimitations of the study are 1) Twenty healthy female subjects - ten females in the age group of 22 – 35 years of age; ten females in the age group of 45 – 60 years of age. 2) All subjects fall within the body mass index (BMI) range of 19 to 34. 3) All subjects healthy with no prior or existing condition of neuromuscular, musculoskeletal or cardio-pulmonary disorders. 4) All subjects competent in basic life support and possessing current American Heart Association® certification to administer CPR. 5) All subjects performed CPR with compressions only and CPR with compressions and ventilations (30:2) continuously on a SkillReporter™ Resusci® Anne (Laerdal®, NY) until self-identified fatigue settled in.

1.4 Assumptions

The study assumed the following 1) All subjects accurately completed the health history questionnaire. 2) All subjects performed CPR to the best of their ability. 3) All subjects' self-identification of fatigue correctly reflects a fatigue condition of the musculoskeletal system. 4) Administering CPR to a SkillReporter™ Resusci® Anne (Laerdal®, NY) simulates to the greatest degree of similarity administering CPR on a human being.

1.5 Limitations

The study had some limitations that need to be considered. First of all, the subjects administered CPR in a controlled laboratory environment. This eliminates several factors that would otherwise significantly affect the physiological and psychological condition of the rescuer. In the controlled laboratory conditions, the subject is relatively more relaxed and free of psychological stress and anxiety. Administering CPR to a manikin alleviates the sense of urgency and demands that would otherwise be accompanying when administering CPR to a human being. In the laboratory conditions, the subjects' are attired in clothing that permit relatively free motion and movement of the body without exerting undue physical discomforts. In real life circumstances this may not be the case. The rescuer's clothing may hinder with proper administration of CPR.

The process of administrating CPR is a cyclic, highly dynamic activity. The force keeps changing throughout the activity. The velocity of motion and range of motion also do not keep constant. This induces several limitations to the inherently flawed electromyogram. Owing to the fact that the activity is dynamic in nature with changing force, velocity and range of motion, cross-talk from other adjacent muscles is very likely to contaminate the EMG signal obtained from the muscle of interest. Moreover, the changing patterns of muscle recruitment and rate of activation due to co-activation and co-contraction also induces a certain level of unreliability into the EMG signals from the muscles of interest. Studying just the primary muscle groups also ignores action from the other groups of muscles – antagonists, synergists, stabilizers and neutralizers.

Yet another limitation of the study would be the fact that the entire sample of the subjects were from Arlington community and therefore the sample might not be fully representative of the population.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Cardio Pulmonary Resuscitation

Cardio Pulmonary Resuscitation or CPR is an emergency technique, comprising of chest compressions and external respiratory support (ventilations), used to facilitate or force adequate quantity of oxygenated blood flow through the coronal and cerebral systems when the natural mechanism fails. The failure of natural mechanisms could be due to various reasons including ventricular fibrillation, severe cardiac arrest, drowning, choking or any other event when oxygenated blood flow to the brain and important body organs declines. To efficiently administer CPR, it is suggested that the victim be lying supine on a hard surface with the rescuer kneeling beside the victim's thorax. The rescuer should then compress the chest with the heel of one hand placed on the lower half of the sternum and the heel of the other hand on top of the first so that the hands would be overlapped and parallel [2]. Sufficiently compressing the chest deep enough and at an appropriate rate could help by forcing blood to flow. Providing external respiration support (ventilation) to supply oxygen to the lungs when the victim has stopped breathing helps prevent prolonged cases of asphyxia [1, 2]. American Heart Association® describes an effective chest compression as a depression of the lower half of the victim's sternum in the center of the chest (between the nipples) to approximately 1 ½ inches to 2 inches and then allowing the chest to fully recoil before compressing it again [2]. Cyclic pressure over the chest creates blood flow by increasing the inter-thoracic pressure and directly compressing the heart. When the chest fully recoils, it permits venous return to the heart, maintaining the circulatory system dynamics [2].

American Heart Association® 2005 guidelines to administer CPR to an adult victim recommend a compression to ventilation ratio of 30:2 at a rate of 100 compressions per minute. Administrating CPR following this recommendation is intended to increase the number of compressions, prevent the occurrence of hyperventilation and for longer periods of uninterrupted chest compressions, ensuring increased coronary artery perfusion pressure and subsequently, return of spontaneous circulation.

American Heart Association® recommends administrating compressions only to the victim when the rescuer is unable or unwilling to administer ventilations. According to some comparative studies done, though compressions only CPR is not as effective as compressions coordinated with ventilations (30:2) CPR, even just administrating compressions only CPR is beneficial and may significantly improve the survival and recovery chances for the victim [1, 2]. The compression rate, however, has to be maintained at about 100 compressions per minute in either case of CPR administration.

CPR studies conducted on humans and porcine have found incomplete chest wall recoil occurring with a higher frequency as the rescuer fatigues [2]. Investigation of the effect of rescuer fatigue on compression rates and depth indicate that these parameters too decline significantly as the rescuer fatigues [2]. Previous research indicates that ‘ineffective compressions’ and intrinsic rescuer fatigue begin to manifest as soon as after one minute of CPR administration. However, in these studies, the rescuers self-identified fatigue only after more than five minutes of CPR administration [2].

2.2 Upper Body Kinetics and Kinematics

Administrating CPR is a highly dynamic activity and with non-linear variations in musculoskeletal force, joint angles (range of motion) and limb velocities. Any dynamic activity is associated with “kinematics” and “kinetics”. Kinematics is concerned mainly with the description of motion whereas kinetics deals with the forces that cause or are responsible for the motion. Kinematics uses three important parameters – position (displacement), velocity (speed) and acceleration to describe motion both spatially and temporally. Position or displacement describes the motion in space. Velocity or speed defines the rate at which the changes in position occur and acceleration is the rate of change of velocity or speed associated with the motion. Using these three parameters the motion can be studied and analyzed at different points in space and time. This would thus enable to comprehensively break down the motion and characterize it to aid comparison to identify the effects of fatigue, pathology etc on motion in space and in time.

To study the forces that cause motion would require its kinetic descriptors. Kinetics effectively describes the effect of extraneous and internal forces on motion. *Newton’s Laws of Motion* characterizes the relation between forces and motion. Newton’s Law of Inertia states that an object will continue in its state of rest or motion unless acted on by an external force. Newton's Law of Acceleration describes a linear relationship between the force acting on a body and the acceleration produced in the body by the virtue of its mass. Newton's Law of Action-Reaction implies the equality of opposing forces along the line of force action. These principles of motion characterization help define the various kinetic descriptors. Inertia relates to the difficulty with which a body's velocity is changed. Mass is the quantitative measure of inertia. Momentum defines the amount of motion possessed by a body. It is indicated by both the mass and velocity of the body.

The interaction of external loads and internal musculoskeletal forces are responsible for the human body movement. External loads are exemplified by torques, forces due to body mass (gravity), inertial force and force due to surroundings (ground reaction force, center of pressure, friction). An imbalance between the various components of these forces along with the internal muscle forces produces human body motion. A significant result of the imbalance of the forces is the production of rotation action at the joints. All motion of the human body is associated with a certain amount of rotation of the body segments about their joint axes. The force that is capable of producing rotation at a joint is defined as torque or moment of force.

The forces due to body mass evaluate the effect of gravity on human motion, by the virtue of the body mass. Defined as weight, it is essentially a distributed force with the net effect depicted at a central location, known as the center of mass. Center of mass of a body is identified by *segmental analysis* of the body. This approach considers the human body to be a system formed of various segments, rigid in nature and joined at the ends by smooth pin points, which are analyzed individually to identify first the individual segments' center of mass and then proceeding to locate the center of mass of the entire body. Previous studies done on cadavers have successfully determined various regression equations to estimate different anthropometric segmental dimensions like weight and center of mass based on segment length [3, 4, 5, 6]. Using various indicators like gamma radiation, radio isotopes etc the regression equations have been derived to a sufficiently high level of accuracy [4, 5]. Once the center of mass of a segment is determined, its inertia or inertial force can be determined. Inertia is a body's resistance to motion due to its mass. Knowing the inertial force helps comprehend the effect of external forces on the segment and also helps in understanding the inertial force exerted by the segment on the other linked segments.

Forces in the environment also significantly effect and define the dynamics of human motion. The reaction forces from the ground or support surfaces, resistance from the fluids surrounding the body (water or air) are some instances of forces exerted by the surrounding on the body. The reaction forces from the ground or support surfaces, known as Ground Reaction Force (GRF), represent the reaction forces transmitted through the body corresponding to its acceleration. GRF is essentially the sum of pressures distributed under the segment in contact with the ground or support surface. The location or point of application of the GRF under the segment is known as center of pressure. The center of pressure is indicative of the stability of the segment with respect to the ground or support surface.

GRF, and thus the center of pressure, is directly influenced by the mass and acceleration of the center of mass of the segment. The magnitude of GRF is equal to the magnitude of the weight of the body when the acceleration is zero. A change in acceleration of the body due to individual segment acceleration causes the GRF to change in parallel and to oscillate about the body-weight line. A GRF greater than body weight indicates upward acceleration of center of mass and likewise, a GRF lesser than the body weight indicates downward acceleration of center of mass. GRF can thus help in mapping the loci of the center of mass during any movement by describing the change in acceleration of the center of mass with respect to time, considering that the changes in acceleration precede changes in position.

GRF and center of pressure represent the forces corresponding to the vertical component of the reactive forces. The reactive forces acting horizontally also influence the movement by producing friction or shear force in the segment. Friction or shear force corresponds to the horizontal progression of the center of mass i.e. it represents the acceleration of the center of mass in the anterior-posterior and medio-lateral direction. Friction varies linearly with GRF and thus with the body weight. So heavier the segment is greater is the frictional or shear force produced.

Analyzing the internal musculoskeletal forces require the use of the same principles and theories as does for analyzing external forces. Musculoskeletal forces are studied as an interaction between the joint reaction forces and muscle forces. Joint reaction forces represent the reaction of the linked body segment to the compressive forces in the joint. The muscle force is indicative of the net pulling action of the muscles that cross the joint.

The joint reaction force can be resolved into three components – one component of compressive force and two tangential components of shear force. These forces are sufficiently large and significant and vary over the range of motion of the joint. Muscle activity is responsible for a large amount of joint reaction forces. The tangential component of the muscle forces translate and add to the compressive forces at the joint. Joint reaction forces can be estimated by employing inverse dynamics. Using inverse dynamics, joint torques and forces can be determined from the acceleration measured.

Muscles exert only a pulling action on a segment. So movements across joints are controlled and smoothly executed by the synchronized action of agonists and antagonists muscle groups. To estimate the muscle force non-invasively, electromyography or EMG is generally employed. The amplitude of EMG is known to linearly vary with the force generated by the muscle for isometric contractions [7]. For a highly dynamic, non-isometric actions like when administrating CPR, different algorithms exist that would enable determining muscle force using EMG amplitude [7].

CPR is an activity which involves, relatively, to a larger extent using the upper body to efficiently execute. Thus the biomechanical analysis of human body when administrating CPR would involve the kinetic and kinematics study of the upper body by defining various segments about joints including the neck, shoulders, elbows, wrist, thorax (upper, middle and lower), hip and knee.

2.3 Electromyography and Muscle Fatigue

The force generated by a muscle depends on two factors – the physiological condition of the muscle and the neurological innervations to the muscle. The nervous system coordinates movements and force generation in muscles by controlling the activation pattern of the muscle fibers and the rate of activation of the muscle fiber (recruitment and firing rate). The nervous system stimulates a motor unit which causes an action potential to propagate through all the muscle fibers connected to that particular motor unit. Thus the nervous system manipulates the muscle force generation by turning 'on' or 'off' motor units as required and by regulating the rate of firing of the motor units. Muscle fibers' response to nervous stimulation depends to a large extent on its physiological factors like the type of muscle fiber (slow twitch, intermediate or fast twitch), the thickness of muscle fibers, acid-base balance (pH), rate of blood flow through the muscle etc. A slow twitch fiber is thinner when compared to the other two types of muscle fibers, and as the name suggests, takes longer to respond, generates a relatively lower force but has high resistance to fatigue whereas a fast twitch fiber is thicker, responds quicker, generates a high force but fatigues rapidly. Other factors like blood flow, pH balance etc effect the conduction velocity of the muscle fibers. All these factors affect the quality and duration of the action potential generated along the muscle fiber membrane.

An action potential is essentially an electric wave that traverses across the muscle fiber membrane. The electrical activity associated with multiple muscle fibers sums up in time to produce an electric voltage strong enough to be detected at the surface of the skin with sensors. This cumulative electric signal is known as electromyogram or EMG. When measuring with non-invasive sensors placed on the surface of the skin in the vicinity of the muscle of interest, the signal is known as surface EMG or SEMG. SEMG is thus the sum total of the action potentials of all the muscle fibers activated in the recording zone of the sensors placed on the surface of the skin.

The EMG signals recorded are influenced both qualitatively and quantitatively by various factors, mainly categorized into *causative, intermediate* and *deterministic* factors [7]. The causative factors include physiological conditions associated with the muscles and also include the influence of sensor configuration, location of sensor with respect to the innervation zone of the muscle and orientation of muscle fibers with respect to the sensor on the signal. The intermediate factors include the inter electrode distance as this effects the band pass filtering characteristics of the sensor, detection volume of the sensor, amplification or cancellation of the EMG signals as the signals from various motor units overlap in time, cross talk from adjacent active muscles or motor units, amount of tissue or fat between the sensor and muscle etc. The deterministic factors include the actual number of activated motor units and the number detected by the sensors, firing rate of the motor units, recruitment stability of the motor units etc. These are critical factors with respect to EMG measurement and must be carefully considered and accounted for to obtain reliable and significant EMG signal.

Once recorded, the EMG signal is then analyzed to derive meaning and correlation to muscle force and other characteristics. To serve this purpose, the EMG signal is processed to obtain its amplitude and median frequency (MF). Since EMG is a varying continuous signal in time, its amplitude is obtained from its root mean square (RMS) value. RMS is computed using the following formula:

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} EMG(i)^2}$$

EMG amplitude or RMS value generally increases as the force generated by a muscle increases.

To obtain the power characteristics of the EMG signal and to observe its variation over time, power spectrum is derived. From the power spectrum of the EMG signal, the median frequency (MF) is obtained. MF is essentially the frequency that divides the power spectrum into two regions having same area or power under the amplitude-frequency curve. MF is computed using the following formula:

$$\int_{0}^{Fmed} S(f)df = \int_{Fmed}^{\infty} S(f)df$$

MF tends to shift along the power spectrum depending on the muscle force characteristics. It is thus a very good indicator of muscle fatigue. MF tends to shift towards the left of the power spectrum as the muscle fatigues.

Considering all the above mentioned factors to record and analyze EMG signal, ideally, reliable data would be obtained only for activities which are isometric in nature, are constant with respect to force generated, velocity of limb movement and range of motion of the joint [7]. CPR, however, being a highly dynamic activity with constantly changing force, velocity and range of motion requires a different approach for analysis.

EMG analysis for CPR can be accomplished by processing the EMG signals in a near-isometric epochs or ‘windows’ of the record and extrapolating to the interpretation of the entire signal. Since CPR is a cyclic activity, the windows can be fixed based on joint angles in time and all analyses would be made in this window. So, for example, a window could be defined for when the shoulder angle varies in the range 120 ± 2^{o}. Thus for all the subsequent cycles of CPR, EMG would be analyzed in this particular window. This eliminates spatial and temporal inconsistencies and enables the data to be compared between cycles.

Muscle fatigue is defined as a decrement in the muscle capability of force generation. A fatigued muscle is required to exert a greater effort in order to maintain the level of force. Muscle fatigue is associated with changes in the muscle physiological characteristics like decreased pH (due to accumulation of lactic acid), decreased muscle recruitment and activation, changes in muscle fiber conduction velocity etc which affects the force generation capability of the muscle changing the movement kinetics and kinematics. Muscular fatigue is associated with changes in EMG, joint kinetics and kinematics and blood lactate concentration among other factors.

As a person fatigues, the movement progressively becomes more uncoordinated and loses its effectiveness. CPR, being a high energy activity, induces fatigues into the subjects almost within a minute of the start of CPR [2]. The fatigue first manifests itself through at the microscopic level and then gradually develops and becomes evident at the macroscopic level, the implication being that the subjects’ identification of fatigue occurs relatively later in time. Proper analyses of EMG from the primary movers can indicate the initiation of fatigue and also the progress of fatigue.

2.4 Blood Lactate and Muscle Fatigue

A by-product of metabolism in the human body is lactic acid. Lactic acid is continually produced by the muscle tissues and is also continually cleared or removed from the site by the flowing blood i.e. the production rate of lactic acid is balanced by its clearance rate. When a muscle tissue contracts faster or for a longer duration of time, the production rate of lactic acid escalates as does clearance rate. The increase in clearance rate of lactic acid, however, has a ceiling value and eventually the production rate of lactic acid exceeds the clearance rate. This leads to accumulation of lactic acid at the muscle tissue. Accumulated lactate indicates increased proton release from the muscular cellulites which causes decreased cellular and blood pH [8]. A decrease in pH as observed with the accumulation of protons and subsequently lactic acid causes the conduction velocity of the associated muscle fibers to change, thus affecting the force generating (or contraction generating) capacity of the muscles. This induces a sensation of pain and fatigue at the muscle and also altering its physiological conditions.

Lactic acid produced by the muscle tissues is constantly cleared by the blood flowing through the muscle. As the muscle activity increases, the blood flow through the muscle also increases to a point after which the clearance rate of lactic acid is not sufficient to prevent accumulation of lactic acid. Sampling the blood and analyzing it for the amount of lactic acid present in it would directly indicate the lactic acid concentration at the muscle tissue. Thus lactic acid concentration in the blood can be used as direct indicator of the physiological and chemical conditions of the muscle at the initial phases (low and sub-maximal level) of physical activity [9]. It can help establish the onset of muscle fatigue and the point of maximal muscle activity.

CHAPTER 3

METHODS

3.1 Design

The study incorporated two research designs to evaluate the various different parameters of the protocol. The first was a 2 x 2 x 2 mixed model repeated measures statistical research design to evaluate (i) the changes in joint kinetics and kinematics of the wrist, elbow, shoulder, and the hip joint; (ii) quality of CPR i.e. depth of chest compression, rate of chest compression, volume of delivered air, ventilation duration, and hand placement; (iii) total time to self-identified fatigue and (iv) changes in SEMG value and time of maximum activity of the various muscles relative to the peak compression force associated with administrating CPR. The first factor, a between factor, compared between two Groups (younger females, older females), the second factor, a within factor, compared repeated measures for two CPR types (compressions only, compressions with ventilations (30:2)) and the third factor, also a within factor, compared repeated measures the various parameters at two different points in time (onset and end of CPR administration)

The second design was a 2 x 2 x 3 mixed model repeated measures design to investigate blood lactate concentration. The first factor was a between factor comparing between two Groups (female lay persons, female nurses). The second factor was a within factor comparing repeated measures for two CPR types (compressions only, compressions with ventilations (30:2)) and the third factor was also a within factor comparing repeated measures for three time points (pre-CPR, post-CPR, 5 minutes post-CPR).

The study is essentially comparing CPR administration by younger females to that by older females. The study has also been designed to evaluate the differences that occur when administrating CPR with compressions only to administrating CPR with both compressions and ventilation in a ratio of 30:2 (American Heart Association® 2005 guidelines). CPR of either type is administered continuously by the subject until the subject experiences self identified fatigue or a maximum of 10 minutes. The biomechanical, physiological and neuromuscular condition of the rescuer is also investigated over time to compare the condition at the onset of CPR administration with the conditions at the end of CPR administration. Differences in blood lactate are observed over time i.e. pre-CPR, post-CPR and 5 minutes post-CPR.

3.2 Subjects

Twenty, healthy female subjects volunteered to participate in this study. Of the twenty, ten were younger females in the age range of 22 to 35 years and the remaining ten were older females in the age range of 45 to 60 years. The subjects were all within a body mass index (BMI) range of 19 to 34. The subject groups were chosen considering that these groups are representative of the population that is generally called upon to administer CPR in out-of-hospital and in-hospital situations.

All subjects signed a University Institutional Review Board for Human Subject Research approved informed consent and filled up a health history questionnaire. The subjects were excluded if they had any prior or existing pathology of the neuromuscular, musculoskeletal or cardio-pulmonary physiology that could significantly affect the results. The subjects who participated in the study were all competent in basic life support and all held a current American Heat Association® certification to administer CPR.

Each subject reported to the lab on two days and administered CPR with compressions only on one day and administered CPR with compressions and ventilations (30:2) on another day. Compensation in the form of gift certificates was provided to subjects attending both the sessions.

3.3 Experimental Protocol

All the subjects were scheduled for a total of two lab sessions, one on two separate days. Each lab session was scheduled for 60 minutes. The subjects first signed an informed consent (UTA IRB approved) and filled out a health questionnaire. The subjects then changed into spandex sports apparel to facilitate marker and sensor placements and stability. The subjects were then set up to record biomechanical data and SEMG. For biomechanical assessment, reflective biomechanical markers were set on to the subjects' skin. Seven reflective biomechanical markers were placed laterally on the left side of the subject and two markers were placed medially to record motion in the sagittal plane. Markers were placed laterally on the trunk at the level of T7 or seventh thoracic vertebra, the greater trochanter (hip), the femoral lateral epicondyle (knee), the lateral malleolus (ankle), on the lateral edge of the acromion process (shoulder), on the humeral lateral epicondyle (elbow), on the ulnar styloid process (wrist), one marker was placed medially on the top of the head and another medially on the proximal phalanx of the third digit on the right hand [4, 5, 6]. The various systems of segments defined by the markers included the head, the trunk; left and right thighs, left and right shanks, left and right upper arms, left and right forearms and left and right hands. Segmental masses and center of mass locations were obtained from female anthropometric data tables established by DeLeva and Zatsiorsky [4, 5].

The subjects were then prepped for sensors to record SEMG. The SEMG muscle sites were identified and the surface of the skin, shaved, if required, using a disposable razor, scrubbed with alcohol pads and surface sensors affixed. The muscles identified as critical for CPR activity and from which SEMG were recorded included (i) lateral head of triceps brachii, (ii) anterior deltoid, (iii) pectorals major, (iv) biceps brachii, (v) lattisimus dorsi, (vi) upper trapizius, (vii) middle trapezium, (viii) erector spinae (ix) external oblique (x) hamstring and (xi) quadriceps.

The SEMG sensors used were of the single differential type and consisted of two parallel bars, each 1.0cm long, 1-2mm wide and spaced 1.0cm apart with a band width of 20-450 Hz and a roll-off of 80dB/decade. The sensors had a common mode rejection ratio of 92dB, noise 1.2uV and input impedance greater than 100 MΩ. The muscles were located on the midline of the muscle belly, medially with respect to the myotendinous junction and nearest innervation zone, with the detection surface of the sensor perpendicular to the length of muscle fibers. Once the markers and sensors were in place, the subject's finger was sterilized using an alcohol pad and the surface pricked using a single use, disposable prick to obtain a blood sample for pre-CPR blood lactate analysis. The blood was sampled using an YSI® 1500 Sport Lactate Analyzer to investigate the lactic acid concentration. This instrument analyzes about 25ml of blood sample with a precision level of ±2% within a measurement range of up to 30mmol/L.

The EMG sensors were then connected to a 16 channel Bagnoli™ desktop EMG system (Delsys®, MA). The system specifications include amplification of 100, 1000 or 100,000 and overall noise less than 1.2uV. The SEMG signals were sampled at 1000 Hz for a 16 bit signal resolution. SEMG signal fidelity was tested and proper signals through all the sensors verified. CPR was administered on a SkillReporter™ Resusci® Anne (Laerdal®, New York) which returned a feedback of the quality of CPR by evaluating the depth of compression, rate of compression, duration of ventilation, volume of delivered air, and hand placement. The manikin was placed on an AMTI force plate such that the compression point on the manikin was centered on the force plate. This helped investigate the magnitude and direction of ground reaction force (GRF) that the subject or rescuer experience at the wrist and progressively transmitted through the upper body. The AMTI force plate (model OR6-7-1000), comprises of strain gauges attached to load cells at the four corners of the platform which measure the forces and moments exerted on its surface. The arrangement of the load cells and strain gauges on the force platform enable it to simultaneously measure forces and moments in three dimensions (i.e. along the X, Y and Z axes). The raw force and moment signals obtained at a sampling frequency of 360 Hz from the force platform load cells and strain gauges were amplified by a high-gain amplifier before being digitized and analyzed further. Thus, an accurate measure of the GRF along the Z direction (vertical) could be obtained.

The biomechanical reflective marker configuration was tracked using a six MCam2 camera Vicon® 460 Motion Capture system. The cameras tracked with a resolution of 1.3 megapixels at a frame rate of 60 Hz. The cameras were positioned so as to track the 7 laterally placed markers and 2 medially placed markers and define the segments' motion in the sagittal plane. This helped develop a dynamic model that permits the study of CPR based on the kinematics and kinetics interactions between the body segments. First and second order derivatives applied to the planar motion of a single segment resulted in the general kinematics equation. An analytical link segment model representing the rescuer administrating CPR in the sagittal plane was then developed based on the general kinematics equations of the single segment. However, the development of the model was based on certain assumptions. It was assumed that rescuer was bilaterally symmetrical and that a 2-D dynamic model of the rescuer administrating CPR in the sagittal plane was valid. It also required that the segments be treated as rigid rods with the joints between the segments being frictionless. It was also assumed that the female anthropometric data set used to determine the segment masses and center of mass location truly represented the subjects' anthropometric measurements and that any variation did not result in significant differences in the result.

The subject then administered CPR either with the compression only or with compressions and ventilations in a ratio of 30:2. The subject was provided with an active feedback for the initial 30 seconds regarding the depth and rate of compressions and hand placement after which no feedback of any kind was provided. The subject continually administered CPR until self-identified fatigue (identified as exertion on Borg's scale) manifested or to a maximum of 10 minutes. The subjects' rate of perceived exertion (RPE) on Borg's scale was recorded at 5 minutes and at the end of CPR administration. The subjects were asked to stop if and when the stress or pain in any joint(s) and muscle(s) was equivalent to an RPE of about 17 (high level of difficulty experienced) before the 10 minutes were up. Another blood sample was obtained from the subject immediately after CPR administration was ended to analyze for blood lactate concentration post-CPR. Yet another blood sample was obtained 5 minutes after the subject finished administrating CPR to analyze for blood lactate concentration 5 minutes post-CPR. The markers and sensors were removed off the subject and a sterile band-aid applied at the finger prick on the subject. The subject was then asked to answer a feedback questionnaire which outlined their conception of fatigue, pain and other physiological conditions as they felt while administrating CPR.

The whole process starting with the application of markers and sensors was repeated at the second appointment of the subject, the difference being in the administration of CPR. If compressions-only CPR was administered in the first visit, then the subject administered compressions and ventilations CPR in the second visit and vice versa.

3.4 Data Collection, Processing and Analyses

Data collected can be classified into five categories (i) biomechanical data includes kinetics and kinematics data for the wrist, elbow, shoulder, and hip joints, (ii) CPR quality assessment includes depth of chest compression, rate of chest compression, volume of delivered air, ventilation duration, and hand placement, (iii) SEMG data includes integrated EMG (IEMG) and time of maximum activity of the muscle relative to the peak compression force for various muscles critical in administering CPR, (iv) blood lactate analysis data at three points in time i.e. pre-CPR, post-CPR and 5 minutes post-CPR and (v) total time to self fatigue.

3.4.1. Biomechanical Data

The biomechanical data was obtained using the AMTI force plate, the reflective biomechanical markers and Vicon® Motion Capture system. Each subject's height, mass and hand thickness were individually recorded and utilized to estimate the biomechanical parameters. The data to be analyzed was then isolated using Vicon® Workstation® software. The first 30 compressions for all the trials were eliminated and the immediately following 90 compressions were digitized and saved for analysis of biomechanical parameters at the onset of CPR administration. Likewise, the last 90 compressions of the CPR administered were digitized and saved to analyze the biomechanical parameters at the end of CPR administration. The digitized data obtained from the Vicon® Workstation® were processed and analyzed using a custom built program in Visual Basic® (Microsoft® Corporation). The program was designed to read the digitized data file output by the Vicon® Motion Capture system software and translate the three dimensional data into two dimensions, and using inverse joint dynamics to compute the angles, forces and torques at the wrist, elbow, shoulder, and hip joint. The Y-axis (anterior-posterior position) and Z-axis (vertical force) data from the force platform were translated into the X-axis (anterior-posterior position) and Y-axis (vertical force) respectively of the 2-D dynamic model. The data from the Vicon® 460 Motion Capture system along the X-axis (anterior-posterior position) and Z-axis (vertical force) were translated to the X-axis (anterior-posterior position) and Y-axis (vertical force) respectively of the 2-D dynamic model. The AMTI force plate provided with the compression force for every compression. The compression force data obtained were then normalized to the subjects' body weight. A fourth order low pass Butterworth digital filter was applied to eliminate noise and smooth the relevant data extracted from the Vicon® output file. A cut-off frequency of 8Hz was applied. Only the position data was filtered and the velocity and acceleration of motion were computed from the filtered position data. Using inverse dynamics, the joint forces and torques were then computed. Joint angles, joint torques, horizontal force and vertical force were obtained for wrist, elbow, shoulder and hip. Figures 3.1.(1-4) through 3.4.(1-4) depict the parameters graphed for all the joints as they vary with the compression force applied. The compression force is graphed in broken line and the biomechanical data are the solid lines.

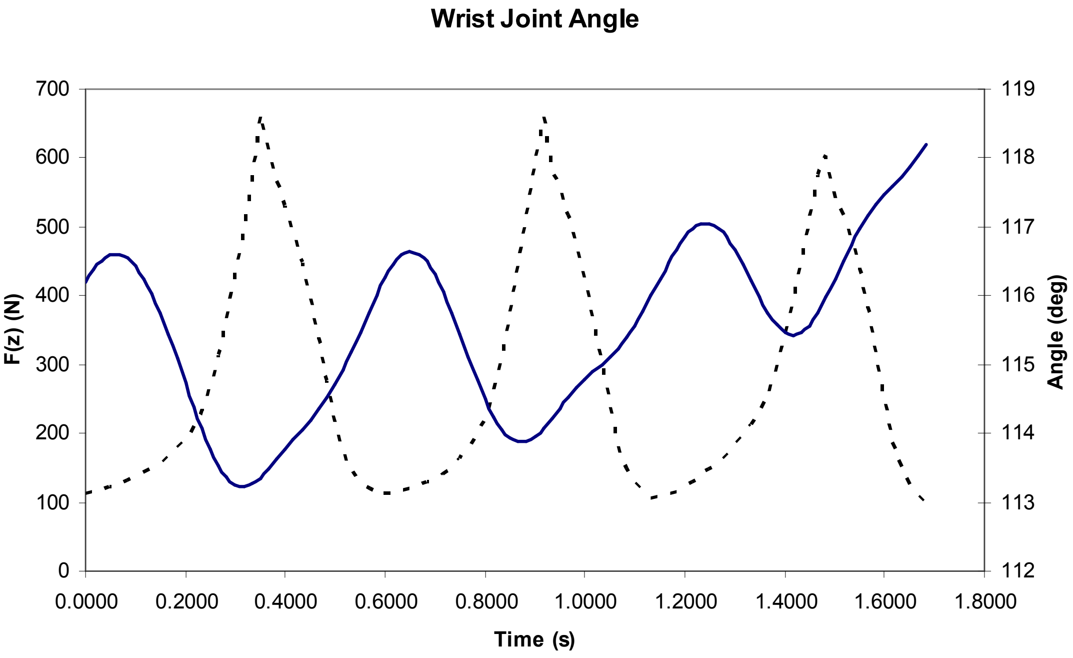

Figure 3.1 Wrist joint angles for three compressions

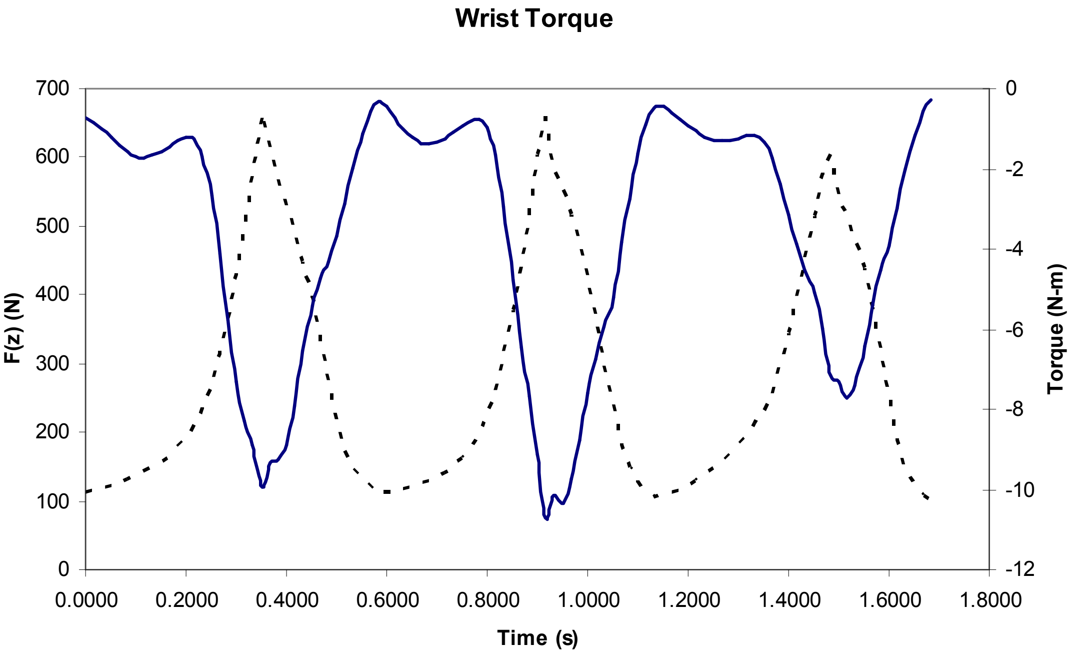

Figure 3.2 Wrist joint torques for three compressions

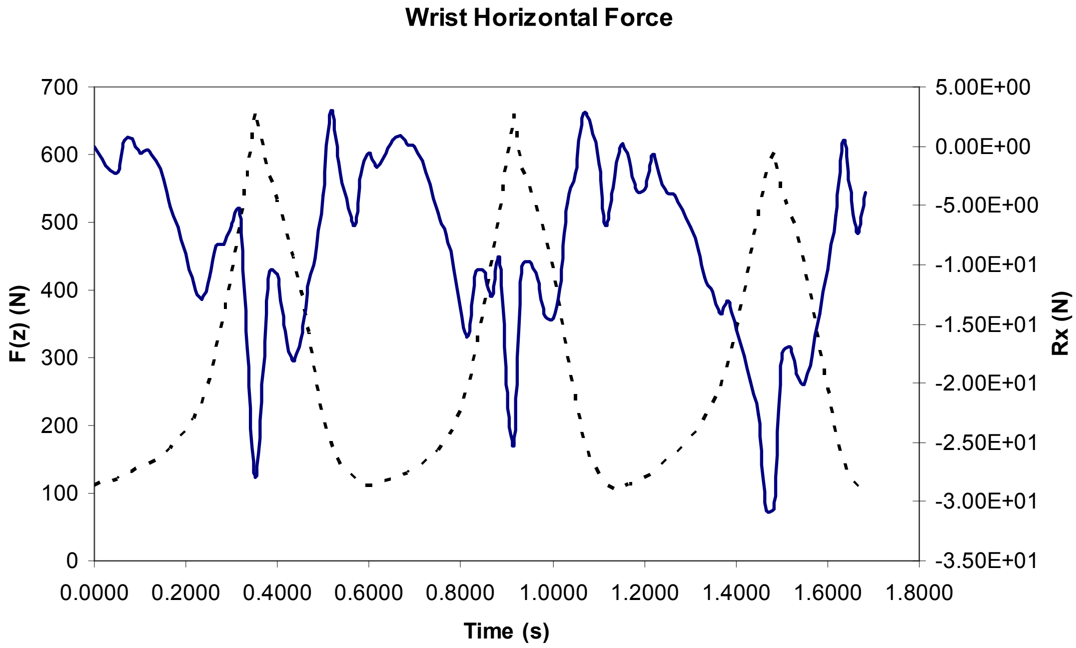

Figure 3.3 Wrist joint horizontal forces (Rx) for three compressions

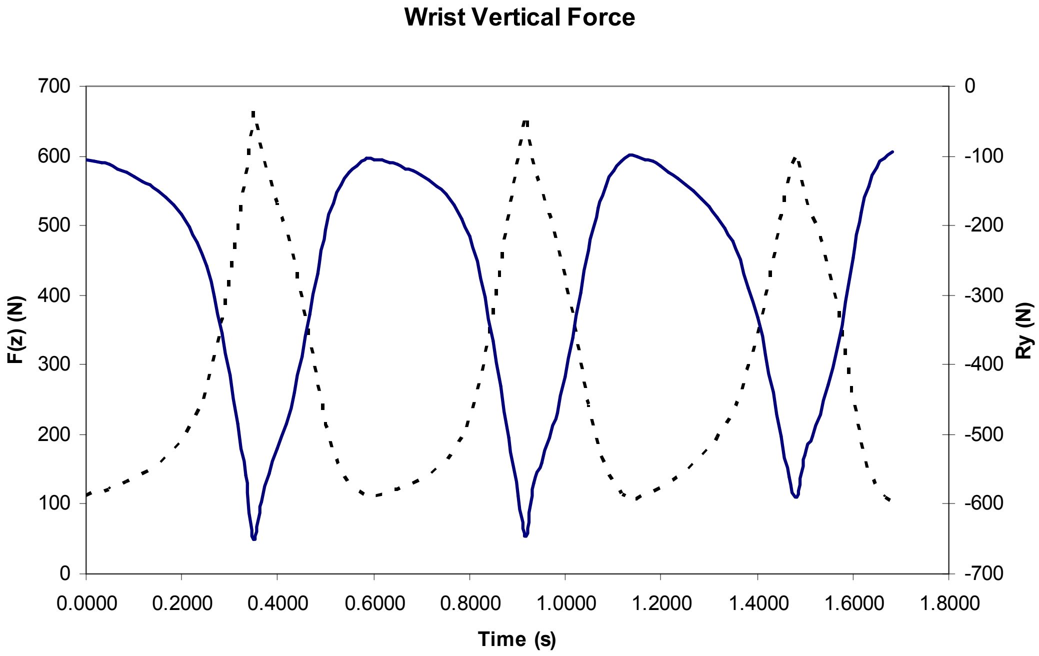

Figure 3.4 Wrist joint vertical forces (Ry) for three compressions

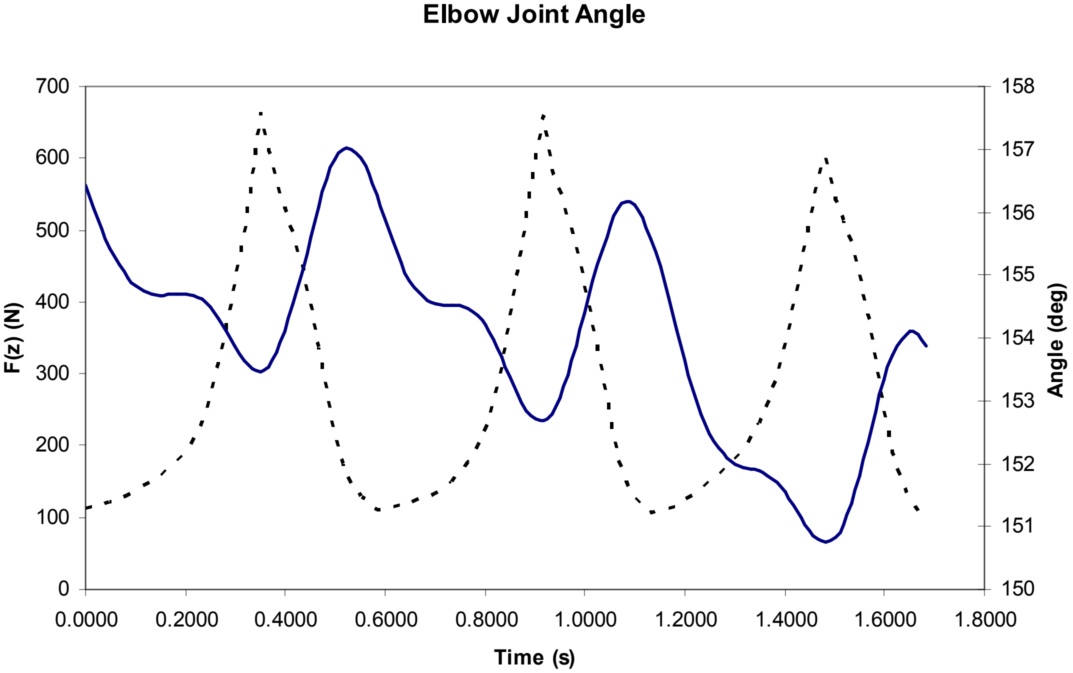

Figure 3.5 Elbow joint angles for three compressions

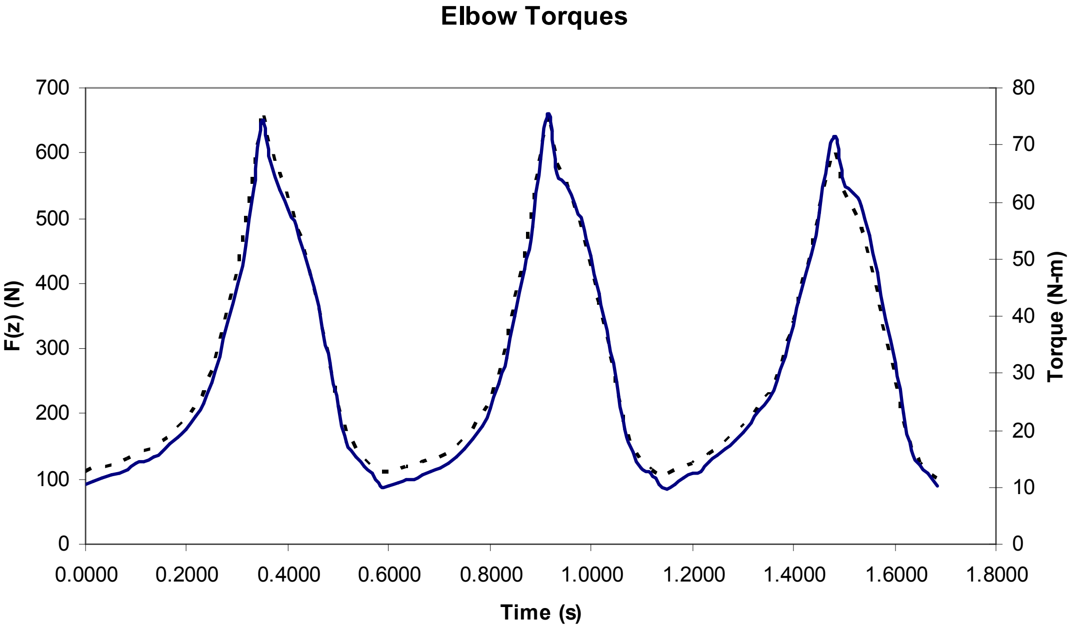

Figure 3.6 Elbow joint torques for three compressions

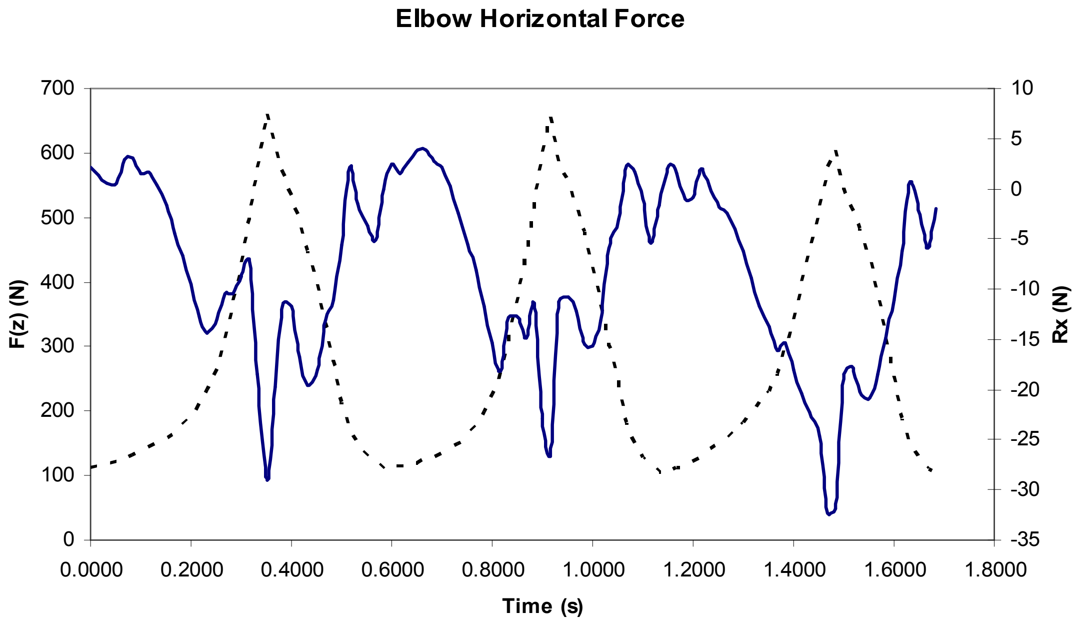

Figure 3.7 Elbow joint horizontal forces (Rx) for three compressions

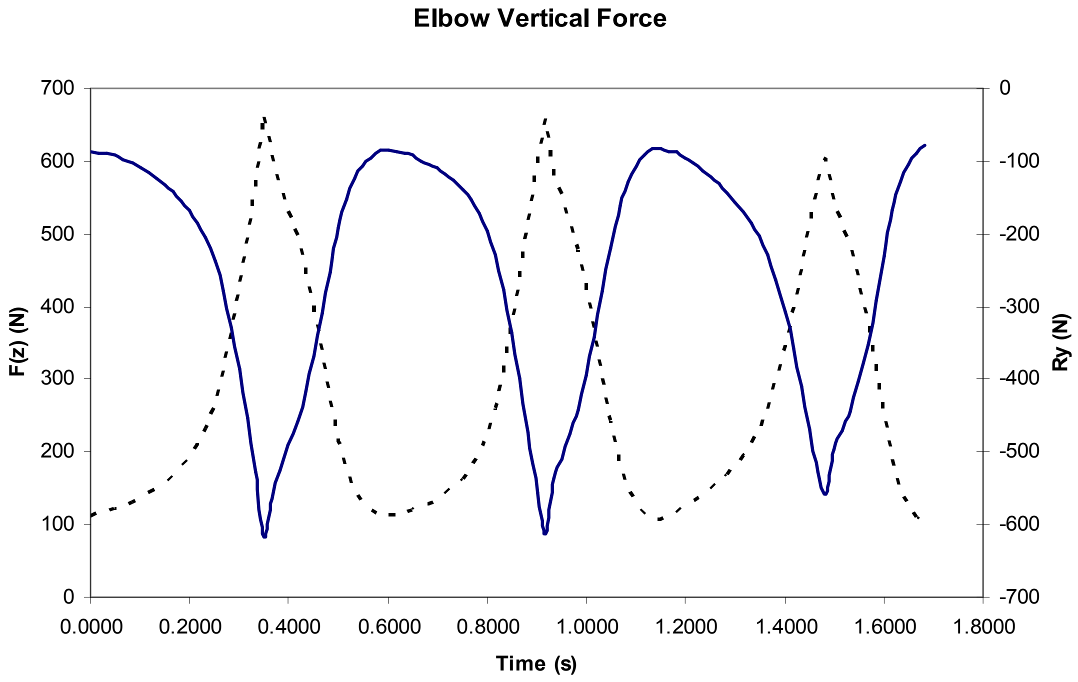

Figure 3.8 Elbow joint vertical forces (Ry) for three compressions

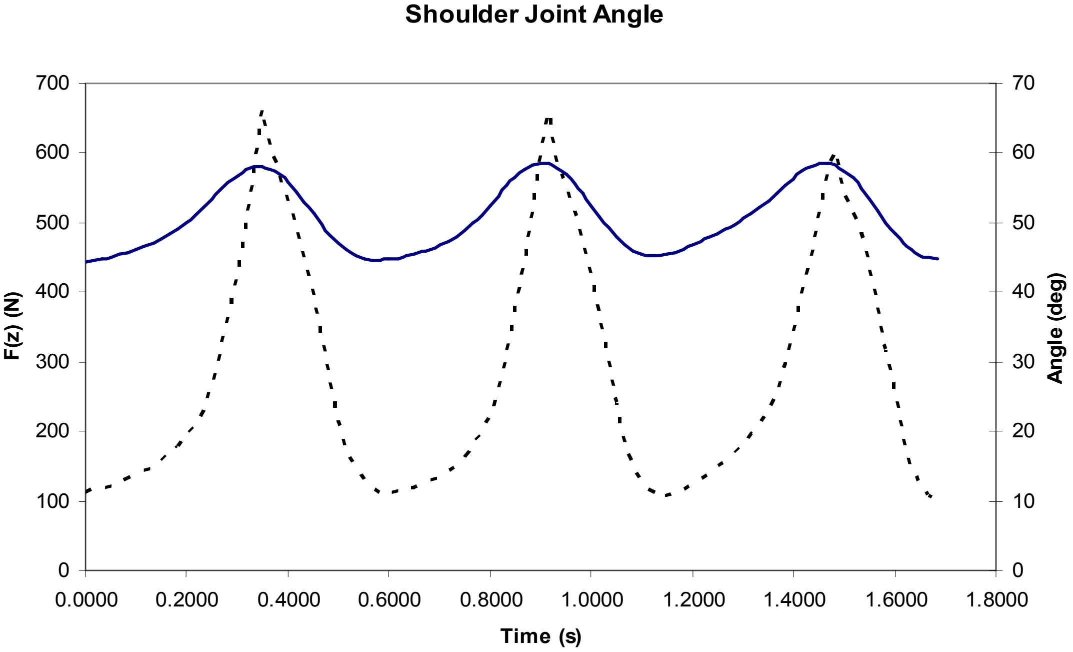

Figure 3.9 Shoulder joint angles for three compressions

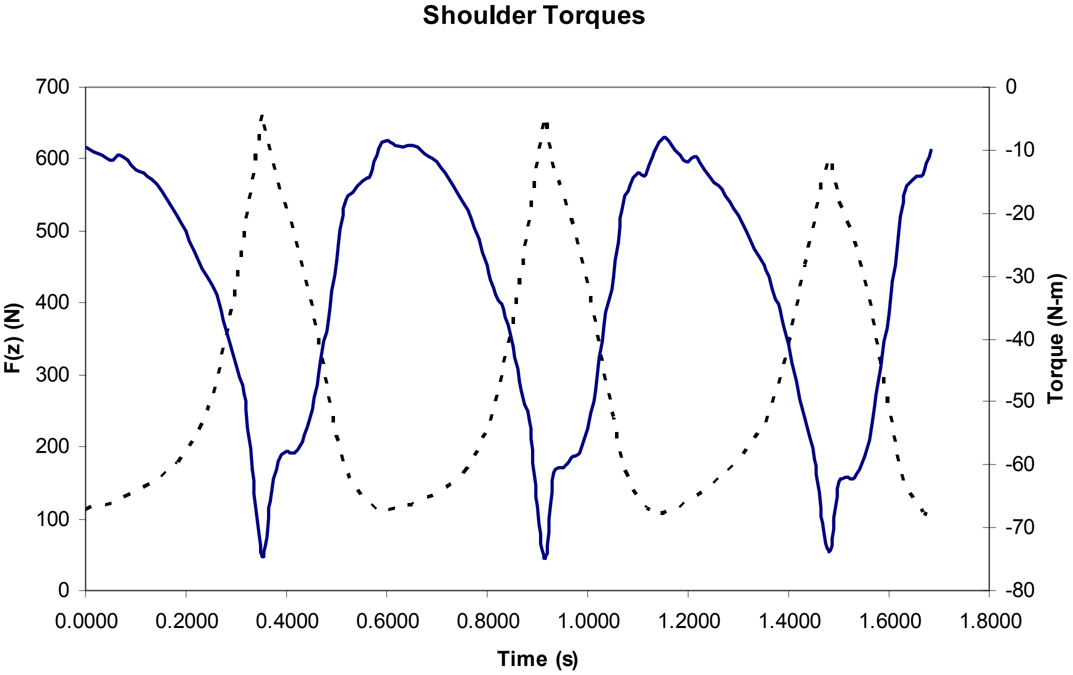

Figure 3.10 Shoulder joint torques for three compressions

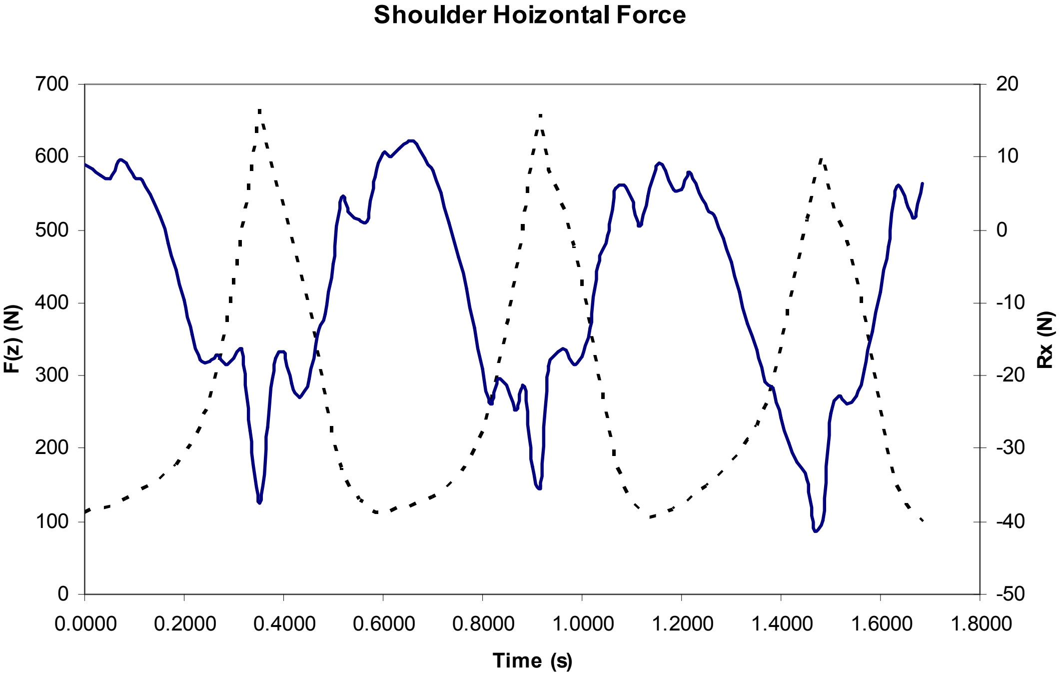

Figure 3.11 Shoulder joint horizontal forces (Rx) for three compressions

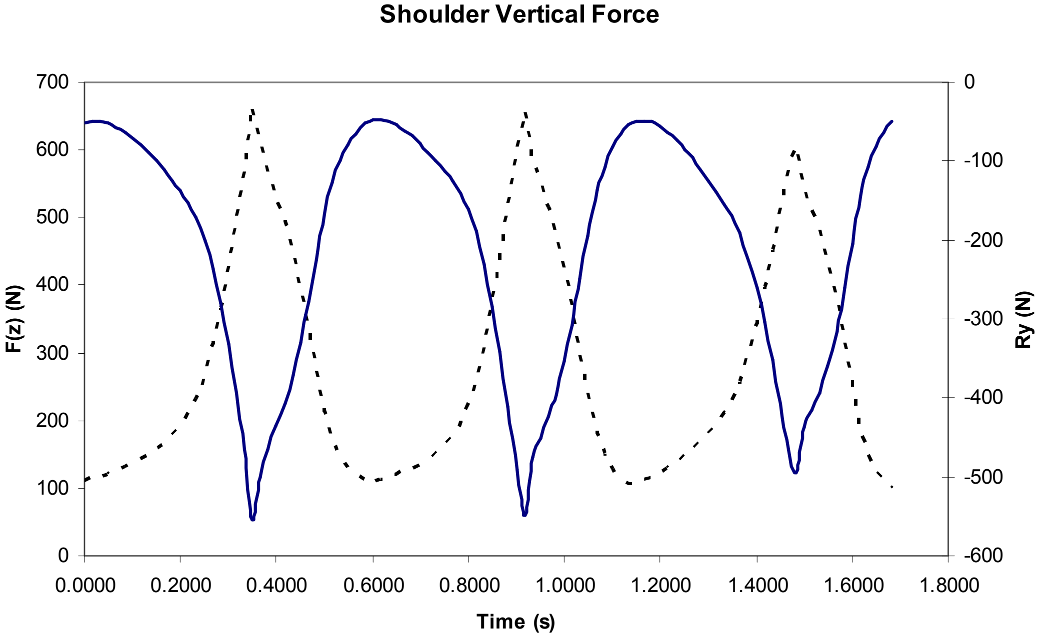

Figure 3.12 Shoulder joint vertical forces (Ry) for three compressions

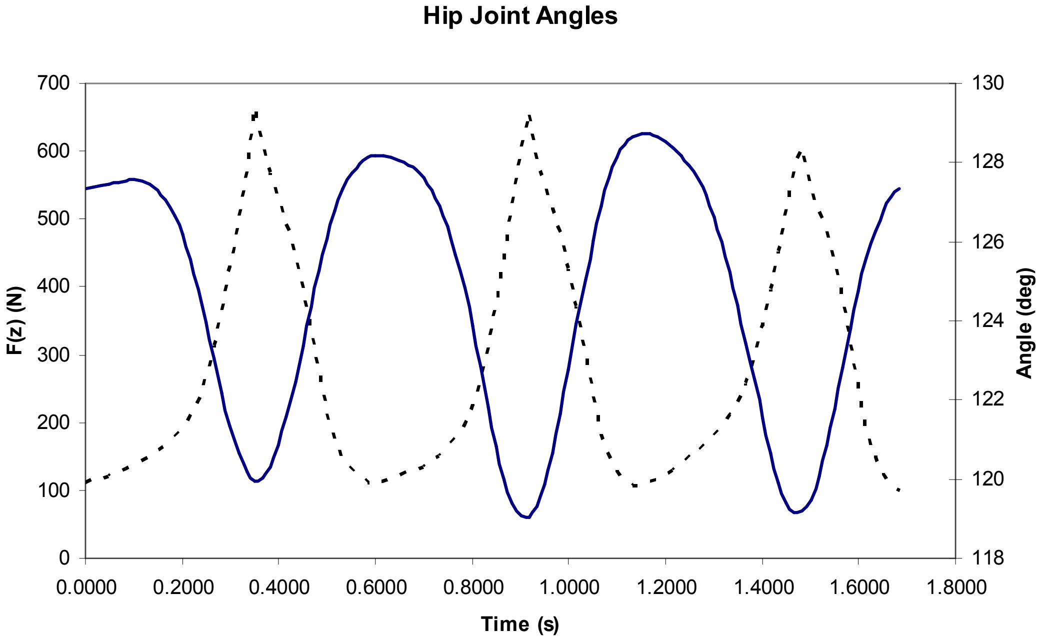

Figure 3.13 Hip joint angles for three compressions

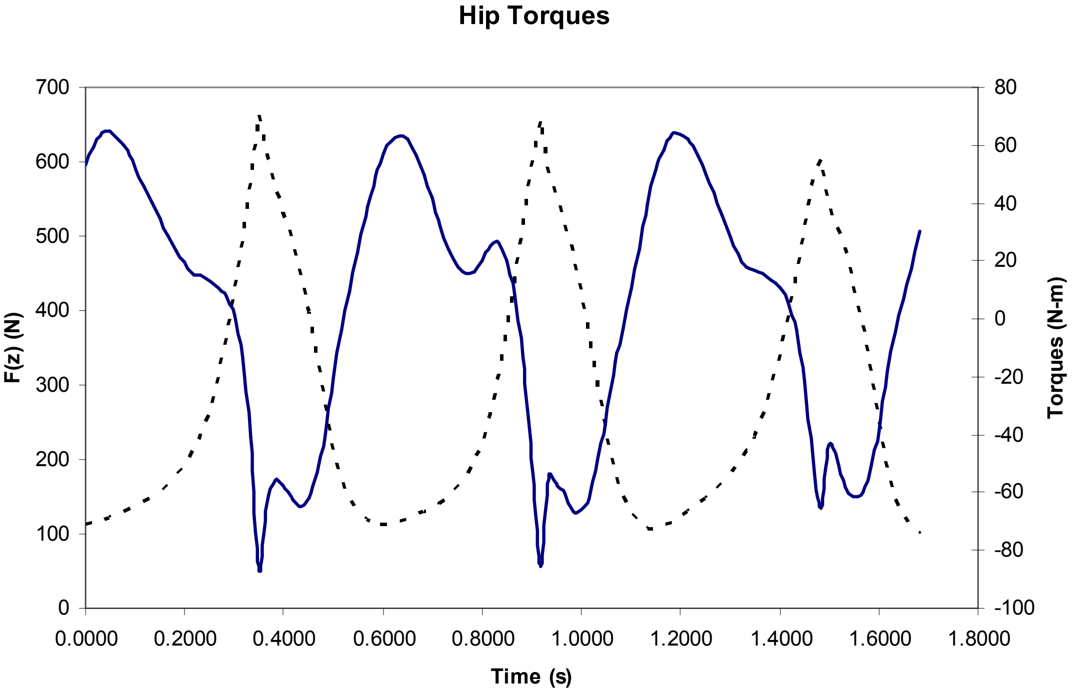

Figure 3.14 Hip joint torques for three compressions

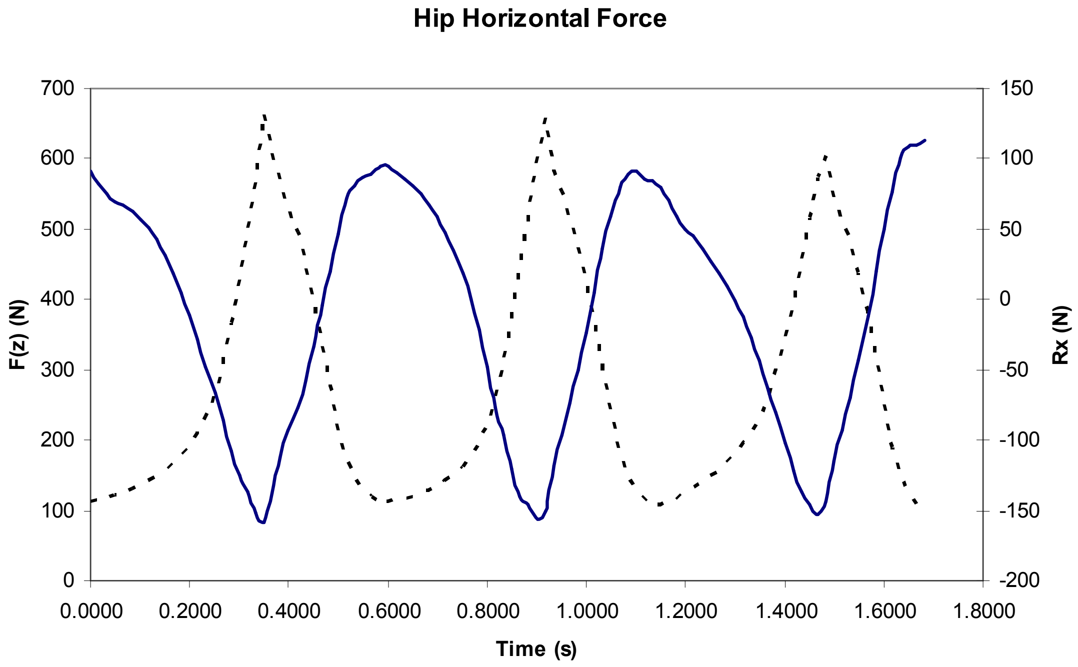

Figure 3.15 Hip joint horizontal forces (Rx) for three compressions

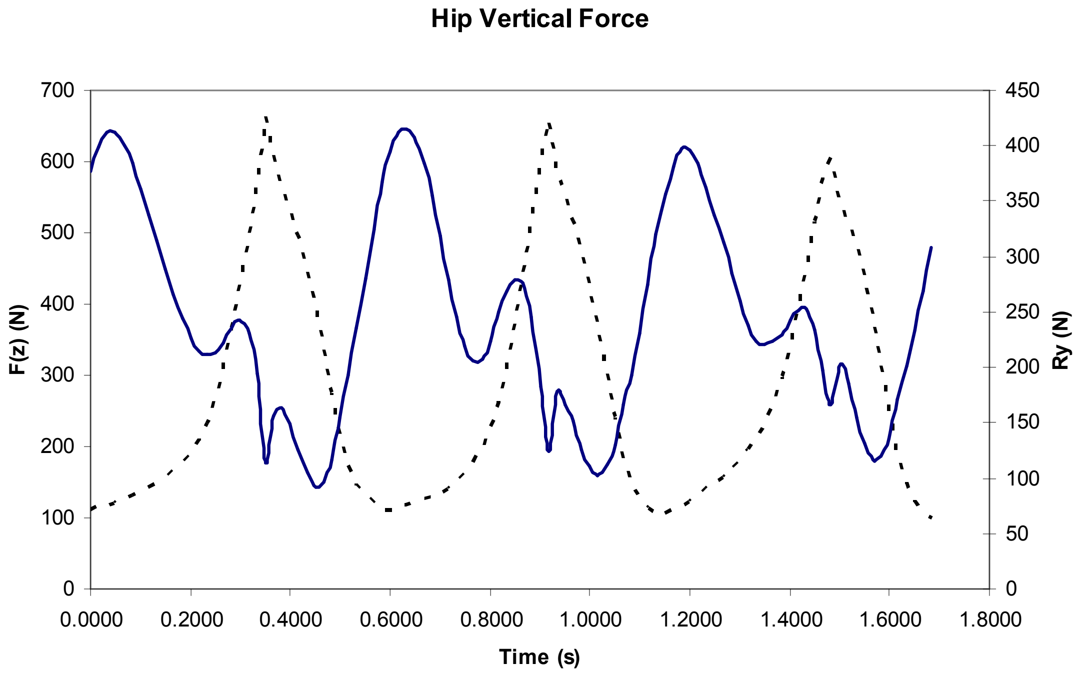

Figure 3.16 Hip joint vertical forces (Ry) for three compressions

These data were further resolved to obtain the joints' range of motion (RoM), positive and negative torques, positive and negative horizontal forces and positive and negative vertical forces. Positive and negative torques were obtained depending on the direction of the torque vector. A positive torque implied extension of the joint and a negative torque indicated joint flexion. The resolution of forces was different from that of the torques. Local maxima and minima of the forces were determined and were labeled positive or negative relative to each other. Thus a peak force at the end of a positive slope was labeled positive and a peak force at the end of a negative slope was labeled negative irrespective of its value.

3.4.2. CPR Quality Assessment

CPR assessment was provided by the SkillReporter™ Resusci® Anne (Laerdal®, NY). The SkillReporter™ software accompanying the manikin generated a complete feedback report on the CPR administered and details of depth of every compression (inches), average over a cycle and average over all cycles, rate of compression (compressions per minute), duration of ventilation (seconds) and volume of delivered air (mL) can be obtained. The sensors in the manikin also gave feedback on the hand placement and indicated any change in hand placement over time. The quality of compressions administered was analyzed over time by segmenting the data obtained. The initial 30 compressions were ignored and the immediately following 90 compressions were analyzed to obtain the quality (depth and rate) of compressions at the onset of CPR. The final 90 compressions of the CPR administered were analyzed to obtain the quality (depth and rate) of compressions at the end of CPR administration. The ventilations were analyzed over the entire time of CPR administered.

3.4.3. SEMG Processing and Analyses

SEMG was recorded from 11 muscle sites including (i) lateral head of triceps brachii, (ii) anterior deltoid, (iii) pectorals major, (iv) biceps brachii, (v) lattisimus dorsi, (vi) upper trapizius, (vii) middle trapezium, (viii) erector spinae (ix) external oblique (x) hamstring and (xi) quadriceps. SEMG recorded through the Bagnoli™ desktop EMG systems (Delsys®, MA) was analyzed to obtain integrated EMG (IEMG) and time of maximum activity of the muscle relative to the peak compression force using a custom built EMG data analysis software in Visual Basic® (Microsoft® Corporation). The data to be analyzed was first isolated using the custom built software. The first 30 compressions for all the trials were eliminated and the immediately following 90 compressions were saved for analysis of SEMG parameters at the onset of CPR administration. Likewise, the last 90 compressions of the CPR administered were saved to analyze the SEMG parameters at the end of CPR administration. CPR being a highly dynamic, non-isometric activity with changing force, velocity and range of motion required analysis of SEMG in epochs or windows. The size of the window was fixed with respect to the duration of an individual compression. This means that the width of the window with respect to time kept varying with fatigue as the activity progressed. The SEMG raw data in each window were first rectified, the dc component was removed, and then a linear envelope obtained by low pass filtering with a cut off frequency of 20 Hz. The integrated EMG (IEMG) value was computed by integrating the linear envelope over each compression. The average of all 90 compressions was then used computed and used for statistical analysis of the muscle signal. The time of occurrence of the SEMG linear envelope peak was then compared to that of the compression peak and the time of maximum activity of the muscle relative to the peak compression force for the various muscles were obtained. Figure 3.5 depicts the linear envelope of EMG from the lateral head of triceps brachii relative to the compression force (graphed in broken line).

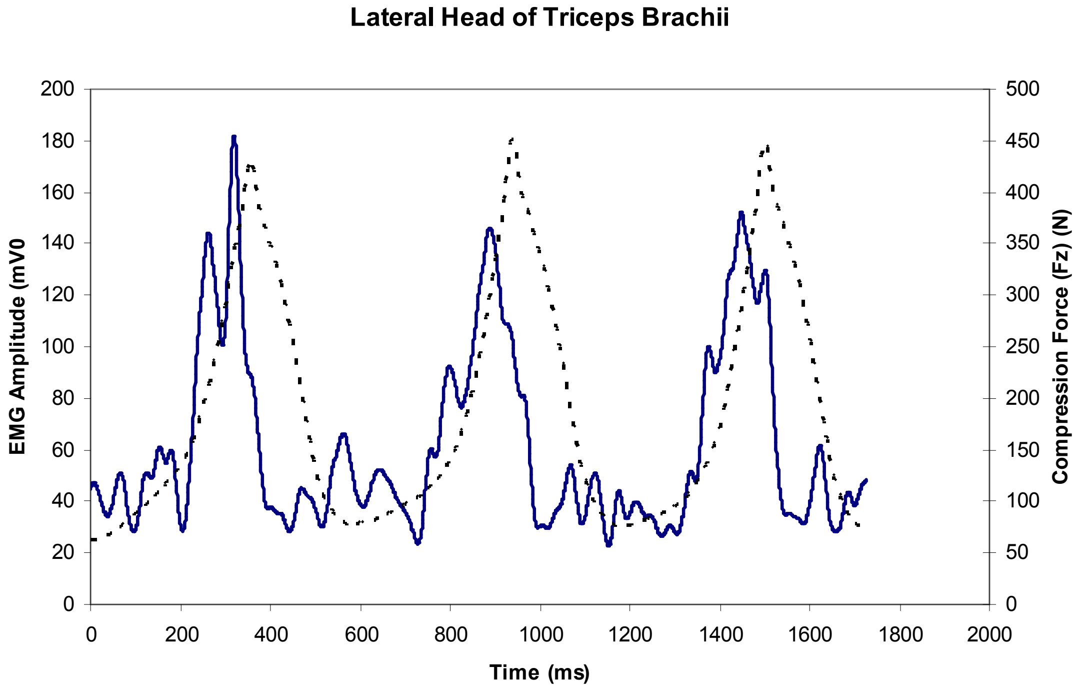

Figure 3.17 IEMG of the lateral head of triceps brachii relative to three compressions

3.4.4. Blood Lactate Analysis

Blood samples were obtained from the subjects at three points in time – pre-CPR, post-CPR and 5 minutes post-CPR. The blood sample was analyzed using YSI® 1500 Sport Lactate Analyzer to determine the concentration of lactic acid in the blood sample (mmol/ml), indicating the amount of lactic acid accumulated in the skeletal muscles.

3.4.5. Time to Fatigue

The time to fatigue (minutes) was determined for all subjects manually by marking the start time when they start administrating CPR until they stop administrating further CPR. Rate of perceived exertion (RPE) was obtained at 5 minutes and at the end of CPR administration and compared to investigate the effects of condition and age on the exertion experienced by the subjects as they administered CPR compressions only and compressions and ventilations.

3.5 Statistical Analysis

NCSS 2001 was used to perform statistical analyses on the data obtained to compare the effects of the various factors on CPR administration. Each variable was tested for normality using Kolomogorov-Smirnov and Shapiro-Wilk normality tests. A three-way mixed factorial ANOVA, comparing the Group effects (younger females with older females), CPR type effects (compressions only with compressions and ventilations (30:2)) and time effect (onset of CPR with end of CPR) was performed on the biomechanical data (angles, torques and forces for wrist, elbow, shoulder, and hip), CPR quality assessment (depth of compression, rate of compression, volume of delivered air, duration of ventilation, and hand placement), SEMG data (IEMG and time of maximum activity of the muscle relative to the peak compression force from 11 muscles) and time to fatigue. A three-way mixed factorial ANOVA, comparing Group effects (younger females with older females), CPR type effects (compressions only with compressions and ventilations (30:2)) and Time effects (pre-CPR with post-CPR and 5 minutes post-CPR), was used on the data from blood lactate analysis. ANOVA was interpreted using a step down process beginning with the interactions of highest order. Tukey’s corrections were applied to analyze the main effects when the main effects were not statistically significant. When the main effects were significant, they were broken down into simple effects which were then analyzed using Tukey-Kramer’s post-hoc tests. For all the variables, the effect size and power of the statistic were also estimated. The confidence level for all the statistical analyses was set at 95%.

CHAPTER 4

RESULTS

4.1 Biomechanical Results

The normalized compression force (Fz) averaged over the 90 compressions at the onset of CPR administration and averaged over the 90 compressions at the end of CPR administration was found to have a significant time effect ($p < 0.001$; $\eta^2 = 0.99$) (Figure 4.1). The average normalized compression force was found to be much lower in the end of the CPR administration for both the groups and for both the types of CPR administered (Mean ± SE: 7.50 ± 0.11 N/kg at onset; 6.77 ± 0.11 N/kg at the end).

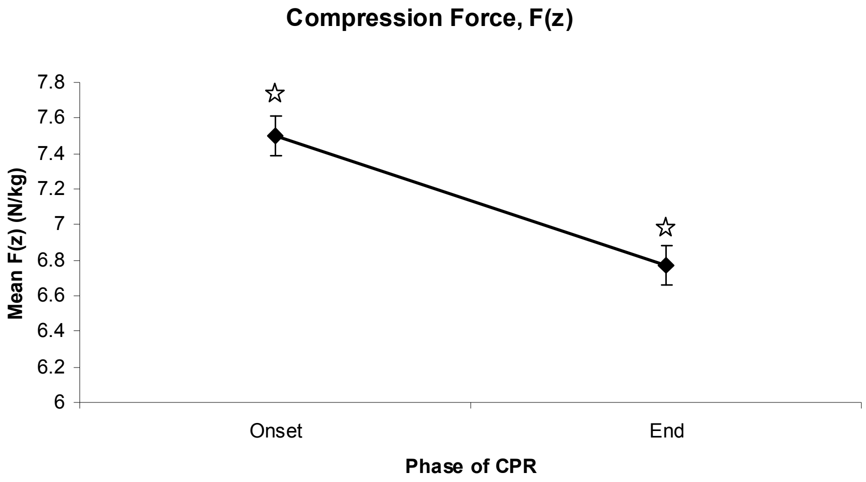

Figure 4.1 Compression Force, F(z), Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

The biomechanics at the wrist, elbow, shoulder and hip were evaluated in terms of (i) joint range of motion (RoM), (ii) positive horizontal force, (iii) negative horizontal force, (iv) positive vertical force, (v) negative vertical force, (vi) positive joint torque normalized to body weight and (vii) negative joint torque normalized to body weight.

For the wrist a significant time effect ($p < 0.05$; $\eta^2 = 0.54$) was observed for the positive horizontal force (Figure 4.2). The positive horizontal force was relatively higher at the onset of CPR administration than at the end of CPR administration for both the groups and for both the types of CPR administered (Mean ± SE: 46.10 ± 0.73 N at onset; 43.83 ± 0.73 N at the end).

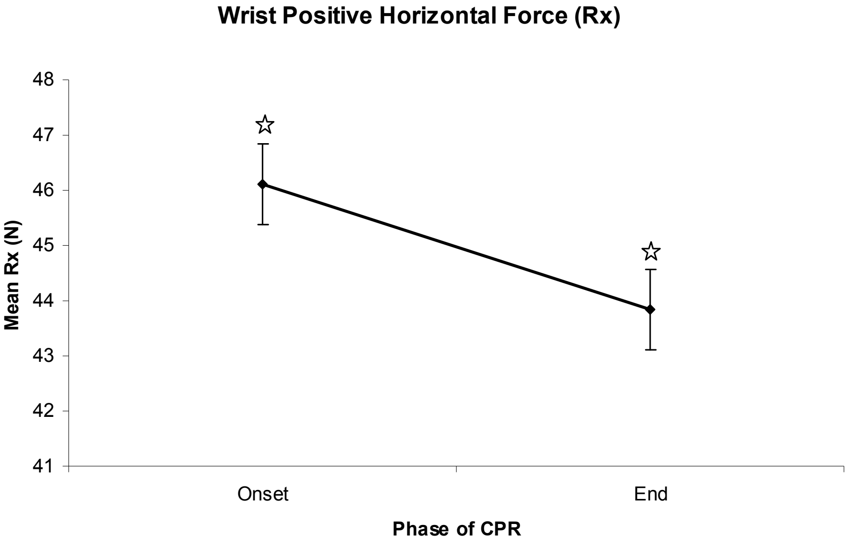

Figure 4.2 Wrist Average Positive Horizontal Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.05$

A time effect ($p < 0.001$; $\eta^2 = 0.99$) and a two way interaction (CPR Type x Time; $p < 0.05$; $\eta^2 = 0.53$) was obtained for the negative vertical force (Figures 4.3, 4.4). The negative vertical force was found to decrease at the end of CPR administration (Mean ± SE: -496.52 ± 7.45 N at onset; -445.75 ± 7.45 N at the end). A greater difference was obtained between the onset of CPR administration and end of CPR administration for the compressions only type of CPR (Mean ± SE- Compressions only: -493.96 ± 5.42 N at onset; -431.33 ± 5.42 N at end; Mean ± SE - Compressions with ventilations: -499.09 ± 5.42 N at onset; -460.16 ± 5.42 N at end).

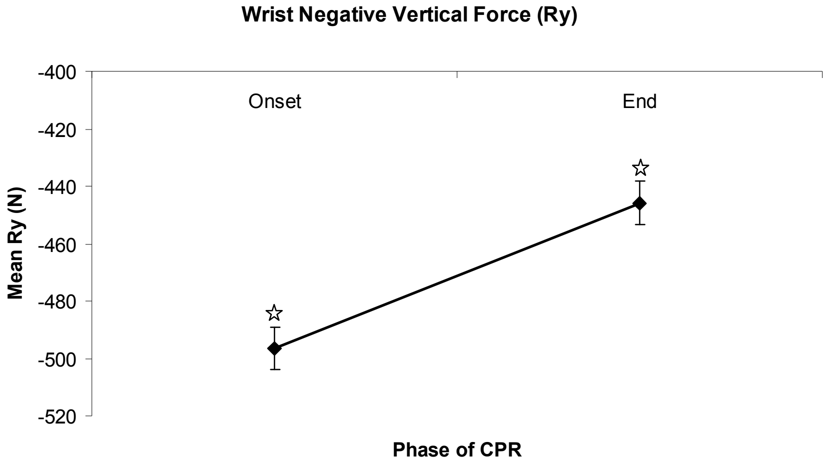

Figure 4.3 Wrist Average Negative Vertical Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

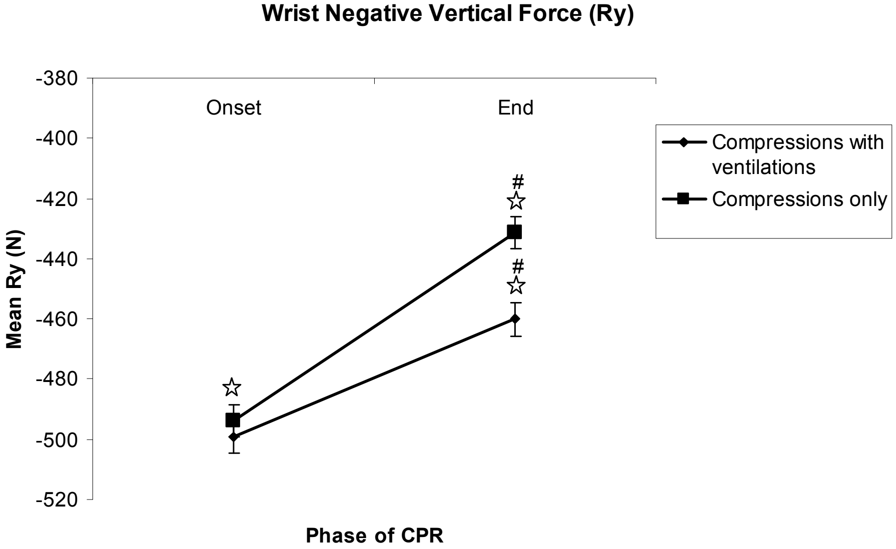

Figure 4.4 Wrist Average Negative Vertical Forces, Condition x Time Interaction.
Bars represent Standard Error. * implies significant difference between Onset and End; # implies significant difference between End-Compressions with ventilations and End-Compressions only at $p < 0.05$

A significant two way interaction (Group x Time interaction; $p < 0.05$; $\eta^2 = 0.54$) was obtained for positive joint torque normalized to body weight (Figure 4.5). The positive joint torque was lower at the end of CPR administration for the older group compared to that at the end of CPR administration for the younger group (Mean $\pm$ SE – End: 0.306 $\pm$ 0.016 N-m/kg for older; 0.38 $\pm$ 0.014 N-m/kg for younger). No other parameters differed significantly for the wrist.

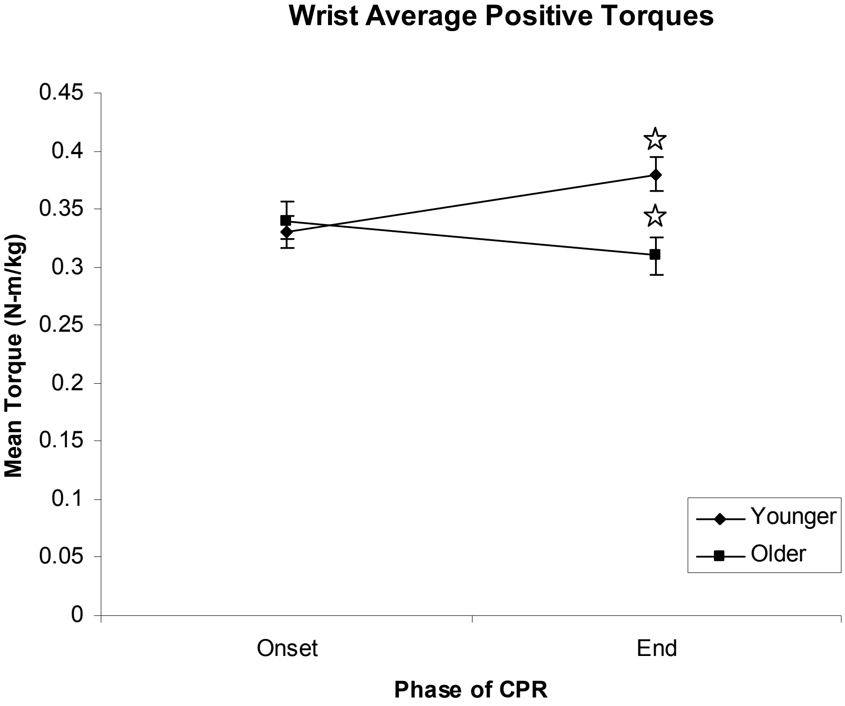

Figure 4.5 Wrist Average Positive Torques, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.05$

At the elbow, a significant time effect ($p < 0.05$; $\eta^2 = 0.65$) was observed for the positive horizontal force (Figure 4.6). The positive horizontal force was relatively higher at the onset of CPR administration than at the end of CPR administration for both the groups and for both the types of CPR administered (Mean + SE: 46.50 + 0.63 N at onset; 44.28 + 0.63 N at the end).

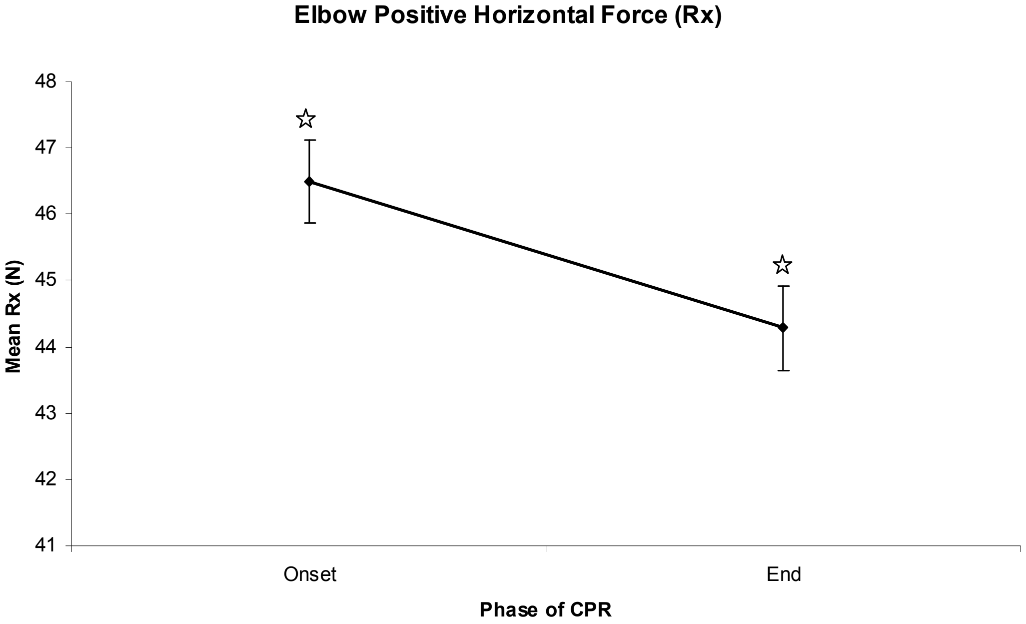

Figure 4.6 Elbow Positive Horizontal Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.05$

A time effect ($p < 0.001$; $\eta^2 = 0.995$) and a two way interaction (CPR Type x Time; $p < 0.05$; $\eta^2 = 0.53$) was obtained for the negative vertical force (Figures 4.7, 4.8). The negative vertical force was found to decrease at the end of CPR administration (Mean + SE: -472.24 + 7.3 N at onset; 421.70 + 7.3 N at the end). A greater difference was obtained between the onset of CPR administration and end of CPR administration for the compressions only type of CPR (Mean + SE- Compressions only: -469.88 + 5.34 N at onset; -407.67 + 5.34 N at end; Mean + SE- Compressions with ventilations: -474.59 + 5.34 N at onset; -435.74 + 5.34 N at end).

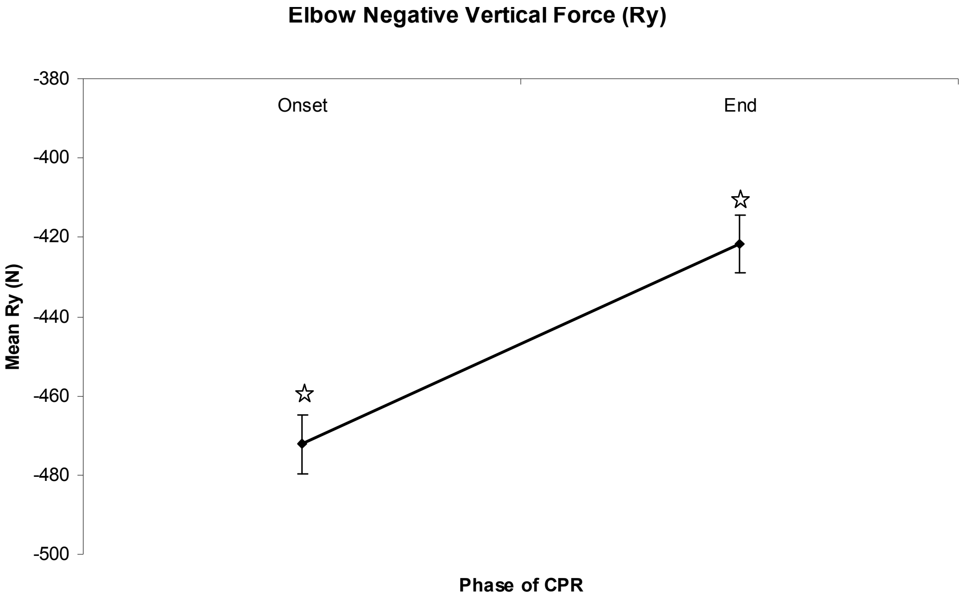

Figure 4.7 Elbow Negative Vertical Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

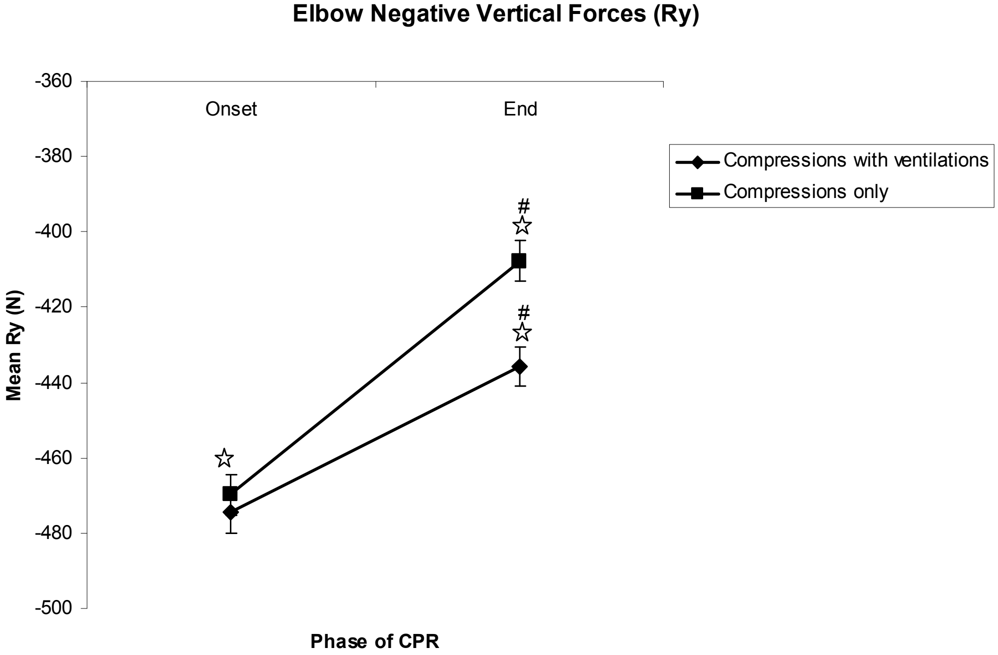

Figure 4.8 Elbow Negative Vertical Forces, Condition x Time Intereaction.
Bars represent Standard Error. * implies significant difference between Onset and End;
implies significant difference between End-Compressions with ventilations and End-Compressions only at $p < 0.05$

A significant time effect ($p < 0.001$; $\eta^2 = 0.999$) was found for the positive joint torque normalized to body weight at the elbow (Figure 4.9). The torque was found to be significantly decreased at the end of CPR administration (Mean ± SE: 0.116 ± 0.015 N-m/kg at onset; -2.43 ± 0.015 N-m/kg at the end).

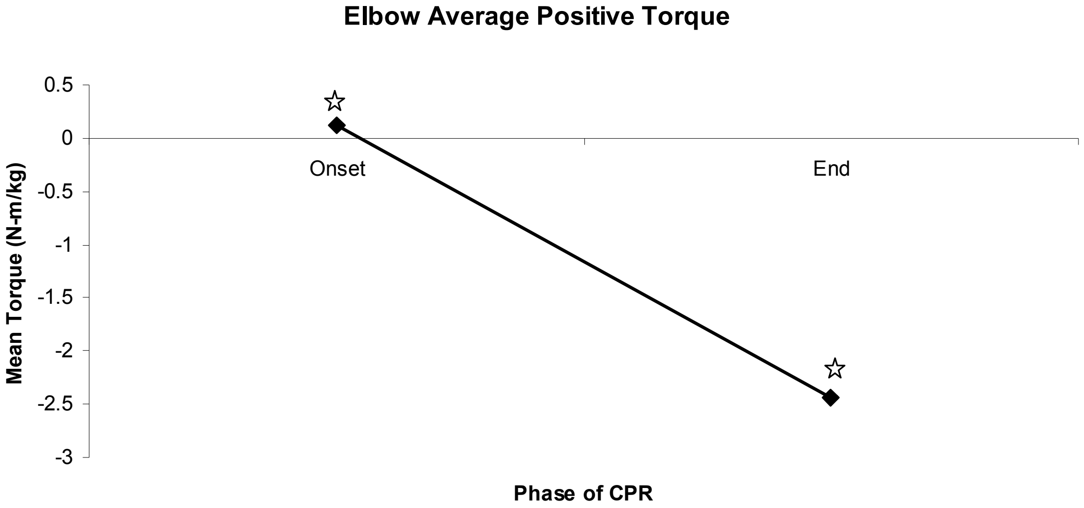

Figure 4.9 Elbow Average Positive Torques, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

A time effect ($p < 0.05$; $\eta^2 = 0.58$) was also observed on the negative joint torque normalized to body weight (Figure 4.10). The torque was found to increase towards the end of the CPR administration (Mean ± SE: -0.22 ± 0.014 N-m/kg at the onset; -0.27 ± 0.014 N-m/kg at the end). No other parameters were significantly different for the elbow joint.

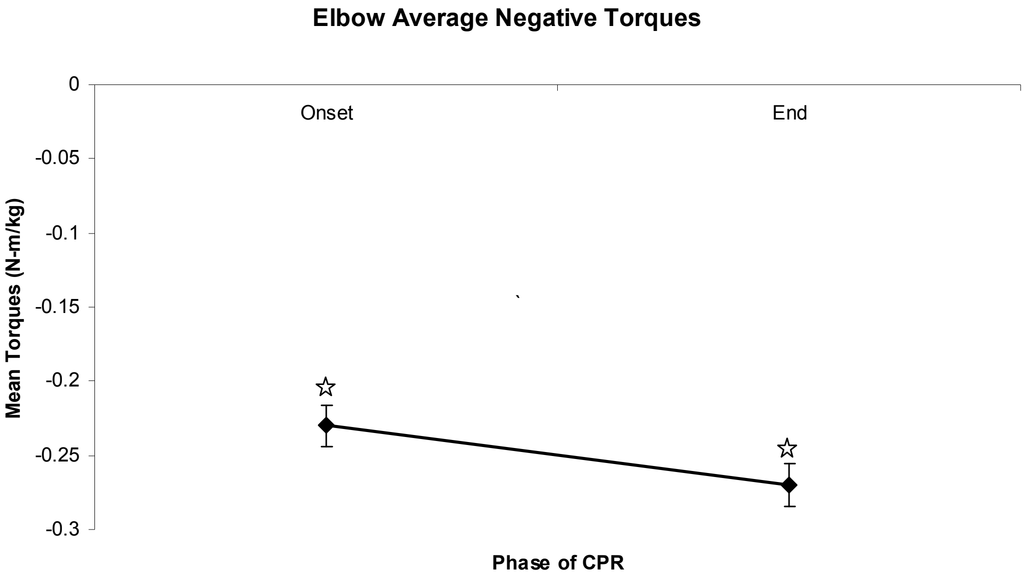

Figure 4.10 Elbow Average Negative Torques, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.05$

For the shoulder, a significant time effect ($p < 0.05$; $\eta^2 = 0.66$) was obtained for the RoM (Figure 4.11). The shoulder RoM was found to decrease at the end of CPR administration (Mean $\pm$ SE: $15.44 \pm 0.44^{\circ}$ at onset; $13.87 \pm 0.44^{\circ}$ at end).

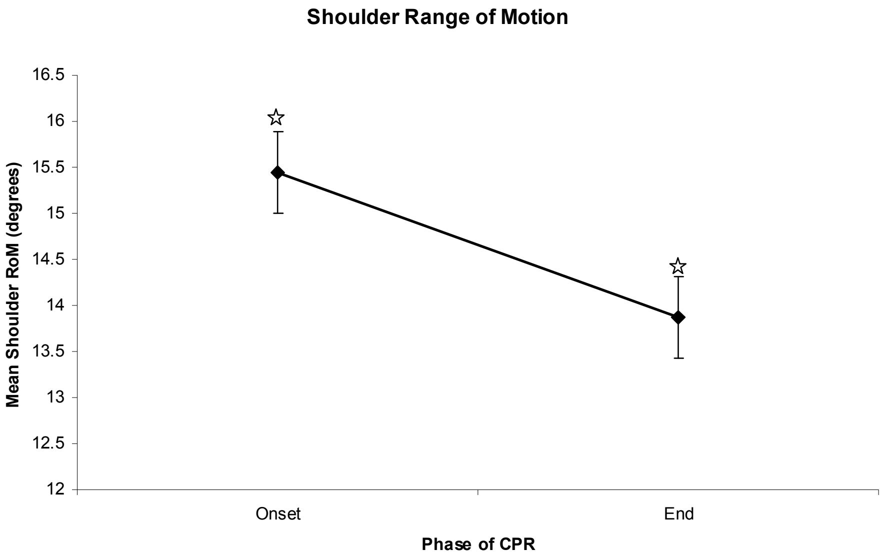

Figure 4.11 Shoulder Range of Motion, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.05$

A significant time effect ($p < 0.01$; $\eta^2 = 0.82$) was obtained for the positive horizontal force (Figure 4.12). The positive horizontal force was found to decrease at the end of CPR administration (Mean $\pm$ SE: 49.08 $\pm$ 0.43 N at onset; 47.18 $\pm$ 0.43 N at end).

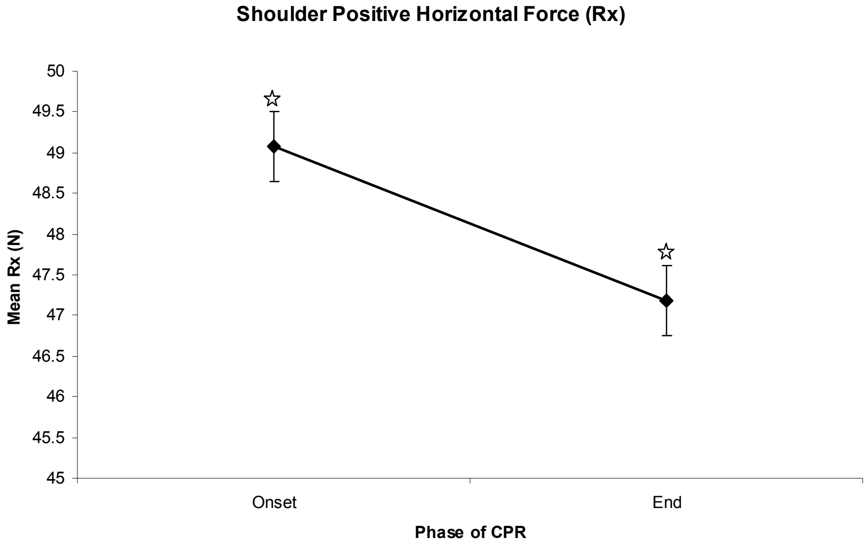

Figure 4.12 Shoulder Positive Horizontal Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.01$

A significant time effect ($p < 0.001$; $\eta^2 = 0.997$) was also obtained for the negative vertical force with a reduction being observed at the end of CPR administration (Mean $\pm$ SE: -426.40 $\pm$ 6.98 N at onset; -376.22 $\pm$ 6.98 N at end) (Figure 4.13).

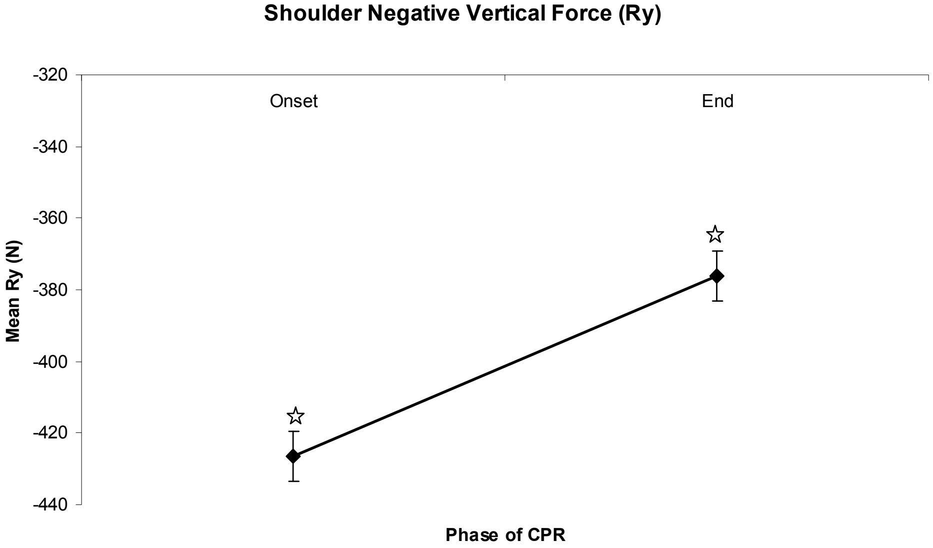

Figure 4.13 Shoulder Negative Vertical Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

A significant two way interaction (CPR Type x Time) was found for the positive joint torque at the shoulder normalized to body weight ($p < 0.01$; $\eta^2 = 0.82$) (Figure 4.14). A greater difference was obtained between the onset of CPR administration and end of CPR administration for the compressions with ventilations type of CPR and also a significant difference was found between the end positive joint torques for both the CPR types (Mean ± SE- Compressions only: 0.61 ± 0.019 N-m/kg at onset; 0.58 ± 0.019 N-m/kg at end; Mean - Compressions with ventilations: 0.60 ± 0.019 N-m/kg at onset; 0.68 ± 0.019 N-m/kg at end).

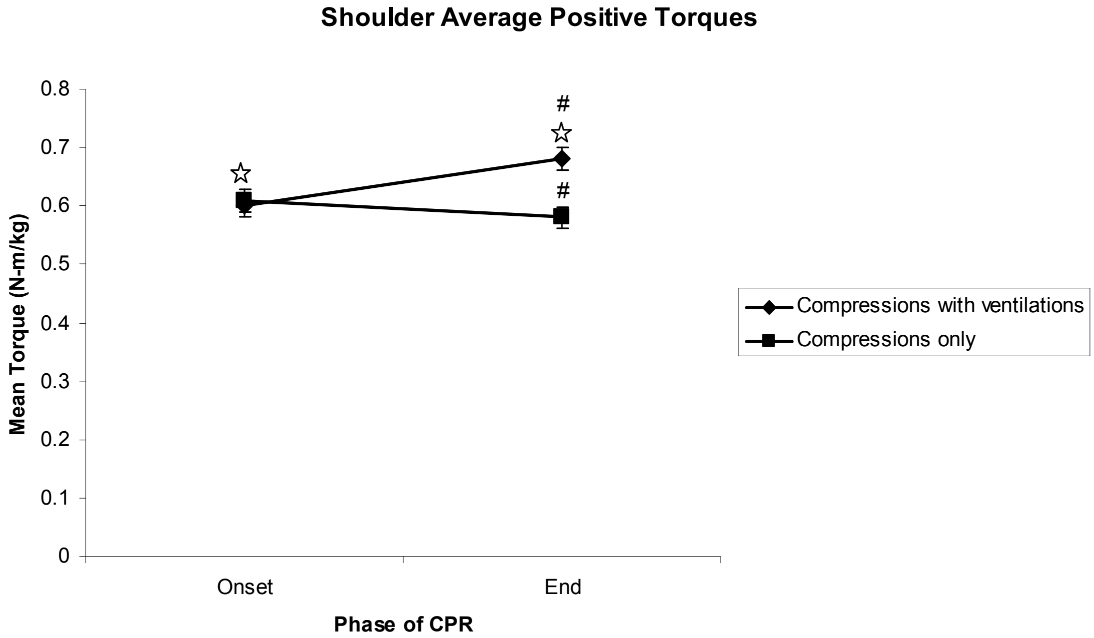

Figure 4.14 Shoulder Average Positive Torques, Condition x Time Interaction. Bars represent Standard Error. * implies significant difference between Onset and End for Compression with ventilations type of CPR; # implies significant difference between End-Compressions with ventilations and End-Compressions only at $p < 0.01$

A time effect ($p < 0.001$; $\eta^2 = 0.92$) was also observed on the negative joint torque normalized to body weight (Figure 4.15). The torque was found to increase towards the end of the CPR administration (Mean ± SE: 0.19 ± 0.016 N-m/kg at the onset; 0.27 ± 0.016 N-m/kg at the end). No other parameters were significantly different for the shoulder joint.

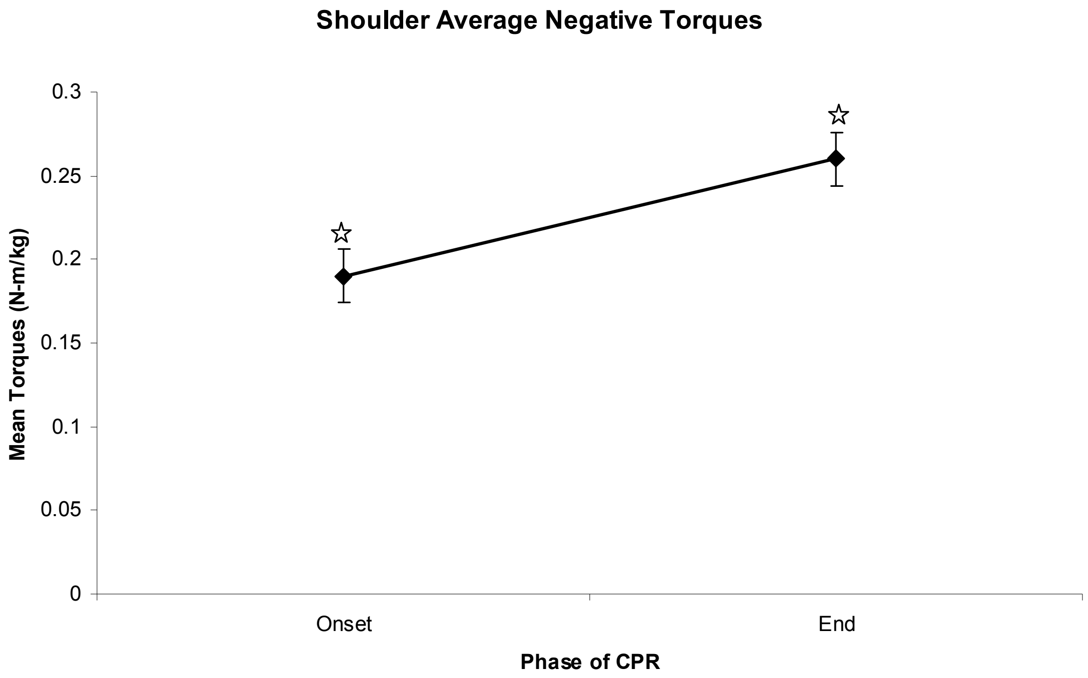

Figure 4.15 Shoulder Average Negative Torques, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

At the hip joint, a significant time effect ($p < 0.001$; $\eta^2 = 0.999$) was observed for the positive horizontal force (Figure 4.16). The parameter was found to be decline towards the end of CPR administration (Mean $\pm$ SE: 111.56 $\pm$ 1.53 N at onset; 99.74 $\pm$ 1.53 N at the end).

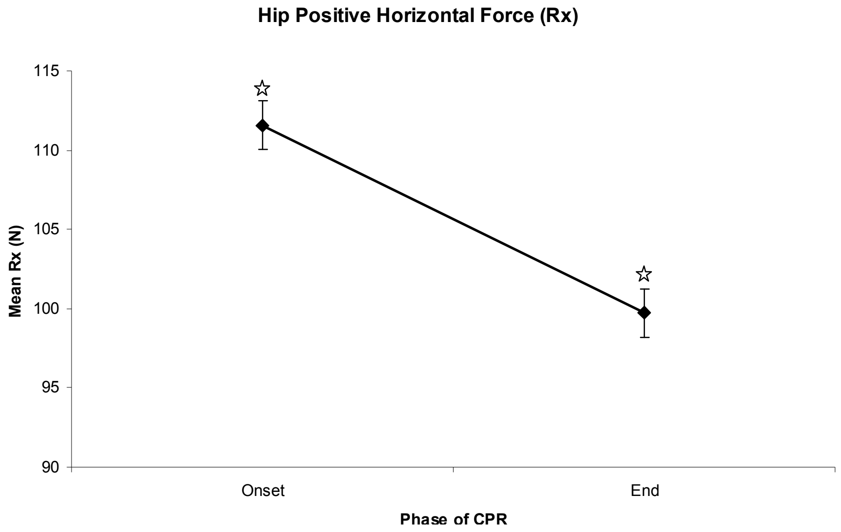

Figure 4.16 Hip Positive Horizontal Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

A significant time effect ($p < 0.01$; $\eta^2 = 0.91$) was also observed for negative horizontal force (Figure 4.17). It was found to decrease at the end of the CPR administration (Mean ± SE: -54.28 ± 2.39 N at onset; -42.31 ± 2.39 N at the end).

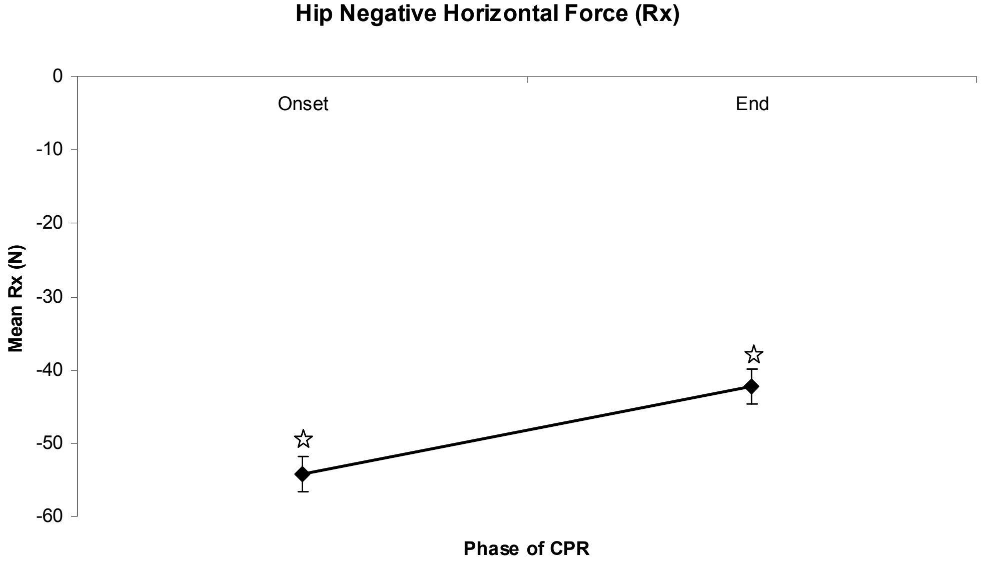

Figure 4.17 Hip Negative Horizontal Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.01$

The negative vertical force was also observed to vary significantly with time ($p < 0.001$; $\eta^2 = 0.999$) (Figure 4.18). The parameter registered an increase at the end of CPR administration (Mean ± SE: 56.57 ± 4.80 N at onset; 105.13 ± 4.80 at the end).

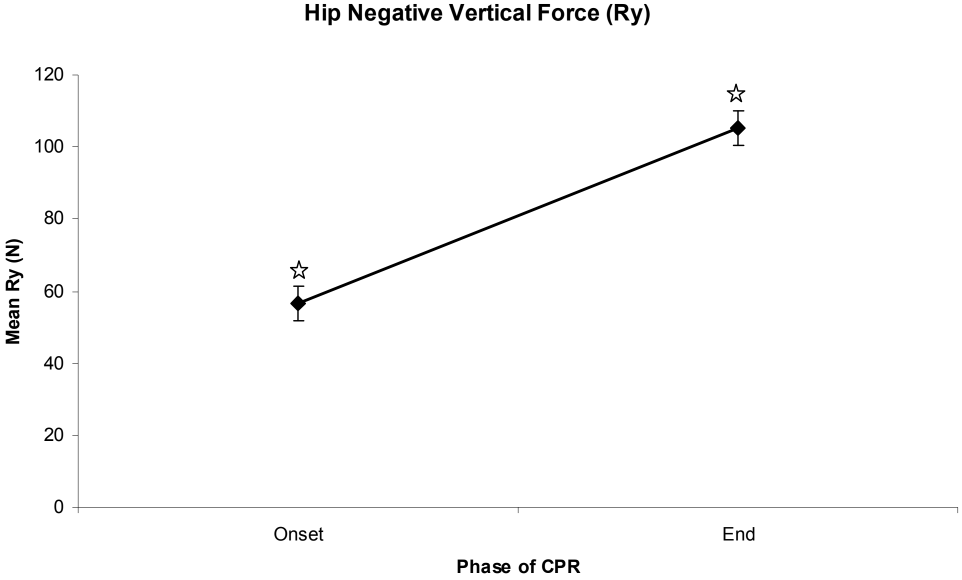

Figure 4.18 Hip Negative Vertical Forces, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

A two way interaction (Group x CPR Type) was observed for the positive joint torque normalized to body weight at the hip ($p < 0.05$; $\eta^2 = 0.59$) (Figure 4.19). Significant differences were observed between and within the two groups for both the CPR types (Mean ± SE– Compressions only: 1.42 ± 0.14 N-m/kg for younger; 1.75 ± 0.16 N-m/kg for older; Mean ± SE– Compressions with ventilations: 1.59 ± 0.14 N-m/kg for younger; 1.22 ± 0.16 N-m/kg for older).

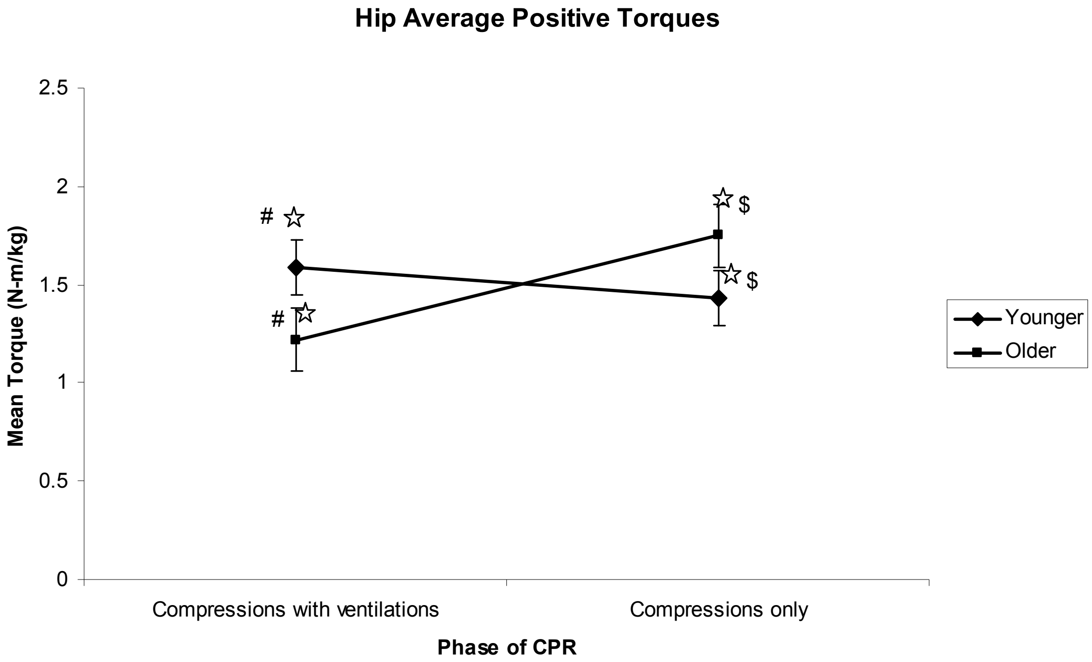

Figure 4.19 Hip Average Positive Torques, Condition x Group Interaction.
Bars represent Standard Error. * implies significant difference between Onset and End for both types of CPR; # implies significant difference between Onset-Compressions with ventilations and Onset-Compressions only; $ implies significant difference between End-Compressions with ventilations and End-Compressions only at $p < 0.01$

A time effect ($p < 0.001$; $\eta^2 = 0.996$) was also observed on the negative joint torque normalized to body weight (Figure 4.20). The torque was found to decrease towards the end of the CPR administration (Mean $\pm$ SE: -0.28 $\pm$ 0.06N-m/kg at the onset; 0.15 $\pm$ 0.06 N-m/kg at the end). No other parameters were significantly different for the hip joint.

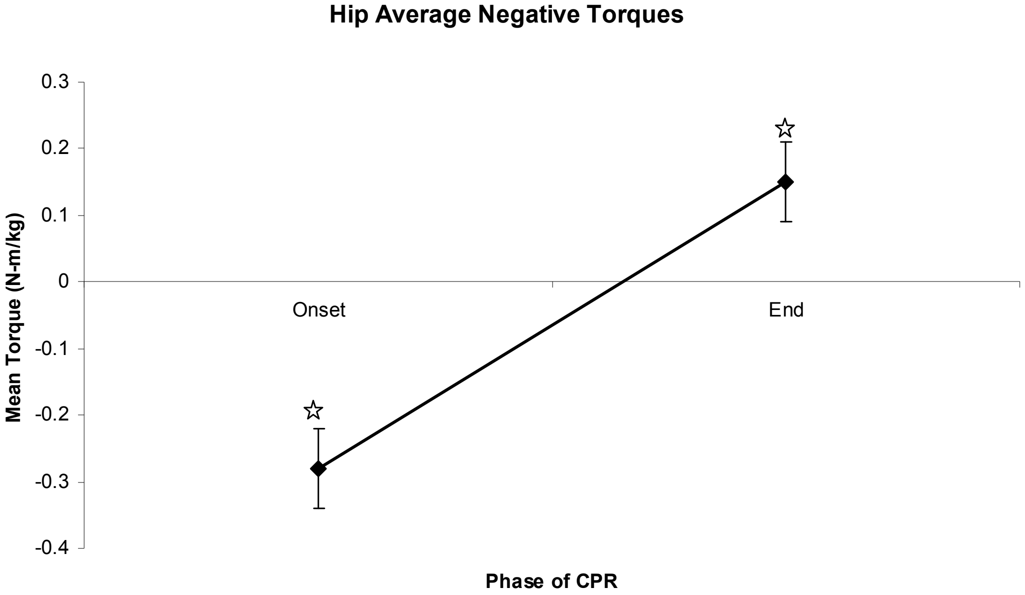

Figure 4.20 Hip Average Negative Torques, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

4.2 CPR Quality Assessment

Compressions were analyzed in segmented sections at the onset and end of every CPR trial to evaluate (i) total number of compressions, (ii) number of compressions with errors, (iii) average number of compressions per minute, (iv) average compression depth and (v) average compression rate.

A significant time effect ($p < 0.01$; $\eta^2 = 0.93$) was observed for the number compressions with errors with greater number of errors at the end of CPR administration (Mean ± SE: 29.3 ± 4.10 at onset; 50.23 ± 4.10 at the end) (Figure 4.21).

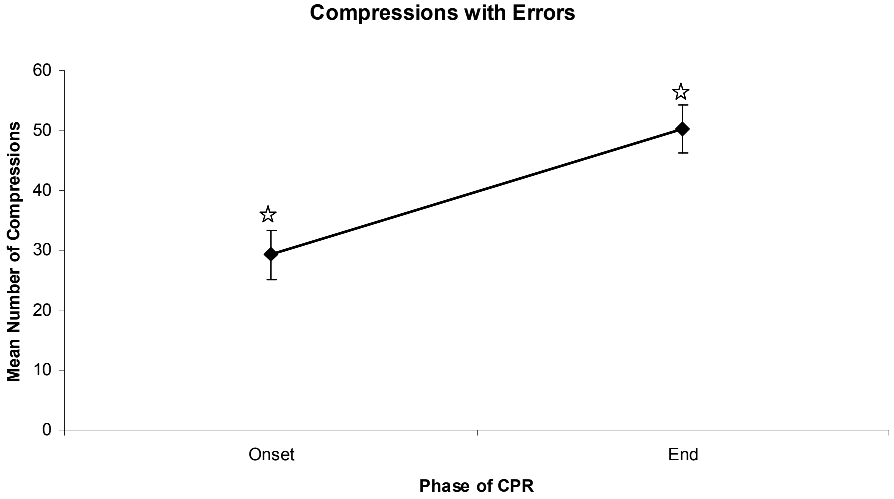

Figure 4.21 Compressions with Errors, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.01$

A condition effect ($p < 0.001$; $\eta^2 = 0.93$) and a time effect ($p < 0.001$; $\eta^2 = 0.995$) was observed for the average compression depth (Figures 4.22, 4.23). It was found to be significantly lower for compressions only type of CPR (Mean $\underline{+}$ SE: 39.87 $\underline{+}$ 0.48 mm for compressions only; 42.31 $\underline{+}$ 0.48 mm for compressions with ventilations). The average compression depth was also found to be decrease significantly at the end of CPR administration (Mean $\underline{+}$ SE: 43.22 $\underline{+}$ 0.62 mm at onset; 38.97 $\underline{+}$ 0.62 mm at the end). None of the other parameters were found to be significantly different.

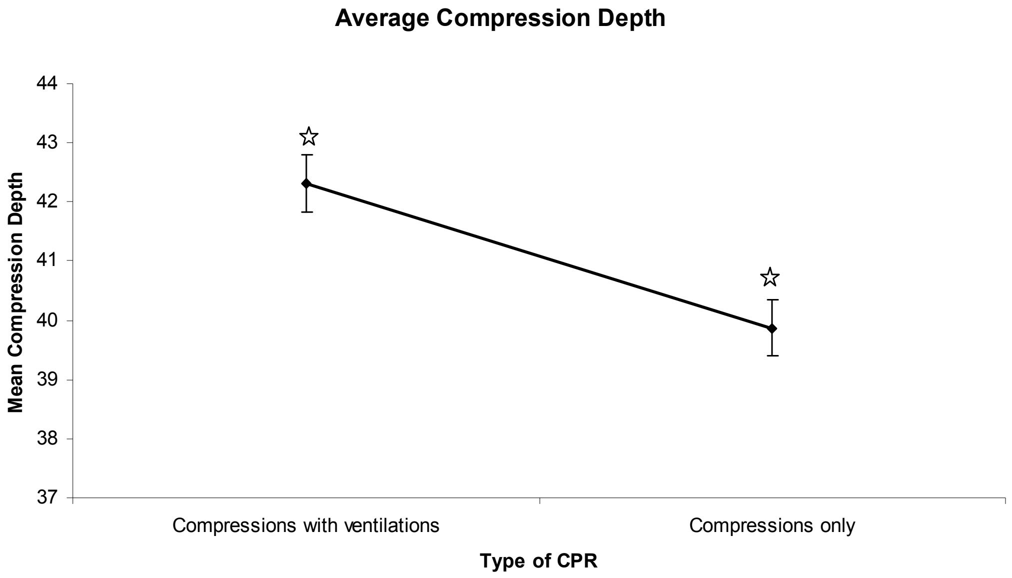

Figure 4.22 Average Compression Depth, Condition Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

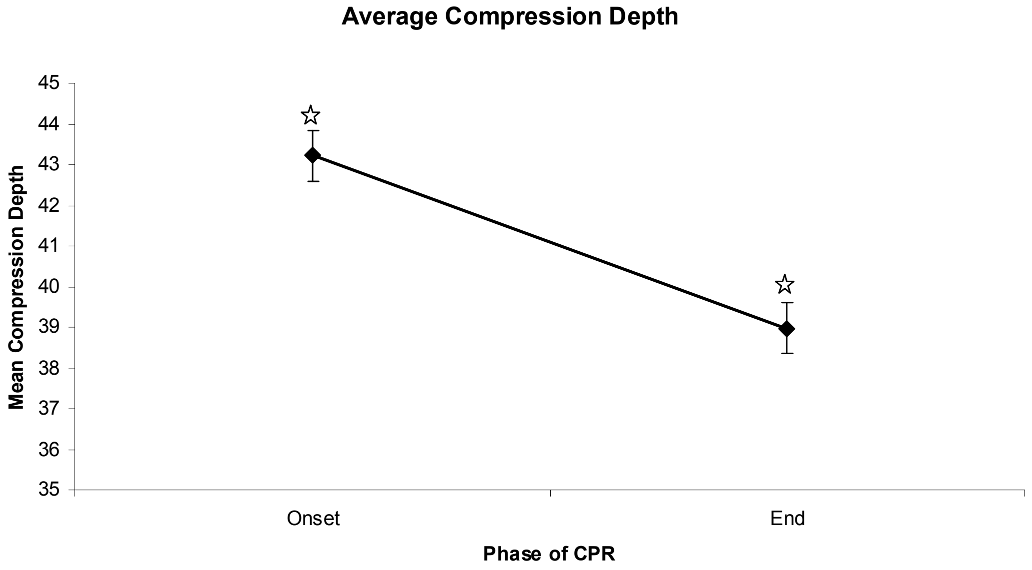

Figure 4.23 Average Compression Depth, Time Effects.
Bars represent Standard Error. * implies significant difference at $p < 0.001$

Ventilations were analyzed to observe (i) effective ventilations, (ii) ventilations with inadequate volume and (iii) average ventilation flow rate. No differences between either groups for both the CPR types were observed.

4.3 SEMG Results

SEMG data was analyzed to evaluate the effect of groups, CPR types and time on the IEMG value and time of peak activity of the muscles with respect to the peak compression force. No significant differences in muscle activity, determined by the IEMG amplitude were found for the lateral head of triceps brachii, erector spinae, hamstrings and quadriceps muscles.

A significant time effect ($p < 0.001$; $\eta^2 = 0.99$) was found for the IEMG of the anterior deltoid muscle. The muscle activity was found to decrease towards the end of CPR administration (Mean ± SE: 30.48 ± 1.36 mV at onset; 21.75 ± 1.36 mV at the end). A significant time effect ($p < 0.05$; $\eta^2 = 0.62$) was also found for the IEMG of the pectorals major muscle. The muscle activity was found to decrease towards the end of CPR administration (Mean ± SE: 19.10 ± 1.25 mV at onset; 14.86 ± 1.25 mV at the end). The biceps brachii also indicated a similar significant time effect ($p < 0.001$; $\eta^2 = 0.98$). The muscle activity was found to decrease towards the end of CPR administration (Mean ± SE: 23.70 ± 1.26 mV at onset; 16.10 ± 1.26 mV at the end). A significant time effect ($p < 0.05$; $\eta^2 = 0.72$) was observed for the IEMG of the lattisimus dorsi muscle. The muscle activity was found to decrease towards the end of CPR administration (Mean ± SE: 16.28 ± 1.18 mV at onset; 11.78 ± 1.18 mV at the end). The upper trapezius also had a significant time effect ($p < 0.001$; $\eta^2 = 0.999$). The muscle activity was found to decrease towards the end of CPR administration (Mean ± SE: 15.41 ± 0.73 mV at onset; 9.79 ± 0.73 mV at the end). The middle trapezium activity was also found to have a significant time effect ($p < 0.001$; $\eta^2 = 0.997$).The

IEMG registered a decrease at the end (Mean ± SE: 13.98 ± 0.69 mV at onset; 9.02 ± 0.69 mV at the end). A similar time effect ($p < 0.001$; $\eta^2 = 0.97$) was observed for the external oblique. The activity again decreased at the end of CPR administration (Mean ± SE: 13.80 ± 0.91 mV at onset; 8.53 ± 0.91 mV at the end). These effects have been graphed in Figure 4.24.

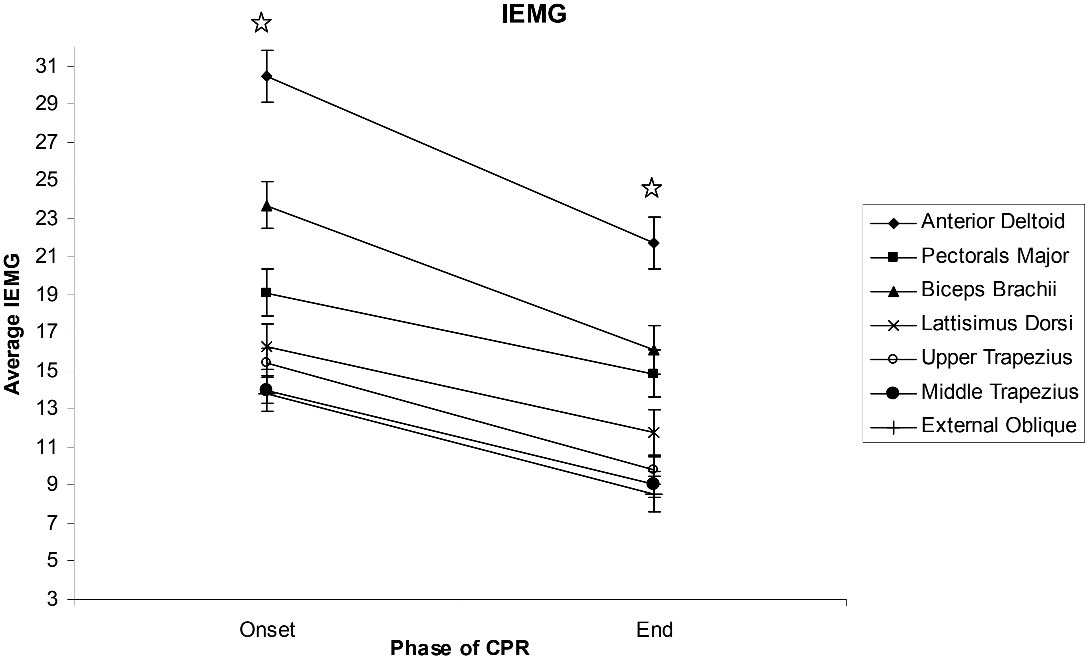

Figure 4.24 IEMG, Time Effects.
Bars represent Standard Error. * implies significant differences at $p < 0.001$

The time of peak muscle activity relative to the peak compression force applied registered no significant differences for the lateral head of triceps brachii, pectorals major, biceps brachii, lattisimus dorsi, middle trapezium, external oblique, hamstrings and quadriceps. The anterior deltoid was found to have a significant group effect ($p < 0.05$; $\eta^2 = 0.54$). It was found that the older group time of peak muscle activity was much later than that for the younger group (Mean ± SE: -126.08 ± 63.42 ms for older; -

316.35 ± 60.17 ms for the younger). The upper trapezius was also found to have a significant group effect ($p < 0.05$; $\eta^2 = 0.57$). It was found that the older group time of peak muscle activity was much later than that for the younger group (Mean ± SE: -93.28 ± 60.58 ms for older; -283.2 ± 57.47 ms for the younger). The erector spinae also indicated a significant group effect ($p < 0.05$; $\eta^2 = 0.51$). It was found that the older group time of peak muscle activity was much later than that for the younger group (Mean ± SE: -10.14 ± 70.88 ms for older; -216.48 ± 67.25 ms for the younger). Figure 4.25 graphs these effects.

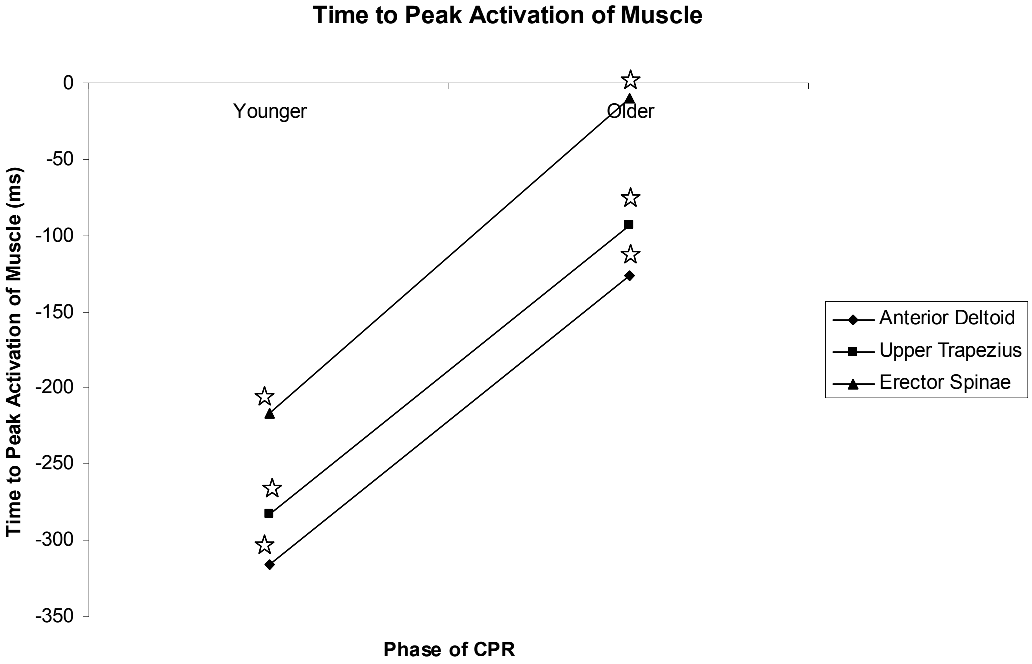

Figure 4.25 Times to Peak Activation of Muscle, Group Effects.
* implies significant differences at $p < 0.05$

4.4 Blood Lactate Results

A significant time effect ($p < 0.001$; $\eta^2 = 1.00$) was observed for the concentration of lactate in blood (Figure 4.26). The concentration of lactate in blood was found to be significantly higher Post-CPR from Pre-CPR and from 5 minutes Post-CPR (Mean ± SE: 1.37 ± 0.096 mmol/ml for pre-CPR; 2.73 ± 0.096 mmol/ml for post CPR; 2.09 ± 0.096 mmol/ml for 5 minutes post CPR).

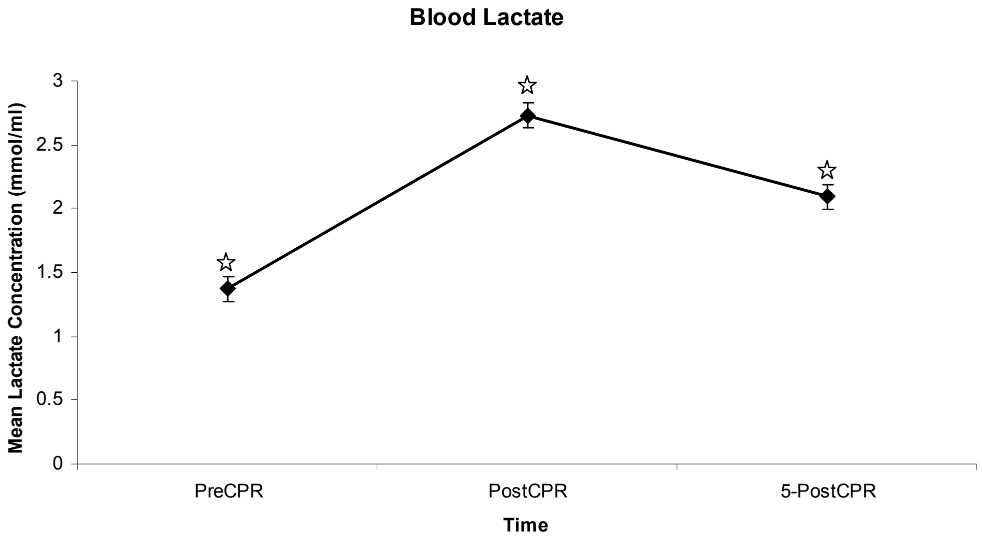

Figure 4.26 Blood Lactate Concentrations, Time Effects.
* implies significant differences at $p < 0.001$

4.5 Time to Fatigue

The time to fatigue was not influenced by either the type of CPR or the age of the subject. However, the type of CPR administered had a significant effect ($p < 0.001$; $\eta^2 = 0.99$) on the rate of perceived exertion (RPE) (Figure 4.27). The RPE for the compressions only type of CPR was considerably higher than that for compressions with ventilations CPR (Mean ± SE: 13.33 ± 0.18 for compressions with ventilations type of CPR; 14.46 ± 0.18 for compressions only).

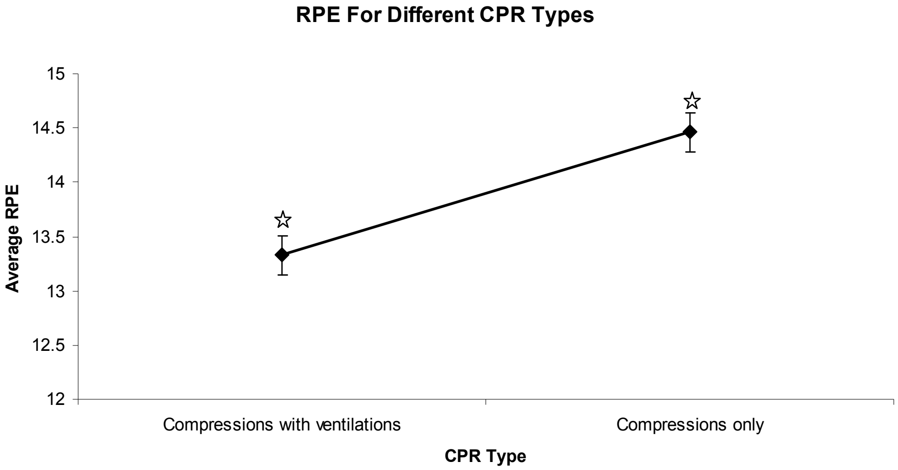

Figure 4.27 RPE for different CPR Types, Condition Effects.
* implies significant differences at $p < 0.001$

A significant difference ($p < 0.001$; $\eta^2 = 1.00$) was also found in the RPE obtained at 5 minutes from RPE obtained at the end of CPR administration (Figure 4.28). The exertion experienced by the subjects towards the end of CPR administration was considerably higher (Mean ± SE: 12.78 ± 0.17 at 5 minutes; 15.03 ± 0.17 at the end of CPR administration).

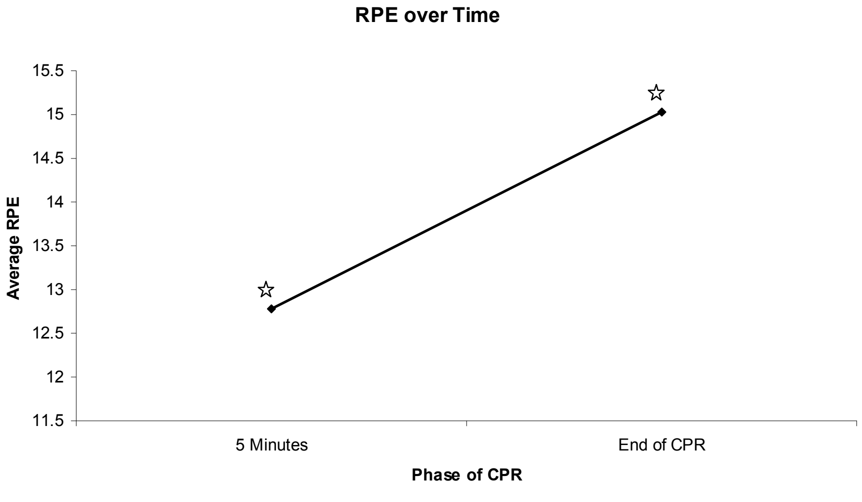

Figure 4.28 RPE at different times during CPR administration, Time Effects.
* implies significant differences at $p < 0.001$

CHAPTER 5

DISCUSSION

The primary purpose of this study was to observe the effects of age and type of CPR administered on fatigue and quality of CPR administered as the subjects administered CPR continuously until self identified fatigue (identified as exertion on Borg's scale) settled in or to a maximum of 10 minutes. Twenty subjects administered both CPR with compressions only and CPR with compressions and ventilations. Six of the total forty CPR trials were stopped prematurely before 10 minutes when the subjects' RPE equaled 17. Of these six trials, five were compressions only type of CPR (administered by four younger subjects and one older subject) and one was compressions and ventilations type of CPR (administered by one older subject).

The CPR type had a strong influence on the quality of compressions administered. From the results it is evident that the quality of compressions deteriorated to a much greater extent for compressions only type of CPR when compared to compressions with ventilations type of CPR. Greater numbers of compressions were recognized as erroneous over time and a larger decline of the average depth of compressions observed for compressions only type of CPR. This finding is substantiated by the fact that the subjects perceived greater exertion for the compressions only type of CPR. It is also reflected in the effect of CPR type on the negative vertical forces at the wrist and elbow and on the positive joint torques normalized to body weight at the shoulder and hip. A greater decline of the negative vertical force was observed towards the end of CPR administration for the compressions only type of CPR. This simply implies that the vertical component of the compression force applied by the subject was significantly lower for the compressions only type of CPR than was for the compressions with ventilations type of CPR. A greater decline in the positive torques at the shoulder and hip for the compressions only type of CPR relative to the compressions with ventilations type of CPR also indicate the reduction of the compressive force towards the end.

However, for the compressions with ventilations type of CPR though the compressions administered were of better quality, the quality of ventilations with respect to the volume of air delivered was poor. Majority of the ventilations delivered in a single trial were reported as having insufficient volume. This could also be due to the fact that manikins require volume of ventilation to fall within the range of 700-1000 ml. American Heart Association® guidelines recognizes ventilation volume of 500-600 ml also to be sufficient [2].

The age factor, as investigated with the two groups of subjects, had no significant effect on the quality of CPR administered irrespective of the type of CPR. However, the pattern of activation of muscles was considerably influenced by the age factor. A significant age effect was observed for the SEMG time of peak activation relative to the peak compression force. In three of the major upper body muscles involved in the act of CPR administration, anterior deltoid, upper trapezius and the erector spinae, it was found that the younger subjects' activation pattern differed from that of the older subjects. The younger subjects activated these muscles earlier on than the older subjects. Thus, the younger subjects start using these muscles early and apply force for a longer time till peak compression force is generated. An age effect was also observed for the positive joint torques normalized to body weight at the wrist and the hip joints. The positive joint torque at the elbow was significantly lower for the older group than for the younger group towards the end of CPR administration.

Another aspect of the study compared the various parameters at the onset of CPR administration to that at the end of CPR administration i.e. the effects of time on these parameters were observed. Quality of CPR administered and manifestation of fatigue were both strongly influenced by the time factor. The RPE of the subjects indicated a rise as time progressed. The quality of CPR significantly depreciated over time as reflected in the increased number of erroneous compressions towards the end and reduced average depth of compressions towards the end. Fatigue manifestation was indicated clearly towards the end of CPR administration by the analysis of lactate concentration in blood which registered a significant rise post-CPR for both the groups and for both the types of CPR administered. Fatigue manifestation was also reflected in the assessment of the various biomechanical parameters. The average compression force normalized to body weight significantly reduced at the end of CPR administration. This is substantiated by the fact that a decline in positive horizontal force and negative vertical force was observed for all the joints. It was also indicated in the reduced activity of most of the upper body muscles associated with CPR towards the end of CPR administration as determined by the IEMG values.

The study also intended to scrutinize the effects of fatigue on the biomechanics of the rescuer. It was observed that with fatigue, the joint torques normalized to body weight significantly deteriorated for the wrist, elbow shoulder and hip joints. Positive torque indicates extension of the joint. This parameter registered a significant decrease with time for the wrist and the elbow. A decline in positive torque implies relatively greater flexion of the joint. Thus, as the rescuer fatigues, more flexion or reduced extension will be observed at the wrist and the elbow. When administering CPR, the wrist is in hyper-extension. With fatigue, the rescuer positions the wrist in a less hyper-extended angle. Similarly the elbow which is at full extension at the start gets flexed more as the rescuer fatigues. The shoulder and the hip registered a decline in negative joint torques normalized to body weight with time. Negative torques indicate flexion of the joint and thus a declining negative torque implies increased extension or reduced flexion of the joint. The shoulder at the start of CPR is further away from the trunk and towards the end as the rescuer fatigues the angle between the trunk and the shoulder and trunk reduces. Likewise, the hip joint flexes relatively less towards the end of the CPR keeping the rescuer upper body more rigid and upright.

The joint forces also indicate the effects of fatigue. A significant decrease in the horizontal and vertical forces was observed for all the joints towards the end of CPR. A decline in vertical force is a direct indicator of a reduction in the amount of “push” the rescuer applies to the victim’s chest. A decrease in the horizontal force towards the end indicates the rescuer tends to “lean” on the victim and does not recoil completely off the victim’s chest.

5.1 Implications

This study is different from all the CPR studies done to date considering that this study focuses on the various aspects of CPR administration from the rescuer's perspective. The rescuer plays the most important role in CPR administration and thus rescuer strength and endurance too need to be given some priority. The CPR protocol should be designed so that it would maximally benefit the victim without causing undue stress and discomfort to the rescuer, helping the rescuer deliver the most effective CPR for a relatively long duration of time.

It is evident from the study that CPR with compressions and ventilation (30:2) was comparatively easier for the rescuers to administer. The overall fatigue and stress experienced by the rescuer over time, as evaluated by the joint torques, forces, IEMG and RPE, was reduced predominantly for CPR with compressions and ventilations in contrast to CPR with compressions only. The quality of compressions delivered was also better for CPR with compressions and ventilations as indicated by the higher average compression depth for CPR with compressions and ventilations.

Rescuer fatigue and its subsequent effect on the quality of CPR should be a primary consideration when designing a CPR protocol. With fatigue, important changes in the rescuer biomechanics were observed which hindered the effective administration of CPR. Some of the more visible changes included reduced hyperextension of the wrist (pushing with fingers and palm), increased flexion ('bending') of the elbows, decreased range of motion of the shoulders (shoulders locked closer to the trunk), reduced extension at the hip (supporting self by leaning over the victim) and increased dependency on the lower body for support (sitting back on haunches) (Figures 5.1 and 5.2).

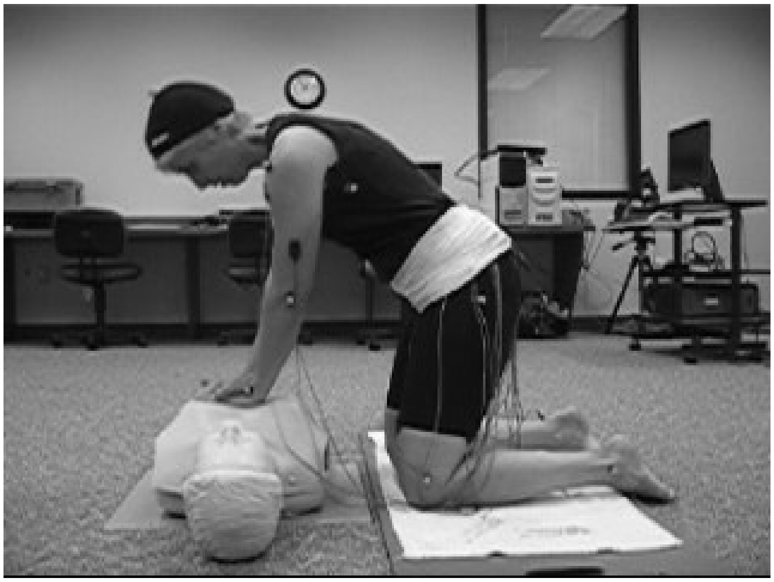

Figure 5.1 Rescuer Posture at the Onset Phase of CPR

Figure 5.2 Rescuer Posture at the End Phase of CPR

These variations in the biomechanical parameters result in uneconomical use of muscles and joints causing increased stress to the rescuer and decreased effectiveness of CPR. With fatigue, the rescuer invariably starts leaning more on the victim causing incomplete recoil of the chest. Moreover, the rate at which the rescuer administers compressions also decreases as the rescuer fatigues.

Ventilations between compression cycles provide the rescuer with a much needed rest. The deep breath taken in by the rescuer to deliver ventilation to the victim oxygenates the rescuer too, improving the cardiovascular functions. The rescuer also experiences improved blood circulation as a result of the physical movement associated with delivering the ventilation to the victim. This delays the build up of fatigue in the rescuer ensuring better quality CPR for a longer duration of time. This also has the added effect of reinforcing the rescuer’s concentration by causing the monotony of the task to break.

More research on CPR from the rescuer’s viewpoint is required. The procedure for CPR must consider the rescuer and be developed to make CPR as easy as possible for the rescuer. For instance, the theory behind administering CPR is to improve oxygenated blood circulation in the victim. This could be made easier by elevating the victims’ legs causing increased venous return of the blood to the heart and therefore increased circulation. Another factor that requires significant consideration is the rate of compressions. Current guidelines require compressions be administered at a rate of 100 to 130 compressions per minute. From the rescuer point of view, this is a high speed, extremely difficult to maintain and physically strenuous. Taking into account a supine heart rate of about 60 to 70 beats per minute in normal persons, the rate at which compressions need to be delivered can be lowered. The rescuer will not only be able to maintain a slow rate for a longer period of time but will also be able to maintain the required depth of compression. Modifying the posture of the rescuer when administering CPR can also lead to better results. For example, if the rescuer is positioned further away from the victim, the rescuer will be able to efficiently apply body weight when giving compressions, gaining a biomechanical advantage (Figures 5.3, 5.4). This would also cause less stress to the joints and muscles.

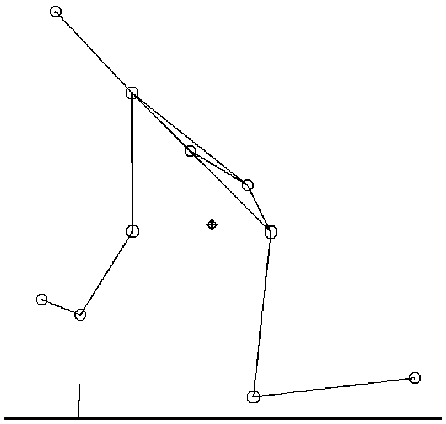

Figure 5.3 Normal Rescuer Posture

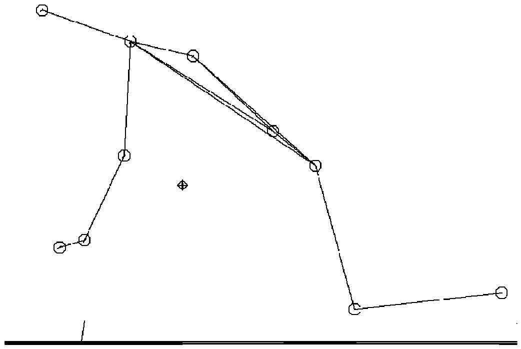

Figure 5.4 Suggested Rescuer Posture

APPENDIX A

BORG SCALE OF PERCEIVED EXERTION

Borg Scale of Perceived Exertion

6	Very, very light work	How you feel when lying in bed or sitting in a chair relaxed. **Little or no effort**
7		
8	Very light	
9		
10		
11	Fairly light	Target range: How you should feel with exercise or activity. **Mild effort**
12		
13	Somewhat hard	
14	Hard	How you felt with the hardest work you have ever done. **Extreme effort**
15		
16	Very hard	
17		
18	Very, very hard	
19		
20	Maximum effort	

APPENDIX B

STATEMENT OF INFORMED CONSENT

THE UNIVERSITY OF TEXAS
AT ARLINGTON

INFORMED CONSENT

PRINCIPAL INVESTIGATOR: _Jesal N. Parekh________________________

TITLE OF PROJECT: Effect of age and cardiopulmonary resuscitation (CPR) techniques on characteristics of muscle fatigue in females trained in CPR administration

This Informed Consent will explain about being a research subject in an experiment. It is important that you read this material carefully and then decide if you wish to be a volunteer.

PURPOSE:

The purpose of this study is to study muscle fatigue during CPR among the two most likely types of persons to be called upon to perform CPR: females between the ages of 45 and 60 (the most likely persons to do out-of-hospital CPR) and females between the ages of 22 and 35 years of age (the most likely persons to do in-hospital CPR). All subjects will be of average height and weight.

The specific purposes of this research study are as follows:

1. To determine what changes in surface electromyography (sEMG) amplitude and frequency occur as a consequence of muscular fatigue over time associated with multiple cycles of CPR.
2. To determine the changes in upper body kinematics (joint angles) over time with multiple cycles of CPR.
3. To determine the changes in depth compression and the rate of compression over time with multiple cycles of CPR.
4. To quantify fatigue in terms of changes in blood lactate quantity over time with multiple cycles of CPR.
5. To determine time to fatigue

DURATION

In this study I will be scheduled for two appointments. The sessions will last for approximately 60 minutes. The first appointment will consist of a health history and assessment for age and body mass index (BMI). Surface electrodes to measure EMG will be placed on your muscles, reflective markers to track motion will be placed on your joints and baseline blood lactate will be measured prior to data collection. Data will be collected as CPR is performed using either compressions only or breaths and compressions. The American Heart Association® guidelines (30:2(compressions:breaths)) will be used and CPR will be performed on a Resusci® Anne SkillReporter. The second appointment will involve the same data collection procedures as you perform the alternate condition.

The total number of subjects participating is 20.

INFORMED CONSENT

PRINCIPAL INVESTIGATOR: _Jesal N. Parekh________________________

TITLE OF PROJECT: Effect of age and cardiopulmonary resuscitation (CPR) techniques on characteristics of muscle fatigue in females trained in CPR administration

PROCEDURES

The procedures, which will involve you as a research subject, include:

1. To be included in this study, you will report to the Biomechanics Laboratory (Room 150) in the Activities Building and fill out a health history questionnaire. If you are for any reason unable to or not certified to administer CPR as per the American Heart Association® 2005 guidelines (30:2) you will be excluded from the study. If you are selected to participate in this study, you will be scheduled for two appointments.
2. At the first appointment you will be required to complete a health history questionnaire. You will then be required to change into black shorts and sleeveless t-shirts provided by researchers. These clothing are necessary for accurate collection of biomechanical data. Locations along your arm and back will be prepped for electrode placement by shaving about a 2 inch circular area to remove excessive hair. After shaving these locations, the shaved areas will be cleaned by wiping the skin with an alcohol pad and a gauze pad. Then the surface electrodes will be placed over each location. Then electrode cables will then be attached to the electrodes and the quality of the muscle signals will be verified by having me perform a light contraction. If any of the muscle signals show signs of poor connections, the electrodes will be replaced and the signal quality will be checked again. Next, a finger on your non dominant hand will be cleaned with an alcohol pad prior to be pricked for a blood sample. After cleaning, the finger will be pricked with a sterile lancet and sample of my blood will be collected. After the blood sample is taken a sterile band aid will be placed over my finger. Biomechanical retroreflective surface markers will then be placed on joints of your upper extremity and trunk.
3. You will then begin administering CPR using American Heart Association® guidelines (30:2) on a Resusci® Anne SkillReporter continuously until self-identified fatigue settles in to a maximum of 10 minutes. At the end of CPR administration (when you report self fatigue), another blood sample will be taken and your finger will again be pricked with a sterile lancet and a small sample of blood will be taken. Once again a sterile band aid will be placed over the skin prick location. You will then rest for 5 minutes and another blood sample will be obtained post CPR using the same procedure as mentioned above.
4. The biomechanical markers will then be removed and you will be scheduled for your second appointment where you will experience the same procedures with a different CPR technique.

POSSIBLE RISKS/DISCOMFORTS

The possible risks and/or discomforts of your involvement are muscle soreness due to CPR administration, knee and/or elbow joint pain and a risk of infection due to the finger prick.

INFORMED CONSENT

PRINCIPAL INVESTIGATOR: _Jesal N. Parekh________________________

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Throughout the tests you will be monitored by laboratory personnel trained in CPR and First Aid. Emergency (911) will be called for any emergency situations.

POSSIBLE BENEFITS

The possible benefits of your participation are:

1. Improved understanding of the onset of muscular fatigue during CPR administration and its effect on the quality of CPR administered.

ALTERNATIVE PROCEDURES / TREATMENTS

There are no alternative procedures or courses of treatment. **However, you can elect not to participate in the study at any time with no negative consequences.**

CONFIDENTIALITY

Every attempt will be made to see that your study results are kept confidential. A copy of the records from this study will be stored in (Office of Dr. Mark Ricard) for at least three (3) years after the end of this research. The results of this study may be published and/or presented at meetings without naming you as a subject. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the UTA IRB, and personnel particular to this research (Mark Ricard, Kinesiology Department) have access to the study records. Your records will be kept completely confidential according to current legal requirements. They will not be revealed unless required by law, or as noted above.

FINANCIAL COSTS

The possible financial costs to you as a participant in this research study are:

1. There should be no financial costs to you as a participant unless you incur medical treatment outside the UTA covered costs.

COMPENSATION FOR RESEARCH PARTICIPATION:

You will receive $200 for your participation in this research study if you complete both sessions of testing. You will receive your payment (gift certificates) at the Department of Kinesiology after the second data collection appointment. You will not receive payment if you do not attend both sessions.

INFORMED CONSENT

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The University of Texas at Arlington (UTA) will pay the cost of emergency first aid for any injury that occurs as a result of your participation in this study. UTA will not pay for any other medical treatment. Claims against UTA or any of its agents or employees may be submitted according to the Texas Tort Claims Act (TTCA). These claims may be settled to the extent allowable by state law as provided under the TTCA, (Tex. Civ. Prac. & Rem. Code, secs. 101.001, et seq.). For more information about claims, you may contact the Chairman of the Institutional Review Board of UTA at 817/272-1235.

CONTACT FOR QUESTIONS

If you have any questions, problems or research-related medical problems at any time, you may call Jesal Parekh at 682-552-7862 (jesal.parekh@uta.edu) or Dr. Mark Ricard at 817-272-0764 (ricard@uta.edu) or at the Biomechanics Laboratory 817-272-7146.

You may call the Chairman of the Institutional Review Board at 817/272-1235 for any questions you may have about your rights as a research subject.

VOLUNTARY PARTICIPATION

Participation in this research experiment is voluntary. You may refuse to participate or quit at any time. You may quit by calling Jesal Parekh at 682-552-7862 (jesal.parekh@uta.edu). You will be told immediately if any of the results of the study should reasonably be expected to make you change your mind about staying in the study.

VOLUNTARY PARTICIPATION

By signing below, you confirm that you have read or had this document read to you. You will be given a signed copy of this informed consent document. You have been and will continue to be given the chance to ask questions and to discuss your participation with the investigator.

You freely and voluntarily choose to be in this research project.

PRINCIPAL INVESTIGATOR: ____
DATE

____
SIGNATURE OF VOLUNTEER DATE

_______Subject Initials

APPENDIX C

HEALTH HISTORY QUESTIONNAIRE

THE UNIVERSITY OF TEXAS
AT ARLINGTON

DEPARTMENT OF KINESIOLOGY

HEALTH STATUS QUESTIONNAIRE

Name____ Today's Date________

Home Address____

City_______________________________ State_________ Zip_________________

Email Address____

Home Phone_________________________ Work Phone _______________________

Best Time to Contact _______________________________ AM PM (Circle One)

Birth Date (mm/dd/yyyy) ______/______/_____________ Age______ Gender F M

Height _________ (ft) _________ (in) Weight _________ (lbs) _________ (kgs)

EMERGENCY CONTACT INFORMATION

Name____ Relationship____________

Phone Number __________________________

MEDICATIONS

1. Are you currently taking prescription or non-prescription (over-the-counter) medication or pills? YES NO
2. Do you have medication allergies? YES NO

If you answered yes to any of the above question(s) please explain: ________________

____

____

____

GENERAL HEALTH STATUS

1. Please check if you have had problems or are currently having problems with any the following:

   ( ) High Blood Pressure
   ( ) Heart Disease or Dysfunction
   ( ) Tingling/ Numbness/Weakness in Your Legs
   ( ) Tingling/ Numbness/Weakness in Your Arms
   ( ) Poor Circulation in Your Legs or Feet
   ( ) Poor Circulation in Your Legs or Feet
   ( ) Difficulty kneeling
   ( ) Other Allergies or Hypersensitivities
   ( ) Hypersensitivity to Needles
   ( ) Acute Infection
   ( ) Edema
   ( ) Arthritis
   ( ) Diabetes
   ( ) Blood/Bleeding Disorder
   ( ) Skin Disorder
   ( ) Currently Pregnant
   ( ) Other ______________________________
   ( ) None

If you answered yes to any of the above question(s) please explain and list time frames:

____

____

____

ORTHOPEDIC HEALTH STAUS

1. Have you ever had an injury, such as a sprain, muscle or ligament tear, or tendonitis, which interfered with daily activities? If yes, circle affected area(s) below and explain.

Lower Back	Hip	Thigh	Knee
Calf	Shin	Ankle	Foot/Toes

Explain: ____

____

____

2. Have you had any broken or fractured bones or dislocated joints? If yes, circle affected area(s) below and explain.

Lower Back	Hip	Thigh	Knee
Calf	Shin	Ankle	Foot/Toes

Explain: ____

____

____

3. Have you had a bone or joint injury that required x-rays, MRI, CT, surgery, injections, rehabilitation, physical therapy, a brace, a cast, or crutches? If yes, circle affected area(s) below and explain.

Lower Back	Hip	Thigh	Knee
Calf	Shin	Ankle	Foot/Toes

Explain: ____

____

____

I hereby state that, to the best of my knowledge, my answers to the above questions are complete and correct.

Signature of Subject ___________________________________ Date ______________

APPENDIX D

POST-CPR FEEDBACK FORM I

Subject Feedback

Type of CPR Administered:
(a) Compressions only (b) Compressions with Ventilations

1. What joint(s) and/or muscle(s) experienced the most stress and/or pain?

2. At what point in time during CPR administration did the conception of pain and/or stress occur? (Early on, middle or later during CPR administration)

3. At what point in time during CPR administration could you identify significant fatigue? (Early on, middle or later during CPR)

4. At any point during CPR administration, could you recognize ineffective CPR administration?

APPENDIX E

POST-CPR FEEDBACK FORM II

Subject Feedback

Subject______

Rank your pain at each of the listed joints on a scale of 0 to 5. (0 for no pain, 5 for severe pain)

Right Wrist ________ Left Wrist ________ Right Elbow ________

Left Elbow ________ Right Shoulder ________ Left Shoulder ________

Neck ________ Upper Back ________ Mid Back ________

Low Back ________ Hip ________ Knee ________

Rank your pain at each of the listed muscle groups on a scale of 0 to 5. (0 for no pain, 5 for severe pain)

Biceps ________ Triceps________ Trapezius ________

Low Back ________ Quadriceps ________ Hamstring ________

Rank your physical activity level (circle one)

0	1	2	3	4	5
(not active)					(very active)

How many hours in a week do you perform physical activity?

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BIOGRAPHICAL INFORMATION

Jesal N. Parekh was born in India on 31st May, 1983. She schooled in India and obtained a Baccalaureate in Technology specializing in Electronics and Biomedical Engineering. A penchant for Biomechanics encouraged her to pursue a Master's degree in Exercise Physiology at the University of Texas at Arlington. She plans on obtaining her doctorate from University of Michigan.