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THE EFFECT OF PENETRATING TRUNK TRAUMA AND MECHANICAL VENTILATION ON THE RECOVERY OF ADULT SURVIVORS AFTER HOSPITAL DISCHARGE

Helena van Aswegen

A thesis submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy

Johannesburg, 2007

DECLARATION

I, Helena van Aswegen, declare that this thesis is my own work. It is being submitted for the degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

…….

…….day of ……., 2007

PUBLICATIONS AND PRESENTATIONS ARISING FROM THIS STUDY

PUBLICATIONS

Van Aswegen, H, Eales, CJ & Richards, GA 2007, 'Establishing the reliability of test procedures in order to investigate the effect of penetrating trunk trauma and prolonged mechanical ventilation on the recovery of adult survivors', *South African Journal of Physiotherapy,* vol. 63, no. 1, pp. 22 – 27.

Van Aswegen, H, Eales, CJ, Richards, GA, Goosen, J, Becker, P & Mudzi, W 2008, 'The effect of penetrating trunk trauma on the recovery of adult survivors: a pilot study', *Physiotherapy Theory and Practice,* April 2008 (accepted for publication March 2007).

PAPERS PRESENTED

Van Aswegen, H, Eales, CJ & Richards, GA 2005, 'The effect of penetrating trunk trauma and prolonged mechanical ventilation on the recovery of adult survivors after hospital discharge: Reliability test results', *The South African Society of Physiotherapy 2nd International Congress*, 25 – 28 May 2005, Sandton, Johannesburg, South Africa.

Van Aswegen, H, Eales, CJ, Richards, GA & Goosen, J 2006, 'The effect of penetrating trunk trauma and mechanical ventilation on survivor recovery: pilot study results', *International Trauma Congress of the Trauma Society of South Africa*, 14 – 17 June 2006, Durban, South Africa.

Van Aswegen, H, Eales, CJ, Richards, GA, Goosen, J & Mudzi, W 2007, 'The effect of penetrating trunk trauma on the recovery of adult survivors: a pilot study', *World Confederation of Physical Therapy Congress*, 2 – 6 June 2007, Vancouver, Canada.

Van Aswegen, H, Eales, CJ, Richards, GA & Goosen, J 2007, 'The effect of penetrating trunk trauma on the recovery of adult survivors', *South African Society of Physiotherapy Education Congress*, 24 September 2007, Durban, South Africa.

Van Aswegen, H, Eales, CJ, Richards, GA & Goosen, J 2007, 'Quality of life of ICU survivors', *South African Society of Physiotherapy Education Congress*, 23 September 2007, Durban, South Africa.

ABSTRACT

South Africa has a high incidence of violence and death due to unnatural causes. Gunshot and/or multiple stab wounds to the trunk are consequently injuries commonly seen in South African hospitals. Penetrating injuries often necessitate explorative surgical intervention to identify and treat injuries to the internal organs. Patients are managed in the intensive care unit and frequently return to theatre for abdominal lavage prior to eventual wound closure. Critical illness with prolonged mechanical ventilation and immobilization results in some degree of muscle dysfunction. Survivors of critical illness suffer from poor functional capabilities and decreased quality of life. No formal rehabilitation programmes exist in South Africa for these patients following discharge. *Purpose:* To determine if patients that survived penetrating trunk trauma recover adequately spontaneously following critical illness over the first six months following discharge from the hospital. *Methods:* A prospective, observational study was conducted. Patients with penetrating trunk trauma were recruited from four intensive care units in Johannesburg. Patients who received mechanical ventilation < 5 days were placed in Group 1 and those who received mechanical ventilation ≥ 5 days were placed in Group 2. Lung function tests, dynamometry, quality of life, six-minute walk distance and oxygen uptake tests were performed over six months following discharge from the hospital. The obtained results for dynamometry, exercise capacity and quality of life were compared between groups and to that measured for a healthy (age and sex-matched) control group. *Results and Discussion*: No pulmonary function abnormalities were detected for subjects in Groups 1 or 2. Distance walked during 6MWD test was significantly reduced for subjects in Group 2 compared to the control group [one-month ($p = 0.00$), three-months ($p = 0.00$)]. Morbidity correlated significantly with distance walked by subjects in Group 2 during 6MWD test [three-months ($p = 0.03$), six-months ($p = 0.02$)]. No statistically significant differences were found between subjects during the VO_{2peak} test although subjects in Group 1 performed better clinically than those in Group 2. At one-month there was a significant reduction in upper and lower limb strength for subjects in Group 2 compared to those in Group 1 and the controls ($p = 0.00 – 0.04$). Similar results were detected at the three- and six-month assessments. ICU and hospital length of stay did demonstrate a significant relationship with muscle strength at one and three months following discharge for subjects in Group 2. Severity of illness and morbidity in ICU did not have a significant relation to muscle strength for subjects in Groups 1 or 2 at any of the assessments. Subjects in Group 1 had a significant reduction in right deltoid and triceps strength compared to the controls at one-month ($p = 0.00$ respectively) only. No significant differences in upper and lower limb muscle strength

were detected between the control group and subjects in Group 1 three and six months after discharge. Subjects in both groups had similar limitations in physical and mental aspects of quality of life one-month after discharge. Subjects in Group 1 reported a quality of life comparable to the control group by three-months. Subjects in Group 2 had significant limitations in the physical components of quality of life at three- and six-months compared to those in Group 1 and the controls [p = 0.00 – 0.02]. *Conclusion*: Subjects in Group 1 recovered adequately on their own within three months after discharge from hospital with regard to muscle strength, exercise capacity and all aspects of quality of life. Subjects in Group 2 presented with significant limitations in exercise capacity, muscle strength and the physical aspects of quality of life even at six months after discharge. Impaired function was related to the duration of critical illness and immobility. A physiotherapist-led rehabilitation programme may be indicated for survivors of penetrating trunk trauma that received prolonged mechanical ventilation to address cardiovascular endurance and peripheral muscle strength retraining between one and three months after discharge to address the physical disabilities observed in these subjects.

ACKNOWLEDGEMENTS

I would like to thank the following people:

- My heavenly Father for blessing me with peace, joy and insight and for guiding me through this process.

- My dad, mom, brothers and sisters for their wonderful love, support and encouragement.

- My thesis supervisors: Prof CJ Eales, Prof GA Richards and Dr J Goosen for their encouragement, guidance and wisdom.

- Mr Christo van der Westhuizen and Mr Arrie Oberholster, Pulmonary Function Unit, Pulmonology Department, Johannesburg Hospital for conducting the pulmonary function tests for this study.

- Mr Zac van Heerden, Centre for Exercise Science and Sport Medicine, Wits Education Campus, Johannesburg for conducting the oxygen uptake tests for this study.

- Ms Nonceba Mbambo, Head of the Physiotherapy Department, Faculty of Health Sciences, University of the Witwatersrand, for her support and encouragement and for allowing me time away from the office to write up this thesis.

- My colleagues at the Physiotherapy Department and all my friends, especially Adéle van der Merwe, Anne O'Brien and Helene Joubert for their support and encouragement.

- My physiotherapy colleagues and friends Lizanne Nel, Ronel Roos, Silmara Hanekom and Paula MacLaurin for taking up my duties in the Physiotherapy department for three months to give me the opportunity to complete this thesis.

- All the subjects that participated in this study with such enthusiasm as none of this would have been possible without them!

FUNDING

Financial support for this study was received from the following institutions:

- Thuthuka programme for Researchers in Training at the National Research Foundation;

- Ellen Hodges Medical Faculty Research Endowment Fund of the University of the Witwatersrand.

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LIST OF ABBREVIATIONS

%	percentage
6MWD	six-minute walk distance
abd	abdomen
ACS	abdominal compartment syndrome
ACTH	adrenocorticotropic hormone
ADH	antidiuretic hormone
ADL	activities of daily living
AIDS	Acquired Immunodeficiency Syndrome
ANOVA	analysis of variance
AP	adductor pollicis
APACHE	Acute Physiology and Chronic Health Evaluation
ARDS	Acute Respiratory Distress Syndrome
ATP	adenosine triphosphate
b/min	beats/minute or breaths/minute
BMI	body mass index
BP	bodily pain
COPD	chronic obstructive pulmonary disease
CT	computed tomography
DBP	diastolic blood pressure
D_{LCO}	diffusion capacity of carbon monoxide
DPL	diagnostic peritoneal lavage
ECG	electrocardiogram
EQ-5D	EuroQol 5-D
F	female
FAI	functional aerobic impairment
FEV_1	forced expiratory volume in 1 second
FEV_1/FVC	ratio of forced expiratory volume in 1 second to forced vital capacity
FRC	functional residual capacity
FVC	forced vital capacity
GH	general health
GIT	gastrointestinal tract
GSW	gunshot wound
HIV	human immunodeficiency virus

HR	heart rate
IAH	intra-abdominal hypertension
ICU	intensive care unit
IGF-1	insulin-like growth factor-1
IL	interleukin
IOD	injury on duty
JHTU	Johannesburg hospital trauma unit
LOS	length of stay
M	male
m	meter/s
MCS	mental component summary score
MH	mental health
ml/kg/min	millilitre per kilogram bodyweight per minute
mmHg	millimetres of mercury
mo	month
MOD	multiple organ dysfunction
MODS	multiple organ dysfunction syndrome
MV	mechanical ventilation
N	Newton
n	sample size
NHP	Nottingham Health Profile
NO	nitric oxide
NOS	nitric oxide synthase
NS	not significant
PCS	physical component summary score
PEEP	positive end-expiratory pressure
PF	physical function
PMNL	polymorphonuclear leukocytes
QOL	quality of life
RCT	randomised controlled trial
RE	role emotional
ROM	range of motion
ROS	reactive oxygen species
RP	role physical
RQ	respiratory quotient

RR	respiratory rate
RV	residual volume
SaO_2	arterial oxygen saturation
SARS	severe acute respiratory syndrome
SBP	systolic blood pressure
SD	standard deviation
SF	social function
SF-36	Medical Outcomes 36-item Short Form
SIP	Sickness Impact Profile
SIRS	systemic inflammatory response syndrome
SOFA	Sequential Organ Failure Assessment
TLC	total lung capacity
TNF-α	tumour necrosis factor-alpha
TRISS	Trauma and Injury Severity Score
VO_{2peak}	peak oxygen uptake
VT	vitality

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

South Africa has a high incidence of violence and death due to unnatural causes. Sixty thousand unnatural deaths occurred in South Africa in 2004 and violence accounted for 39% of these deaths (NIMSS 2004). Unspecified unnatural causes of death have been listed by Statistics South Africa as one of the five leading causes of mortality amongst the South African population. Unnatural causes include assault, motor vehicle accidents and suicide (Statistics South Africa 2002). The leading external cause of death in 2004 was firearms (22.7%) followed by sharp force injury (14.7%) (NIMSS 2004). Statistics South Africa stated that unspecified unnatural deaths accounted for 15.6% mortality amongst South African males over the period 1997 – 2001. Males were three times more likely to die of unspecified unnatural causes than females for the same time period (Statistics South Africa 2002; Monzon-Torres & Ortega-Gonzalez 2004). Homicide is one of the major causes of death for men in South Africa (Bowley et al 2004) with a reported rate of 52 firearm deaths/100 000 in Johannesburg (Nicol 2005) and a firearm related homicide of 63/100 000 (Allard & Burch 2005).

Gunshot wounds and/or stab wounds to the trunk are consequently injuries commonly seen in South African hospitals. Bowley reported that penetrating trauma accounted for almost 60% of all trauma cases in South Africa (Bowley et al 2005) and common underlying factors contributing to these injuries are alcohol and drug abuse (Bowley et al 2004). Penetrating injuries often necessitate explorative surgical intervention to identify and treat injuries to the internal organs. A midline abdominal incision is used especially for gunshot wounds as the bullet may ricochet unpredictably and cause widely separated injuries (Wilson and Bender 1996). These patients often require re-look laparotomies with frequent returns to theatre for abdominal lavage prior to eventual wound closure (Wilson and Bender 1996). During this period patients are managed in the intensive care unit (ICU) and undergo prolonged mechanical ventilation (MV) and bed rest.

Muscle dysfunction after critical illness is a recognised consequence of prolonged MV and bed rest, malnutrition, the effect of certain drugs administered during critical

illness and increased muscular catabolism due to sepsis (Winkelman 2004; Lewis 2003; Bruton, Conway & Holgate 2002). Critically ill patients can lose up to 2% muscle mass per day which may take up to one year to rebuild (Griffiths & Jones 1999). The 2002 Brussels Roundtable Discussions among intensive care practitioners concluded that survivors of intensive care suffered from poor functional capabilities, decreased quality of life (QOL), and decreased rate of return to work and placed an increased burden and stress on families and informal caregivers. These factors led to increased economic costs for the patient, families and the society (Angus & Carlet 2003; Combes et al 2003; Jones et al 2003; Niskanen et al 1999).

There is a dearth of literature regarding the implementation of rehabilitation structures (guidelines and/or programmes) specific for survivors of intensive care for their long-term health and well being as well as that of their relatives (Angus & Carlet 2003).

1.2 STATEMENT OF PROBLEM AND JUSTIFICATION FOR RESEARCH

Patients with penetrating trunk trauma that are treated in the ICU with MV suffer from muscle weakness and dysfunction due to the effects of critical illness and prolonged bed rest on the human body. Males are often the breadwinners in a family (Statistics South Africa 2005, p. 94, 101, 125, 131) and most frequently are the victims of penetrating trunk trauma (Bowley et al 2004; Monzon-Torres & Ortega-Gonzalez 2004). This prolonged recovery is likely to impact both the micro and macro economy of South Africa. The researcher is unaware of any database that portrays the rate of recovery (relating to pulmonary function, muscle strength, exercise capacity and health-related QOL) of adult survivors of penetrating trunk trauma after hospital discharge. Rehabilitation programmes exist in South Africa for patients with chronic cardiac and/or pulmonary diseases, which have been shown to be effective in improving these patients' abilities to participate in cardiovascular exercises (improving ability to cope with work and activities of daily living [ADL]) and played a role in improving these patients QOL. Without knowledge of possible limitations in the recovery rate of survivors of trauma, it is not known whether they too would benefit from a rehabilitation programme after discharge from the hospital.

1.3 RESEARCH QUESTIONS

a. How do penetrating trunk trauma and MV influence the recovery of adult survivors over a six-month period after hospital discharge?
b. Is there a difference in the recovery rate over six months between survivors of penetrating trunk trauma with MV < 5 days and those with MV ≥ 5 days?
c. When do survivors of penetrating trunk trauma and MV have muscle strength, exercise capacity and QOL comparable to that of a healthy control group after hospital discharge?

1.4 SIGNIFICANCE OF RESEARCH

Males are traditionally the breadwinners in a family and sustain penetrating trunk trauma due to assault more frequently than females. A prolonged recovery after critical illness can impact both on the economic status of the family and of South Africa in general. The researcher decided to investigate the recovery rate of adult survivors of penetrating trunk trauma and MV over a six-month period after hospital discharge. Results from this study could be used to support further research to establish whether an exercise rehabilitation programme is indicated for this patient population after hospital discharge. Exercise rehabilitation could potentially enable these patients to return to their jobs sooner and have a positive impact on the economic status of the patient, the family and the South African economy.

1.5 RESEARCH AIMS

a. To establish the recovery rate of adult survivors of penetrating trunk trauma and MV over a six-month period after hospital discharge in relation to pulmonary function, exercise capacity, muscle strength and health-related QOL.
b. To establish the difference in recovery rate in relation to the above-mentioned outcomes between survivors of penetrating trunk trauma with MV < 5 days and those with MV ≥ 5 days.
c. To establish any differences in recovery rate between survivors of penetrating trunk trauma and MV and other survivors of critical illness.

1.6 RESEARCH OBJECTIVES

- To determine the inter- and intra-observer correlation for data collected during the six-minute walk distance (6MWD) test and hand-held dynamometry among data collectors.

- To determine and compare the change in pulmonary function between survivors of penetrating trunk trauma with MV < 5 days and those with MV ≥ 5 days from one month to six months after discharge from the hospital.
- To determine and compare the change in exercise capacity (VO_{2peak}) between survivors of penetrating trunk trauma with MV < 5 days and those with MV ≥ 5 days from one month to six months after discharge from the hospital.
- To determine and compare the change in distance walked (VO_{2peak} test and 6MWD test) between survivors of penetrating trunk trauma with MV < 5 days and those with MV ≥ 5 days from one month to six months after discharge from the hospital.
- To compare the distance walked (6MWD test) between survivors of penetrating trunk trauma and MV at one, three and six months to that of a matched healthy South African control group (once-off assessment).
- To determine and compare the change in muscle strength between survivors of penetrating trunk trauma with MV < 5 days and those with MV ≥ 5 days from one month to six months after discharge from the hospital.
- To compare the difference in muscle strength between survivors of penetrating trunk trauma and MV at one, three and six months to that of a matched healthy South African control group (once-off assessment).
- To determine and compare the change in health-related QOL between survivors of penetrating trunk trauma with MV < 5 days and those with MV ≥ 5 days from pre-admission status (retrospective) to six months after discharge (prospective) from the hospital.
- To compare the health-related QOL of survivors of penetrating trunk trauma and MV at one, three and six months to the health-related QOL of a matched healthy South African control group (once-off assessment) as well as to the health-related QOL results reported in other critical care literature.

1.7 TYPE OF STUDY

A longitudinal observational prospective study was performed on a cohort of adult patients that survived penetrating trunk trauma and MV and fitted the inclusion and exclusion criteria set for this study. These patients were divided into two groups: Group 1 included those who were ventilated < 5 days and Group 2 those ventilated ≥ 5 days. Each patient was allocated a code number in order to maintain confidentiality of information obtained.

1.8 SUMMARY

South Africa has a high incidence of violence and a large number of patients sustain penetrating trunk trauma in the form of gunshot wounds or multiple stab wounds. This type of injury often necessitates surgical intervention and management in intensive care. Surgical intervention and the intensive care environment often lead to the development of infection and prolonged immobility. The medical literature has emphasised the need for rehabilitation after critical illness over the last 5-6 years but no studies have been carried out in South Africa or internationally that have investigated the recovery rate of survivors of penetrating trunk trauma and MV. The results of this study will establish a database for the recovery rate of such survivors in Johannesburg to allow assessment of the effectiveness of an exercise rehabilitation programme in a further study.

Chapter 2 consists of an in-depth discussion of the literature on the effects of trauma on the human body. The effects of critical illness, prolonged immobilisation and prolonged MV on the human body are also discussed as well as the effects of critical illness on the QOL of survivors.

CHAPTER 2

LITERATURE REVIEW

This review aims to critically evaluate evidence found in the medical literature on the effects of trauma on the human body. It also evaluates the effects of critical illness, prolonged immobilisation and prolonged MV on the human body as well as the effects of critical illness on the QOL of survivors. In addition it aims to provide the evidence to support research into this specific patient population. A short summary of the findings will be provided after discussion of each section.

Thomson (2003) stated that trauma is a condition that kills young people in the prime of their economically productive lives. The hidden epidemic is a term often used when referring to trauma as it gets much less media attention than the human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) pandemic but has an equally high mortality rate.

2.1 TRAUMA AND THE HUMAN BODY

2.1.1 Systemic Response to Trauma

Local and systemic responses are activated by various factors such as injury, surgery, burns, dehydration, sepsis and acute medical illness. Acute injury/trauma leads to loss of lean body- and skeletal mass and precedes the process of recovery and wound repair. Traditionally the response to trauma is divided into two phases namely the ebb phase and the flow phase (Boffard 2003). The ebb phase occurs immediately following trauma and is associated with severe shock. This phase is characterized by decreased cardiac output, decreased body temperature and decreased oxygen consumption. The development of lactic acidosis is common (Boffard 2003; Winkler & Manchester 1996).

The flow phase follows resuscitation that includes fluid, inotropic drugs, MV and transfusion. The flow phase is divided into catabolic and anabolic phases. During the catabolic phase, body cell mass is affected by lysis (destruction) of cellular protoplasm that occurs after injury. The products of cellular lysis are released into the extracellular fluid. Nitrogen is excreted in the urine as urea. Increased amounts of creatine are released into the blood and increased amounts of creatine are released into the urine especially with injuries to the skeletal muscles. Prolonged

immobilisation and starvation contribute to the rapid loss of muscle bulk and affects all aspects of wound healing (Boffard 2003). Severe tissue loss also occurs due to alterations in carbohydrate, fat and protein metabolism. Cachexia leads to 15% of deaths in trauma patients due to sepsis-induced organ dysfunction and malnutrition, days to weeks after the initial traumatic event (Delano & Moldawer 2006).

The anabolic phase includes weight gain and restoration of fat and protein stores (Winkler & Manchester 1996). This is achieved through reduced sodium losses from urine, saliva, sweat and gastrointestinal juices. This is significant as sodium content determines the total osmolality of extracellular fluid. The volume of total body water is determined by the sum of the total exchangeable sodium and potassium. Retained sodium after trauma leads to a loss of potassium and an extracellular alkalosis. Conversely, a loss of sodium leads to potassium retention resulting in the development of an extracellular acidosis and hyperkalemia. Fluid retention may also occur after injury to conserve extracellular fluid and is manifested by a rise in urine osmolality due to fluid resorption with a corresponding increase in phosphate, potassium and urea in the plasma (Boffard 2003).

In recent years the traditional view of the systemic response to injury has been expanded. Inflammation, as a result of injury, consists of humoral (triggering of coagulation and fibrinolytic cascades as well as kinin) and cellular (activation of leukocytes and endothelial cells) responses. Exacerbation of the inflammatory response can lead to the development of a systemic inflammatory response syndrome (SIRS) due to an imbalance in the production of pro-inflammatory cytokines (discussed under 'The inflammatory process') (Hietbrink et al 2006). Anti-inflammatory cytokines (discussed under 'The inflammatory process') are released to restore this imbalance but over activation leads to either a compensatory anti-inflammatory response or a mixed antagonist response (Hietbrink et al 2006; Osuchowski et al 2006). The patient's immune system is in disarray and the patient becomes very susceptible to infection which might result in septic syndrome and ultimately multiple organ dysfunction (MOD) (Hietbrink et al 2006; Osuchowski et al 2006).

The initial response to trauma is to access energy from endogenous fat oxidation. Fat provides most of the body's energy requirements during the period in which no food

is ingested. Fat is mobilized from fat stores and converted to free fatty acids and glycerol. These are then circulated to tissues such as the large muscles which can burn the fatty acids directly. Blood sugar starts to rise slowly and insulin production from the pancreas is inhibited (Boffard 2003; Winkler & Manchester 1996). A meta-analysis of randomised controlled trials (RCT) on insulin therapy administration during critical illness showed that hyperglycemia is common in patients with critical illness and also may play a role in the activation of the tissue factor pathway of coagulation (Pittas, Siegel & Lau 2004). This may lead to the development of acute thrombosis. The conclusion was that insulin therapy and tight glucose control had a beneficial effect on short-term morbidity and mortality (Pittas, Siegel & Lau 2004). Hyperglycaemia may contribute to the patient's mortality rate. Gale and co-workers recently published results from a retrospective study that was performed on all trauma patients in their urban hospital (Gale et al 2007). They found that poor glycaemic control was associated with increased morbidity and mortality in critically ill trauma patients and was more pronounced in non-diabetic patients. They also found a greater prevalence of urinary tract infections and complications in non-diabetic trauma patients with poor glycaemic control. These results have prompted many South African trauma surgeons to treat their patients, regardless of admission diagnosis, with insulin therapy to maintain glucose levels within the normal range during their ICU stay.

2.1.2 Endocrine Changes as a Result of Acute Trauma

Trauma also disrupts endocrine homeostasis. Glucocorticoids which protect the body against stress and affect protein and carbohydrate metabolism may increase in response to adrenocorticotropic hormone (ACTH) mediated stimulation of the adrenal cortex. Prolonged production of glucocorticoids can lead to hypertrophy of the adrenal cortex. Blood loss is the most important stimulant of aldosterone. This occurs via the renin-angiotensin system and ACTH both of which stimulate the adrenal cortex to produce aldosterone. Aldosterone supports the circulation through decreased excretion of sodium bicarbonate through the kidneys. Blood loss also stimulates the production of vasopressin/antidiuretic hormone (ADH) from the posterior pituitary, with consequent fluid retention and vasoconstriction of the large blood vessels. Increased catecholamine secretion is the main endocrine response to trauma. These catecholamines, especially epinephrine, inhibit insulin production and increase insulin

resistance. This causes an initial, slight elevation of the blood sugar and a gradual rise in glucagon levels (Boffard 2003; Davis 2001).

2.1.3 Circulatory Shock Following Trauma

Trauma patients often develop circulatory shock due to severe blood loss, myocardial contusion, cardiac tamponade, tension pneumothorax or spinal injury. Shock is defined as inadequate tissue perfusion due to cardiovascular dysfunction and the inability of body cells to metabolize nutrients normally (Schiller & Anderson 2001; Skowronski 1998). Generalized cellular damage occurs as a consequence although the ability of organs to withstand ischaemia varies. Depletion of cellular energy stores in the form of adenosine triphosphate (ATP) with failure of the sodium-potassium pump of cell membranes result in water and sodium influx, cellular oedema and a progressively worsening metabolic acidosis. Myocardial contractibility also may be influenced by traumatic injury, tamponade, mitochondrial calcium losses (Skowronski 1998) or inducible nitric oxide production (Nordhaug et al 2004; Tatsumi et al 2000). With regard to the renal system, oliguria occurs due to renal ischaemia when autoregulation fails or due to ADH and aldosterone secretion. Splanchnic ischaemia occurs early in hypoperfusional states as vital organs such as the brain, heart, lungs and liver are preferentially perfused. Hyperventilation occurs early and is related to lactic acidosis and increased physiological dead space created by reduced pulmonary blood flow. Systemic inflammatory response syndrome results in capillary leak associated with the development of the acute respiratory distress syndrome (ARDS) manifested by progressive posterior atelectasis. Respiratory muscle fatigue from muscle hypoperfusion and increased energy expenditure may lead to respiratory failure (Schiller & Anderson 2001; Skowronski 1998).

Physiological changes that take place include an imbalance between oxygen delivery to body tissues and oxygen demand. Oxygen delivery is reduced due to a reduced cardiac output secondary to hypovolemia and myocardial dysfunction, ARDS and loss of red cell mass. Oxygen consumption is increased due to an increased metabolic rate from excessive sympathetic activity and an increased respiratory rate (Skowronski 1998). The prognosis depends on the severity of the injury, age of the patient and pre-existing illnesses. Survival depends on maintenance of oxygen delivery and effective surgical intervention (Schiller & Anderson 2001; Skowronski 1998).

In summary patients with major trauma, especially penetrating trunk trauma, suffer from blood loss and circulatory shock that can be managed effectively with early aggressive resuscitation and surgical intervention involving maintenance of cardiac output and adequate oxygenation. Prolonged ventilatory support in the ICU is often associated with loss of muscle bulk due to preferential breakdown of muscle instead of fat as a source of calories, after exhausting stores of glycogen in the liver and striated muscle. Oedema develops due to excessive crystalloid administration, extracellular fluid conservation and aldosterone secretion. Hyperglycaemia develops due to insulin inhibition through catecholamines, glucagon and glucocorticoid secretion. Hyperglycaemia may contribute to the patient's mortality rate.

2.2 PENETRATING TRUNK INJURY

Damage caused to the trunk by a penetrating object depends on the shape, size and velocity of the object. The severity of a bullet injury is directly proportional to the amount of kinetic energy that is delivered to the tissues. The mortality of gunshot wounds is eight times higher than that of stab wounds (Thomson 2003).

2.2.1 Low Velocity Penetrating Injuries

Low velocity penetrating injuries from civilian gunshot wounds or stab wounds damage only those tissues with which they come into direct contact. Non-disintegrating bullets do not deliver significant kinetic energy to the tissues and cause less damage than disintegrating bullets. The path that handgun bullets follow through the body is unpredictable due to their low velocity and deflection may occur through bone or parenchymal organs such as the liver (Westaby 1994). The most commonly injured organs are the stomach, liver, small bowel and the colon. Interestingly, abdominal vascular injuries are common following penetrating trunk trauma (Feliciano 2003; Feliciano 2004). Abdominal injuries may accompany chest wounds or vice versa.

2.2.2 High Velocity Penetrating Injuries

High velocity wounds can be caused by fragments of explosive devices such as grenades, bombs or high velocity bullets from machine guns or rifles. High velocity bullets cause damage to tissues in the path of the bullet but also to remote organs. Shock waves radiate from the missile tract through the tissues forcing them to

accelerate violently forwards and outwards. A large cavity is so formed that may be 10 – 15 times the diameter of the missile. This creates a vacuum that sucks debris, air and bacteria from the external environment into the primary missile tract and the cavity collapses over a period of a few milliseconds. Blood vessel and nerve damage as well as shattering of bones may result without these structures being directly hit by the bullet. Necrotic tissue and debris create an ideal nidus for infection and gas gangrene may develop in neglected wounds or those that have undergone inadequate debridement (Owen-Smith & Fichelle 1994; Westaby 1994).

2.2.3 Penetrating Chest Trauma

Penetrating injuries of the chest are the most lethal of injuries. The site and size of the wound to the chest wall determines the condition of the patient. The patient's capacity to ventilate depends on the subsequent ability to sustain a negative intrapleural pressure (due to air leak from the lung into the pleural space), the extent of the parenchymal injury and oxygen delivery to the tissues (ventilation-perfusion ratio). The cough reflex may also be impeded and the patient may struggle to clear airway secretions (De Groot & Van Oppell 2003). Pneumothoraces, lung collapse, diaphragmatic rupture and cardiovascular injury may all contribute to severe respiratory distress which can be life threatening if left unattended (Malosky & Ferrari 2001; Livingstone & Hauser 2004). Thoracotomy is indicated in the presence of cardiac tamponade, acute haemodynamic deterioration and radiographic evidence of bronchial, esophageal, tracheal and great vessel injury (Keilin et al 2003).

2.2.4 Penetrating Abdominal Trauma

The size of an abdominal organ and its contact with the anterior abdominal wall determines the frequency with which the organ is wounded. The small intestine is the most commonly injured organ in the abdomen (Thomson 2003). Penetrating abdominal injuries are not immediately life threatening unless a major blood vessel is damaged. Stab wounds to the abdomen are easier to manage than those to the chest and involve injury to the major abdominal vasculature 10% of the time (Feliciano 2003). Stab wounds to the back are often accompanied by abdominal injuries that can be successfully assessed through computed tomography (CT) (Fletcher et al 1989). A gunshot wound that penetrates a major artery or vein and the colon is potentially lethal initially due to haemorrhage and subsequently due to sepsis through the possible contamination of either the vascular wound repair site or the peritoneum

(Feliciano 2004). The mortality rate increases in proportion to the time between injury and surgery (Adesanya et al 2000). The mortality rate of low velocity abdominal injuries is 5 – 10% in the civilian population whereas high velocity abdominal injuries have a mortality rate of 10 – 30% often arising from multiple organ failure (Owen-Smith & Fichelle 1994).

2.2.5 Medical Management of Penetrating Injuries

The ideal time of arrival at the hospital after injury is 30 minutes to one hour (also referred to as the golden hour), before the patient experiences prolonged hypoxia and blood loss. However, the actual time elapsed between injury and time of arrival in South Africa is usually longer. At Johannesburg Hospital it was reported to be as long as 120 minutes prior to initiation of therapy (Goosen et al 2003). The authors attributed this to the poor condition of roads in townships that make fast access very difficult; the delay in extraction of victims from the township and the overcrowding of emergency rooms at tertiary care facilities that further delayed the onset of appropriate treatment (Goosen et al 2003). The patient with haemodynamic stability upon admission could be observed through serial abdominal examinations however penetrating injuries usually require explorative laparotomy. Similarly, laparotomy is required if the patient presents with multiple organ injuries, haemodynamic instability, prolonged hypoxia, significant intra-abdominal blood loss or evidence of hollow visceral injury (Adesanya et al 2000; Nance & Rotondo 2001; Wilson & Bender 1996). The vertical abdominal incision gives the surgeon sufficient exposure to the intra-abdominal organs to identify injuries, control bleeding and contain contamination (Niggebrugge et al 1999; Pryor et al 2004). Where possible all dead and contaminated tissue is excised to leave healthy tissue behind (Owen-Smith & Fichelle 1994). Damage control is a concept that is being used more frequently locally (Goosen et al 2003) as well as internationally (Kirkpatrick et al 2006). It is a concept of staged repair where the initial procedure is limited to an abbreviated procedure to stop bleeding, control contamination, and packing for capillary oozing. The visceral cavity is left open, the patient stabilized in the ICU and returned for definitive repair once stabilized (Moore et al 1998; Rotondo et al 1993). The administration of large volumes of intravenous fluid during surgery may result in excessive swelling of the intestines, mesentery and retroperitoneal tissues in patients with severe abdominal trauma. The abdominal walls become less compliant due to oedema and closure of the abdominal fascia may lead to increased intraperitoneal pressure. This may result in

decreased blood flow to the hepatic, renal and intestinal organs due to intra-abdominal hypertension (IAH) or compartment syndrome. Should sepsis supervene, multiple relook procedures would be required to wash out and debride collections. Patients are monitored and managed in the ICU until they have stabilised (McArthur & Judson 1998; Nance & Rotondo 2001).

Controversy does exist over the non-surgical and surgical management of penetrating abdominal injuries. Advocates for non-surgical intervention in haemodynamically stable patients (through diagnostic peritoneal lavage (DPL) and CT-scans) explain that negative laparotomy procedures (no organ damage found during surgery) may place the patient at higher risk of early and late postoperative complications and potential mortality (Brakenridge et al 2003; Kelemen et al 1997; Velmahos et al 2001; Weigelt & Kingman 1998). However, DPL is not sensitive enough to detect bowel perforation and if perforation of the bowel is suspected, immediate laparotomy is indicated (Kelemen et al 1997). Pryor and colleagues (2004) raised the point that if a patient were managed conservatively, he/she would need continuous evaluation by an experienced surgeon to detect deterioration and the need for surgery. On the other hand, Adesanya and colleagues (2000) reported no postoperative complications in their patients that received negative laparotomies due to penetrating abdominal trauma. Demetriades and colleagues (1993) reported that non-therapeutic surgery for penetrating trauma in their subjects at Chris Hani Baragwanath hospital carried a significant mortality rate. They concluded that selective conservatism was the management style of choice. The delay in arrival time at the hospital and the overcrowded emergency rooms in Johannesburg hospitals that were reported by Goosen and co-workers (2003) may contribute to a situation were emergency laparotomy is indicated more frequently than not.

2.2.6 **Wound Healing After Surgery**

Wound healing consists of four phases that overlap significantly. The first phase is inflammation which involves vasodilation of the small vessels around the wound site, leakage of proteins and plasma into the site of injury and the penetration of white cells through endothelial walls. The length of this phase depends on the extent of tissue injury (Madden & Arem 1981; Van Wingerden 2003a). The second phase is epithelialisation which involves thickening of the epidermis around the edges of the wound within 24 – 48 hours after surgery. Re-epithelialisation occurs through the

activities of the basal cells. The third phase is the cellular phase which starts 10 days after surgery and involves the deposition of fibroblasts in the wound site with the secretion of collagen. Rapid capillary proliferation and endothelial cell activity contribute to the formation of fibrin strands at the wound site (Madden & Arem 1981; Van Wingerden 2003a). Shomaf (2003) reported that collagen production started as early as the second day following small bowel anastomoses and only on day 10 following colonic anastomoses. The final phase of wound healing is fibroplasia. This phase starts four to five weeks after surgery and is characterized by a reduction in fibroblast production and collagen fibres become prominent to provide adequate strength to scar tissue (Madden & Arem 1981). Van Wingerden (2003b) expressed a similar viewpoint and stated that all wounds should heal and strengthen in the first two weeks after surgery but that the skin and fascia take longer to regain their original strength (a few months).

2.2.7 **Complications Following Laparotomy Procedure**

2.2.7.1 **Respiratory Complications**

Respiratory complications such as atelectasis may arise due to diaphragmatic splinting by the oedematous abdominal contents after surgery. This might lead to prolonged MV to correct the resultant hypoxaemia (Wilson & Bender 1996). Atelectasis may also occur postoperatively due to the effect of anaesthesia on the lung tissue. The functional residual capacity (FRC) reduces by 0.5 – 1 litre (ℓ) from the upright position to supine and the administration of general anaesthesia used to cause a 15 – 20% reduction in FRC (Goto & Cooper 1993). This is limited by appropriate recruitment and the application of positive end-expiratory pressure (PEEP) during the surgical procedure (Duggan & Kavanagh 2005). The result of a reduction in FRC is reduced lung compliance and increased airway resistance (Duggan & Kavanagh 2005; Goto & Cooper 1993). Brismer and colleagues (cited in Goto and Cooper 1993, p. 740) showed on CT-scan that atelectasis occurred within five minutes of general anaesthetic administration in the dependent lung regions even in healthy patients. It should be noted that these older studies did not use appropriate PEEP. Without recruitment and PEEP during MV, posterior atelectasis results in intrapulmonary shunting and hypoxaemia (Duggan & Kavanagh 2005; Goto & Cooper 1993). Non-humidified gases decrease mucociliary function and increase secretion viscosity (Goto & Cooper 1993).

2.2.7.2 **Wound Complications**

Wound complications include infection and dehiscence of the abdominal fascia (Niggebrugge et al 1999). Surgical site infection or wound infection as well as contamination of the abdominal cavity by perforated bowel are frequent and are proportional to the degree of contamination, the skill of the surgeon and the delay pre-operatively. Untreated severe sepsis, septic shock or organ dysfunction may occur. Therapy involves source control and early administration of appropriate antibiotics to reduce morbidity and mortality (Owen-Smith & Fichelle 1994). Intra-abdominal hypertension and abdominal compartment syndrome (ACS) are associated with significant morbidity and mortality in patients with abdominal trauma (Malbrain et al 2006). Intra-abdominal pressure should be measured frequently to prevent the onset of IAH and ACS (Malbrain et al 2006). Staged abdominal wall reconstruction may be necessary after the final laparotomy. This is indicated where immediate wound approximation is not possible due to severe bowel oedema, IAH or sepsis (Cohen et al 2001).

In summary the severity of injury after penetrating trunk trauma depends on the type of weapon used, the velocity of the projectile and the resultant distribution of kinetic energy to the surrounding tissues. Penetrating chest injuries need immediate investigation due to the risk of imminent hypoxaemia from pulmonary contusion, pneumothorax, atelectasis and ARDS, all of which may cause respiratory failure. In addition cardiovascular injury may cause acute hypotension from haemorrhage, myocardial injury, arrhythmia, tamponade or blood loss. In the 1980's it was common practice to manage all patients with penetrating abdominal trauma with mandatory laparotomy procedures. However this method of management often led to the development of organ injury intraoperatively and unnecessarily exposed patients to greater morbidity. Various authors suggest that penetrating abdominal injuries be managed conservatively if the patient is haemodynamically stable. However, this might not be feasible in the South African context due to delayed time of arrival at the emergency department and the haemodynamic instability that may already be present. An explorative laparotomy is indicated if bowel perforation is suspected or the patient is unstable or deteriorates. Patients with penetrating trauma of the chest or abdomen

may need to be managed and monitored in the ICU for the development of respiratory and wound complications as discussed above.

The researcher will now review the factors that are relevant in contributing to disability in survivors of penetrating trunk trauma.

2.3 THE INFLAMMATORY PROCESS

The human body is protected from a wide range of microorganisms through the immune system mediated through antigen presenting cells and inflammatory cells consisting of polymorphonuclear leukocytes (PMNL), macrophages and lymphocytes. These cells produce pro-inflammatory and anti-inflammatory cytokines, lymphokines and eicosanoids that mediate the response to an inflammatory stimulus (infective or not). Pro-inflammatory mediators include interleukins (IL) 1 and 6, tumour necrosis factor-alpha (TNF-α), prostaglandins, leukotrienes and reactive oxygen species (ROS) (Grimble 1999; Mukhopadhyay, Hoidal & Mukherjee 2006). Anti-inflammatory mediators cause immunosuppression and include IL-4, IL-10, IL-13, soluble TNF receptors and IL-1 receptor antagonist. This response is known as SIRS which if severe, presents with hypotension and multiple organ dysfunction syndrome (MODS). Cytokines such as the IL and TNF-α are released into the circulation by macrophages and monocytes in inflamed tissues. Cytokines are proteins that are produced by white blood cells. Cytokine receptors can be found on white blood cells, endothelial cells, epithelial cells and parenchymal cells (Thomas 1997; Winkelman 2004). IL facilitates inflammation, promotes white cell proliferation and infiltration and can be classified as pro-inflammatory, anti-inflammatory or have both properties (Winkelman 2004). Research is frequently conducted on the role of IL-1, IL-6 and IL-10 in critical illness (Winkelman 2004).

2.3.1 Interleukin-1

IL-1 can be categorised as IL-1A and IL-1B. Both bind to receptors on the cell membrane (Winkelman 2004) and small amounts can elicit an inflammatory response throughout the body. IL-1 is therefore associated with the development of SIRS and causes clinical reactions such as fever, malaise and loss of appetite and sleep (Winkelman 2004).

IL-1 promotes the adhesion of leukocytes to the endothelium resulting in capillary leak, stimulates the production of white blood cells from bone marrow and promotes prostaglandin production. Both IL-1A and IL-1B are toxic to muscle tissue (Winkelman 2004). IL-1A influences insulin-growth factor and this leads to muscle protein breakdown. IL-1B is known to be involved with apoptosis (planned cell death with subsequent phagocytosis by other cells) and contributes to the reduction of muscle mass (Winkelman 2004). IL-1 and TNF-α induce the production of C-reactive protein from the liver which is also pro-inflammatory (Andreoli et al 1993).

2.3.2 **Interleukin-6**

IL-6 is released from T-cells, mast cells, epithelial cells, pulmonary epithelial cells and myocytes. It stimulates the activation of neutrophils and natural killer cells with further release of IL-1 and TNF-α. It enhances B-cell production as well as antibody production by B-cells (Winkelman 2004) and as inflammation becomes chronic it slows the production of IL-1 and TNF-α and promotes the release of anti-inflammatory mediators. Research has shown that persistently high levels of circulating IL-6 are associated with an increased risk of mortality in patients suffering from sepsis, trauma or burns (Winkelman 2004). IL-6 enhances the infiltration of myocytes with prostaglandins, which leads to breakdown of protein, degeneration of myocytes and muscle atrophy. IL-6 has been associated with maintenance of homeostasis during exercise through the regulation of glucose metabolism by skeletal muscles (Winkelman 2004).

2.3.3 **Interleukin-10**

IL-10 is an anti-inflammatory cytokine that inhibits the production of pro-inflammatory cytokines by macrophages or monocytes. Low levels of IL-10 in the intensive care patient can be associated with excessive inflammation and muscle damage and lead to the development of SIRS. High levels of IL-10 may provide protection against inflammatory myopathy. Myocyte damage as a result of disease progression is best controlled by maintaining a balance between pro-inflammatory cytokines (IL-1 and IL-6) and anti-inflammatory cytokines (IL-10) (Pretorius 2003; Winkelman 2004).

2.3.4 Tumour Necrosis Factor-Alpha

TNF-α is released into the circulation during the early phase of injury or infection. TNF-α produces similar metabolic and physiologic actions to IL-1 namely fever, anorexia, muscle proteolysis, increased gluconeogenesis, hypertriglyceridemia, increased protein synthesis in viscera, increased production of acute phase proteins, increased plasma copper and decreased plasma zinc and iron concentrations (Grimble 1999; Mukhopadhyay, Hoidal & Mukherjee 2006).

2.3.5 Reactive Oxidant Mediated Injury

Recent developments in the medical literature propose that systemic oxidative stress plays a role in the development and manifestation of critical illness. Oxidative stress has been defined as "a condition in which accumulation of free radicals or the inability of antioxidants to counter the accumulation of free radicals creates an imbalance between production of reactive oxygen species and protection of antioxidants" (Goodyear-Bruch & Pierce 2002, pp 545). In health small amounts of ROS are essential to life, forming a major component of our intrinsic defence systems in the form of phagocyte derived hydrogen peroxide and hypochlorous acid. These and others that are produced as by-products of normal metabolism, (such as purine and arachidonic acid metabolism) are neutralized by the major endogenous anti-oxidants glutathione, catalase, superoxide dismutase and albumin and exogenous anti-oxidants such as vitamin C, vitamin E, β carotene and selenium. However in illness, increased generation of ROS results in the consumption of anti-oxidants and an oxidant/anti-oxidant imbalance ensues (Cuzzocrea, Thiemerman & Salvemini 2004; Salvemini & Cuzzocrea 2002). ROS themselves stimulate the inflammatory response by increasing the release of cytokines and thus activate the inflammatory cascades (Goodyear-Bruch & Pierce 2002). Loss of control of the production of ROS in SIRS and sepsis leads to direct cellular injury through oxidative damage to cellular proteins, interstitial cell structures and the destruction of cell membranes. This sequence of events may result in multiple organ failure (Abilés et al 2006; Goodyear-Bruch & Pierce 2002; Zhang, Slutsky & Vincent 2000). Studies have shown that the plasma levels of vitamins C and E are reduced in patients with sepsis. Low plasma vitamin C levels are predictive of the development of MODS (Borrilli et al 1996; Bulger & Maier 2001; Kalokerinos, Dettman & Meakin 2005). Endotoxin, released from gram-negative bacteria in the damaged gut as a consequence of hypoperfusion, phagocyte derived ROS and disseminated intravascular coagulation, plays a role in the release of

cytokines and ROS during SIRS and sepsis. Kalokerinos and co-workers advocate the administration of oral and intravenous vitamin C to critically ill patients to reduce the movement of endotoxin from the gut into the bloodstream and to maintain adequate concentrations of vitamin C in the blood plasma to reduce the activity of endotoxin during sepsis (Kalokerinos, Dettman & Meakin 2005). Ely and colleagues stated that MODS occurring as a result of sepsis is the most common cause of mortality among critically ill patients without coronary complications (Ely, Kleinpell & Goyette 2003).

2.3.6 **Pathogenesis of Muscle Weakness**

TNF-α increases the production of catabolic cytokines (IL-1 and IL-6) and causes anorexia (Jackman & Kandarian 2004; Reid & Li 2001; Winkelman 2004). This catabolic effect leads to the disruption of myogenesis (formation of muscle tissue) (Andreoli et al 1993). It causes muscle breakdown in inflammatory diseases such as cancer, chronic obstructive pulmonary disease (COPD), AIDS and sepsis, which contributes to weakness, fatigue and limited mobility (Reid & Li 2001). TNF-α binds to Type 1 TNF-α receptors leading to an increased production of ROS from mitochondrial electron transport chains in skeletal muscle (Reid & Li 2001). Nuclear factor-κB is activated causing increased activity of the ubiquitin/proteasome pathway that accelerates degradation of the bulk of all intracellular proteins, especially myofibrillary protein and promotes muscle weakness (Jackman & Kandarian 2004; Reid & Li 2001; Winkelman 2004).

Wilcox and associates postulated more than a decade ago that TNF-α might be a mediator of contractile dysfunction of the diaphragm in patients with inflammatory diseases (1996 cited by Reid, Lännergren & Westerblad 2002). Reid conducted a laboratory study comparing the effect of TNF-α on the contractile function of a murine diaphragm and the flexor digitorum brevis muscle. They found that TNF-α induced contractile dysfunction on both through its effect on the myofilaments (Reid, Lännergren & Westerblad 2002). They stated that TNF-α promotes the production of ROS and nitric oxide (NO) derivatives. Reid and co-workers (2002, p. 482) stated that "ROS and NO derivatives decrease the tetanic force in intact muscle fibres without altering the tetanic [Ca^{2+}] transients. Myofilament proteins are thus more sensitive to modulation than proteins regulating voltage-dependent calcium release". They also postulated that contractile losses induced by TNF-α could be partially prevented by the administration of antioxidants and NO synthase (NOS) inhibitors during

inflammatory processes (Reid, Lännergren & Westerblad 2002). Jackman and Kandarian postulated that TNF-α and other cytokines act as triggers for muscle wasting due to the effect of cachexia on the body as a whole. They stated that ROS contribute to the cytokine-induced muscle wasting (Jackman & Kandarian 2004).

The hypermetabolic state that develops following acute trauma is an adaptive response that provides endogenous substrates to maintain the inflammatory response, essential organ function and to promote healing of wounded tissues. This hypermetabolic response is prolonged in patients with critical illness and induces profound loss of lean body mass through ongoing proteolysis. Critically ill patients may lose 10% or more of their muscle mass per week particularly if inadequate nutrition is provided (Cerra et al 1997). In addition functional impairment of organs such as the gastrointestinal tract (GIT), liver, kidneys and heart as part of the MODS may be exacerbated by inadequate nutrition (Cerra et al 1997). Extreme muscle weakness and fatigue compound the respiratory and cardiovascular complications described above and frequently prolong the duration of MV (Cerra et al 1997). Hyperglycemia increases the risk of sepsis and mortality, prolongs MV and length of ICU and hospital stay and increases the potential for critical illness polyneuropathy and renal failure (Van den Berghe et al 2001). Impaired function of the anterior pituitary gland leads to low levels of insulin-like growth factor-1 (IGF-1) and testosterone. The low levels of these anabolic hormones may contribute to the wasting syndrome (catabolism) that is common amongst critically ill patients (Vanhorebeek & Van den Berghe 2004).

2.3.7 **Hospital-Acquired Sepsis**

The incidence of hospital-acquired sepsis has increased during the last few decades (Pretorius 2003). Resistant gram-negative bacilli and gram-positive cocci are commonly found in the hospital environment and the relative immunosuppression described above places the trauma patient at risk for the development of sepsis. Patients with penetrating trunk trauma that undergo MV are at further risk due to the endotracheal tube and urinary and central venous catheters which bypass the normal defence mechanism (Pretorius 2003). Parenteral and enteral feeding solutions may also provide a source for infection if contaminated during the preparation process (Pretorius 2003). The severity of an infection is determined both by the defence response of the patient and the virulence of the organism (Ely, Kleinpell & Goyette

2003). Survival is determined not only by the severity of the underlying illness/injuries but also by the inflammatory process, the development of organ failure (Jacobs, Zuleika & Mphansa 1999), the provision of adequate nutrition and whether or not nosocomial sepsis occurs (Rello et al 1997).

2.4 SEVERITY OF ILLNESS IN TRAUMA PATIENTS

Severity of illness scoring systems were developed in the 1980's to help predict the outcome of patients with critical illness. Limitations to the use of these systems do exist and were summarized by Antonelli and co-workers (1999) as follows:

a. The treatment that patients receive from medical staff influences the prognostic value of severity of illness scoring systems;
b. The scores obtained with these systems are more applicable to patient populations and not to individual patients;
c. Components of some of the scores are not always easily available in the ICU on a daily basis.

The Acute Physiology and Chronic Health Evaluation (APACHE) score was developed in 1981 at the George Washington University Medical Centre to describe accurately the severity of illness of various groups of patients (Wong & Knaus 1991). The APACHE II was developed in 1985 and represented a simplified version of the APACHE score. APACHE II is the most widely used and studied scoring system to date (Palazzo 2003; Pretorius 2003).

It is composed of three parts:

a. The acute physiology score composed of 12 laboratory and physical variables
b. The patient's age
c. A chronic health evaluation

APACHE II scores range from 0 – 71 and a score > 30 predicts a mortality of at least 70% (Pretorius 2003). An evaluation of the APACHE II in 5 815 patients across 13 medical centres showed a direct correlation with hospital mortality (Wong & Knaus 1991). Unfortunately the APACHE II does not have a component for anatomical injury and therefore its ability to predict outcome in trauma patients in the ICU is questionable (Antonelli et al 1999).

The Sepsis-related Organ Failure Assessment (SOFA) was developed in 1994 during a consensus conference organized by the European Society of Intensive Care Medicine (Vincent et al 1996; Vincent et al 1998). This scoring system was developed to assess the degree of organ dysfunction that critically ill patients developed over time. The SOFA was designed to be used in various patient populations and was renamed the Sequential Organ Failure Assessment (Vincent et al 1996; Vincent et al 1998). It consists of scores for six organ systems (brain, cardiovascular, coagulation, renal, hepatic and respiratory) and organ function is scored from zero (normal) to four (extremely abnormal) on a daily basis (Palazzo 2003; Pretorius 2003). The nature of the SOFA scoring system gives insight into the degree of organ failure and the morbidity of the critically ill patient. This system was not designed to compete with existent severity scores that predict mortality, but to complement them. However a good correlation of the SOFA with mortality was obtained through retrospective analysis using the European/North American Study of Severity System database (Antonelli et al 1999; Vincent et al 1998). Janssens and colleagues found that the SOFA score could be related successfully to ICU length of stay in patients with acute cardiovascular disorders. They found that a score < 6 indicated a higher survival rate whereas those with a score > 6 were 13.2 times more likely not to survive (Janssens et al 2001). Antonelli and co-workers found that a SOFA score > 5 together with age > 65 years was associated with a significant increase in mortality (Antonelli et al 1999).

Timsit and co-workers reported that the SOFA scoring system had good internal consistency to predict ICU mortality at any time during the first week of admission in a group of patients with medical and surgical diagnoses. They concluded that the SOFA could be used in this population to estimate the contribution of the severity of the underlying illness to the risk of death. They also stated that daily severity of illness scores predicted mortality in ICU more accurately than severity scores recorded on admission only (Timsit et al 2002). Bota and co-workers reported that the SOFA and the MOD score performed well in predicting mortality in a general ICU population that consisted of 949 patients. They found that the SOFA and MOD score compared well with the APACHE II. They also reported that the SOFA and MOD score were slightly better in predicting mortality in patients suffering from shock compared to the APACHE II (Bota et al 2002). Ferreira and co-workers reported that whereas the daily use of the APACHE II to predict ICU outcome had never been validated, an increase in SOFA score over time was associated with increased

morbidity and thus an increase in mortality. They concluded that the daily use of the SOFA was a good prognostic indicator in the medico-surgical ICU (Ferreira et al 2001).

In summary, patients with critical illness suffer from excessive loss of lean body mass and muscle weakness and fatigue may prolong MV. Other consequences of critical illness include a suppressed immunity associated with the development of sepsis and organ dysfunction. Both the APACHE II and SOFA scores were used in this study to predict mortality on admission to ICU and to describe the degree of organ dysfunction (morbidity) that patients presented with and developed during their ICU stay. The decision was made to use these scoring systems based on the fact that all the components needed to calculate the scores, were easily available in the trauma ICU from which patients were recruited for our study. The Trauma and Injury Severity Score (TRISS) was not used as its accuracy in predicting survival in adult trauma patients has been questioned, especially in Asian and African countries (Joosse et al 2005; Millham & LaMorte 2004).

2.5 PROLONGED IMMOBILISATION AND ITS EFFECT ON THE HUMAN BODY

The physical deconditioning that result from prolonged bed rest is not new to medical science. Hippocrates described loss of muscle strength and reduced exercise performance following prolonged bed rest and inactivity in the earliest medical journals. Bed rest is generally an unavoidable consequence of critical illness (Convertino, Bloomfield & Greenleaf 1997; Winkelman 2004). The adverse effects of prolonged bed rest in the supine position include loss of hydrostatic pressure in the cardiovascular system below the level of the heart; elimination of longitudinal compressive forces on the lower limbs and spine with reduced muscle force exerted on all weight bearing bones; a significant decrease in total energy utilization and detrimental effects on the musculoskeletal system with regard to muscle power, endurance and size of muscle fibres (Convertino, Bloomfield & Greenleaf 1997). This results in weakness and easy fatigability of the diaphragm and skeletal muscles (Winkelman 2004). Disuse atrophy is exacerbated by the effects of steroids and neuromuscular blocking agents on the muscle fibres (Bolton 1996), malnutrition and the systemic inflammatory response and prolonged periods of continuous mandatory

ventilation (Winkelman 2004). Acquired weakness in the ICU is often caused by critical illness myopathy due to the abovementioned factors. This condition is characterized by reduced amplitudes of compound motor action potentials with preservation of sensory nerve action potentials. Atrophy of type II and I muscle fibres occur and muscle fibre necrosis has also been reported. A consistent finding is the loss of myosin thick filaments (Khan, Burnham & Moss 2006).

2.5.1 The Effect of Exercise on Serum Levels of Pro- And Anti-Inflammatory Cytokines

Winkelman suggests that exercise can influence the serum levels of pro- and anti-inflammatory cytokines by restoring the imbalance that exists during critical illness and suggests that exhaustive exercise has the potential to increase the levels of IL-6, IL-10 and TNF-α dramatically (Winkelman 2004). Similar effects of exhaustive exercise on the release of ROS were reported by Kalokerinos (2005). Moderate exercise slows the atrophic changes that occur due to disuse by improving blood flow to muscles and joints. Therapeutic activities that are performed by physiotherapists and nursing staff on patients in the ICU include positional changes from supine to side lying, passive joint range of motion (ROM) movements, sitting up over the side of the bed and transferring from bed to chair. Winkelman and colleagues studied the effect of low-level activity (position changes and passive ROM movements) on the levels of IL-6 and IL-10 in a group of 10 patients with prolonged MV. They reported that activity did not exacerbate the levels of circulating IL-6 and IL-10 and that low-level activity in the ICU may play a role in restoring the balance in cytokine activity. The small sample size however restricted the interpretation of their findings (Winkelman et al 2007).

In summary, inflammation inhibits the production of protein and the protein content of muscle tissue. This leads to loss of muscle mass and power. Inactivity, in the presence of inflammation, may contribute to the destruction of muscle cells. IL-1, IL-6 and TNF-α are involved in muscle breakdown during an inflammatory reaction whereas IL-10 inhibits the actions of the above-mentioned cytokines. Low-level exercise may slow the atrophic changes that occur due to disuse by improving blood flow to muscles and joints providing that the patient is not too sedated to participate in these exercises. The recovery rate of muscle power and endurance in survivors of

penetrating trunk trauma and MV is not known; hence the decision was made to conduct this study.

2.6 PROLONGED MECHANICAL VENTILATION AND ITS EFFECT ON PULMONARY FUNCTION

Patients that present with penetrating trunk trauma are often managed with MV. The aim of MV is to unload the work of the respiratory muscles, especially the diaphragm, so reducing the work of breathing of the exhausted patient (Chang et al 2005). Mechanical ventilation may lead to immobility that has detrimental effects on the respiratory system. Decreased FRC, decreased lung compliance, retained secretions and atelectasis are some complications that may be caused by immobility and positive pressure ventilation. The imbalance between the load on the respiratory system and the capacity of the respiratory muscles is a major contributor to weaning failure (Nava et al 2002). The respiratory muscles are skeletal muscles and contain type I (slow) and type II (fast) fibres. The diaphragm contains 50% type I and 50% type II fibres. Type I fibres have more aerobic capacity than type II fibres and are adapted to perform prolonged muscle activity. Type I fibres are more resistant to fatigue and are suitable for endurance training (Pierce 1995). Type II fibres contract rapidly due to increased calcium uptake. They are adapted for high-intensity activity and thus strength training (Pierce 1995). Immobility causes type IIa fibres to convert to type IIb fibres that have a lower aerobic capacity. The number and density of mitochondria also decrease due to immobility (Nava et al 2002).

Selective diaphragmatic atrophy may develop after 48 hours of controlled MV. Chang supported this finding in 2005 by showing that a negative relationship existed between the number of ventilator days and the fatigue resistance index in their ICU survival population. They speculated that atrophy occurred in the oxidative fibres of the diaphragm due to prolonged MV (Chang et al 2005). The degree of respiratory muscle weakness that develops is related to the duration of ventilation and may lead to delayed weaning (Chang et al 2005). Malnutrition and stress may also compound the respiratory muscle weakness (Nava et al 2002; Pierce 1995).

Mechanically ventilated patients with penetrating trunk trauma are thus at risk of developing weakness of the respiratory muscles that may lead to prolonged weaning

from the ventilator. Secondary chest complications such as ventilator-induced lung injury, ventilator-associated pneumonia, atelectasis of the dependent lung regions or even ARDS may arise due to prolonged MV and critical illness. Restrictive, obstructive and even a combination of restrictive and obstructive lung disease may occur in patients that had suffered from ARDS. These abnormalities were detected on follow-up after hospital discharge at three, six and 12 months (Heyland, Groll & Caesar 2005; Herridge et al 2003; Neff et al 2003). It is not known whether survivors of penetrating trunk trauma are at risk for the development of permanent obstructive or restrictive lung disorders as a result of MV although it is known that patients are more likely to suffer from neurological disability in the long term (Bolton 1996). The researcher hopes to answer this question with this study.

2.7 QUALITY OF LIFE OF INTENSIVE CARE SURVIVORS

Socrates stated in an Athenian court that he feared some things more than death and that it was not merely life itself but the QOL that counted most (Eales et al 2004). Patients who suffer from critical illness may be offered the possibility of survival through treatment received in ICU. The success of ICU management has over several decades been measured by ICU and hospital survival statistics and QOL after discharge is often overlooked. Very few studies conducted on ICU outcome in the 1970s to the early 1990s focussed on the patient's perception of QOL. Questions such as the patient's satisfaction with the level of health-related QOL after ICU intervention and the justification of the cost associated with ICU intervention largely remained unanswered.

With the vast increases in health care expenditure, the concept of health-related QOL has featured increasingly as an important component of patient care and of clinical studies and health economic evaluations (Tseng, Lu & Gandek 2003). Research conducted into the health-related QOL of ICU survivors may provide information on recovery from illness and the need to develop specific services for patients after hospital discharge designed to enhance recovery (DeVon & Ferrans 2003).

2.7.1 Quality of Life of Intensive Care Survivors after Hospital Discharge

The researcher found only two systematic reviews that have been conducted on the QOL of ICU survivors. Heyland and colleagues published a review of the ICU literature and concluded that few QOL instruments had been validated for use in the

ICU population up to 1995. Therefore they were not able to make any clear judgements regarding the QOL of ICU survivors (Heyland et al 1998). Dowdy and colleagues published a systematic review in 2005 in which they concluded that although the Sickness Impact Profile (SIP) and the Medical Outcomes 36-item Short Form (SF-36) had been extensively validated in the ICU population, the Nottingham Health Profile (NHP) and the EuroQol 5-D (EQ-5D) questionnaire had not. They focussed their review on the general ICU population and reviewed 21 articles that represented a total of 7 320 patients. The main results from their review were that most ICU survivors reported lower QOL in all domains than the QOL reported by the general population. They concluded that QOL related to physical function showed improvement over time and was associated with age and severity of illness. QOL related to mental health did however not improve over time and this was not associated with age or severity of illness (Dowdy et al 2005).

Cuthbertson and colleagues, in a prospective study, evaluated health-related QOL in a general ICU population over a period of 12 months after discharge. They found a decline in QOL related to physical function at three months after discharge, which slowly improved up to 12 months but was still lower than that reported for the general UK population. They also reported an unexpectedly good QOL related to mental health and contributed this finding to a possible 'mental high' experienced by the survivors as they might have felt that they managed to 'cheat death' (Cuthbertson et al 2005).

A prospective study conducted by Granja and co-workers found that survivors of sepsis had a fair health-related QOL at six months post discharge, similar to that reported by a group of non-septic patients at the six-month assessment (Granja et al 2004). Wehler and colleagues reported in a prospective study a reduction in QOL related to physical function in survivors of MODS who had no chronic health problems prior to admission to ICU when evaluated at the six-month follow up assessment. They found that patients who did have chronic health problems prior to the development of MODS, reported a QOL related to physical function at six-months that had returned to pre-admission levels (Wehler et al 2003). Niskanen and colleagues found that psychological aspects of QOL were restored more rapidly than physical aspects at six months after hospital discharge in 368 patients who had an ICU length of stay (LOS) more than four days. They postulated that catabolism of muscle

tissue after critical illness might play a role in limiting functional capacity in ICU survivors (Niskanen et al 1999). Konopad and colleagues reported that survivors of ICU tended to have a decreased level of activity up to one year following discharge from the hospital (Konopad et al 1995). Jagodic and colleagues reported that survivors of abdominal sepsis and survivors of trauma still had reduced QOL two years after discharge from the ICU (Jagodic HK, Jagodik K & Podbregar 2006).

The 2002 Brussels Roundtable Discussions among intensive care practitioners concluded that survivors of intensive care suffered from poor functional capability, decreased QOL, and fewer returned to work. Subsequently they placed an increased burden and considerable stress on families and informal caregivers. These factors led to increased economic costs for the patient, their families and society (Angus & Carlet 2003).

In 2003 Combes evaluated outcomes and health-related QOL in ICU survivors that received MV for more than 14 days. Findings indicated that ICU survivors had decreased energy levels, decreased physical mobility and more sleep disorders up to three years after hospital discharge. They also had impaired pulmonary-specific QOL compared to the control group. The authors suggested that outpatient rehabilitation might help to improve the outcome of ICU survivors (Combes et al 2003).

As patients with penetrating trunk trauma are susceptible to the development of sepsis and ARDS, the researcher evaluated studies of health-related QOL published in peer-reviewed journals in survivors of sepsis and ARDS. Heyland and colleagues assessed the health-related QOL of survivors of sepsis at 16 months following discharge from ICU with the SF-36 in a cross-sectional study. They found that these patients had statistically significant decreases in physical functioning, role physical, general health, vitality and social functioning compared to that of a normal population (Heyland et al 2000). Davidson and colleagues used a prospective, matched, parallel cohort study design to compare the health-related QOL of sepsis and trauma patients with ARDS using trauma and sepsis patients without ARDS as controls at one year after discharge from ICU. They found that the domains of physical activities were decreased in the ARDS patients whereas they found no differences in the role emotional domains of the SF-36 (Davidson et al 1999). Herridge and colleagues investigated the health-related QOL of survivors of ARDS over a one-year period using the SF-36 in a

prospective observational study. They found a statistically significant reduction in all physical domains at three, six and 12 months between the study group and a normal control population. They also found no differences in the emotional domains compared to controls (Herridge et al 2003).

All of the above studies were prospective or retrospective analyses, non-experimental in design except for the reviews published by Heyland and colleagues (1998) and Dowdy and colleagues (2005). No RCTs that examined health-related QOL were found during the literature search. However, a RCT study design that includes QOL may only be indicated for trials that focus on drug intervention in patient management. This was not the focus of the current research project.

2.7.2 Outcome Measures Used in Quality of Life Assessment in ICU Survivors

Health-related QOL is defined as the patient's perception of the quality of their performance with regard to physical and psychological function, social interaction and overall satisfaction with their health status. Other factors that influence health-related QOL are age, sleep disturbance, pain, personal productivity and the health and well being of others (Eales et al 2004; Graf et al 2003; Seedat et al 2006; Schipper, Clinch & Olweny 1996). QOL does fluctuate over time as a result of changes in any or all of its component parts. The primary strategy for QOL evaluation is to measure changes with time precedent and inclusive of the disease process, rather than regarding a single value as the benchmark of a response to a specific disease. Whereas a disease often has a finite time of onset and duration, QOL is a lifelong continuous variable (Schipper, Clinch & Olweny 1996). QOL measurements may be limited by cultural differences between socioeconomic or ethnic groups (Schipper, Clinch & Olweny 1996).

Various QOL measurement tools have been employed in populations that have been critically ill. These include tools that give quantitative results such as the NHP, the SIP, the SF-36 and the EQ-5D. Tools such as Patrick's Perceived Quality of Life questionnaire may provide qualitative information. The focus of the current research project was on quantitative QOL assessment and therefore qualitative tools will not be discussed further.

The SIP, SF-36, NHP and EQ-5D are all generic QOL measurement tools that can be applied to patient populations regardless of the underlying condition. The NHP measures functional status with 38 questions (consisting of yes/no statements) that are scored in six domains: physical mobility, pain, sleep, energy, emotional reactions and social isolation (Dowdy et al 2005). The patient scores QOL on the SIP through 136 questions that are divided into 12 domains and take 30 – 45 minutes to complete. The SIP has been used by various researchers in the ICU population and has good reliability and variability when compared with other QOL tools (Dowdy et al 2005; Jurkovich, Mock & MacKenzie 1995; Lipsett et al 2000). The EQ-5D is a five-item generic measurement of QOL and can also be used for economic analysis studies. The NHP and the EQ-5D have not been comprehensively validated for use in the ICU population (Dowdy et al 2005).

The International Quality of Life Assessment project was founded in 1991 at the New England Medical Center in Boston, United States of America. Its goals were to translate and validate, and obtain normative data for the SF-36 on an international level (Wood-Dauphine 2000). The SF-36 was constructed to fill the gap between much more lengthy surveys and relatively coarse single-item measures. The SF-36 was developed to satisfy the minimum psychometric standards necessary for group comparisons involving generic health concepts. The eight health concepts in the SF-36 were selected from the 40 in the Medical Outcomes Study to represent those most frequently measured in widely used health surveys and those most commonly affected by disease and treatment. Reliability of the eight scales and two summary measures were established through internal consistency and test-retest methods (Ware 1996).

The SF-36 is suitable for self-administration or administration by a trained interviewer in person or by telephone, to persons aged 14 or older. It can be administered in 5 – 10 minutes with a high degree of acceptability and data quality (Ware 1996). The SF-36 uses 36 items to measure eight quality of life domains. These domains are physical functioning, role physical (limitations due to physical problems), bodily pain, general health perception, vitality, social functioning, role emotional (limitations due to emotional problems) and mental health. There is a further single item that assesses changes in the respondent's health over the past year (Dowdy et al 2005). Summary scores for physical and mental health can be calculated

from these items. Scale and summary scores range from 0 to 100. Higher scores reflect a better quality of life (Wehler et al 2003).

Heyland and co-workers (2000) reported that the SF-36 had better feasibility, content validity, internal consistency, discriminative ability and more responsiveness to clinical improvement when compared with other generic health status instruments in the critical care population. They showed an internal consistency of > 0.78 for 7 of the 8 domains of the SF-36 in a population of sepsis survivors (Heyland et al 2000). A test-retest reliability of > 0.75 for both summary scales and each of the eight domains of the SF-36 was reported (Heyland et al 2000). Chrispin and colleagues reported a Cronbach alpha > 0.75 for all the domains of the SF-36 when administered to a mixed ICU population. Good content validity was also reported (Chrispin et al 1997). Dowdy (2005) and Wehler (2003) confirmed that the SF-36 had been comprehensively validated in the critical care population. It has however been shown to have good internal consistency, test-retest reliability and validity in populations outside of ICU as well.

DeVon and Ferrans (2003) reported that the SF-36 was a good measure of health status in patients with cardiovascular disease as it showed good content and construct validity. Internal consistency was good with Cronbach's alpha correlation > 0.75 and test-retest reliability with intraclass correlation > 0.5 for most of the SF-36 domains. Essink-Bot and co-workers compared the SF-36 to the NHP, EQ-5D and the COOP/WONCA generic QOL tools in patients with migraine. They concluded that the SF-36 had the highest internal consistency (Cronbach's alpha > 0.78 for all domains) and best discriminative ability of all four QOL tools (Essink-Bot et al 1997).

2.7.3 **Use of the SF-36 in South Africa**

Only two studies could be identified that used the SF-36 in the South African context. The first study was that by O'Keefe and Wood (1996) to assess the QOL of HIV sufferers (n = 134) in a multiracial context. These authors translated the SF-36 into Afrikaans and Xhosa as more than 30% of their participants were Afrikaans speaking and more than 20% were Xhosa speaking and could not understand the English version of the SF-36. They also administered the English, Afrikaans and Xhosa versions of the SF-36 to a control group that consisted of 114 volunteers. They reported good concurrent validity of the Afrikaans and Xhosa versions with median weighted κ of 0.73 (Afrikaans version) and 0.57 (Xhosa version). They concluded that

the SF-36 could adequately differentiate between healthy and infected individuals in this population in the Western Cape (O'Keefe and Wood 1996).

The second study was that conducted by Benitha and Tikly (2007) that investigated the health-related QOL and functional disability in black South Africans with rheumatoid arthritis and systemic lupus erythematosus. This study was conducted at the Chris Hani Baragwanath hospital in Johannesburg, South Africa. The authors used the UK English version of the SF-36 and enrolled only those patients who could speak English, as there were no Tswana or isiZulu translations of the SF-36 available. The authors emphasized the need to formally validate the use of the SF-36 in the South African setting (Benitha and Tikly 2007). These authors did not however review the article described above that was published by O'Keefe and Wood in 1996.

No literature could be found regarding the use of the SF-36 in the critical care population in South Africa.

In summary it is clear that in general, ICU survivors suffer from a reduction in physical and sometimes mental health-related QOL after discharge from ICU that may persist up to a period of three years. Survivors of trauma-related sepsis and of ARDS also present with persistent reductions in physical health from three months up to two years. As all of these studies were conducted in Europe and the United States of America, most of the trauma-related injuries included orthopaedic trauma, pulmonary contusion (motor-vehicle accidents or fall from heights) and blunt abdominal trauma. The patients in the proposed study suffered from penetrating trunk trauma and the results of the above-mentioned studies may not be directly related to our patient population. Therefore the decision was made to investigate the health-related QOL of this patient group. The SF-36 was selected because it was faster to administer than the SIP and has been used in South Africa in other study populations with acceptable results. It has also had been used in numerous studies involving ICU survivors and was reported to have high internal consistency and validity in this population.

2.8 CONCLUSION

The literature presented in this chapter portrayed the detrimental effects of injury, inflammation, critical illness and immobility on the human body. Survivors of critical illness of all cause seem to suffer from excessive loss of lean body mass that leads to muscle weakness and fatigue. This seems to result in a prolonged reduction in health-related QOL especially in the physical health domain. As most of the research presented in this chapter was conducted internationally with little emphasis on patients that survived penetrating trunk trauma, not all of the results may be applicable to this specific South African population. Hence the decision was made to investigate the effects of penetrating trunk trauma and MV on the recovery of survivors in relation to muscle strength, exercise capacity, lung function and QOL, over the first six months following discharge from the hospital.

The next chapter of this thesis will describe the methodology that was followed in order to conduct the proposed study.

CHAPTER 3

METHODOLOGY

The methodology discussed in this chapter is based on the findings of the literature review discussed in chapter 2 and the reliability tests described in appendix I. The study design, sample population, hypotheses tested, data collection procedure and instruments used are discussed in detail. The main methods used for data analysis are given. Ethical considerations are addressed towards the end of this chapter.

3.1 STUDY DESIGN

A longitudinal observational prospective study was performed on a cohort of adult patients that survived penetrating trunk trauma and fitted the inclusion and exclusion criteria of this study. These patients were divided into two groups: Group 1 consisted of those that were ventilated < 5 days and Group 2 consisted of those ventilated ≥ 5 days. Stricker and colleagues stated that there exists no generally accepted definition of prolonged ICU stay as other authors reported time periods that differed from 4 days to 30 days (Stricker, Cavegn, Takala & Rothen 2005). Each patient was allocated a code number in order to maintain confidentiality.

3.2 RESEARCH METHOD

Quantitative data were collected. Pulmonary function was determined by spirometry (flow volume loop) and plethysmography. Exercise capacity and peak oxygen uptake were determined by treadmill walk tests at maximal heart rate as well as by the 6MWD test. Muscle strength was determined by hand-held dynamometry. QOL was assessed by the SF-36 questionnaire in the form of ordinal data.

3.3 VARIABLES

Independent variable: Recovery rate over six months after ICU discharge

Dependent variables: Pulmonary function test results (peak flow, FVC, FEV_1, FEV_1/FVC, D_{LCO}, TLC, RV)

Exercise capacity [VO_{2peak}, distance walked, maximal heart rate, respiratory quotient (RQ)]

Muscle strength (Deltoid, biceps, triceps, quadriceps, hamstrings and abdominals)

Quality of life (SF-36 domains and summary scores)

Confounding variables: Smoking status

HIV status

Complications following surgery

3.4 HYPOTHESES

a. There is a delay in recovery and an abnormality in pulmonary function in adults from ICU discharge up to six months as a result of penetrating trunk trauma and MV.
b. There is a delay in recovery and an abnormality in exercise capacity in adults from one month to six months after hospital discharge as a result of penetrating trunk trauma and MV.
c. There is a delay in recovery and an abnormality in muscle strength in adults from one month to six months after hospital discharge as a result of penetrating trunk trauma and MV.
d. There is a delay in recovery and an abnormality in health-related QOL in adults from pre-admission up to six months after hospital discharge from ICU as a result of penetrating trunk trauma and MV.

3.5 SAMPLE SELECTION

The sample was selected from four major trauma centres in the area of Johannesburg:

- Trauma ICU (10 beds) and the Multidisciplinary ICU (18 beds) at Johannesburg Hospital
- Oliver Tambo Trauma ICU (30 beds) at Milpark Hospital, Johannesburg
- Trauma ICU (25 beds) at Union Hospital in Alberton
- General ICU (18 beds) at Chris Hani Baragwanath Hospital, Soweto, Johannesburg.

Patient recruitment started in February 2004 and finished in November 2006. Patients were followed up for their six-month appointments until May 2007.

3.6 INCLUSION CRITERIA

The following patients were included in this study:

- Male and female.
- Ages between 18 – 60 years.
- Patients must have been admitted to ICU, intubated and mechanically ventilated.
- Patients must have suffered penetrating trunk trauma (abdomen and/or chest) in the form of multiple stab wounds or gunshot wounds.
- Patients must be independently mobile or mobile with minimal assistance at hospital discharge.

3.7 EXCLUSION CRITERIA

- Severe developmental disabilities.
- Head injury or other mental disorders.
- Pre-existing restrictive pulmonary disease.
- Pre-existing uncontrolled cardiac disease.
- Pre-existing uncontrolled hypertension.
- Pre-existing peripheral vascular disease.
- Complex fractures of the lower limbs/pelvis which prevent independent mobility at one month after hospital discharge.
- Spinal Cord Injuries.
- Musculoskeletal conditions that impact on independent mobility (rheumatoid arthritis, avascular necrosis).
- Amputations of the lower limbs.

3.8 DATA COLLECTION

3.8.1 Penetrating Trunk Trauma Survivors

The researcher monitored admissions to the ICU of the four recruitment hospitals on a weekly basis. The severity of illness of each potential subject was established within the first 24 hours of admission by means of the APACHE II scoring system and morbidity was established using the SOFA score. The SOFA was calculated daily for the first 7 days of ICU stay and thereafter twice weekly for the duration of ICU stay.

The researcher explained the purpose of the study to potential subjects after transfer from ICU to the ward. Subjects were approached by the time they had been on the ward for 48 hours. Each subject was given the Subject Information Sheet and Consent

Form (see appendix II). Upon receiving consent, the researcher verified contact details and baseline data was collected. This included the following:

- Completion of the SF-36 questionnaire (interviewer administered) to assess retrospective pre-admission health-related QOL (recall based on four weeks).
- Completion of the demographic questionnaire (interviewer administered – see appendix III) to assess pre-admission level of exercise/sport participation, level of income, level of support at home and past medical history.
- Pulmonary function, in the form of peak flow, was assessed through a Vitalograph peak flow meter (best of three values was recorded) to detect the presence of expiratory airflow limitation.
- Resting heart rate measurement with the Nonin Onyx 9500 Finger Pulse Oximeter to assess cardiovascular fitness level.
- Change in heart rate response (Nonin Onyx 9500 Finger Pulse Oximeter) during a 30-meter walk test to assess cardiovascular fitness at the time of assessment (in general subjects were unable to walk further than 30-meters on the ward due to postoperative pain).

Baseline data, as outlined above, were collected on the ward prior to discharge. Patients who were ventilated < 5 days were allocated to Group 1 and those ventilated ≥ 5 days to Group 2.

3.8.2 Follow-Up Protocol

Subjects were evaluated at one, three and six months following discharge from the hospital. At each visit the subject underwent a pulmonary function test, an oxygen uptake treadmill test, a muscle strength test with a hand-held dynamometer and a standardized 6MWD test. Each subject also completed a demographic questionnaire and the SF-36 QOL questionnaire. The pulmonary function tests were conducted at the Pulmonology Department of Johannesburg Hospital. The oxygen uptake tests, muscle strength tests as well as the 6MWD test were conducted at the Centre for Exercise Science and Sports Medicine on the University of the Witwatersrand Education Campus, Johannesburg.

3.8.3 Dynamometry Protocol

Dynamometry measurements of the left and right deltoid, biceps, triceps, quadriceps and hamstring muscles of each subject were made with a hand-held dynamometer

(MicroFet2™, Hoggan Health Industries). These tests were performed with the subject assuming the following positions:

- Deltoid muscle strength was assessed with the subject seated in an upright position on a chair. The shoulder was held in a 90˚-abducted position with the elbow in 90˚ flexion. The dynamometer was placed just above the lateral epicondyle of the humerus, perpendicular to the shaft of the humerus.
- Biceps muscle strength was assessed with the subject seated in an upright position on a chair. The shoulder was held in a neutral position and the elbow in a flexed position. The dynamometer was placed perpendicular to the shaft of the radius just above the radial styloid process (anterior surface of the forearm).
- Triceps muscle strength was assessed with the subject in a prone position on a plinth. The shoulder was placed at 90˚ abduction and the elbow was extended with the forearm in a neutral position. The dynamometer was placed just above the radial and ulnar styloid processes perpendicular to the shaft of the radius (posterior surface of the forearm). If the subject was unable to assume the prone position due to recent abdominal surgery, the following alternative position was used. The subject was placed in a supine position on a plinth. He/she held the shoulder at a 90° elevated angle with the elbow extended. The dynamometer was placed just above the radial and ulnar styloid processes perpendicular to the shaft of the radius (posterior surface of the forearm).



Figure 3.1: Dynamometer Placement for Triceps Strength Test

- Quadriceps muscle strength was assessed with the subject seated in an upright position on a plinth. The thighs were supported on the plinth; the knees were flexed to 90˚ with the ankles hanging over the side of the plinth. One foot was stabilized on a footstool. The dynamometer was placed just above the malleoli at a 90˚ angle to the tibial crest of the unsupported leg.



Figure 3.2: Dynamometer Placement for Quadriceps Strength Test

- Hamstring muscle strength was assessed with the subject in a prone position on a plinth. The knee was flexed to 90˚. The dynamometer was placed perpendicular to the shaft of the tibia just above the calcaneus (posterior surface of the leg). If the subject was unable to assume the prone position due to recent abdominal surgery, the following alternative position was used. The subject stood in an upright position with his/her arms supported against a wall. The hip was held in the neutral position and the knee flexed to 90°. The dynamometer was placed perpendicular to the shaft of the tibia just above the calcaneus (posterior surface of the leg).

The "break" test technique was used for dynamometry measurements. This consisted of the application of adequate force through the dynamometer to overcome the patient's muscular effort. The test was essentially a concentric muscle strength test. Three measurements were recorded for each muscle and the mean strength calculated

for each muscle group. Results from previous studies have shown that hand-held dynamometry has high intra-observer and inter-observer reliability for knee extensor strength (Bohannon 2001; Roy and Doherty 2004), for elbow flexor and extensor strength (Visser et al 2003; Burns et al 2005) and for shoulder abductors and knee flexors (Visser et al 2003) when tested in various patient populations. The intraclass correlation coefficient for the use of dynamometry for the current data collector was reported to be 0.6 – 0.71 (see appendix 1).

Abdominal muscle strength was assessed through the number of repetitions of abdominal crunches performed in one minute (measured with a stopwatch). The subject was instructed to lie supine on a plinth with his/her knees bent and feet supported on the plinth. The subjects had to lift their head and shoulders up from the plinth until their hands crossed the patella mid-palm. The subjects then returned to the starting position. The researcher supported the feet during the abdominal crunches. One repetition was counted each time the subject's hand crossed the patella mid-palm.

3.8.4 Six-Minute Walk Test Protocol

A standardized protocol was used to administer this test over a distance of 30 meters in the corridor of the Centre for Exercise Science and Sports Medicine. The protocol as described by the American Thoracic Society Statement (2002) and Opasich and co-workers (1998) was followed. The protocol consisted of the following instructions:

- The subject was instructed to walk the 30-meter distance (repeatedly) at his/her own pace in the six minutes.
- The test was supervised and the remaining time was called out every two minutes.
- The subject was encouraged at standard intervals of 30 seconds in the form of "You are doing well" and "Keep up the good work".
- The subject was allowed to stop and rest during the test and then continue as soon as they could resume the walk.
- At the end of the six minutes, the subject was told to stop and the distance covered was recorded.

Measurements of heart rate and peripheral oxygen saturation (Nonin Onyx 9500 Finger Pulse Oximeter), blood pressure (MicroLife® Model BP3BTO-A Automatic

Blood Pressure Monitor), respiratory rate and rate of perceived exertion (Modified Borg Scale) were documented for each subject prior to and after completion of the walk test.

3.8.5 Oxygen Uptake Protocol

A calibrated metabolic cart (Mijnhardt Oxycon OX-4, Mijnhardt, Bunnik, Holland) and a motorized treadmill (Powerjog EG10, Sport Engineering Ltd, Birmingham, England) were used to perform the oxygen uptake test. Heart rate was measured with a three-lead electrocardiogram (ECG) (HP 78351A, Hewlett-Packard GMBH, Boblingen, Germany). A walk protocol for unfit subjects as described by Naughton and Haider (1973) was used. This is an intermittent-incremental protocol. Distance walked was measured through the distance meter on the treadmill. The subjects walked to the point of exhaustion at which time the test was terminated.

3.8.6 Pulmonary Function Test Protocol

Pulmonary function was assessed using the Jaeger System at the Johannesburg Hospital Pulmonology Department. The following measurement devices were used:

- Single breath helium dilution method to measure total lung capacity (TLC).
- Plethysmography to measure forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), FEV_1/ FVC and residual volume (RV).
- Single breath carbon monoxide technique to measure diffusion capacity (D_{LCO}).

These tests were performed according to ATS criteria (Clausen & Wanger 2003) by qualified lung function technologists.

3.8.7 Quality of Life Protocol

The English UK-version SF-36 was used to assess the health-related QOL of the subjects at the different time points. The questionnaire was self-administered and help was only provided to the subject if he/she did not understand what was being asked. No attempt was made by the researcher to influence the subject's responses to the questions asked in the questionnaire. Subjects took on average 10 – 15 minutes to complete the questionnaire.

Data for each subject were recorded on the Outcomes Measurement Sheet (see appendix IV). All the above data was collected in one test session, which took approximately three hours. The data was then coded and captured onto a computer for statistical analysis.

Subjects were re-tested at three and six months after discharge from the hospital for the parameters listed above.

3.8.8 Healthy Control Group

A group of 40 volunteers, resident in Johannesburg and Pretoria, with a similar age, sex and activity-level to the subjects recruited for the study were assessed. None of these volunteers reported any chronic disease conditions. A cross-sectional study design was used to collect data from these volunteers for muscle strength, exercise tolerance and QOL. The same test procedures, as described above for survivors of penetrating trunk trauma, were used to collect data for the above-mentioned parameters. The volunteers were recruited and assessed from January until May 2007. All tests were performed at the Centre for Exercise Science and Sports Medicine, University of the Witwatersrand, Johannesburg.

3.9 DATA ANALYSES

Demographic information described by continuous parameters such as age, length of MV, ICU LOS, LOS in the hospital, severity of illness as well as information on peak flow and resting heart rate in the hospital was summarized using means and standard deviations (SD). A one-way analysis of variance (ANOVA) was performed on the above parameters as well as Bartlett's test to test the assumption of equal variance between each group. The Bonferroni correction was made to control the Type I error. Since one of the groups had a relatively small sample size, the previous results were confirmed using an ANOVA for ranks. Analysis of covariance, with the hospital value taken before discharge taken as covariate, was used to assess the peak flow measures taken at one, three and six months respectively. Heart rate was analysed similarly with the resting heart rate taken before discharge from hospital as covariate.

Demographic information described by categorical parameters such as sex, support at home, monthly income, hand dexterity, abdominal skin grafting, return to exercise/sport and work were summarized using frequencies, percentage and cross-

tables. Groups were compared with respect to the categorical parameters using the chi-square test and Fisher's exact test.

Quantitative information [body mass index (BMI), results from $VO_{2\ peak}$ test, pulmonary function tests, 6MWD test, and dynamometry] was expressed as means and SD. For changes in these outcome measures over time Groups 1 and 2 were compared using a repeated measures ANOVA. At one, three and six months results for Groups 1 and 2 and the control group were assessed using one-way ANOVA, again noting Bartlett's test for equal variance. In pair wise comparisons of these groups Bonferroni corrections were made. Spearman correlations were calculated between the APACHE II scores and the VO_{2peak} and the distance walked during the VO_{2peak} test. The same correlation was done between the APACHE II scores and the distance walked during the 6MWD test. Spearman correlations, using the maximal SOFA scores, were also done for the above mentioned outcomes. Spearman correlations (using the APACHE II scores; the SOFA scores; ICU LOS as well as hospital LOS) were calculated with muscle strength scores taken at one, three and six months.

SF-36 questionnaires were scored with the SF Health Outcomes™ Scoring Software package (Release 1.0) to convert raw scores into domain scores ranging from 0 – 100 (transformed scores). All but one of the 36 items was aggregated into eight domains, which is standard practice. There were no missing data. Values for the Physical Component Summary Score (PCS) and the Mental Component Summary Score (MCS) (norm-based scores) were obtained through merging of the domain scores. Means, SD and medians were calculated for each domain of the SF-36 as well as the summary scores. With respect to SF-36 data, groups were compared i.e. Group 1 with Group 2 and Groups 1 and 2 with the control group respectively using the independent t-test for unequal variance. Similar comparisons were made between Groups 1 and 2 and results obtained by Cuthbertson and colleagues (2005) and Eddleston and colleagues (2000).

The STATA 8 statistical software package was used for all statistical analyses and throughout testing was done at the 0.05 level of significance.

3.10 ETHICAL CONSIDERATIONS

Permission was obtained from the University of the Witwatersrand Committee for Research on Human Subjects (medical) to conduct this study. The clearance number issued was: M03-05-83 (see appendix V).

Consent was obtained from the directors of the hospitals from which subjects were recruited as well as the directors of the ICU at each hospital in order to access the records of potential participants while they were treated in the ICU.

Written consent was obtained from all subjects who participated in the study.

Confidentiality was maintained by coding all data that was captured on the Outcome Measurement Sheets and the database on the computer.

Subjects were allowed to withdraw from this study at any time without compromise of regular treatment.

The results obtained through the above mentioned methodological process are described in chapter 4.

CHAPTER 4

RESULTS

This chapter describes the results obtained from the prospective observational study that was described in the previous chapter.

A total of 203 patients were admitted with penetrating trunk trauma to the ICU of the four recruitment centres from February 2004 until November 2006. All of these patients were intubated and received MV. Forty-two patients (n = 42) gave consent and were included in the study. The remaining participants that fitted the inclusion criteria were excluded due to the following: death due to organ failure in ICU (n = 42), declined participation (n = 38), spinal cord injury or head injury (n = 25), no contact details available after hospital discharge (n = 10), police custody after discharge (n = 8), discharge from hospital prior to consent being obtained (n = 8), residence outside Johannesburg and surrounding area (n = 7), complex lower limb fractures (n = 6), Stephen Johnson's syndrome that led to patients' transfer to a secondary hospital that was not involved in this project (n = 4), unilateral upper limb paralysis due to brachial plexus injury (n = 4), unilateral lower limb paralysis (n = 4), recurrent pleural effusions (n = 1), chronic obstructive pulmonary disease (COPD) (n = 1), epilepsy (n = 1), loss of eyesight due to gunshot wound (n = 1) and history of recurrent myocardial infarction (n = 1).

4.1 DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Thirteen of the participants were allocated to Group 1 and 29 to Group 2 according to length of MV. Demographic characteristics of the participants are outlined in Table 4.1.1.

Table 4.1.1: **Demographic Characteristics of Survivors of Penetrating Trunk Trauma (n = 42).**

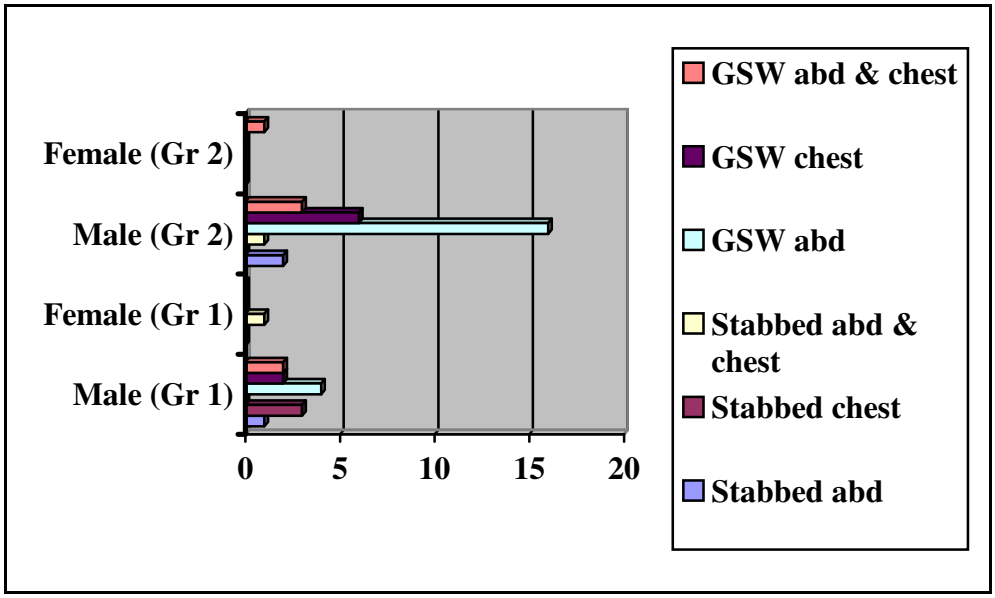
Variable	Group 1 (n = 13)	Group 2 (n = 29)	P-Value
Age (years)	28.3 (8.9)	33.6 (8.2)	NS
Sex	12 Male 1 Female	28 Male 1 Female	NS
APACHE II	20.2 (4.7)	18.7 (4.3)	NS
BMI (kg/m^2) **1-mo** **6-mo**	 22.7 (5.0) 23.5 (5.5)	 24.2 (5.9) 26.4 (6.9)	 NS NS
Maximal SOFA	9.7 (2.9)	11.7 (2.8)	0.038*
Length of MV (days)	2.3 (1.1)	19.5 (13.4)	0.000*
ICU LOS (days)	6.8 (5.6)	26.6 (18.1)	0.000*
Hospital LOS (days)	23.8 (18.4)	42.3 (30.8)	0.013*

**Data expressed as mean (SD); Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; MV = mechanical ventilation; NS = not significant; BMI = body mass index; mo = month; APACHE II = Acute Physiology and Chronic Health Evaluation; SOFA = Sequential Organ Failure Assessment; LOS = length of stay; * = $p < 0.05$.*

The mean APACHE II score for patients in Group 2 (n = 29) was 18.7 (± 4.3) and Group 1 (n = 13) was 20.2 (± 4.7). There was no statistically significant difference in predicted mortality between these two groups. The maximal SOFA score in Group 2 was 11.7 (± 2.8) and that in Group 1 9.7 (± 2.9). There was a statistically significant difference in morbidity between these two groups with Group 2 at greater risk. Subjects in Group 2 had a statistically significant increase in length of ICU stay and hospital LOS.

The subjects that participated in this study sustained a variety of injuries as listed in Figure 4.1.1. The causes for these injuries are summarized in Figure 4.1.2.

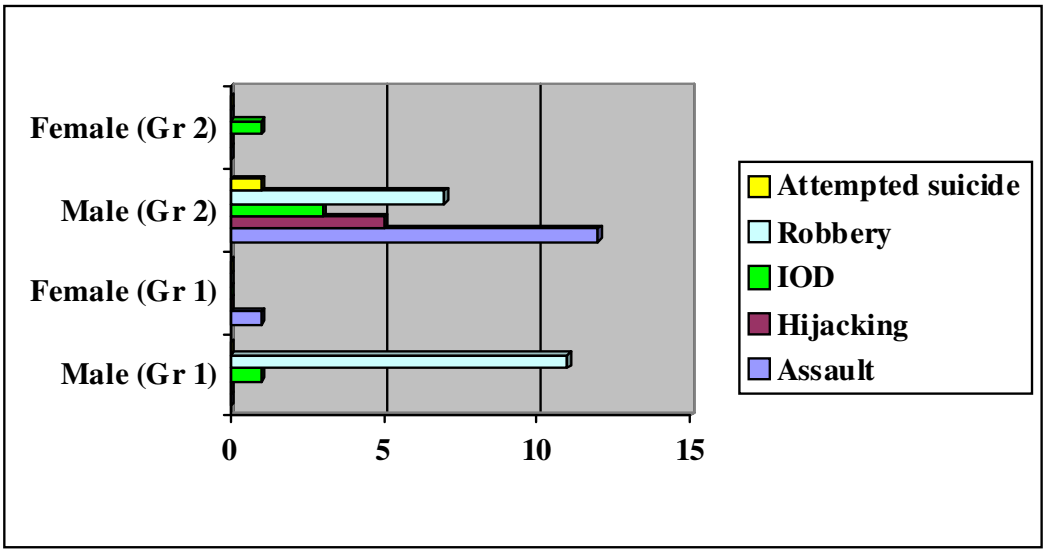
Figure 4.1.1: Mechanism of Injury



Data expressed as numbers; GSW = gunshot wound; abd = abdomen; Gr = group.

Ninety percent of the subjects in Group 2 sustained gunshot-related trauma compared to 62% in Group 1.

Figure 4.1.2: Causes of Penetrating Trunk Trauma



Data expressed as numbers; Gr = group; IOD = injury on duty.

Security guards were mostly admitted due to injury on duty and one policeman in an attempt to commit suicide. Robbery consisted of cell phone and money theft mostly. Assault was due to street fights and family disputes.

Table 4.1.2: Abdominal Organs Injured Through Penetrating Trauma

	Group 1 (n = 8)		Group 2 (n = 23)	
Organs	**N**	**%**	**N**	**%**
Bladder	0	0	3	13
Cecum	0	0	1	4.3
Colon	2	25	14	60.9
Duodenum	1	12.5	4	17.4
Gall bladder	1	12.5	1	4.3
Kidney	1	12.5	4	17.4
Liver	2	25	7	30.4
Pancreas	2	25	0	0
Small Bowel	1	12.5	10	43.5
Spleen	3	37.5	8	34.8
Stomach	3	37.5	6	26.1

N = number; % = percentage; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days.

Organs that were most commonly affected by penetrating abdominal trauma were the spleen and the stomach in Group 1 and the colon, small bowel, spleen, liver and stomach in Group 2 as seen in Table 4.1.2. Two subjects in Group 1 were on inotropic support for four days in total (average days = 2) in contrast to 10 subjects in Group 2 for 37 days in total (average days = 3.7). One subject in Group 1 and six subjects in Group 2 underwent an abdominal skin graft. These subjects all had staged reconstruction of the abdominal wall after the six-month follow-up appointment.

Thirty-two subjects were from the lower socio-economic level as 13 reported a monthly income of less than R1 000 and 19 an income of R1 000 – R5 000. These subjects may therefore have been exposed to crime and violence on a regular basis. Four subjects reported a monthly income of R5 000 – R10 000 and six an income of more than R10 000. One subject in Group 1 and one in Group 2 reported that no support structure was available to them at home upon discharge from the hospital. These subjects worked in Johannesburg but their families lived elsewhere. The rest of the subjects all had a home support structure. All subjects received physiotherapy treatment whilst in hospital to prevent/treat chest complications and to assist mobilization. After discharge from the hospital only one subject in Group 2 received

physiotherapy treatment for a swollen, weak left leg due to femoral vein damage caused by a bullet. None of the subjects received physiotherapy treatment to address general cardiopulmonary and musculoskeletal retraining after discharge from the hospital.

One subject in Group 2 died (2.4%) prior to discharge due to sepsis after surgery. No other deaths were reported up to six months after discharge. Six subjects in Group 1 and five in Group 2 did not come to the one-month follow-up appointment despite several phone calls to arrange the appointments. These subjects were allowed to reschedule their appointments. When they missed the rescheduled appointment and did not answer their phones when the researcher tried to contact them, they were excluded from the rest of the study. Three subjects in Group 2 could not come back for the three-month assessment as they had returned to work and were unable to get time off from work. One subject in Group 1 and three in Group 2 were not able to attend the six-month assessment due to work responsibilities or relocation to other provinces to find work. Group 1 consisted of seven subjects at one and three-months (drop out rate = 46%) after discharge and six subjects at six-months (drop out rate = 14%) after discharge. Group 2 consisted of 23 subjects at one-month (drop out rate = 20%), 20 subjects at three-months (drop out rate = 13%) and 17 subjects at six-months (drop out rate = 15%) after discharge.

At one month after discharge none of the subjects in Group 1 had returned to work but five in Group 2 had returned to work, as they were the sole income providers for their families. Four subjects in Group 1 and 14 in Group 2 had returned to work by the three-month assessment. At the six-month assessment two subjects in Group 1 and four in Group 2 remained unemployed but stated that they felt physically strong enough to work if employment was offered. The return to work rate may seem acceptable but most subjects reported that they were doing less physically demanding work than prior to the incident. Most had taken up desk jobs. No statistically significant difference in return to work rate was detected between the groups for each of the three assessments.

Return to preadmission level of exercise or sport was slow. Three subjects in Group 1 and eight in Group 2 reported a sedentary lifestyle prior to admission to the hospital. At one month none of the subjects had returned to their preadmission level of exercise

or sport. Three subjects in Group 1 and two in Group 2 started to walk as a form of exercise at one-month after discharge. At three-months six subjects in Group 1 and seven in Group 2 were playing soccer at a non-competitive level in addition to walking and some of them ran for short distances. This was statistically significant ($p = 0.019$), as 86% of the subjects in Group 1 had returned to exercise compared to 46% in Group 2. By the six-month assessment, four subjects in Group 1 had returned to their preadmission level of exercise or sport. Ten subjects in Group 2 had returned to exercise/sport at six months but not at the level of participation reported prior to injury. Two subjects in Group 1 and seven in Group 2 still reported a sedentary lifestyle by the six-month assessment.

In Group 1, two subjects (28.5%) reported a history of smoking. Two (8%) in Group 2 reported that they were HIV positive; four (17%) suffered from depression; three (13%) were smokers and two (8%) suffered from hypertension but were on medication.

4.2 PULMONARY FUNCTION TEST RESULTS

All of the outcome measures of the pulmonary function tests (FEV_1, FVC, FEV_1/FVC, TLC, RV, D_{LCO}) were within 80% of the predicted values for subjects in both groups. Results obtained at each of the three assessments are summarized in Table 4.2. Predicted values were according to ECCS new version with a 10% correction made for non-Caucasian subjects (Quanjer et al 1993).

Table 4.2: Pulmonary Function Test Results for Survivors of Penetrating Trunk Trauma at One, Three and Six Months after Discharge

Outcomes	Assessments	Group 1	Group 2	P-value
FVC	1-month	82.0 (4.8)	87.3 (17.9)	0.45
	3-months	89.1 (5.4)	90.2 (14.2)	0.85
	6-months	90.2 (8.3)	92.8 (15.5)	0.69
FEV_1	1-month	84.7 (8.1)	86.9 (15.0)	0.72
	3-months	90.4 (8.0)	88.3 (12.7)	0.68
	6-months	93.5 (10.8)	90.4 (12.4)	0.59
FEV_1/FVC	1-month	103.3 (8.5)	100.9 (11.4)	0.61
	3-months	101.9 (9.9)	98.8 (12.3)	0.55
	6-months	104 (11.8)	97.6 (8.5)	0.16
TLC	1-month	92.4 (5.0)	97.2 (15.5)	0.43
	3-months	99.7 (4.9)	98 (12.2)	0.72
	6-months	100 (4.9)	98.9 (13.1)	0.84
RV	1-month	133.1 (29.9)	138.7 (34.6)	0.7
	3-months	140.7 (28.3)	132.4 (32.4)	0.55
	6-months	138.5 (37.9)	127.89 (27.4)	0.46
D_{LCO}	1-month	97 (29.7)	96.9 (20.6)	0.99
	3-months	107.6 (30.7)	103.5 (19.9)	0.68
	6-months	108.7 (33.9)	111.1 (18.4)	0.82

**Data expressed as percentage of predicted value mean (± SD); FEV_1/FVC expressed as actual ratio; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; FVC = forced vital capacity; FEV_1 = forced expiratory volume in 1 second; FEV_1/FVC = ratio between forced expiratory volume in one second and forced vital capacity; TLC = total lung capacity; RV = residual volume; D_{LCO} = diffusion capacity of carbon monoxide.*

There was no statistically significant difference in pulmonary function parameters between the two groups as seen in Table 4.2. None of the subjects reported a past medical history of chronic obstructive or restrictive pulmonary disease. As mentioned before, two subjects in Group 1 and three in Group 2 had a history of smoking prior to admission to ICU. Adjusted for peak flow measured in hospital, subjects in Groups 1

and 2 were not significantly different with respect to peak flow at one-month (p = 0.799), three months (p = 0.531) or six months (p = 0.915).

4.3 OXYGEN UPTAKE RESULTS

All subjects in Group 1 were able to do an oxygen uptake test at all three assessments. Eighteen of 23 subjects in Group 2 were able to do an oxygen uptake test at the one-month assessment, 19 of 20 subjects were able to do the test at the three-month assessment and 16 of 17 subjects could do the test at the six-month assessment. Five of the subjects in Group 2 experienced lower limb muscle weakness at one-month and could therefore not complete stage two of the uptake test. One subject in Group 2 could not perform the test at three-months due to a viral upper respiratory tract infection. One subject in Group 2 could not perform the test at six-months due to work commitments. The outcomes observed during the uptake test are listed in Table 4.3.1.

Table 4.3.1: Oxygen Uptake Test Results for Survivors of Penetrating Trunk Trauma

Outcomes	Assessment	Group 1	Group 2	P-value
Observed VO_{2peak} (ml/kg/min)	1-month	26.7 (5.8)	26.7 (9.0)	0.99
	3-months	32 (7.6)	28.1 (8.2)	0.28
	6-months	34.5 (10.3)	30.7 (8.2)	0.37
Peak HR (b/min)	1-month	158.9 (17.3)	167.9 (17.9)	0.26
	3-months	175.7 (11.7)	165.2 (19.4)	0.19
	6-months	175 (20.1)	168.2 (20.1)	0.48
$VO_{2distance}$ (m)	1-month	896.9 (434.2)	957 (449.3)	0.76
	3-months	1233 (466.5)	1057.8 (458.6)	0.39
	6-months	1414.7 (502.6)	1278.6 (514.8)	0.58
RQ	1-month	1.02 (0.1)	1.03 (0.1)	0.82
	3-months	1.05 (0.1)	1.03 (0.1)	0.63
	6-months	1.01 (0.1)	1.01 (0.08)	0.97

**Data expressed as mean (± SD); Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; VO_{2peak} = peak oxygen uptake; ml/kg/min = millilitres per kilogram bodyweight per minute; HR = heart rate; b/min = beats per minute; m = metres; RQ = respiratory quotient.*

Subjects in this study were able to exercise within 80% of maximal age predicted heart rate at all three test sessions. However, they were unable to reach a plateau of VO_2 with further increases in workload during the tests and RQ obtained during each test did not reach a value > 1.1. Therefore the criteria for VO_{2max} were not met (Noonan & Dean 2000; Withers et al 2000) and the results were interpreted as VO_{2peak}. There was no statistically significant difference between the two groups with regard to the outcome measures assessed. However, subjects in Group 1 were able to exercise at a higher mean peak heart rate at three and six-months than at one-month. Peak heart rate for the subjects in Group 2 did not improve significantly over the six-month period after discharge. The mean distance walked on the treadmill improved by 517.8 m from one to six-months for subjects in Group 1 and by 321.6 m for those in Group 2 over the six-month period. Subjects in both groups presented with similar observed VO_{2peak} values at one-month following discharge. Observed VO_{2peak} improved by 7.8 ml/kg/min for subjects in Group 1 and by 4 ml/kg/min for those in Group 2 over the six-month period.

The predicted oxygen uptake for each subject in this study was calculated using the regression equations for healthy men and women that were documented by Bruce (1973):

Active men: 69.7 – 0.612 (years of age) (r = -0.704)
Sedentary men: 57.8 – 0.445 (years of age) (r = -0.659)
Active women: 42.9 – 0.312 (years of age) (r = -0.634)
Sedentary women: 42.3 – 0.356 (years of age) (r = -0.734)

The functional aerobic impairment (FAI) of subjects in both groups was calculated using the equation below:

FAI = [(Predicted VO_2 – Observed VO_2)/ Predicted VO_2] x 100 (Bruce 1973).

Results of the above mentioned calculations are reflected in Table 4.3.2 below.

Table 4.3.2: Predicted VO_2 for survivors of penetrating trunk trauma.

Outcomes	Assessment	Group 1	Group 2	P-value
% Pred VO_2 (ml/kg/min)	1-month	55.9 (10.6) (n = 7)	56.8 (18.8) (n = 18)	0.92
	3-months	67 (13.9) (n = 7)	59.6 (14.2) (n = 19)	0.25
	6-months	70.9 (16.6) (n = 6)	64.9 (15.1) (n = 16)	0.55
FAI (%)	1-month	44 (9.8) (n = 7)	43.3 (18.3) (n = 18)	0.90
	3-month	32.9 (12.9) (n = 7)	40.4 (14.1) (n = 19)	0.25
	6-months	29.1 (15.1) (n = 6)	35.1 (15.1) (n = 16)	0.46

**Data expressed as mean (± SD); Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; % Pred VO_2 = percentage of predicted oxygen uptake; ml/kg/min = millilitres per kilogram bodyweight per minute; n = sample size; FAI = functional aerobic impairment.*

The mean predicted VO_2 improved by 14.9% from one to six-months for subjects in Group 1 and by 9.1% for those in Group 2. There was no statistically significant difference in percentage of predicted VO_2 between the groups at one or six months. Subjects in both groups presented with moderate FAI at one month after hospital discharge according to the classification described by Bruce (1973). There was no statistically significant difference in FAI between the groups. Subjects in both groups presented with mild FAI by six months after discharge according to Bruce's classification and no statistically significant difference was detected between the groups.

Severity of illness (APACHE II) was correlated with the distance walked during the oxygen uptake test as well as the observed VO_{2peak}. Results are summarized in Table 4.3.3.

Table 4.3.3: Spearman Correlation between APACHE II Scores and Oxygen Uptake

Outcomes	APACHE II						
	Assessments	Group 1			Group 2		
		Obs (n)	Rho	P-value	Obs (n)	Rho	P-value
Observed VO_{2peak} (ml/kg/min)	1-month	7	-0.818	0.02*	18	-0.208	0.4
	3-months	7	-0.691	0.08	19	0.044	0.85
	6-months	6	-0.144	0.78	16	-0.303	0.25
Distance (m)	1-month	7	-0.618	0.13	18	-0.167	0.5
	3-months	7	-0.818	0.02*	19	0.195	0.42
	6-months	6	0.029	0.95	16	-0.294	0.26

*APACHE II = acute physiology and chronic health evaluation II; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; Obs (n) = number of observations; Rho = Spearman rho; VO_{2peak} = peak oxygen uptake; ml/kg/min = millilitres per kilogram bodyweight per minute; m = metres; * = p < 0.05.*

Severity of illness had a statistically significant correlation with observed VO_{2peak} at one month and with distance walked at three months after discharge for subjects in Group 1. Conversely severity of illness did not have a statistically significant correlation with observed VO_{2peak} or distance walked at any of the assessments for subjects in Group 2.

Morbidity in the ICU (SOFA max) was correlated with the distance walked during the oxygen uptake test as well as the observed VO_{2peak}. Results are summarized in Table 4.3.4.

Table 4.3.4: Spearman Correlation Between Maximal SOFA Scores and Oxygen Uptake

Outcomes	Assessments	SOFA score					
		Group 1			Group 2		
		Obs (n)	Rho	P-value	Obs (n)	Rho	P-value
VO_{2peak} (ml/kg/min)	1-month	7	0.037	0.93	18	-0.237	0.34
	3-months	7	0.243	0.59	19	-0.123	0.61
	6-months	6	0.441	0.38	16	-0.119	0.66
Distance (m)	1-month	7	0.074	0.87	18	-.0182	0.46
	3-months	7	0.037	0.93	19	-0.220	0.36
	6-months	6	0.529	0.28	16	-0.311	0.24

SOFA = sequential organ failure assessment; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; Obs (n) = number of observations; Rho = Spearman rho; VO_{2peak} = peak oxygen uptake; ml/kg/min = millilitres per kilogram bodyweight per minute; m = metres.

Morbidity in the ICU did not have any statistically significant correlation with observed VO_{2peak} or distance walked for either group at any of the three follow-up assessments.

4.4 SIX-MINUTE WALK DISTANCE TEST RESULTS

The healthy control group consisted of volunteers resident in Johannesburg. The volunteers reported no episodes of hospitalisation during the 12 months prior to recruitment. The mean age of this group was 29.5 (± 8.5) years and the mean BMI was 24.9 (± 4) kg/m^2. Thirty-nine were male and one female. There were no statistically significant differences in age (p = 0.074), sex (p = 0.561) or BMI (p = 0.494) between the control group and the other two groups. Thirty-two participated in exercise/sport at least three times per week and eight led a sedentary life. Two volunteers were unemployed, 13 were students and 25 were employed with jobs ranging from gardening to business management and consultancy.

Results of the comparisons of outcomes measured between subjects in Groups 1 and 2 during the 6MWD test are summarized in Table 4.4.1 on the next page.

Table 4.4.1: Heart Rate Results and Distance Walked During the 6MWD Test for Survivors of Penetrating Trunk Trauma

Outcomes	Assessments	Obs (n)	Group 1	Obs (n)	Group 2	P-value
Pre_HR (b/min)	1-month	7	89.4 (8.6)	23	87.4 (13.9)	1.00
	3-months	7	82.3 (13)	20	84 (14.8)	1.00
	6-months	6	83 (10.3)	17	82.9 (16.2)	1.00
Post_HR (b/min)	1-month	7	118.6 (15.3)	23	108.6 (19.3)	0.83
	3-months	7	121.4 (18.6)	20	110.2 (22)	0.76
	6-months	6	124.2 (14.3)	17	110.7 (25.9)	0.67
HR_2min (b/min)	1-month	7	94.4 (11.9)	23	91.8 (12.9)	1.00
	3-months	7	97 (16.1)	20	90.2 (13.1)	0.92
	6-months	6	97.3 (8.6)	17	91.9 (17.7)	1.00
Distance (m)	1-month	7	585.4 (52.1)	23	530.3 (132.1)	0.59
	3-months	7	620 (53.3)	20	580.9 (114.7)	0.97
	6-months	6	633.5 (107.9)	17	604.7 (119)	1.00

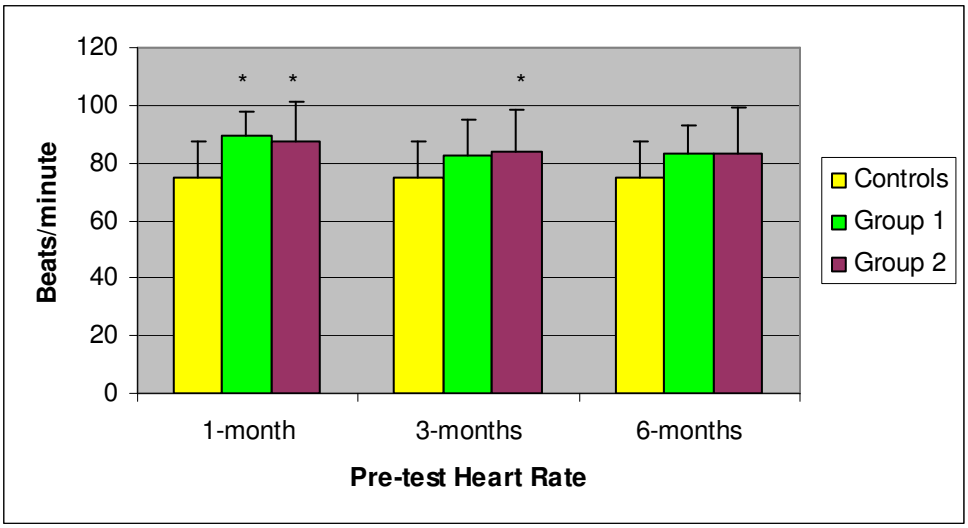
Data expressed as mean (± SD); Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; Obs (n) = number of observations; pre_HR = resting heart rate prior to exercise; post_HR = heart rate immediately following exercise; HR_2min = heart rate after 2 minutes rest; b/min = beats per minute; m = metres.

Resting heart rate (HR) decreased marginally for subjects in both groups over the six-month period. Heart rate immediately after exercise increased marginally for both groups over the six-month period. Distance walked increased by 48.1m (7.6%) for the subjects in Group 1 and by 74.4 m (12.3%) for those in Group 2. There was no statistically significant difference noted in any of the parameters measured between the groups over the six-month period. There were no statistically significant differences found in blood pressure, oxygen saturation, respiratory rate and modified Borg scale values between Groups 1 and 2 over the six-month period. Adjusted for

resting heart rate measured in hospital, subjects in Groups 1 and 2 were not significantly different with respect to resting heart rate at one-month (p = 0.941), three months (p = 0.575) or six months (p = 0.774).

Figures 4.4.1 and 4.4.2 display the heart rate results obtained during the 6MWD test for subjects in Groups 1 and 2 and the control group.

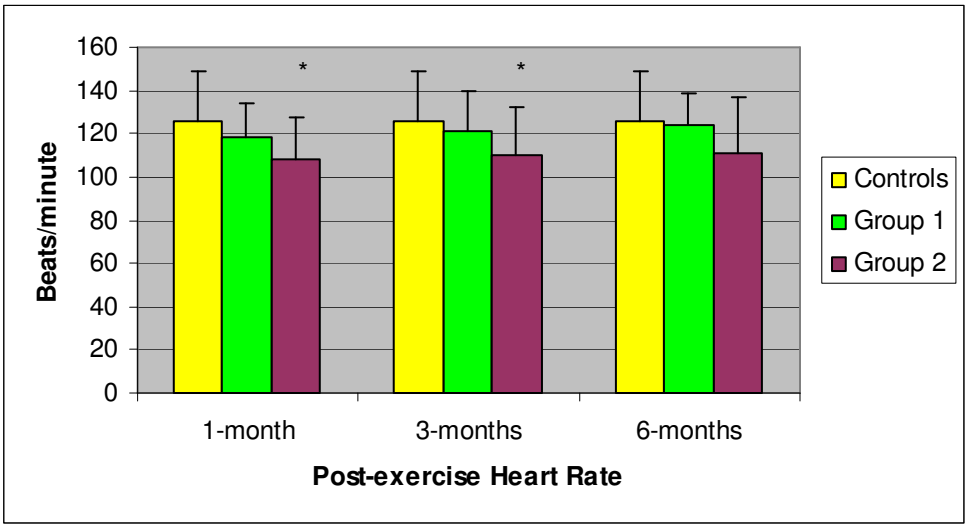
Figure 4.4.1: Heart Rate Results Obtained Prior to the 6MWD Test



*Data expressed as means; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; * = p < 0.05.*

Resting heart rate of subjects in Group 1 was significantly higher (p = 0.02) at one month after discharge than that of the healthy control group. Resting heart rate was significantly higher at one (p = 0.00) and three months (p = 0.04) for subjects in Group 2 compared to the control group.

Figure 4.4.2: Heart Rate Results Obtained Immediately after the 6MWD Test

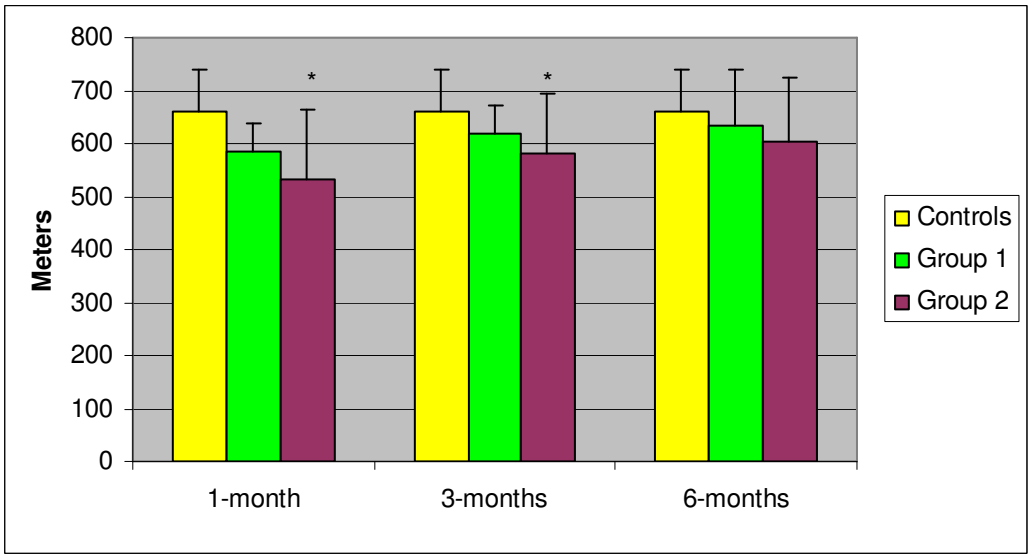


*Data expressed as means; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; * = p < 0.05.*

Heart rate measured immediately after exercise was significantly lower in Group 2 at one (p = 0.00) and three months (p = 0.03) compared to that of the control group. No other statistically significant differences were observed between Groups 1 and 2 and the control group at the respective assessments.

Figure 4.4.3 displays the distance walked (in meters) by subjects in Groups 1 and 2 and the control group during the 6MWD test.

Figure 4.4.3: Distance Walked During the 6MWD Test



*Data expressed as means; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; y-axis = distance in meters; * = p < 0.05.*

The control group walked significantly further during the 6MWD test than subjects in Group 2 at one (p = 0.00) and three months (p = 0.00). No statistically significant differences were observed between these groups at six months. Subjects in Group 1 walked similar distances to those of the control group and no statistically significant differences were observed between these groups at any of the assessments. There were no statistically significant differences in distance walked between subjects in Group 1 and those in Group 2 at any of the assessments. A comparison of the remaining vital signs measured during the 6MWD test is displayed in Tables 4.4.2 and 4.4.3.

Table 4.4.2: Vital Signs Measured During the 6MWD Test for Subjects in Group 1 and the Control Group.

	1-month					3-months					6-months				
	Group 1 (n = 7)		Control (n = 40)		P-value	Group 1 (n = 7)		Control (n = 40)		P-value	Group 1 (n = 6)		Control (n = 40)		P-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Pre SBP	135.7	16.4	137.5	13.1	0.8	132.6	11.2	137.5	13.1	0.3	140.5	19.2	137.5	13.1	0.7
Pre DBP	89.8	6.3	86.9	9.7	0.3	90.1	14.7	86.9	9.7	0.6	85.6	7.6	86.9	9.7	0.7
Pre SaO_2	95.8	1.7	96	1.4	0.8	93.6	2.9	96	1.4	0.07	96.8	1.1	96	1.4	0.1
Pre RR	21.1	4.3	18.4	3.9	0.1	19.4	4.6	18.4	3.9	0.6	19.3	4.4	18.4	3.9	0.6
Pre MBS	1.1	1.6	0.6	0.8	0.4	1.5	1.1	0.6	0.8	0.1	0.08	0.2	0.6	0.8	0.00*
Post SBP	139.3	16.1	152.5	16.9	0.09	145.7	20.2	152.5	16.9	0.45	136	13.7	152.5	16.9	0.04*
Post DBP	92.4	9.2	89.8	9.5	0.5	91.7	9.2	89.8	9.5	0.65	93	7.7	89.8	9.5	0.4
Post SaO_2	93	5.7	95.3	1.8	0.35	92.5	6	95.3	1.8	0.3	94	6.3	95.3	1.8	0.65
Post RR	29.1	5.7	29.3	5.4	0.9	28.3	4.9	29.3	5.4	0.6	29	1.9	29.3	5.4	0.7
Post MBS	2.3	2.1	2.7	1.6	0.6	2.7	1.9	2.7	1.6	0.9	1.1	1.0	2.7	1.6	0.01*

*Group 1 = mechanical ventilation < 5 days; SD = standard deviation; Pre SBP = resting systolic blood pressure prior to 6MWD test; Pre DBP = resting diastolic blood pressure prior to walk test; Pre SaO_2 = resting oxygen saturation prior to walk test; Pre RR = resting respiratory rate prior to walk test; Pre MBS = resting score on modified Borg scale prior to walk test; Post SBP = systolic blood pressure immediately after walk test; Post DBP = diastolic blood pressure immediately after walk test; Post SaO_2 = oxygen saturation immediately after walk test; Post RR = respiratory rate immediately after walk test; Post MBS = score on modified Borg scale immediately after walk test; * = $p < 0.05$.*

The only statistically significant difference found in vital signs between these groups was at six months. The control group had a significantly higher score on the modified Borg scale than the subjects in Group 1. Systolic blood pressure (SBP) after the walk test was also significantly higher in the control group compared to that of the subjects in Group 1. The same comparison in vital signs was done between Group 2 and the control group.

Table 4.4.3: Vital Signs Measured During the 6MWD Test for Subjects in Group 2 and the Control Group

	1-month					3-months					6-months				
	Group 2 (n = 23)		Control (n = 40)		P-value	Group 2 (n = 20)		Control (n = 40)		P-value	Group 2 (n = 17)		Control (n = 40)		P-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Pre SBP	125.7	14	137.4	13.1	0.00*	128.9	12.1	137.4	13.1	0.01*	128.5	13.1	137.4	13.1	0.02*
Pre DBP	83.4	8.2	86.9	9.7	0.1	86.6	10.4	86.9	9.7	0.9	83.7	8.5	86.9	9.7	0.2
Pre SaO_2	96	1.8	96	1.4	0.9	95.8	1.8	96	1.4	0.6	95.5	1.7	96	1.4	0.3
Pre RR	20.4	3.4	18.4	3.9	0.04*	20	3.7	18.4	3.9	0.1	20.9	4.4	18.4	3.9	0.05*
Pre MBS	1.3	1.4	0.6	0.8	0.02*	0.8	0.9	0.6	0.8	0.3	0.7	0.9	0.6	0.8	0.6
Post SBP	140.1	18.3	152.5	16.9	0.01*	139.8	13.6	152.5	16.9	0.00*	141	14.2	152.5	16.9	0.01*
Post DBP	88.8	9.5	89.8	9.5	0.7	89.7	7.5	89.8	9.5	0.9	86.7	7.4	89.8	9.5	0.1
Post SaO_2	96.7	2.1	95.3	1.8	0.01*	95	3.1	95.3	1.8	0.6	95.3	2.1	95.3	1.8	0.9
Post RR	27.2	3.6	29.3	5.4	0.06	27.9	4.1	29.3	5.4	0.3	29.7	3.6	29.3	5.4	0.7
Post MBS	3.3	2.1	2.7	1.6	0.2	2.4	1.8	2.7	1.6	0.5	2.2	2.2	2.7	1.6	0.4

*Group 2 = mechanical ventilation ≥ 5 days; SD = standard deviation; Pre SBP = resting systolic blood pressure prior to 6MWD test; Pre DBP = resting diastolic blood pressure prior to walk test; Pre SaO_2 = resting oxygen saturation prior to walk test; Pre RR = resting respiratory rate prior to walk test; Pre MBS = resting score on modified Borg scale prior to walk test; Post SBP = systolic blood pressure immediately after walk test; Post DBP = diastolic blood pressure immediately after walk test; Post SaO_2 = oxygen saturation immediately after walk test; Post RR = respiratory rate immediately after walk test; Post MBS = score on modified Borg scale immediately after walk test; * = $p < 0.05$.*

The control group presented with a significant higher pre-test and post-test SBP than those in Group 2 one month after discharge. Subjects in Group 2 presented with a statistically significant higher pre-test respiratory rate (RR) and modified Borg scale

score and significantly higher post-test arterial oxygen saturation (SaO_2) at one month. The control group still presented with a significantly higher SBP pre- and post-test when compared to those in Group 2 at three months. The same trend was observed at six months as well as a significantly higher pre-test RR for subjects in Group 2 compared to the control group. As reported previously, there was no statistically significant difference in BMI between the control group and subjects in Group 2 and therefore BMI could not have influenced the SBP. Control group data was reviewed and the researcher found that three subjects presented with abnormally high resting blood pressure values prior to the 6MWD test. None of these subjects reported a history of hypertension during assessment. The data for these subjects were removed from the database and comparisons were made again with subjects in Groups 1 and 2 as summarized in Tables 4.4.4 and 4.4.5 below.

Table 4.4.4: Adjusted Blood Pressure Comparison Between the Control Group and Subjects in Group 1

	1-month					3-months					6-months				
	Group 1 (n = 7)		Control (n = 37)		P-value	Group 1 (n = 7)		Control (n = 37)		P-value	Group 1 (n = 6)		Control (n = 37)		P-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Pre SBP	135.7	16.4	135.9	12.4	0.97	132.6	11.2	135.9	12.4	0.51	140.5	19.2	135.9	12.4	0.62
Pre DBP	89.8	6.3	85.3	7.9	0.15	90.1	14.7	85.3	7.9	0.46	85.6	7.6	85.3	7.9	0.92
Post SBP	139.3	16.1	151.6	17.2	0.12	145.7	20.2	151.6	17.2	0.51	136	13.7	151.6	17.2	0.05*
Post DBP	92.4	9.2	88.7	8.9	0.38	91.7	9.2	88.7	8.9	0.48	93	7.7	88.7	8.9	0.29

*Group 1 = mechanical ventilation < 5 days; SD = standard deviation; Pre SBP = resting systolic blood pressure prior to 6MWD test; Pre DBP = resting diastolic blood pressure prior to walk test; Post SBP = systolic blood pressure immediately after walk test; Post DBP = diastolic blood pressure immediately after walk test; * = $p < 0.05$.*

Table 4.4.5: Adjusted Blood Pressure Comparison Between the Control Group and Subjects in Group 2

	1-month					3-months					6-months				
	Group 2 (n = 23)		Control (n = 37)		P-value	Group 2 (n = 20)		Control (n = 37)		P-value	Group 2 (n = 17)		Control (n = 37)		P-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Pre SBP	125.7	14	135.9	12.4	0.00*	128.9	12.1	135.9	12.4	0.04*	128.5	13.1	135.9	12.4	0.06
Pre DBP	83.4	8.2	85.3	7.9	0.39	86.6	10.4	85.3	7.9	0.64	83.7	8.5	85.3	7.9	0.53
Post SBP	140.1	18.3	151.6	17.2	0.02*	139.8	13.6	151.6	17.2	0.00*	141	14.2	151.6	17.2	0.02*
Post DBP	88.8	9.5	88.7	8.9	0.95	89.7	7.5	88.7	8.9	0.65	86.7	7.4	88.7	8.9	0.39

*Group 2 = mechanical ventilation ≥ 5 days; SD = standard deviation; Pre SBP = resting systolic blood pressure prior to 6MWD test; Pre DBP = resting diastolic blood pressure prior to walk test; Post SBP = systolic blood pressure immediately after walk test; Post DBP = diastolic blood pressure immediately after walk test; * = $p < 0.05$.*

Systolic blood pressure after the walk test remained significantly higher in the control group compared to that of subjects in Group 1 at six months. After blood pressure was adjusted for the control group, the subjects in Group 2 still had a statistically significant lower resting SBP than the control group at one and three months but not at six months. The SBP after exercise was also significantly lower for subjects in Group 2 at all three assessments when compared to the control group.

Severity of illness (APACHE II) was correlated with the distance walked during the 6MWD test. Results are summarized in Table 4.4.6.

Table 4.4.6: Spearman Correlation Between APACHE II Scores and Distance Walked During the 6MWD Test

Outcomes	APACHE II						
	Assessments	Group 1			Group 2		
		Obs (n)	Rho	P-value	Obs (n)	Rho	P-value
Distance (m)	1-month	7	0.327	0.47	23	-0.066	0.76
	3-months	7	-0.036	0.93	20	-0.247	0.29
	6-months	6	0.463	0.35	17	-0.127	0.62

APACHE II = acute physiology and chronic health evaluation II; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; Obs (n) = number of observations; Rho = Spearman rho; m = metres.

No statistically significant correlation was found between the severity of illness and distance walked for either group over the six-month period after hospital discharge.

Morbidity in the ICU (SOFA max) was correlated with the distance walked during the 6MWD test. Results are summarized in Table 4.4.7.

Table 4.4.7: Spearman Correlation Between Maximal SOFA Scores and Distance Walked During the 6MWD Test

Outcomes	SOFA score						
	Assessments	Group 1			Group 2		
		Obs (n)	Rho	P-value	Obs (n)	Rho	P-value
Distance (m)	1-month	7	0.074	0.87	23	-0.256	0.23
	3-months	7	-0.187	0.68	20	-0.473	0.03*
	6-months	6	0.617	0.19	17	-0.533	0.02*

*SOFA = sequential organ failure assessment; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; Obs (n) = number of observations; Rho = Spearman rho; m = metres; * = p < 0.05.*

Morbidity in the ICU had a statistically significant correlation with distance walked during the 6MWD test at three and six months after discharge for subjects in Group 2. Morbidity did not have a significant correlation with distance walked for subjects in Group 1 over the same time period.

4.5 DYNAMOMETRY RESULTS

4.5.1 Change in Muscle Strength Over Six Months Between Groups 1 and 2

The difference in muscle strength from one to six months after hospital discharge is summarized in Tables 4.5.1.1, 4.5.1.2, and 4.5.1.3.

Table 4.5.1.1: Muscle Strength of Survivors of Penetrating Trunk Trauma One Month after Hospital Discharge

Muscles	Group 1 (n = 7)		Group 2 (n = 23)		P-value
	Mean (N)	SD	Mean (N)	SD	
L Deltoid	160.1	25.4	120.3	34.2	0.014*
R Deltoid	145.9	29.6	122.6	32.6	0.323
L Biceps	239.4	52.2	155.5	66.5	0.002*
R Biceps	239.8	58	162.5	68	0.002*
L Triceps	157.8	26.9	117.9	47.6	0.04*
R Triceps	158.2	35.3	119.9	42.4	0.042*
L Quadriceps	199.5	26.8	155.4	56.7	0.17
R Quadriceps	214.1	32.4	145.7	64.6	0.011*
L Hamstring	171.8	35.7	115.8	55.6	0.004*
R Hamstring	157	39.9	113.5	52.1	0.028*

*N = Newton; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; SD = standard deviation; L = left; R = right; * = p < 0.05.*

Subjects in Group 1 had a significant greater strength with regard to most muscle groups one month after discharge compared to those in Group 2. Subjects in Group 1 were able to do an average of 25 abdominal crunches (SD ± 5.9) and those in Group 2 an average of 23 abdominal crunches (SD ± 8.8) in one minute one month after discharge. Abdominal muscle strength for subjects in Group 1 at one month was not significantly different (p = 0.562) compared to that of subjects in Group 2.

Table 4.5.1.2: Muscle Strength of Survivors of Penetrating Trunk Trauma Three Months After Hospital Discharge

Muscles	Group 1 (n = 7)		Group 2 (n = 20)		P-value
	Mean (N)	SD	Mean (N)	SD	
L Deltoid	175.9	49.8	139.5	35.7	0.056
R Deltoid	180.8	42.5	144.5	37.5	0.07
L Biceps	270.1	48.1	197.4	67.1	0.008*
R Biceps	261.9	44.7	208.6	61.8	0.029*
L Triceps	187.8	36.6	144.4	40.5	0.014*
R Triceps	177.1	29.8	145.9	36.8	0.09
L Quadriceps	230.8	38.9	189.3	60.8	0.262
R Quadriceps	243.1	41.9	183.8	73.3	0.055
L Hamstring	184.4	40.2	140.2	55.6	0.033*
R Hamstring	181.7	38.3	140.7	51.4	0.038*

*N = Newton; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; SD = standard deviation; L = left; R = right; * = p < 0.05.*

Subjects in Group 1 had a statistically significant greater biceps, triceps and hamstring muscle strength compared to those in Group 2 three months after discharge. However, deltoid and quadriceps muscle strength improved for subjects in Group 2 to such an extent that no significant difference in strength between these muscle groups were detected between Groups 1 and 2 at three months. Subjects in Group 1 were able to do an average of 26 abdominal crunches (SD ± 7.9) and those in Group 2 an average of 25 abdominal crunches (SD ± 9.2) in one minute. Abdominal muscle strength for subjects in Group 1 at three months was not significantly different (p = 0.728) compared to those in Group 2.

Table 4.5.1.3: Muscle Strength of Survivors of Penetrating Trunk Trauma Six Months After Hospital Discharge

Muscles	Group 1 (n = 6)		Group 2 (n = 17)		P-value
	Mean (N)	SD	Mean (N)	SD	
L Deltoid	181.5	27.5	150.5	23.2	0.078
R Deltoid	187.6	38.5	156.7	28.3	0.162
L Biceps	279.9	40.8	211.6	61.8	0.017*
R Biceps	270.7	23.3	212.3	59.9	0.016*
L Triceps	187.4	28.2	148.7	35.9	0.035*
R Triceps	195	28.9	155.4	31.2	0.024*
L Quadriceps	263.9	18.3	197.2	59.1	0.031*
R Quadriceps	257.7	27.7	184.9	56.9	0.008*
L Hamstring	179.6	27	141.7	44.9	0.047*
R Hamstring	183.9	36.9	147.5	44.4	0.067

*N = Newton; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; SD = standard deviation; L = left; R = right; * = p < 0.05.*

Six months after discharge a significant difference in biceps, triceps, quadriceps and hamstring muscle strength existed between the groups. Subjects in Group 1 had greater strength in all these muscle groups than those in Group 2. Subjects in Group 1 were able to do an average of 31 abdominal crunches (SD ± 8.6) and those in Group 2 an average of 30 abdominal crunches (SD ± 12.3) in one minute. Abdominal muscle strength for subjects in Group 1 was not significantly different (p = 0.826) compared to that in Group 2 six months after discharge.

4.5.2 Muscle Strength Between Survivors of Penetrating Trunk Trauma and the Control Group

Muscle strength of subjects in Groups 1 and 2 was compared with that of the healthy control group. The aim was to establish at which time point the strength of the subjects in Groups 1 and 2 had returned to normal values. The results of these comparisons are summarized in Tables 4.5.2.1 and 4.5.2.2.

Table 4.5.2.1: Comparison of Upper Limb Muscle Strength Between Group 1 and the Control Group

Muscles	1-month			3-months			6-months		
	Group 1 (n = 7)	Control (n = 40)	P-value	Group 1 (n = 7)	Control (n = 40)	P-value	Group 1 (n = 6)	Control (n = 40)	P-value
L Deltoid	160.1 (25.4)	183 (30.7)	0.2	175.9 (49.8)	183 (30.7)	1.0	181.5 (27.5)	183 (30.7)	1.0
R Deltoid	145.9 (29.6)	195.1 (34.2)	0.00*	180.8 (42.5)	195.1 (34.2)	1.0	187.6 (38.5)	195.1 (34.2)	1.0
L Biceps	239.4 (52.2)	280 (45.4)	0.2	270.1 (48.1)	280 (45.4)	1.0	279.9 (40.8)	280 (45.4)	1.0
R Biceps	239.8 (58)	278.4 (34.9)	0.19	261.9 (44.7)	278.4 (34.9)	1.0	270.7 (23.3)	278.4 (34.9)	1.0
L Triceps	157.8 (26.9)	188.5 (29.7)	0.12	187.8 (36.6)	188.5 (29.7)	1.0	187.4 (28.2)	188.5 (29.7)	1.0
R Triceps	158.2 (35.3)	208.1 (30.3)	0.00*	177.1 (29.8)	208.1 (30.3)	0.06	195 (28.9)	208.1 (30.3)	0.99

*Data expressed as mean (± SD) Newton; L = left; R = right; Group 1 = mechanical ventilation < 5 days; * = $p < 0.05$.*

Subjects in Group 1 presented with a statistically significant weaker right deltoid and right triceps muscle strength at one month when compared to the control group. This muscle weakness had resolved at three months as there was no statistically significant difference in strength between the groups at three or six months.

Table 4.5.2.2: Comparison of Upper Limb Muscle Strength Between Group 2 and the Control Group

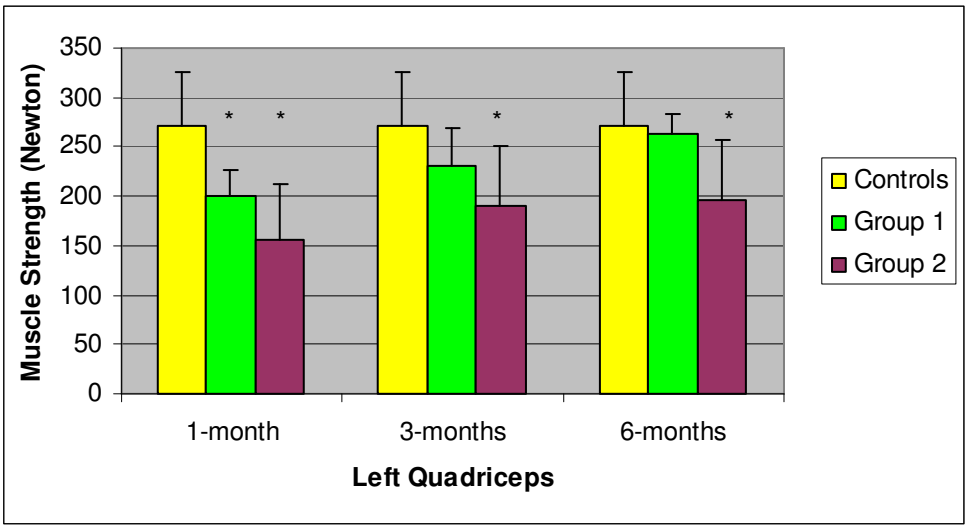
Muscles	1-month			3-months			6-months		
	Group 2 (n = 23)	Control (n = 40)	P-value	Group 2 (n = 20)	Control (n = 40)	P-value	Group 2 (n = 17)	Control (n = 40)	P-value
L Deltoid	120.3 (34.2)	183 (30.7)	0.00*	139.5 (35.7)	183 (30.7)	0.00*	150.5 (23.2)	183 (30.7)	0.00*
R Deltoid	122.6 (32.6)	195.1 (34.2)	0.00*	144.5 (37.5)	195.1 (34.2)	0.00*	156.7 (28.3)	195.1 (34.2)	0.00*
L Biceps	155.5 (66.5)	280 (45.4)	0.00*	197.4 (67.1)	280 (45.4)	0.00*	211.6 (61.8)	280 (45.4)	0.00*
R Biceps	162.5 (68)	278.4 (34.9)	0.00*	208.6 (61.8)	278.4 (34.9)	0.00*	212.3 (59.9)	278.4 (34.9)	0.00*
L Triceps	117.9 (47.6)	188.5 (29.7)	0.00*	144.4 (40.5)	188.5 (29.7)	0.00*	148.7 (35.9)	188.5 (29.7)	0.00*
R Triceps	119.9 (42.4)	208.1 (30.3)	0.00*	145.9 (36.8)	208.1 (30.3)	0.00*	155.4 (31.2)	208.1 (30.3)	0.00*

*Data expressed as mean (± SD) Newton; L = left; R = right; Group 2 = mechanical ventilation ≥ 5 days; * = $p < 0.05$.*

Subjects in Group 2 presented with weakness of all upper limb muscle groups from one to six months after hospital discharge when compared to a group of healthy individuals.

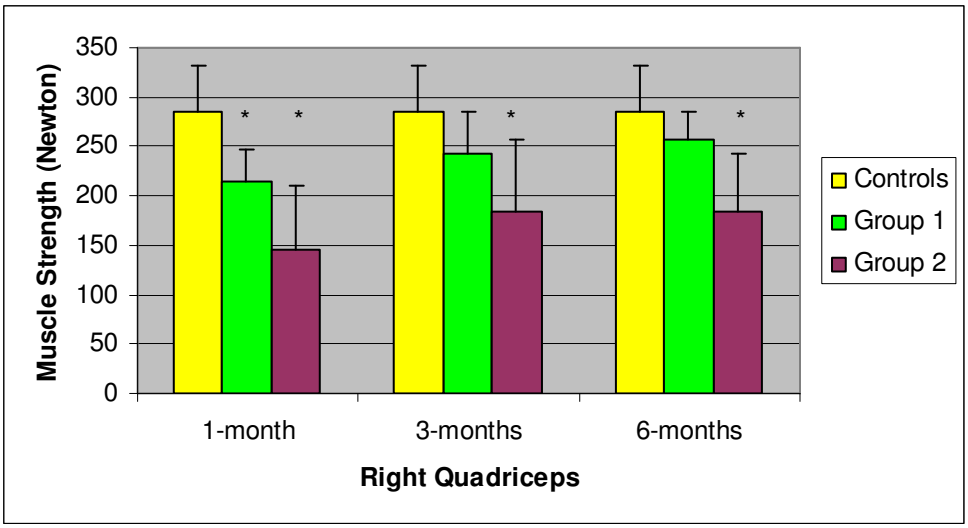
Lower limb muscle strength comparisons are summarized in Figures 4.5.2.1, 4.5.2.2, 4.5.2.3 and 4.5.2.4.

Figure 4.5.2.1: Quadriceps Strength Comparisons Between Survivors of Penetrating Trunk Trauma and the Control Group for the Left Limb



*Data expressed as means; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; * = $p < 0.05$.*

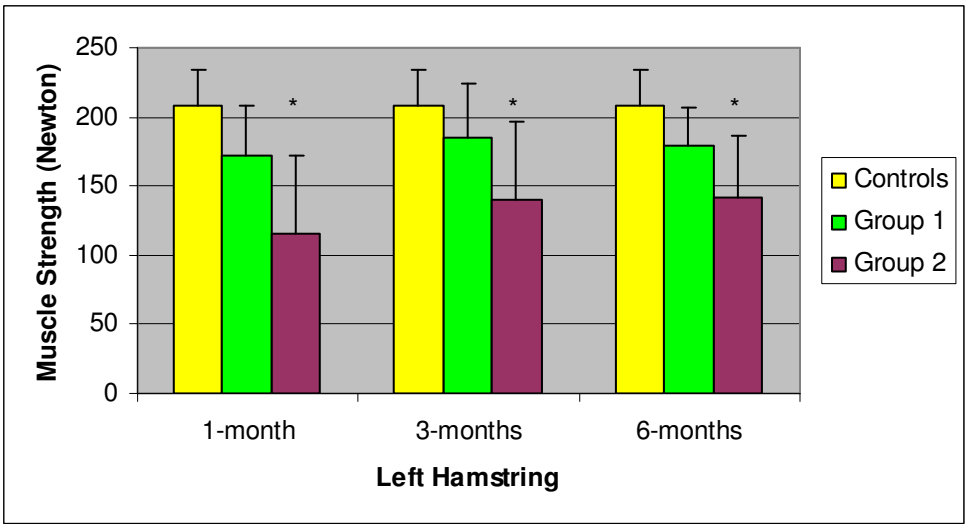
Figure 4.5.2.2: Quadriceps Strength Comparisons Between Survivors of Penetrating Trunk Trauma and the Control Group for the Right Limb



*Data expressed as means; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; * = $p < 0.05$.*

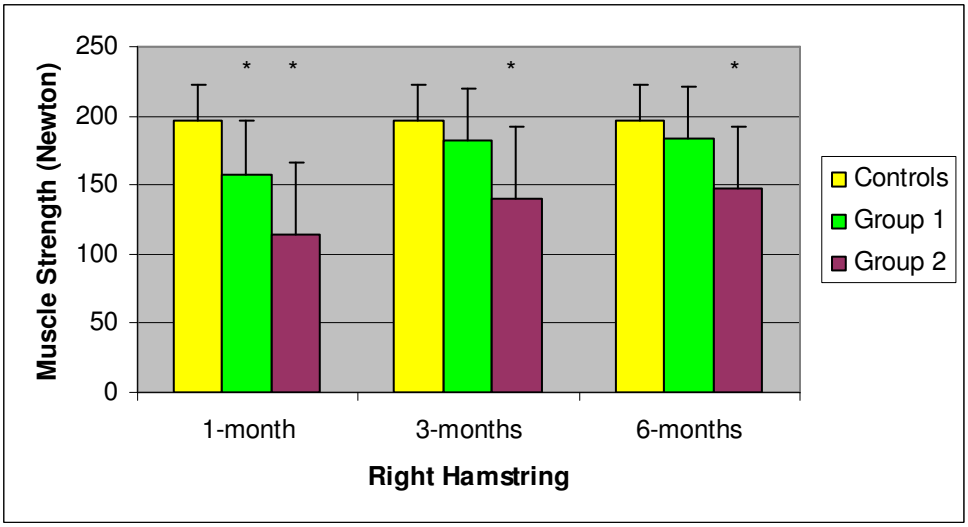
Subjects in Group 1 presented with a statistically significant weaker left and right quadriceps ($p = 0.00$ respectively) muscle strength at one month when compared to the control group. Subjects in Group 2 presented with significant weakness of left and right quadriceps ($p = 0.00$ respectively at all assessments) muscle groups from one to six months after hospital discharge when compared to a group of healthy individuals.

Figure 4.5.2.3: Hamstring Strength Comparisons Between Survivors of Penetrating Trunk Trauma and the Control Group for the Left Limb



*Data expressed as means; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; * = p < 0.05.*

Figure 4.5.2.4: Hamstring Strength Comparisons Between Survivors of Penetrating Trunk Trauma and the Control Group for the Right Limb



*Data expressed as means; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; * = p < 0.05.*

Subjects in Group 1 presented with a statistically significant weaker right hamstring (p = 0.03) muscle strength at one month when compared to the control group. Subjects in Group 2 presented with significant weakness of left and right hamstring

muscle groups from one to six months ($p = 0.00$ respectively at all assessments) after hospital discharge when compared to a group of healthy individuals.

Subjects in Group 1 were able to do an average of 31 abdominal crunches (SD ± 8.6) in one minute at six months and those in the control group an average of 44 abdominal crunches (SD ± 14.6). Abdominal muscle strength for subjects in Group 1 was significantly weaker ($p = 0.019$) compared to that of the control group. Subjects in Group 2 were able to do an average of 30 abdominal crunches (SD ± 12.3) in one minute at six months and those in the control group an average of 44 abdominal crunches (SD ± 14.6). Abdominal muscle strength for subjects in Group 2 at six months was also significantly weaker ($p = 0.001$) compared to that of the control group.

The majority of subjects in Groups 1 and 2 and in the control group were right-handed and Fischer's exact test revealed no statistically significant difference in hand dominance between these groups ($p = 0.374$). As mentioned in the previous section, there were no statistically significant differences in age ($p = 0.074$), sex ($p = 0.561$) or BMI ($p = 0.494$) between the control group and the other two groups.

4.5.3 Relationship Between Severity of Illness, Morbidity, ICU and Hospital Length of Stay and Muscle Strength

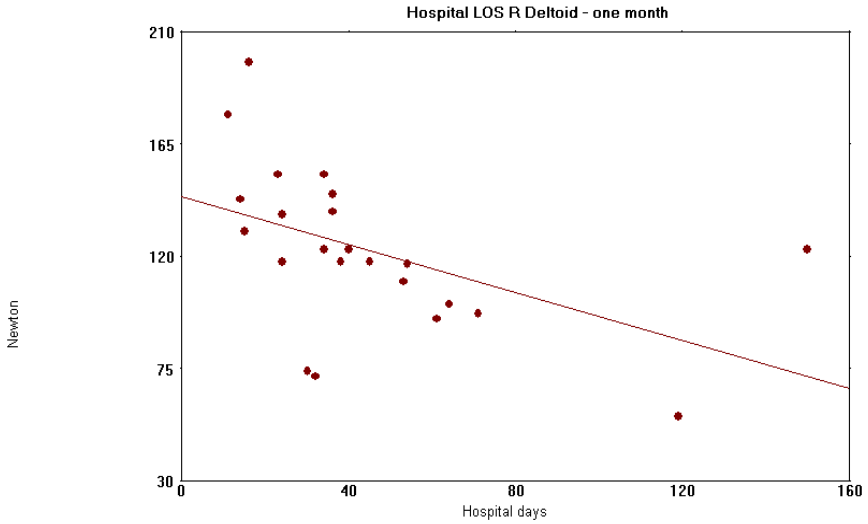
Spearman's correlation was calculated for severity of illness (APACHE II) and muscle strength for subjects in Groups 1 and 2. No statistically significant relationship was found between APACHE II scores and muscle strength at any of the three assessments for subjects in Groups 1 or 2. Thus a weak association existed between APACHE II scores and muscle strength for subjects in both groups.

Similar correlations were calculated for morbidity (maximal SOFA) and muscle strength for subjects in Groups 1 and 2. No statistically significant relationship was found between maximal SOFA scores and muscle strength for subjects in Groups 1 or 2 at any of the three assessments. Thus a weak association existed between SOFA scores and muscle strength for subjects in both groups.

Spearman's correlation was calculated for ICU LOS and muscle strength for subjects in Groups 1 and 2. There was no statistically significant relationship between ICU LOS and muscle strength for subjects in Group 1 at one, three or six months after hospital discharge. A strong degree of association was found between ICU LOS and right deltoid (rho = -0.513; p = 0.012), right triceps (rho = -0.473; p = 0.022) and right hamstring (rho = -0.549; p = 0.006) strength for subjects in Group 2 at one month. There was a strong degree of association between ICU LOS and left triceps (rho = -0.445; p = 0.049) strength at three months for subjects in Group 2. No association between ICU LOS and muscle strength was observed for subjects in Group 2 at six months after hospital discharge.

Similar correlations were calculated for hospital LOS and muscle strength for subjects in Groups 1 and 2. No significant association was observed between hospital LOS and muscle strength for subjects in Group 1 at one, three or six months after hospital discharge. A strong association was found between hospital LOS and left deltoid (rho = -0.553; p = 0.006), right triceps (rho = -0.613; p = 0.001), left hamstring (rho = -0.587; p = 0.003) and right hamstring (rho = -0.753; p = 0.000) strength for subjects in Group 2 at one month. Figure 4.5.3.1 portrays the correlation between hospital LOS and right deltoid strength at one month.

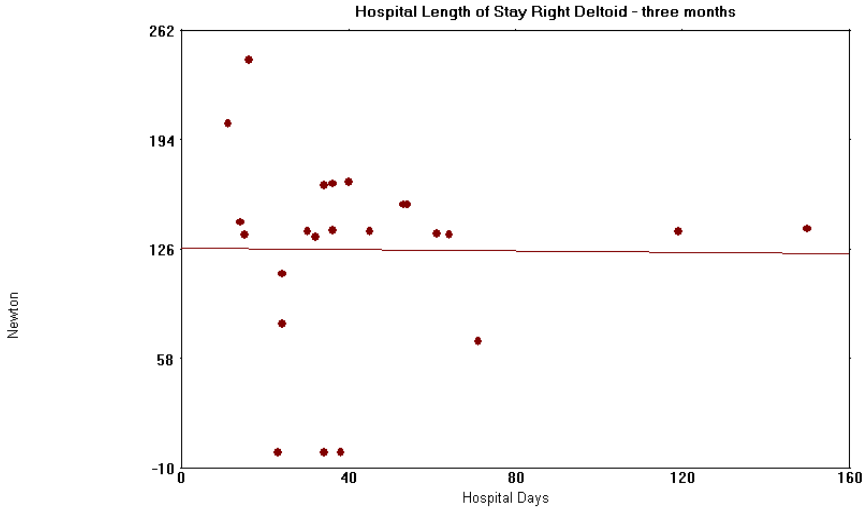
Figure 4.5.3.1: Spearman Correlation for Hospital LOS and Right Deltoid Strength for Subjects in Group 2 One Month After Hospital Discharge (n=23).



A strong association was found between hospital LOS and deltoid muscle strength (rho = -0.613; p = 0.001) for subjects in Group 2 one month after hospital discharge.

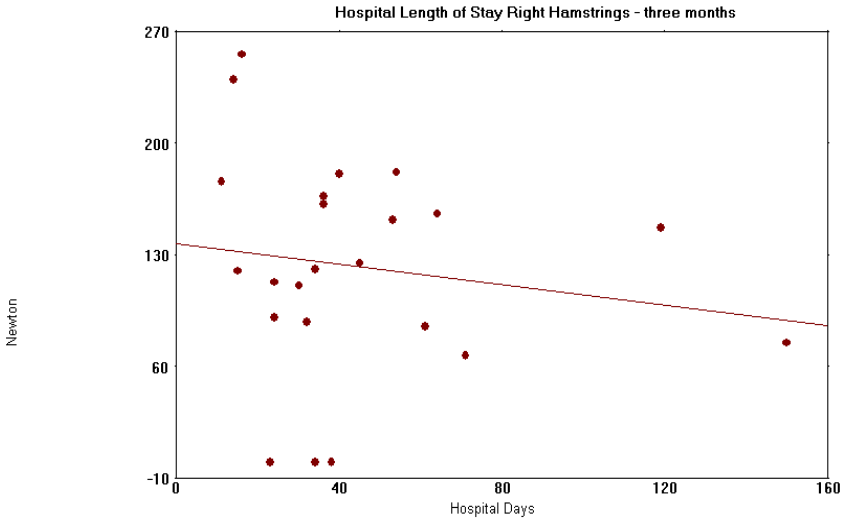
A strong association between hospital LOS and left deltoid (rho = -0.569; p = 0.008), left triceps (rho = -0.589; p = 0.006) and right triceps (rho = -0.556; p = 0.01) strength existed three months after hospital discharge for subjects in Group 2. Figures 4.5.3.2 and 4.5.3.3 portray the correlation between hospital LOS and right deltoid and right hamstring strength, respectively, for subjects in Group 2.

Figure 4.5.3.2: **Spearman Correlation for Hospital LOS and Right Deltoid Strength for Subjects in Group 2 Three Months After Hospital Discharge (n=20).**



Hospital LOS was significantly correlated with right hamstring (rho = -0.452; p = 0.045) strength three months after discharge. Figure 4.5.3.3 is displayed on the next page.

Figure 4.5.3.3: Spearman Correlation for Hospital LOS and Right Hamstring Strength for Subjects in Group 2 Three Months After Hospital Discharge (n = 20)



Hospital LOS was strongly associated with right hamstring (rho = -0.459; p = 0.041) strength three months after discharge. No association between hospital LOS and muscle strength was observed six months after discharge for subjects in Group 2.

4.6 QUALITY OF LIFE RESULTS

The SF-36 questionnaire was self-administered one, three and six months after discharge and help was only provided if the subject did not understand what was being asked. No attempt was made by the researcher to influence the subject's responses to the questions asked. Subjects took on average 10 – 15 minutes to complete the questionnaire.

4.6.1 Pre-Admission QOL Compared to QOL at Subsequent Assessments for Survivors of Penetrating Trunk Trauma

Comparisons were made between the pre-admission QOL (domain and summary scores) and the QOL (domain and summary scores) assessed at one, three and six months after discharge for subjects in each group. These comparisons are summarized in Tables 4.6.1.1, 4.6.1.2, 4.6.1.3 and 4.6.1.4 below. Higher scores represent a better QOL.

Table 4.6.1.1: Pre-Admission QOL Compared to QOL Assessed at One, Three and Six Months for Subjects in Group 1

Domains	Mean scores of SF-36 domains (0 – 100)								
	Pre-adm (n = 13)	1-mo (n = 7)	P-value	Pre-adm (n = 13)	3-mo (n = 7)	P - value	Pre-adm (n = 13)	6-mo (n = 6)	P-value
PF	98.5 (3.1)	75 (14.7)	0.000 *	98.5 (3.1)	89.3 (10.5)	0.008 *	98.5 (3.1)	92.5 (10.3)	0.068
RP	100 (0.0)	10.7 (28.3)	0.000 *	100 (0.0)	75 (43.3)	0.046 *	100 (0.0)	79.2 (40.0)	0.068
BP	97.5 (6.0)	55.3 (14.6)	0.000 *	97.5 (6.0)	74.7 (20.7)	0.001 *	97.5 (6.0)	95.7 (10.6)	0.627
GH	97.5 (6.3)	72.4 (14.7)	0.000 *	97.5 (6.3)	77.1 (22.5)	0.006 *	97.5 (6.3)	90.7 (6.5)	0.043 *
VT	98.8 (2.1)	55 (7.0)	0.000 *	98.8 (2.1)	68.6 (11.0)	0.000 *	98.8 (2.1)	73.3 (16.3)	0.000 *
SF	98.1 (4.6)	60.7 (22.1)	0.000 *	98.1 (4.6)	83.9 (17.2)	0.011 *	98.1 (4.6)	89.6 (14.6)	0.068
RE	94.9 (12.5)	57.1 (53.4)	0.023 *	94.9 (12.5)	100 (0.0)	0.298	94.9 (12.5)	83.3 (40.8)	0.353
MH	96.9 (4.3)	66.9 (11.9)	0.000 *	96.9 (4.3)	76.6 (11.8)	0.000 *	96.9 (4.3)	80.7 (18.6)	0.007 *

*Data expressed as transformed mean (± SD); Group 1 = mechanical ventilation < 5 days; Pre-adm = pre-admission; 1-mo = 1-month; 3-mo = 3-months; 6-mo = 6-months; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; * = p < 0.05.*

Table 4.6.1.2: Pre-Admission SF-36 Summary Scores Compared to SF-36 Summary Scores Assessed at One, Three and Six Months for Subjects in Group 1

Domains	Mean summary scores of SF-36								
	Pre-adm (n = 13)	1-mo (n = 7)	P-value	Pre-adm (n = 13)	3-mo (n = 7)	P - value	Pre-adm (n = 13)	6-mo (n = 6)	P-value
PCS	58.9 (0.8)	42.8 (3.9)	0.000*	58.9 (0.8)	51.2 (9.0)	0.005*	58.9 (0.8)	57.2 (5.5)	0.268
MCS	60.4 (3.0)	44.9 (10.5)	0.000*	60.4 (3.0)	53.3 (3.9)	0.000*	60.4 (3.0)	51.8 (6.1)	0.000*

*Data expressed as norm-based mean (± SD); Group 1 = mechanical ventilation < 5 days; Pre-adm = pre-admission; 1-mo = 1-month; 3-mo = 3-months; 6-mo = 6-months; PCS = physical health summary score; MCS = mental health summary score; * = p < 0.05.*

From the tables above it is clear that QOL as assessed with the SF-36 at one month after discharge was significantly reduced in all domains for subjects in Group 1 compared to retrospective pre-admission QOL for the same group. The same trend is noted for QOL at three months. Only the role emotional (RE) domain was not statistically significantly different at the three-month assessment. At six months, QOL related to physical function [physical function (PF), role physical (RP), bodily pain (BP) and physical health summary score (PCS)] had improved but there was still a significant difference in QOL related to general health (GH) (p = 0.043). Quality of life related to some domains of mental health [social function (SF) and RE] had improved but there was still a statistically significant difference in mental health domains related to vitality (VT) (p = 0.000), mental health (MH) (p = 0.007) and the mental component summary scores (MCS) (p =0.000) at six months.

Table 4.6.1.3: Pre-Admission QOL Compared to QOL Assessed at One, Three and Six Months For Group 2

Domains	Mean scores of SF-36 domains (0 – 100)								
	Pre-adm (n = 29)	1-mo (n = 23)	P-value	Pre-adm (n = 29)	3-mo (n = 20)	P - value	Pre-adm (n = 29)	6-mo (n = 17)	P-value
PF	100 (0.0)	59.8 (20.9)	0.000*	100 (0.0)	65.5 (22)	0.000*	100 (0.0)	71.2 (15.2)	0.000*
RP	99.1 (4.6)	5.7 (15.3)	0.000*	99.1 (4.6)	27.5 (37.9)	0.000*	99.1 (4.6)	60.3 (40.5)	0.000*
BP	99.5 (2.9)	51.9 (18.2)	0.000*	99.5 (2.9)	55.7 (20.1)	0.000*	99.5 (2.9)	64.1 (22.5)	0.000*
GH	95.7 (5.9)	65.9 (15.5)	0.000*	95.7 (5.9)	67.1 (20.1)	0.000*	95.7 (5.9)	72.2 (17.3)	0.000*
VT	93.8 (11.2)	62.3 (17.5)	0.000*	93.8 (11.2)	64.5 (15.6)	0.000*	93.8 (11.2)	70.9 (18.2)	0.000*
SF	97.4 (10.2)	64.2 (26.8)	0.000*	97.4 (10.2)	67.5 (21.9)	0.000*	97.4 (10.2)	78.7 (19.1)	0.000*
RE	98.9 (6.1)	56.1 (46.4)	0.000*	98.9 (6.1)	68.3 (36.6)	0.000*	98.9 (6.1)	82.4 (33.5)	0.012*
MH	93.1 (10.5)	66.9 (17.1)	0.000*	93.1 (10.5)	73.8 (17.2)	0.000*	93.1 (10.5)	78.6 (15.7)	0.000*

*Data expressed as transformed mean (± SD); Group 2 = mechanical ventilation ≥ 5 days; Pre-adm = pre-admission; 1-mo = 1-month; 3-mo = 3-months; 6-mo = 6-months; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; * = $p < 0.05$.*

Table 4.6.1.4: Pre-Admission SF-36 Summary Scores Compared to SF-36 Summary Scores Assessed at One, Three and Six Months for Group 2

Domains	Mean summary scores of SF-36								
	Pre-adm (n = 29)	**1-mo (n = 23)**	**P-value**	**Pre-adm (n = 29)**	**3-mo (n = 20)**	**P - value**	**Pre-adm (n = 29)**	**6-mo (n = 17)**	**P-value**
PCS	59.4 (0.9)	38.5 (5.1)	0.000*	59.4 (0.9)	40.8 (8.3)	0.000*	59.4 (0.9)	45.4 (8.4)	0.000*
MCS	59 (5.3)	47.9 (10.8)	0.000*	59 (5.3)	50.6 (7.8)	0.000*	59 (5.3)	53.8 (8.4)	0.013*

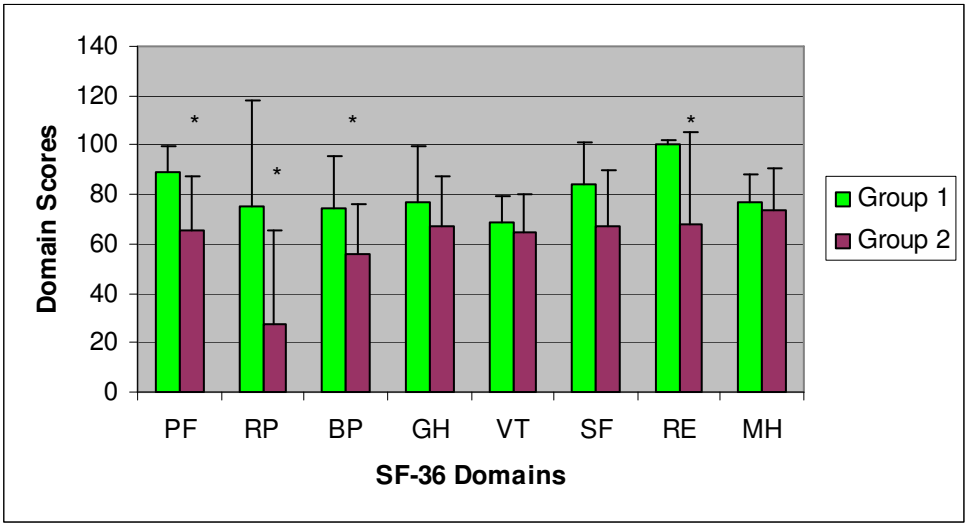
*Data expressed as norm-based mean (± SD); Group 2 = mechanical ventilation ≥ 5 days; Pre-adm = pre-admission; 1-mo = 1-month; 3-mo = 3-months; 6-mo = 6-months; PCS = physical health summary score; MCS = mental health summary score; * = $p < 0.05$.*

It is clear from Tables 4.6.1.3 and 4.6.1.4 that QOL as assessed with the SF-36 at one month after discharge was significantly reduced in all domains for subjects in Group 2 compared to retrospective pre-admission QOL for the same group. The same trend is noted for QOL related to physical and mental health at three and at six months.

4.6.2 SF-36 Results for Subjects in Group 1 compared with Those in Group 2

A comparison was made between Groups 1 and 2 for the mean SF-36 domain scores at one, three and six months. No statistically significant difference was found for the domain or summary scores between the groups one month after hospital discharge. Results of comparisons between these groups at three and six months are summarized in Figures 4.6.2.1 and 4.6.2.2 below.

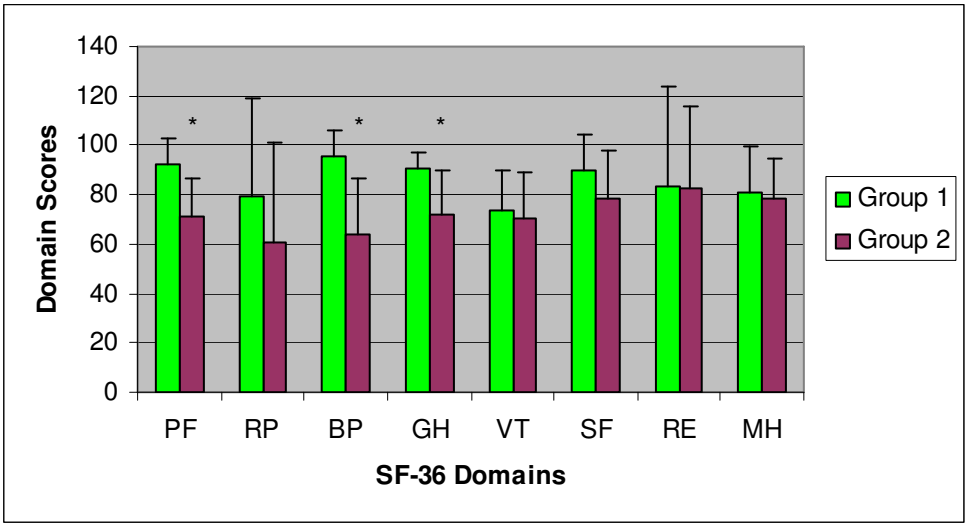
Figure 4.6.2.1: SF-36 Domain Score Comparisons at Three Months After Hospital Discharge



Data expressed as transformed means; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days.

There was a statistically significant difference between the groups for the PF ($p = 0.011$), RP ($p = 0.01$), BP ($p = 0.042$) and RE ($p = 0.032$) domains at the three-month assessment as shown in Figure 4.6.2.1 above. A statistically significant difference was also detected between the groups for the PCS summary score ($p = 0.01$) but not for the MCS summary score ($p = 0.403$).

Figure 4.6.2.2: SF-36 Domain Score Comparisons at Six Months After Hospital Discharge



Data expressed as transformed means; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days.

There was a statistically significant difference between the groups for the PF ($p = 0.004$), BP ($p = 0.003$) and GH ($p = 0.02$) domains at the six-month assessment as shown in Figure 4.6.2.2 above. A statistically significant difference was also present between the groups for the PCS summary score ($p = 0.004$) but not for the MCS summary score ($p = 0.616$).

4.6.3 Quality of life of Survivors of Penetrating Trunk Trauma Compared to QOL of a Healthy South African Control Group

Forty volunteers completed the SF-36 questionnaire at the same time that they were assessed for muscle strength and exercise capacity. The results of this once-off QOL assessment were then compared to that of subjects in Groups 1 and 2 to judge at which time period after discharge the subjects' scores would be comparable to that of a healthy group of individuals of similar age, BMI and sex. Comparisons between subjects in Group 1 and the control group are summarized in Tables 4.6.3.1 and 4.6.3.2 below.

Table 4.6.3.1: SF-36 Domain Score Comparisons Between Group 1 and the Control Group

Domains	Mean scores of SF-36 domains (0 – 100)								
	1-month			3-months			6-months		
	Gr 1 (n = 7)	Control (n = 40)	P-value	Gr 1 (n = 7)	Control (n = 40)	P-value	Gr 1 (n = 6)	Control (n = 40)	P-value
PF	75 (14.7)	96.3 (8.5)	0.000*	89.3 (10.5)	96.3 (8.5)	0.06	92.5 (10.3)	96.3 (8.5)	0.333
RP	10.7 (28.3)	90.6 (23.8)	0.000*	75 (43.3)	90.6 (23.8)	0.168	79.2 (40.0)	90.6 (23.8)	0.322
BP	55.3 (14.6)	87.2 (15.2)	0.000*	74.7 (20.7)	87.2 (15.2)	0.063	95.7 (10.6)	87.2 (15.2)	0.198
GH	72.4 (14.7)	83.8 (16.3)	0.091	77.1 (22.5)	83.8 (16.3)	0.351	90.7 (6.5)	83.8 (16.3)	0.317
VT	55 (7.0)	71.1 (20.1)	0.042*	68.6 (11.0)	71.1 (20.1)	0.745	73.3 (16.3)	71.1 (20.1)	0.8
SF	60.7 (22.1)	90 (16.5)	0.000*	83.9 (17.2)	90 (16.5)	0.378	89.6 (14.6)	90 (16.5)	0.953
RE	57.1 (53.4)	81.2 (32.2)	0.109	100 (0.0)	81.2 (32.2)	0.133	83.3 (40.8)	81.2 (32.2)	0.884
MH	66.9 (11.9)	78.4 (15.1)	0.062	76.6 (11.8)	78.4 (15.1)	0.763	80.7 (18.6)	78.4 (15.1)	0.741

*Data expressed as transformed mean (± SD); Group 1 = mechanical ventilation < 5 days; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; * = $p < 0.05$.*

Table 4.6.3.2: SF-36 Summary Score Comparisons Between Group 1 and the Control Group

Summary Scores	Mean SF-36 summary score values								
	1-month			3-months			6-months		
	Gr 1 (n = 7)	Control (n = 40)	P-value	Gr 1 (n = 7)	Control (n = 40)	P-value	Gr 1 (n = 6)	Control (n = 40)	P-value
PCS	42.8 (3.9)	57.6 (5.1)	0.000*	51.2 (9.0)	57.6 (5.1)	0.011*	57.2 (5.5)	57.6 (5.1)	0.855
MCS	44.9 (10.5)	50.3 (10.3)	0.212	53.3 (3.9)	50.3 (10.3)	0.464	51.8 (6.1)	50.3 (10.3)	0.725

*Data expressed as norm-based mean (± SD); Group 1 = mechanical ventilation < 5 days; PCS = physical health summary score; MCS = mental health summary score; * = $p < 0.05$.*

Quality of life related to physical health (PF, RP, BP and PCS) was significantly different between Group 1 and the control group at one month. The SF (p = 0.000) and VT domains (p = 0.042) were also significantly different between the two groups

at one month. The PCS (p = 0.011) was significantly different between the groups at three months. There were no statistically significant differences in any of the other domains or the MCS between the groups at three months. By six months, no statistically significant differences were observed between the groups for any of the domains or summary scores.

Comparisons between subjects in Group 2 and the control group are summarized in Tables 4.6.3.3 and 4.6.3.4 below.

Table 4.6.3.3: SF-36 Domain Score Comparisons Between Group 2 and the Control Group

Domains	Mean scores of SF-36 domains (0 – 100)								
	1-month			3-months			6-months		
	Gr 2 (n = 23)	Control (n = 40)	P-value	Gr 2 (n = 20)	Control (n = 40)	P-value	Gr 2 (n = 17)	Control (n = 40)	P-value
PF	59.8 (20.9)	96.3 (8.5)	0.000*	65.5 (22)	96.3 (8.5)	0.000*	71.2 (15.2)	96.3 (8.5)	0.000*
RP	5.7 (15.3)	90.6 (23.8)	0.000*	27.5 (37.9)	90.6 (23.8)	0.000*	60.3 (40.5)	90.6 (23.8)	0.000*
BP	51.9 (18.2)	87.2 (15.2)	0.000*	55.7 (20.1)	87.2 (15.2)	0.000*	64.1 (22.5)	87.2 (15.2)	0.000*
GH	65.9 (15.5)	83.8 (16.3)	0.000*	67.1 (20.1)	83.8 (16.3)	0.001*	72.2 (17.3)	83.8 (16.3)	0.019*
VT	62.3 (17.5)	71.1 (20.1)	0.087	64.5 (15.6)	71.1 (20.1)	0.202	70.9 (18.2)	71.1 (20.1)	0.965
SF	64.2 (26.8)	90 (16.5)	0.000*	67.5 (21.9)	90 (16.5)	0.000*	78.7 (19.1)	90 (16.5)	0.028*
RE	56.1 (46.4)	81.2 (32.2)	0.015*	68.3 (36.6)	81.2 (32.2)	0.171	82.4 (33.5)	81.2 (32.2)	0.904
MH	66.9 (17.1)	78.4 (15.1)	0.008*	73.8 (17.2)	78.4 (15.1)	0.294	78.6 (15.7)	78.4 (15.1)	0.966

*Data expressed as transformed mean (± SD); Group 2 = mechanical ventilation ≥ 5 days; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; * = $p < 0.05$.*

Table 4.6.3.4: SF-36 Summary Score Comparisons Between Group 2 and the Control Group.

Summary Scores	Mean SF-36 summary score values								
	1-month			3-months			6-months		
	Gr 2 (n = 23)	Control (n = 40)	P-value	Gr 2 (n = 20)	Control (n = 40)	P-value	Gr 2 (n = 17)	Control (n = 40)	P-value
PCS	38.5 (5.1)	57.6 (5.1)	0.000*	40.8 (8.3)	57.6 (5.1)	0.000*	45.4 (8.4)	57.6 (5.1)	0.000*
MCS	47.9 (10.8)	50.3 (10.3)	0.383	50.6 (7.8)	50.3 (10.3)	0.915	53.8 (8.4)	50.3 (10.3)	0.23

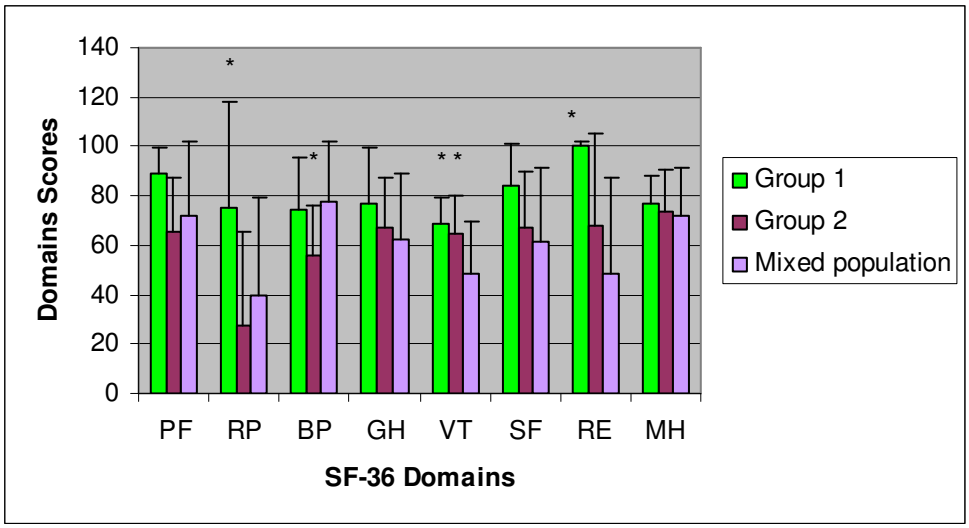
*Data expressed as norm-based mean (± SD); Group 2 = mechanical ventilation ≥ 5 days; PCS = physical health summary score; MCS = mental health summary score; * = $p < 0.05$.*

QOL related to physical health (PF, RP, BP, GH and PCS) was significantly different between Group 2 and the control group at one month as was QOL related to mental health (SF, RE and MH). At three months, scores in the VT, RE and MH domains were not significantly different between the groups. MCS was also not significantly different between the groups at three months. QOL related to physical health (PF, RP, BP, GH and PCS) was significantly different between the groups at six months whereas QOL related to mental health was not except for the SF domain ($p = 0.028$).

4.6.4 Quality of Life Of Survivors of Penetrating Trunk Trauma Compared to Other ICU Survivors

A search through the literature on QOL (measured with the SF-36) related to survivors of trauma in the ICU over the first six months after discharge from the hospital revealed limited information. Data from research published by Eddleston and co-workers (2000) and Cuthbertson and co-workers (2005) were compared with the QOL data from the current study. These comparisons are summarized in Figures 4.6.4.1, 4.6.4.2 and 4.6.4.3 below.

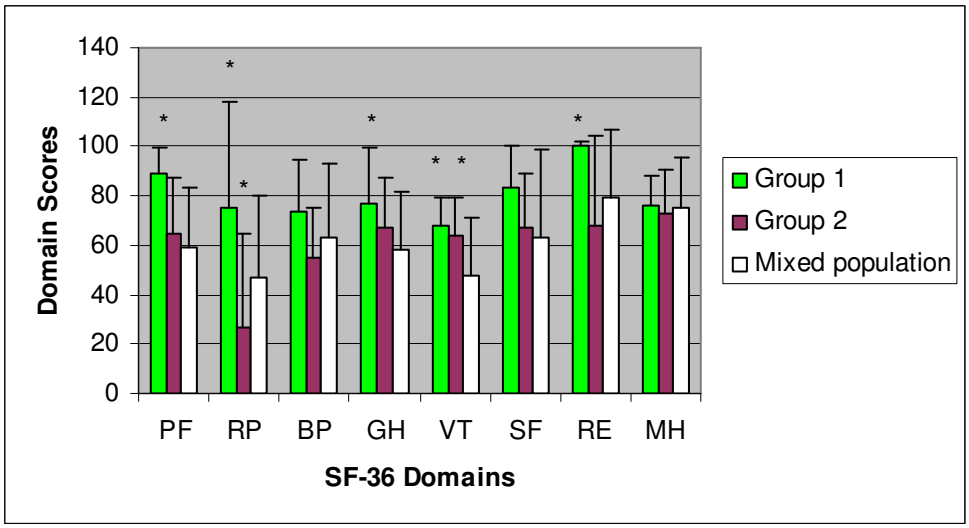
Figure 4.6.4.1: QOL Comparisons at Three Months After Discharge Between Survivors of Penetrating Trunk Trauma and Eddleston's Mixed ICU Population



*Data expressed as transformed means; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; mixed population = Eddleston's ICU population data; * = $p < 0.05$.*

There was a statistically significant difference in scores between Group 1 and Eddleston's population for the RP ($p = 0.033$), VT ($p = 0.017$) and RE ($p = 0.001$) domains at three months. The only statistically significant differences between Group 2 and Eddleston's population were in the BP ($p = 0.000$) and VT ($p = 0.003$) domains at three months. Figures 4.6.4.2 and 4.6.4.3 are displayed on the next page.

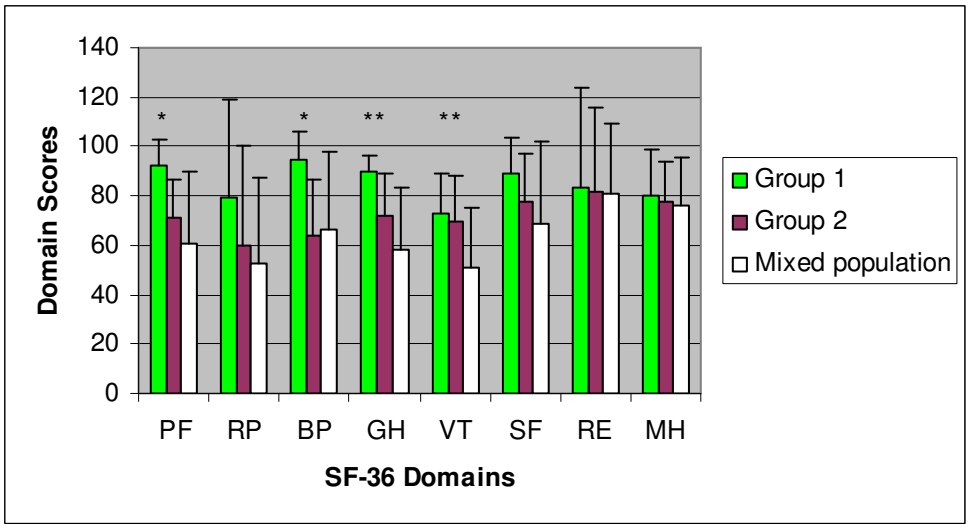
Figure 4.6.4.2: **QOL Comparisons at Three Months after Discharge Between Survivors of Penetrating Trunk Trauma and Cuthbertson's Mixed ICU Population**



*Data expressed as transformed means; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; mixed population = Cuthbertson's ICU population data; * p = < 0.05.*

There was a statistically significant difference in scores between Group 1 and Cuthbertson's population for the PF (p = 0.001), RP (p = 0.03), GH (p = 0.03), VT (p = 0.02) and RE (p = 0.05) domains at three months. The only statistically significant differences between Group 2 and Cuthbertson's population were in the RP (p = 0.01) and VT (p = 0.002) domains at three months.

Figure 4.6.4.3: QOL Comparisons at Six Months After Discharge Between Survivors of Penetrating Trunk Trauma and Cuthbertson's Mixed ICU Population



*Data expressed as transformed means; PF = physical function; RP = role physical; BP = bodily pain; GH = general health; VT = vitality; SF = social function; RE = role emotional; MH = mental health; Group 1 = mechanical ventilation < 5 days; Group 2 = mechanical ventilation ≥ 5 days; mixed population = Cuthbertson's ICU population data; * = $p < 0.05$.*

There was still a statistically significant difference in scores between Group 1 and Cuthbertson's population for the PF ($p = 0.009$), BP ($p = 0.02$), GH ($p = 0.002$) and VT ($p = 0.03$) domains at six months. The only statistically significant differences between Group 2 and Cuthbertson's population were in the GH ($p = 0.03$) and VT ($p = 0.001$) domains at six months.

This chapter summarized the results obtained through the prospective, observational study that was performed with survivors of penetrating trunk trauma who received MV over various time periods. The next chapter offers an in-depth discussion of these results.

CHAPTER 5

DISCUSSION

One of the important findings of this study was that subjects that received a short period of MV, recovered adequately on their own by the third month after discharge with regard to muscle strength, exercise capacity and QOL. However, subjects that received prolonged MV showed some improvement in muscle strength, exercise capacity and the physical components of QOL but were still significantly weaker than those in Group 1 and the controls six months after hospital discharge. Bertolli (2002) reported that the number of civilian gunshot wound victims at the trauma unit of Johannesburg Hospital had risen as high as 150 per month in 1999 and continued to rise to 160 per month in 2001. Bowley reported a prevalence of 67% gunshot/stab wound related admissions to Johannesburg Hospital Trauma Unit (JHTU) in August 2002 (Bowley et al 2004). This prevalence underlines the importance of research into the rate of recovery of survivors of penetrating trunk trauma. This chapter starts with a description of the characteristics of the study population and thereafter an in-depth discussion of the main findings will follow. Comparisons will be made between results obtained from the current study and those published in the literature by fellow researchers.

5.1 DEMOGRAPHIC CHARACTERISTICS OF THE STUDY POPULATION

This prospective observational study investigated the effect of penetrating trunk trauma and MV on the recovery of adult survivors over the first six months following discharge from the hospital. All the participants in this study sustained civilian, low-velocity gunshot and stab wounds. The majority of participants in this study were male (96%). Similar demographics were reported by Monzon-Torres and Ortega-Gonzalez (2004) in their study on penetrating abdominal trauma in the Limpopo province, South Africa and by Bowley and colleagues (2004) in their study on trauma admissions to Johannesburg Hospital. Subjects who suffered gunshot or stab wounds to the abdomen mostly had injuries to the colon, small bowel, spleen, stomach and liver. Monzon-Torres and Ortega-Gonzalez (2004) and Adesanya and co-workers (2000) reported a similar pattern of organ injury. No statistically significant differences were detected between subjects that suffered penetrating trunk trauma and received MV for a short period and subjects with a similar diagnosis that received MV for a prolonged time period with regard to age, sex or BMI. The subjects in these groups were thus comparable.

The leading two causes of injury in the current study were assault and robbery and this is consistent with the studies published in South Africa over the period 2003 – 2007. Allard and Burch (2005) stated that South Africa had a high prevalence of interpersonal violence. Bowley and colleagues (2004) reported that a high percentage of interpersonal violence was related to alcohol and cannabis misuse in Johannesburg. Gun free South Africa (2007) reported 133 657 armed robberies for the time period 2003/4. Thirty-two of the 42 participants in the current study were from a lower socioeconomic background as their reported monthly income was below R5 000. Butchart and colleagues (2000) conducted a survey in a low-income Johannesburg township of 90 000 inhabitants that included 1 075 participants. These participants stated that 51% of injuries sustained the year before the survey was due to violence in their community. They stated that the main causes of violence were unemployment and alcohol and drug abuse. The authors found that a relationship existed between alcohol/drug abuse and interpersonal violence associated with money, intimacy and power (gang-related). These subjects may have been more at risk of violence in their community than the other subjects in our study.

Only two participants in the current study knew about their HIV status. This may seem odd due to the high prevalence of HIV/AIDS in South Africa which has been so widely published in the literature and in the media over the past 5 – 10 years. Bowley and co-workers (cited in Goosen et al 2003) conducted a blinded audit in the JHTU in 2002 and documented a 37% prevalence of HIV positivity among the patients admitted for care. However, the South African government does not allow indiscriminate HIV-testing without consent and therefore testing is only performed on trauma patients in Johannesburg hospitals if a staff member has suffered a needle stick injury (Goosen et al 2003). Patients admitted to the JHTU may already have been HIV positive but this was mostly unknown to them and their caregivers. Correlations between HIV status of the participants in this study and the various outcome measures assessed were impossible for this reason.

Participants that suffered penetrating trunk trauma and received MV for a short period (Group 1) initially presented with a higher APACHE II score on admission to ICU than participants that received prolonged MV (Group 2). Some authors have commented that prognostic severity of illness scores such as the APACHE II might be more applicable to patient populations and not necessarily to individuals (Antonelli et

al 1999; Timsit et al 2002). This seems consistent with our study sample. However, participants in Group 2 had significantly greater morbidity that led to a longer ICU and hospital LOS of 26 and 42 days respectively. In addition this group required more inotropic support indicating a more severe initial injury or inflammatory response or the subsequent development of sepsis. Participants in Group 1 also recovered sooner than those in Group 2.

All participants in this study received physiotherapy treatment during their ICU and hospital stays. Physiotherapy treatment involved treatment of the chest to resolve or prevent pulmonary complications as well as mobilization both in the ICU and on the wards. The seven participants with open abdomens (one in Group 1 and six in Group 2) in the ICU had a delay in participation in mobilization and consequently experienced a longer period of bed rest. Recently authors in Canada and the United States of America published studies that reviewed the effect of immobility on patients in ICU and expressed their concern over the lack of physiotherapist involvement in the rehabilitation of their patients in ICU (Morris 2007; Morris & Herridge 2007). The observed level of physiotherapist involvement in the rehabilitation of subjects in this study is supported by the findings of a survey conducted by Van Aswegen and Potterton (2005) to identify the scope of practice of physiotherapists in South African ICU's. They found that 100% of physiotherapists in public hospitals and 95% of physiotherapists in private sector hospitals were involved in mobilizing patients in the ICU. It is probable that the subjects in this study suffered less complications of immobility during their time in ICU and on the wards due to the level of physiotherapist involvement in their care and all were independently mobile at discharge from the hospital.

5.2 RECOVERY OF MUSCLE STRENGTH DURING THE FIRST SIX MONTHS FOLLOWING DISCHARGE

5.2.1 Muscle Strength Recovery of Subjects in Group 1

Statistically significant greater muscle strength was observed for this group compared to Group 2 at one, three and six months following discharge from the hospital. Group 1 presented with a reduction in muscle strength when compared with a healthy control group specifically with regard to the right deltoid, right triceps, left and right quadriceps and right hamstring muscles at one month after discharge. The subjects in

this group as well as the subjects in the control group were predominantly right-handed and therefore this difference in muscle strength was more notable in the right-sided muscle groups than in the left-sided muscle groups.

This group had an average of 6.8 days stay in the ICU. SIRS, that is triggered by trauma and blood loss, leads to the release of pro-inflammatory cytokines (IL-1, IL-6, TNF-α) that cause muscle protein breakdown, muscle atrophy and weakness (Winkelman 2004). In addition Malone (2006, p. 96 – 97) stated that the amount of muscle mass and strength lost is proportional to the duration of bed rest. The catabolic effects of inflammation and immobilization were relatively limited for this group in that they had significantly lower morbidity and shorter ICU and hospital LOS than Group 2. This was confirmed by the fact that no relationship was found between muscle strength and severity of illness, morbidity, ICU and hospital LOS at any of the assessments. However, Berg and colleagues (1997) reported a rate of 2 – 3% loss of muscle mass in the quadriceps muscle group after 1 – 6 weeks of bed rest in a group of healthy subjects which accounts for the significant reduction in quadriceps strength observed at the one-month assessment relative to healthy controls.

The reduction in muscle strength was no longer evident at the three and six-month assessments. Improvement in upper and lower limb strength was similar for this group of subjects over the six-month period. Kern and colleagues (2001) quantified the activity of upper and lower limb muscles in a group of 14 healthy men and women during two 10-hour recording sessions. They found that upper limb muscles were activated 67% more than lower limb muscles during ADL. They also found that when leg muscles were activated, their average burst amplitude was greater than that of the hand or arm muscles. It is probable that participation in general ADL following discharge from the hospital might have led to the strengthening of peripheral muscles in Group 1 over a relatively short period of time despite the absence of a planned rehabilitation programme. Abdominal muscle strength was significantly reduced for this group of survivors compared to the control group and was still present at six months. This may have an impact on core stability which has the potential to lead to postural and back problems in the long term.

5.2.2 Muscle Strength Recovery of Subjects in Group 2

Survivors in this group presented with a statistically significant reduction in strength in most peripheral muscles at all three test sessions compared to those in Group 1. They also had significantly weaker peripheral and core muscle strength when compared with the healthy control group. Although improvement in muscle strength was seen over the six-month period, their overall strength did not improve to the levels observed in Group 1 and the controls. This weakness would have been related to the inflammatory response and immobilization as described above. This was confirmed by the significant relationship found between hospital LOS and strength at one and three months and between ICU LOS and strength at one month after hospital discharge. High levels of IL-6 and high and low levels of the anti-inflammatory cytokine IL-10 are associated with poor outcome in trauma and sepsis (Winkelman et al 2007). Winkelman and colleagues postulated that IL-6/IL-10 ratio could be a powerful predictor of outcome in the ICU. In their preliminary report on 10 subjects that underwent prolonged MV (> 10 days), these authors concluded that low level activity (rolling and position changes and passive ROM movements) in the ICU contributed to a reduction in IL-6 levels and might play a role in achieving balance between the pro- and anti-inflammatory cytokines to reduce the effect of critical illness on muscle strength (Winkelman et al 2007). All the subjects in our study received physiotherapy treatment in the ICU and on the wards prior to discharge and at that stage would have benefited from this proposed effect on circulating cytokine levels.

Group 2 survivors in our study had an average ICU and hospital LOS of 26.6 and 42.3 days respectively. Their morbidity was significantly higher than subjects in Group 1 with a significantly higher incidence of sepsis and organ failure. TNF-α production is increased as a consequence of activation of the inflammatory response. It is responsible for the production of ROS and NO from PMNL, monocytes and the vascular endothelium. All three contribute to muscle breakdown and weakness. Nitric oxide further contributes to muscle protein breakdown through the ubiquitin-proteasome pathway (Jackman & Kandarian 2004; Reid & Li 2001; Winkelman 2004). Lanone and colleagues (2000) investigated the effects of sepsis on muscle contractile failure in a group of 16 patients. Biopsies from the rectus abdominis muscles were compared with biopsies taken from patients without sepsis that underwent elective surgery. The authors found a marked decrease in the contractile

force of the rectus abdominis muscles of those with sepsis compared to the controls. They ascribed this finding to the fact that high levels of NOS were present in the muscle samples taken from patients with sepsis. Nitric oxide synthase leads to the production of NO which interacts with ROS to form peroxynitrites that directly attack contractile proteins (Lanone et al 2000).

Eikermann and colleagues (2006) performed a similar experiment on patients that had survived sepsis and MODS. They investigated the effect of sepsis and MODS on the strength and fatigue of the adductor pollicis (AP) muscle. They found that AP muscle force was significantly decreased (by 30%) compared with controls but that no fatigability was observed. They concluded that the decrease in muscle force was due to a sepsis-induced myopathy as the compound muscle action potential and nerve conduction velocity was normal, implying no neural injury (Eikermann et al 2006). None of the subjects in Group 2 received neuromuscular blocking agents during their ICU stay and none of them had difficulty weaning from MV after the inflammatory response, sepsis and/or organ failure was reversed. It is probable therefore that the observed muscle weakness could be ascribed to significant muscle catabolism due to inflammation, sepsis or trauma-related and not to critical illness polyneuropathy (Garnacho-Montero et al 2001; Tennilä et al 2000). We did not however perform electromyography so this cannot be confirmed.

We found that upper limb muscle strength was significantly reduced at all three assessments for subjects in Group 2. This finding contradicts that of LeBlanc and colleagues (1992) who confined eight healthy males to bed for a period of 17 weeks. They found that the rate of loss of muscle strength was variable throughout muscle groups with the quadriceps and gastrocnemius muscles most affected and the upper limb and back muscles the least. They ascribed this finding to the fact that mobility in bed utilized arm muscles to a greater extent than leg muscles. The difference in pattern observed might be ascribed to muscle protein catabolism due to inflammation/sepsis which was not present in the patients in the Le Blanc study.

Clark and colleagues (2006a, 2006b) investigated the effect of four weeks of unilateral lower limb suspension on neuromuscular function adaptations in the plantar flexor (gastrocnemius and soleus) and knee extensor (quadriceps) muscles in 12 healthy subjects. They concluded that atrophy explained < 10% of the loss in strength

in these muscles. They stated that neural factors such as slowed conduction velocity in the nerves and across the neuromuscular junction explained 48% of the observed strength losses. Kawakami and colleagues (2001) stated that the observed reductions in strength in the vastus lateralis muscle group of their subjects after 20 days of bed rest was due to variations in central activation of nerve impulses specifically, decreased motor-neuron excitability, and impaired ability to activate motor units. These authors also reported a minimal relationship between muscle atrophy and muscle strength. Clark and colleagues (2006b) acknowledged that factors such as muscle fibre type, changes in muscle architecture and decreases in motor unit discharge rate could also influence changes in muscle strength observed during immobilization.

Muscle biopsies and electromyography assessments were beyond the scope of the current research project. Taking all of the above into consideration, it would be reasonable to conclude that the significant muscle weakness observed in Group 2 was due to a combination of prolonged immobilisation in the ICU and the prolonged exposure to inflammatory cytokines. Although the activity of inflammatory cytokines ceases after initial source control and any sepsis and organ failure has resolved, recovery from the effect of muscle protein breakdown seems to be prolonged and incomplete even at six months following discharge. The researcher was unable to identify any other studies on survivors of critical illness where muscle strength was objectively tested with dynamometry. Therefore the above-mentioned discussion was based on results from research that was conducted on healthy subjects and in the laboratory setting. There is a dearth of literature on the recovery of muscle strength in survivors of critical illness over the first 12 months after discharge from the hospital.

5.3 RECOVERY OF EXERCISE CAPACITY DURING THE FIRST SIX MONTHS FOLLOWING DISCHARGE

5.3.1 Recovery of Exercise Capacity of Subjects in Group 1

The VO_{2peak} values of 26.7, 32 and 34.5 ml/kg/min at one, three and six-months after discharge respectively, indicate a below average oxygen uptake when compared to normative data of American males between 18 and 35 years of age (40 – 46 ml/kg/min) (Shvartz and Reibold, 1990). No normative data for oxygen uptake in non-athletes could be found in the South African context. By six months after

discharge four of the six subjects had returned to their usual pre-injury exercise or sporting activities.

Exercise capacity seemed to improve at a faster pace over six months following discharge for this group of subjects than for those in Group 2. There was a 14.9% increase in the percentage of predicted oxygen uptake, a 517.8-meter increase in treadmill walk distance and an improvement of FAI from a moderate to a minimal level over the six-month period. This improvement occurred despite the fact that no pulmonary dysfunction or improvement in pulmonary function was detected for this group at any of the assessments and probably represented an increase in cardiac or skeletal muscle function and/or oxygen extraction ratio. This is borne out of the finding that the resting HR recovered faster in Group 1 subjects with a 23 beat/minute decline from a mean of 106 beats/minute (measured on the ward prior to discharge) to 82.3 beats/minute at three-months and 83 beats/minute at six-months. At these latter time points there was no statistical difference in resting HR between these subjects and the controls indicating normalisation of cardiovascular function. Contributing factors to the higher resting HR at one month may be the deconditioning effect of bed rest and NO and ROS mediated myocardial injury as described in the previous section. The increase in resting HR was the only manifestation of potential cardiovascular dysfunction as there was no significant difference in the 6MWD test between these subjects and the controls at any of the three assessments.

Six months after discharge, Group 1 subjects had a significantly lower level of exertion (measured with the Modified Borg Scale) before and after the 6MWD test than the controls. They also had a significantly lower SBP after the 6MWD test than the controls. A possible explanation for this finding may be that most of these subjects came from a low socio-economic background and regularly walked long distances to and from the taxi rank to their homes and place of work, a form of enforced exercise. The control group consisted of volunteers that were mostly students or employees in various sectors of the community. Most of these volunteers were from a higher socio-economic background than the study subjects and would have access to their own transport between home and work. The lower SBP and level of exertion after exercise in Group 1 subjects might be due to their relative level of fitness.

The predicted risk of mortality in ICU, as estimated by the APACHE II score, seemed to be related to the one-month VO_{2peak} and the three-months walk distance during the oxygen uptake test. There was no relationship between in-hospital morbidity, as estimated by the SOFA score, and exercise capacity, as measured with the 6MWD test and the oxygen uptake test, at any of the three assessment points. This was not unexpected as Group 1 subjects had significantly lower SOFA scores than Group 2 subjects. The short ICU stay also favoured these subjects' improvement in exercise capacity after discharge.

5.3.2 Recovery of Exercise Capacity of Subjects in Group 2

The VO_{2peak} values of 26.7, 28.1 and 30.7 ml/kg/min at one, three and six-months after discharge respectively, also indicated a below average oxygen uptake when compared to normative data of American males between 18 and 35 years of age (40 – 46 ml/kg/min) (Shvartz and Reibold, 1990). By six months after discharge 10 of the 18 subjects had returned to exercise or sporting activities but were not yet performing at the same level as reported prior to injury. These subjects seemed to recover more slowly with regard to exercise capacity over the six months following hospital discharge than those in Group 1. There was a 9.1% increase in the percentage of predicted oxygen uptake, a 321.6-meter increase in treadmill walk distance and a small increase in mean post-exercise HR during the uptake test over the six-month period. Five subjects were not able to perform the uptake test at one month. Seiler (2005) stated that reduced aerobic capacity of skeletal muscles might cause fatigue prior to reaching maximal oxygen uptake levels. Despite the slower recovery rate the subjects in this group still showed an improvement in FAI from a moderate to a minimal level over six months. Their minimal level of FAI was still higher than that observed for subjects in Group 1. No pulmonary function abnormalities were detected for subjects in Group 2.

These subjects' resting HR recovered more slowly. Resting HR dropped by 13.9 beats/minute from a mean of 97.9 beats/minute (measured on the ward prior to discharge) to a mean of 84 beats/minute and 82.9 beats/minute at three and six months respectively. The higher resting HR, RR and level of perceived exertion prior to exercise was statistically significant at one month and could be explained by the effect of immobility and critical illness on cardiovascular dysfunction and deconditioning (Convertino, Bloomfield & Greenleaf 1997; Malone 2006).

The cardiovascular response to acute exercise consists of an increase in sympathetic nervous system-mediated increases in cardiac output, stroke volume, HR and SBP, with diastolic blood pressure (DBP) unchanged or slightly decreased (Williams 2000). This typical response to the 6MWD test was observed for subjects in the control group. However, subjects in Group 2 had a lower HR and SBP after exercise and a shorter walk distance at one and three months. These changes were statistically significant. The resting HR prior to exercise was also higher for these subjects at three months compared to the controls. These subjects had a higher SOFA score which was associated with prolonged ICU and hospital stay and contributed to muscle atrophy and weakness as described in the previous section as well as by other authors (Malone 2006; Young & Hammond 2004). This may have prevented the subjects in this group from exercising at the intensity that the control group was able to maintain during the 6MWD test.

The researcher observed a lower mean resting SBP for subjects in this group at one (SBP = 125.7 mmHg) and three months (SBP = 128.9 mmHg) which was statistically significant relative to the control group (SBP = 135.9 mmHg). This was not observed in Group 1 subjects. One explanation for this finding is abnormal muscle and vascular tone. Blunted baroreceptor-mediated activity due to immobility leads to abnormal vascular tone and results in cardiovascular dysfunction and hypovolaemia. The result is orthostatic intolerance when a subject moves from the supine to an upright position (Hasser & Moffitt 2001). The cardiovascular system response to an upright position may take more than five weeks to normalize in subjects confined to bed rest for 21 days or longer (Olson, Johnson & Thompson 1990).

Another explanation for this finding is that four subjects had a loop ileostomy following penetrating abdominal trauma. The colon is bypassed by this procedure and since the colon is responsible for fluid and electrolyte reabsorption, ileal fluid loss (Kennedy et al 1983; Nightingale 2001) may have contributed to the lower resting SBP at one and three months. General surgical practice in Johannesburg is that closure of a loop ileostomy takes place three to six months after primary surgery. This is consistent with the recommended time to closure of a minimum of 8.5 weeks following primary surgery (Perez et al 2006). This might explain why no differences

in systolic blood pressure were observed between this group and the control group at the six-month assessment.

A third explanation for the lower resting SBP may be that six subjects in this group had abdominal skin grafts prior to staged abdominal wall closure at six months. As mentioned before, the sympathetic nervous system is stimulated at the initiation of exercise and during exercise. Splanchnic vasoconstriction and an increase in abdominal muscle tone increase venous return which augments cardiac output (Guyton 1991, p. 202 - 203). This response would have been reduced in the subjects with abdominal skin grafts due to an inability to increase abdominal muscle tone and may have resulted in a sub optimal systolic response.

There was no relationship between the predicted risk of mortality in ICU, as estimated by the APACHE II score, and exercise capacity, as assessed with the 6MWD test or the VO_{2peak} test. In-hospital morbidity, as estimated by the SOFA score, did however correlate significantly with 6MWD at three and six months. There was no relationship between the SOFA score and the treadmill distance walked during the oxygen uptake test at any point of assessment. A possible explanation for this finding is that the treadmill test is performed at increasing inclinations and speed and the subject is forced to walk faster and further on this moving surface. This effect is not present during the 6MWD test as the subject walks on a still horizontal surface and is more likely to perform at true capacity. Changes due to the effect of morbidity and muscle weakness on exercise capacity would be more apparent during the 6MWD test. The 6MWD proved more sensitive in detecting limitations in exercise capacity than the VO_{2peak} test.

5.3.3 Exercise Capacity Compared with Other ICU Groups

There are few studies that investigated the effects of critical illness on recovery of exercise capacity in survivors over the first six months after discharge.

Herridge and colleagues (2003) evaluated the outcome of 109 adult survivors of ARDS over a one-year period following discharge. These patients had a median APACHE II of 23, median ICU LOS of 25 days and a median hospital LOS of 48 days. They reported a median 6MWD of 281m and 396m at three and six-months respectively. The subjects in Group 1 in our study performed better than the above

with median walk distances of 633m and 680m respectively as did subjects in Group 2 with median walk distances of 586.5m and 626m respectively. This indicated that survivors of penetrating trunk trauma might not have been as severely ill as the subjects in Herridge's cohort. Trauma patients are at risk of developing sepsis and possibly ARDS (Michell, 2003) and therefore the results of our study should be viewed with caution. Herridge and colleagues reported the presence of restrictive pulmonary complications in 6% of their study population due to ARDS in contrast with our subjects, none of who had any post discharge pulmonary dysfunction. Although a small number, this might have had an impact on overall walk distance in Herridge's group.

Hui and colleagues (2005) examined the impact of severe acute respiratory syndrome (SARS) on pulmonary function, exercise capacity and health-related QOL on 110 survivors at three and six months following discharge from ICU. A mean hospital LOS of 32.4 days was reported for the SARS survivors. They reported a mean 6MWD of 464m at three months and 502m at six months and a decrease in pulmonary gas exchange in 15% of their survivors at six months after discharge. Survivors of penetrating trunk trauma (Groups 1 and 2) in our study presented with mean 6MWD of 620m and 580.9m at three months and 633.5m and 604.7m respectively at six months. As discussed above the subjects in our study performed better due to the fact that no pulmonary dysfunction was reported for any of these subjects. The decrease in exercise capacity seen in Group 2 was apparently due to muscle deconditioning.

The studies conducted by Herridge and colleagues (2003) and Hui and colleagues (2005) were the only studies that could be identified in the ICU literature where exercise capacity of survivors of critical illness was objectively assessed. There is a lack of literature on the recovery of exercise capacity in survivors of critical illness over the first year after discharge from the hospital.

5.4 RECOVERY OF HEALTH-RELATED QOL IN SURVIVORS OF PENETRATING TRUNK TRAUMA DURING THE SIX MONTHS AFTER HOSPITAL DISCHARGE

The SF-36 questionnaire was used to assess health-related QOL in survivors of penetrating trunk trauma at one, three and six months after discharge from hospital.

Group 1 subjects had a significant decrease in physical, social and mental aspects of health-related QOL at one and three months after discharge when compared to reported pre-morbid status. Quality of life related to physical health had returned to pre-morbid status at six months but some limitations in mental health persisted. Group 2 subjects had a significant decrease in all aspects of physical, social and mental health-related QOL at one, three and six months after discharge from hospital when compared to reported pre-morbid status.

The health-related QOL for survivors of penetrating trunk trauma compared to that reported by a healthy control group, painted a different picture. Those in Group 1 had no difference in the social and mental health aspects of health-related QOL at three and six months compared to controls. The PCS, although significantly decreased when compared with the control group at three months, had by six months returned to a level comparable with all aspects reported by the control group. Group 2 had a significant reduction in all physical components of health-related QOL when compared to controls at all three assessments. Mental health aspects of health-related QOL had however returned to a level comparable with that reported by the control group at three and six months.

It seems that survivors of penetrating trunk trauma reported a higher status of pre-morbid health-related QOL than that reported by the control group. Wehler and colleagues (2003) stated that men were known to report high levels of health-related QOL. However, the majority of subjects in our study as well as those in the control group were men and therefore gender may not have attributed to this difference in reported health-related QOL. Badia (2001) (cited by Wehler et al 2003) reported that subjects, who had good health prior to an episode of trauma, were likely to report substantial worsening of health-related QOL after discharge from ICU. The life-threatening nature of penetrating trunk trauma made assessment of health-related QOL during resuscitation in the emergency departments of the recruiting hospitals, prior to theatre and ICU, impossible. It is however possible that the episode of acute critical illness that subjects endured may have influenced their ability to report objectively on their pre-morbid health-related QOL.

A comparison of health-related QOL between subjects in both groups revealed a significant reduction in the physical components of health-related QOL at three and

six months following discharge in Group 2 subjects relative to Group 1. The fast recovery of physical aspects of health-related QOL in Group 1 may be explained by the recovery in muscle strength and exercise capacity observed for this group at the three-month assessment. The persistent limitations in health-related QOL related to physical function observed in Group 2 may be explained by the decreased peripheral and core muscle strength observed up to six months following discharge. Exercise capacity for this group also recovered slowly and was comparable to that of the control group only at the six-month assessment.

Eddleston and colleagues (2000) investigated the health-related QOL of 143 survivors of critical illness at three months following discharge from ICU using the SF-36 questionnaire. Thirty-eight were admitted to ICU with trauma or after general surgery. The median duration of ICU stay was 3.8 days and the mean APACHE II score was 18.79. The authors reported that scores for all domains of the SF-36 (except MH) was lower for these subjects than that reported for the general population. We found similar results (except for the VT, RE and MH domains) at three months for Group 2. Eddleston and colleagues also found that younger men reported more limitation in the RP and RE domains at three months than older men (> 65 years). Results from our study showed that the Group 2 subjects (mean age of 33.6 years), had limitations in the RP but not the RE domains at three months.

Our subjects presented with a quick recovery in the mental health components of health-related QOL. Similar findings were reported by Cuthbertson and colleagues (2005) when they investigated the health-related QOL before and after ICU in a mixed ICU population. They found that physical aspects of health-related QOL were significantly decreased in all their subjects at three months after discharge and slowly recovered to pre-morbid levels only by 12-months. Subjects in Group 2 presented with similar limitations in physical aspects of health-related QOL at three and six months when compared to those in Cuthbertson's study. In contrast the mental components of health-related QOL where comparable to pre-morbid levels at three months. They concluded that the quicker recovery in mental health domains might be attributed to a mental high in their subjects "as they had cheated death". It is probable to assume that this 'mental high' was present in subjects in our study as almost all of them commented that they were glad to be alive after their ordeal.

Group 2 subjects had significant reductions in the physical components of health-related QOL compared with their counterparts in Group 1 six months after discharge. Granja and colleagues (2004) assessed the influence of sepsis and MODS on the health-related QOL of survivors at six months following discharge. They reported that survivors of sepsis (median ICU LOS of 8 days) had a fair health-related QOL at six months as assessed by the EQ-5D questionnaire, which was comparable to that of other ICU survivors (median ICU LOS of 3 days) that did not have sepsis. This report is in contrast to the findings of most investigators including those of our study. Wehler and colleagues (2003) also reported a significant reduction in physical aspects of health-related QOL in their survivors of MODS and sepsis (mean ICU LOS of 17 days) six months after discharge. Herridge and colleagues (2003) reported similar findings in survivors of ARDS and stated that impaired muscle function had important effects on the long-term recovery of survivors of critical illness. Ridley and colleagues (1997) investigated the influence of critical illness on health-related QOL on a group of survivors with a variety of diagnoses. They found that previously fit subjects felt that they had a reduction in health-related QOL even at six months following discharge whereas subjects that reported a chronic disease prior to ICU admission did not. This is certainly true for our Group 2 subjects as none of them reported any significant past medical history and yet suffered from significant reductions in physical aspects of health-related QOL.

Subjects in Group 2 suffered from physical impairment related to health-related QOL at six months but none of our survivors suffered from mental impairment. Our findings differ from that of Niskanen and colleagues (1999) who investigated the health-related QOL of 368 survivors of critical illness of whom 107 survivors suffered from complications of a gastroenterology origin, trauma, sepsis/septic shock or major surgery. Health-related QOL was assessed with the NHP at six months following discharge and was compared to that of a healthy control group. Survivors had a mean APACHE II ranging between 10.9 – 11.9 and a mean ICU LOS ranging between 14.8 – 19.6 days. The authors reported physical problems with mobility in all survivors and that younger survivors suffered from both physical and psychosocial impairment at six months. This is in contrast with our findings. All subjects in our study were under 50 years of age and none suffered from mental impairments at six months as measured with the SF-36 questionnaire.

We found that subjects in Group 1 had made a full recovery six months after hospital discharge whereas subjects in Group 2 still suffered from physical impairment in health-related QOL at six months. Niskanen and colleagues (1999) also reported inter-group variation in recovery time in that some had minimal health-related QOL impairments at six months whereas others required more that six months to recover. This seems to be true for our survivors as well. Niskanen and colleagues (1999) also found that trauma victims and those with respiratory failure needed more time to recover than patients undergoing cardiac surgery and that these subjects needed more rehabilitation after discharge from the hospital. The authors highlighted the importance of muscle catabolism during critical illness and how this might impact on physical recovery. Our study results would support the contention that an interventional rehabilitation programme for Group 2 subjects i.e. those that had higher SOFA scores and consequently required more prolonged ventilation, would be of benefit.

The researcher found that some studies that had been published on the health-related QOL of ICU survivors did a once-off assessment at three (Eddleston et al 2000) or six months (Granja et al 2004; Niskanen et al 1999) after discharge from the hospital. This type of methodology would allow only limited interpretation of the health-related QOL of ICU survivors. Other authors compared pre-morbid health-related QOL with that at three and six months (Cuthbertson et al 2005) or at six months only (Ridley et al 1997; Wehler et al 2003) and so provided a more in-depth interpretation of the changes in health-related QOL and the time taken to recover. In our study, survivors were asked to give a retrospective interpretation of their pre-morbid health-related QOL status upon transfer from ICU to the ward. As some subjects had a longer ICU LOS than others, their ability to recall their pre-morbid health-related QOL status objectively might have been impaired. A better method to obtain pre-morbid health-related QOL status for these subjects might have been to interview relatives that stayed in the same household as the patient. This method was employed by Cuthbertson and colleagues (2005) and Wehler and colleagues (2003). The researcher did consider this approach, but due to the large catchment area that is served by the four recruitment centres used in this study, most family members had to travel great distances to get to the hospital and were only able to visit their relative in ICU during the evening. Some family members were able to visit the hospital only once a week. The limited time period that was available for the researcher to conduct

this study influenced the decision to use the patient to give a retrospective report of health-related QOL status prior to admission.

5.5 EXERCISE AND ITS POTENTIAL ROLE IN THE REHABILITATION OF SURVIVORS OF PENETRATING TRUNK TRAUMA

This prospective observational study revealed that subjects in Group 1 had limitation in muscle strength only at one month after discharge. They had little or no limitation in exercise capacity and showed a fast recovery in health-related QOL with regard to physical health. Subjects in Group 2 had limitations in muscle strength, exercise capacity and in physical aspects of health-related QOL up to six months after discharge from the hospital. This group of survivors were not able to recover adequately on their own over the six-month follow-up period. It is probable that, as mentioned above, an exercise programme might have a role to play in the rehabilitation of these subjects.

It is well known that physical fitness plays a key role in a person's ability to perform ADL, influences their ability to participate in sport and exercise and aids in improving QOL (Blair, LaMonte & Nichaman 2004). Physical fitness involves the cardiovascular, respiratory and musculoskeletal systems. The cardiovascular and respiratory systems are conditioned through aerobic exercise whereas the musculoskeletal system is conditioned through aerobic, resistance and flexibility exercises (Warburton, Nicol & Bredin 2006). As discussed in the literature review, prolonged bed rest results in muscle weakness, poor muscle endurance and rapid loss of calcium from bone (Conroy & Earle 2000; Convertino, Bloomfield & Greenleaf 1997). Skeletal muscle mass, strength and aerobic and anaerobic capacity increase with exercise. Several factors influence muscle strength. Neural control includes the number of motor units that are recruited during a muscle contraction as well as the rate at which the motor units are stimulated. During the first few weeks of resistance training, the brain learns to extract more force from a specific amount of contractile muscle fibre. Muscle cross-sectional area determines the force with which a muscle contracts whereas maintenance of resting muscle length is important to ensure the greatest strength being generated through that muscle, as actin and myosin are in an optimal position for cross-bridge links to form during muscle contraction (Harman 2000). New bone formation is stimulated through weight bearing activities that

exceed the minimal essential strain of bone and enhance the osteoblast activity that stimulates bone growth. Examples of such activities are walking, stair climbing and running (Conroy & Earle 2000).

Cardiopulmonary benefits derived from aerobic exercise include decreased blood pressure, increased stroke volume, with a resultant decrease in resting HR, increased synthesis of high-density lipoproteins and improved insulin sensitivity (Taylor, Bell & Lough 2002). Muscles develop new capillaries which increase the oxygen extraction ratio. More skeletal muscle cell mitochondria are produced as a result of aerobic exercise and maximal oxygen uptake improves as physical fitness improves (Williams 2000). As maximal oxygen uptake increases, less energy is utilized to perform ADL and health-related QOL improves.

Rehabilitation programmes that consist of aerobic and resistance exercises are commonly used in the chronic cardiac and pulmonary disease populations with encouraging results (AACVPR 2004). The Cochrane Database systematic review on pulmonary rehabilitation for patients with COPD was updated in 2005. The reviewers found that pulmonary rehabilitation programmes that lasted at least four weeks relieved dyspnoea and fatigue, increased functional exercise capacity and enhanced patients' sense of control over their condition. The reviewers concluded that these improvements were clinically and statistically significant (Lacasse et al 2005). Bestall and colleagues investigated longitudinal trends in exercise capacity and health status in patients with COPD after pulmonary rehabilitation. They found that patients who received pulmonary rehabilitation maintained exercise capacity and health status up to six months after an eight-week programme and showed significant improvement in exercise tolerance compared with a control group that had no pulmonary rehabilitation (Bestall et al 2003). Taylor and colleagues reviewed the effectiveness of exercise-based cardiac rehabilitation in patients with coronary heart disease. They performed a systemic review and meta-analysis of RCT and concluded that cardiac rehabilitation reduced all-cause and cardiac mortality and led to significant reductions in total cholesterol and triglyceride levels and SBP (Taylor et al 2004). Participation in rehabilitation programmes is standard practice in the management of subjects with chronic cardiac or pulmonary disease due to the health benefits derived by participants.

Jones and co-workers (2003) are the only researchers to date to test the effectiveness of a rehabilitation programme on the recovery of survivors of critical illness in a RCT. They compiled a 93-page rehabilitation package that consisted of a self-directed exercise programme, diagrams and illustrations. The manual also contained advice on a wide range of psychological, psychosocial and physical problems that the ICU survivor could expect to encounter after they had recovered from critical illness. Subjects (n = 69) and controls (n = 57) were comparable and were contacted telephonically three times per week after discharge to monitor progress however subjects in the experimental group were also encouraged to use the self-help rehabilitation manual. All subjects were tested at follow-up clinics at eight weeks and six months. The authors found that the SF-36 physical function score for subjects in the experimental group was closer to normal and significantly different from those in the control group (Jones et al 2003). This was a well-designed study. Some critique on this study includes the fact that the authors didn't objectively measure muscle strength or exercise capacity in their subjects. It was also not clear whether control subjects' return to exercise/sport activities were monitored. Thirdly the authors did not state which professionals were involved in compiling the exercise component of their rehabilitation manual.

Walking is a form of aerobic exercise that involves the large muscle groups and has few, if any, side effects. Walking develops cardiovascular endurance and fitness and strengthens the muscles of the lower trunk and legs (Morris and Hardman 1997). Walking is a natural activity and many subjects in our study adopted this form of exercise, usually through necessity, after discharge from the hospital. Low intensity exercise such as walking is well tolerated by extremely deconditioned individuals and effectively reduces the risk of death from any cause (Warburton, Nicol & Bredin 2006). The introduction of resistance and flexibility exercises for survivors of prolonged MV for upper and lower limb as well as trunk muscles should start after the one-month assessment when significant wound healing has taken place. Subjects with abdominal skin grafts would be advised to wear supportive straps around the abdomen and to avoid the Valsalva manoeuvre during exercise to prevent organ protrusion. Blair and colleagues (2004) and Warburton and colleagues (2006) suggested that moderate intensity exercise (1000 kCal/week) is associated with significant health benefits. A rehabilitation programme for the Group 2 subjects should consist of a graduated increase in exercise intensity such that these subjects may reap the health

benefits of regular physical activity. This is particularly so because MV did not cause any long-term pulmonary function abnormalities and lung capacity and volumes would be optimal to enable them to increase their exercise intensity as their muscle strength improves.

As most of the subjects in this study were from a lower socio-economic background, they might not have the financial means to attend a structured rehabilitation programme at a gymnasium over a four- or six week period. A self-help rehabilitation manual that explains all the aerobic, resistance and flexibility exercises (with diagrams) should be explained and given to the subjects to use at home after the one-month assessment. Regular telephonic contact with subjects should improve compliance until the three-month assessment. The effectiveness of such as manual could be assessed in future studies.

5.6 FACTORS THAT INFLUENCE WOUND HEALING AFTER SURGERY

Many of the subjects in our study that sustained penetrating abdominal trauma had multiple laparotomies as a part of source control. De Hingh and colleagues (2005) conducted an experiment on laboratory rats in which they assessed the influence of repeated laparotomies on the early healing of intestinal anastomoses. Hydroxyproline content (a measure of collagen content), matrix metalloproteinase activity (a measure of proteolitic activity) and myeloperoxidase activity (a measure of neutrophil activation) were not altered through repeated surgical procedures. They found that all rats (controls and a group with induced sepsis) experienced no adverse effects with regard to healing of the anastomoses. It is thus probable to assume that survivors of penetrating trunk trauma would not experience any adverse effects with regard to healing of anatomoses if they participate in an exercise programme one month after hospital discharge.

Nutrition plays an important role in wound healing and Van Wingerden (2003a) emphasized the importance of protein (to maintain humoral and cell-mediated antibody responses), vitamin C (to optimize collagen formation), vitamin A (to maintain a normal epidermis) and zinc (to promote wound healing) in the diet of patients after surgery. Many of the subjects in our study came from a low socioeconomic background and might experience delay in wound healing due to poor nutrition.

A number of the subjects in our study received corticosteroids during their stay in ICU as part of the therapy of severe sepsis. Corticosteroids are known to delay wound healing by suppressing fibroblast production and subsequently collagen formation (Van Wingerden 2003a). Five of the survivors in our study reported a history of smoking. Nicotine inhibits wound healing by causing vasoconstriction and an impaired inflammatory response and epithelialisation. Inhaled carbon monoxide reduces the oxygen-carrying capacity of blood and leads to endothelial cell changes due to increased platelet adhesiveness and tissue ischaemia (Morimoto et al 2007; Van Wingerden 2003a). Smoking is an important risk factor for the development of an incisional hernia up to one year after a laparotomy procedure (Sorensen et al 2005).

Despite these factors wound healing should be well advanced by four to five weeks after hospital discharge. The implementation of an exercise rehabilitation programme one month after discharge should be feasible without any detrimental effects on wound healing.

CONCLUSION OF DISCUSSION SECTION

This study proposed that there is a delay in recovery and an abnormality in a) pulmonary function in adults from ICU discharge up to six months as a result of penetrating trunk trauma and MV; b) exercise capacity in adults from one month to six months after hospital discharge as a result of penetrating trunk trauma and MV; c) muscle strength in adults from one month to six months after hospital discharge as a result of penetrating trunk trauma and MV; d) health-related QOL in adults from pre-admission up to six months after hospital discharge as a result of penetrating trunk trauma and MV. Our findings do not support the four hypotheses with regard to Group 1. However the findings in this study do indicate that the last three hypotheses are supported for subjects in Group 2.

Some limitations were identified during the course of this study and these will be described in the next chapter. Recommendations as a result of this study will also be made.

CHAPTER 6

LIMITATIONS AND RECOMMENDATIONS

6.1 LIMITATIONS

The researcher identified the following limitations while conducting this study:

- The high drop out rate observed in Group 1 subjects is a concern as the small number of subjects might have led to a type II error. Results obtained for this group of subjects at the three assessments should therefore be interpreted with caution. The researcher speculates that these subjects felt well enough from a mental and physical point of view soon after discharge from the hospital such that they did not deem follow-up appointments to be necessary. High dropout rates in trauma patients are well known (Cuthbertson et al 2005; Michaels et al 2000) and were expected during this study.
- The small number of subjects in this study made the separation between those with penetrating chest trauma and those with penetrating abdominal trauma problematic, as the conclusions derived from such results would have been fraught with error. It would have been preferable if these two groups had been studied separately as the recovery process may have differed.
- Abdominal skin grafts were more commonly done in Group 2. This might have influenced the measurement of abdominal muscle strength for this group. Results should be interpreted with caution.
- English was the second or third language of most subjects that participated in this study. The absence of a validated and reliable Tswana and/or isiZulu translation of the SF-36 questionnaire prevented these subjects from completing the health-related QOL assessment in their first language. It must be stated that all subjects that participated in this study were able to read, write and speak English. Interpretation was provided for subjects that did not understand the meaning of a question initially. Despite this the researcher decided to use the SF-36 as it had been used extensively in various ICU settings abroad and comparisons with these studies would have been difficult if it had not been used.
- The researcher did not assess whether feelings of anxiety or depression after ICU (assessed with the Post-traumatic Stress Syndrome 10-Questions Inventory) were

present in this study population. Sukantarat and colleagues (2007) reported that a quarter of survivors of critical illness, who spent three or more days in ICU, suffered from post-traumatic stress disorder. They stated that poor physical recovery might influence the survivor's feelings of anxiety and depression and vice versa. This would be an important variable to consider.

6.2 RECOMMENDATIONS

Results from this observational study enabled the researcher to make the following recommendations:

- The effect of exercise rehabilitation, in the form of aerobic and resistance exercise, on the recovery of survivors of penetrating trunk trauma and prolonged MV needs to be investigated. The most feasible method of administration of rehabilitation would be through a self-help exercise manual with regular telephonic consultation between hospital visits to assess outcome and increase compliance.
- This self-help manual should be available not only in English but also in Tswana and isiZulu.
- The effect of critical illness on the outcome of other patient populations in South Africa should be investigated, as there is a dearth of literature regarding this topic in the South African context. South Africa is a third world country and results obtained from research that is conducted in first world countries may not necessarily be applicable to our population.

CHAPTER 7

CONCLUSION

The aims of this study were to determine the recovery rate of adult survivors of penetrating trunk trauma and MV over a six-month period after hospital discharge in relation to pulmonary function, exercise capacity, muscle strength and health-related QOL and, secondly, to establish the difference in recovery rate between survivors of penetrating trunk trauma with MV < 5 days and those with MV ≥ 5 days. The third aim was to establish any differences in recovery rate between survivors of penetrating trunk trauma and MV and other survivors of critical illness. A prospective, observational study was conducted and quantitative information was collected in the form of pulmonary function tests, dynamometry, oxygen uptake tests, the 6MWD test and the SF-36 health-related QOL questionnaire to answer the research questions.

The most significant finding of this research was that survivors of penetrating trunk trauma that received MV for less than five days were able to recover adequately on their own with regard to exercise capacity, muscle strength and QOL by three months after discharge from hospital. However, those that were ventilated for a more prolonged period of time due to sepsis, SIRS and organ dysfunction had limitations in exercise capacity, muscle strength and the physical components of QOL up to six months after discharge. The limitations in physical components of QOL observed in this group are similar to that reported for other ICU survivors that had prolonged ICU and hospital LOS. No pulmonary dysfunction was observed for any of the subjects in this study.

Exercise rehabilitation is a useful and successful tool in the management of patients with chronic disease. The disabilities encountered in survivors of penetrating trunk trauma and prolonged MV may also be effectively addressed by a physiotherapist-led rehabilitation programme, implemented one month after hospital discharge, which addresses cardiovascular endurance as well as strength training for the abdominal, upper and lower limb muscles. No such programmes exist in South Africa for this group of subjects at present.

This study on the recovery rate of survivors of penetrating trunk trauma who received MV was the first of its kind to be conducted in Johannesburg and in South Africa. This was also one of a few studies, on an international level, that were conducted on survivors of critical illness that objectively assessed the recovery of exercise capacity and muscle strength.

Physiotherapists are involved in the rehabilitation of patients that suffered penetrating trunk trauma in ICU and on the wards on a daily basis. A large portion of the undergraduate training programmes for physiotherapists in South Africa involves training and clinical reasoning in human anatomy, physiology, pathology and exercise science. Physiotherapists are therefore well qualified to be involved in the care of these subjects after discharge for the hospital. In conclusion there seems to be a prominent role for the physiotherapist in the final rehabilitation of survivors of penetrating trunk trauma that received prolonged mechanical ventilation.

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APPENDIX I

ESTABLISHING THE RELIABILITY OF TEST PROCEDURES (PILOT STUDY)

The researcher proposed to monitor the recovery of adult survivors of penetrating trunk trauma and mechanical ventilation for a period of six months after hospital discharge. The six-minute walk distance (6MWD) test would be used to determine the functional capacity of these survivors in the follow-up period. Previous studies showed that the 6MWD was a reliable, valid and reproducible tool to determine the functional abilities of patients with chronic cardiac failure (Demers et al 2001; O'Keefe et al 1998; Opasich et al 1998) and of patients with chronic respiratory disease (AACVPR 2004; Butland, Pang & Gross 1982; Steele 1996).

The hand-held dynamometer could be used to measure strength of a variety of muscles over a prolonged period of time and was proposed to be a suitable tool to monitor recovery of these patients. Results from previous studies showed that hand-held dynamometry had high intra-observer and inter-observer reliability for knee extensor strength (Bohannon 2001; Roy et al 2004), for elbow flexor and extensor strength (Burns et al 2005; Visser et al 2003) and for shoulder abductors and knee flexors (Visser et al 2003) when tested in various patient populations. Hand-held dynamometry measurements would be done to establish muscle strength of adult survivors of penetrating trunk trauma and mechanical ventilation in the main study.

Prior to the execution of the study the inter-observer and intra-observer reliability had to be established between the data collectors involved in the study in order to test the reliability of measurements taken during the main study with the 6MWD and hand-held dynamometer. The aim of this reliability study was to establish the degree of association (a positive correlation or a negative correlation) between the data collected by the respective data collectors in a group of healthy subjects for the above mentioned outcome measures.

METHOD

A correlation study design was used in which the one-tailed hypotheses were:
a) High inter-observer correlation exists for data collected during the 6MWD among data collectors.
b) High intra-observer correlation exists for data collected during hand-held dynamometry among data collectors.

Fifteen people of good health were approached to participate in the study and nine volunteered. The study was conducted on the University of the Witwatersrand Education Campus, Johannesburg, South Africa on two successive Friday afternoons in April 2005 (testing sessions were separated by one week). Inter-observer correlation was determined for the 6MWD as two data collectors would be used to obtain these measurements during the main study. Intra-observer correlation was determined for dynamometry measurements as one data collector would be used to obtain these measurements in the main study due to space limitations. This study was approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (clearance number: M03-05-83).

Six-minute walk distance test

Each volunteer was assessed on the 6MWD. A standardized protocol (ATSS 2002; Opasich et al 1998) was used to administer the test to the volunteers over a distance of 30 meters in the corridor of the Cardiac Rehabilitation Unit. The protocol consisted of the following instructions:

- Volunteers were instructed to walk the measured distance at their own pace while trying to cover as much distance as possible in the 6 minutes.
- The test was supervised and the remaining time was called out every 2 minutes.
- Volunteers were encouraged at standard intervals of 30 seconds in the form of "You are doing well" and "Keep up the good work".
- Volunteers were allowed to stop and rest during the test and then continue as soon as they could resume the walk.
- At the end of the 6 minutes, the volunteer was told to stop and the distance covered was recorded.

- The number of rest stops and the duration of each rest stop were also recorded.

Each volunteer was given 30 minutes to rest before the next 6MWD procedure was performed. All data collectors had an opportunity to familiarize themselves with the procedure on one occasion prior to the testing sessions. Data collectors 1 and 3 tested each volunteer at the same time during the first testing session. Thereafter data collector 2 tested each volunteer individually. At the second testing session data collectors 2 and 3 tested each volunteer at the same time and thereafter data collector 1 tested each volunteer individually. To establish the inter-observer reliability between the data collectors the following measurements were documented on an outcome measure sheet:

- Heart rate was measured, prior to, directly after and two-minutes after completion of the test. This was done manually over the radial artery.
- Respiratory rate was measured, prior to, directly after and two-minutes after completion of the test, by observation of chest wall movement.
- These measurements were made with the volunteer sitting in an upright position.
- The distance covered by each volunteer was also recorded by multiplying the number of completed laps at the end of the test with 30. The additional meters covered during the final lap were added on and the total distance expressed in meters.

The data collected between all data collectors was then compared for correlation.

Dynamometry

Dynamometry measurements were done of the left triceps and right quadriceps muscle on each volunteer with the hand-held dynamometer [MicroFet2, Hoggan Health Industries]. These tests were performed with each volunteer in the following positions:

- Left triceps muscle strength was assessed with the volunteer in a prone position. The shoulder was placed at 90° abduction and the elbow in full extension over the edge of the plinth with the forearm in a neutral position. The dynamometer was placed just above the radial and ulnar styloid processes perpendicular to the shaft of the radius.
- Right quadriceps muscle strength was assessed with the volunteer seated in an upright position on a plinth with the left knee flexed to 90˚ and the foot stabilized on a footstool. The right knee was in full extension. The dynamometer was placed just above the malleoli perpendicular to the tibial crest.

The "break" test technique was used. This consisted of the application of adequate force through the dynamometer to overcome the volunteer's muscular effort. The test was essentially a concentric muscle strength test. All data collectors familiarized themselves with the hand-held dynamometer on one occasion prior to the testing sessions. Volunteers were assessed separately (apart from the other data collectors), three measurements were recorded and the mean calculated for each muscle group. Each volunteer had a 10-minute rest period between testing sessions. Verbal encouragement was provided to each volunteer during testing.

The data collected between all data collectors was then compared for correlation.

STATISTICAL ANALYSIS

The data collected was of an interval/ratio nature. The association between the sets of data was calculated by using the Pearson product moment correlation coefficient. The Excel 2000 programme for Microsoft Windows XP was used for the above mentioned calculations. The one-way analysis of variance (ANOVA) was used to determine the intra-class correlation (ICC) between data collectors (inter-observer correlation) for both the 6MWD and the dynamometry. The ANOVA calculations were performed with the assistance of a statistician with the STATA 8 statistical software package.

RESULTS

A total of nine volunteers participated in this study. Three were female and six male and ages ranged from 21 – 26 years. Data was collected twice for the nine volunteers on two separate occasions and the data analysed as described above. Pearson product moment correlation coefficient results for the 6MWD for heart rate (HR), respiratory rate (RR) and distance walked are presented in Tables 1 and 2.

Table 1: Pearson product moment correlation coefficient results for 6MWD – week 1 (df = 7).

Data Collectors	Pre HR	Post HR	Post HR (2 mins)	Pre RR	Post RR	Post RR (2 mins)	Distance walked
1 & 2	r = 0.85 p < 0.005	r = 0.59 p < 0.05	r = 0.80 p < 0.005	r = 0.50 p = NS	r = 0.52 p = NS	r = 0.75 p < 0.01	r = 0.94 p < 0.0005
1 & 3	r = 0.91 p < 0.0005	r = 0.76 p < 0.01	r = 0.84 p < 0.005	r = 0.72 p < 0.025	r = 0.92 p < 0.0005	r = 0.95 p < 0.0005	r = 0.98 p < 0.0005
2 & 3	r = 0.85 p < 0.005	r = 0.54 p = NS	r = 0.85 p < 0.005	r = 0.60 p < 0.05	r = 0.55 p = NS	r = 0.79 p < 0.01	r = 0.92 p < 0.0005

Pre HR = pre-test heart rate; Post HR = heart rate immediately after test; Post HR (2 mins) = heart rate after 2 minute rest period; Pre RR = respiratory rate prior to test; Post RR = respiratory rate immediately after test; Post RR (2 mins) = respiratory rate after 2 minute rest period; NS=not significant.

Table 2: Pearson product moment correlation coefficient results for 6MWD test – week 2 (df = 7).

Data Collector	Pre HR	Post HR	Post HR (2 mins)	Pre RR	Post RR	Post RR (2 mins)	Distance walked
1 & 2	r = 0.21 p = NS	r = 0.54 p = NS	r = 0.93 p < 0.0005	r = 0.83 p < 0.005	r = 0.52 p = NS	r = 0.84 p < 0.005	r = 0.98 p < 0.0005
1 & 3	r = 0.35 p = NS	r = 0.73 p < 0.025	r = 0.85 p < 0.005	r = 0.74 p < 0.025	r = 0.92 p < 0.0005	r = 0.71 p < 0.025	r = 0.98 p < 0.0005
2 & 3	r = 0.80 p < 0.005	r = 0.83 p < 0.005	r = 0.83 p < 0.005	r = 0.81 p < 0.005	r = 0.55 p = NS	r = 0.86 p < 0.005	r = 1 p < 0.0005

Pre HR = pre-test heart rate; Post HR = heart rate immediately after test; Post HR (2 mins) = heart rate after 2 minute rest period; Pre RR = respiratory rate prior to test; Post RR = respiratory rate immediately after test; Post RR (2 mins) = respiratory rate after 2 minute rest period; NS = not significant.

The subjective nature of manual measurements of HR and RR could have contributed to the weaker correlation found between data collectors as a difference of 1 beat/minute counted over 15 seconds and 1 breath/minute counted over 30 seconds might have influenced data to some extent.

A strong positive Pearson product moment correlation existed for data collected on the six-minute walk test between data collectors 1 and 2 with r ranging from 0.75 to 0.94 for 4 of 7 measurements taken ($p < 0.01$ to $p < 0.0005$) during the first test session as seen in Table 1. The correlation between data collectors 1 and 2 remained strongly positive during the second test session with r ranging from 0.83 to 0.98 for 4 of 7 measurements taken ($p < 0.005$ to 0.0005, Table 2). The correlation between data collectors 1 and 3 was strongly positive with r ranging from 0.72 to 0.98 for 7 of 7 measurements taken ($p < 0.01$ to $p < 0.0005$, Table 1). This positive correlation between data collectors 1 and 3 continued during the second test session with r ranging from 0.71 to 0.98 for 6 of 7 measurements taken ($p < 0.025$ to 0.0005, Table 2). The first test session revealed a strong positive correlation between data collectors 2 and 3 with r ranging from 0.60 to 0.92 for 5 of 7 measurements taken ($p < 0.05$ to 0.0005). Table 2 showed a stronger positive correlation between data collectors 2 and 3 with r ranging from 0.81 to 1 for 6 of 7 measurements taken ($p < 0.005$ to 0.0005). A high degree of association existed between the data collected for all data collectors on the 6MWD.

The ANOVA between data collectors 1 and 3 and 2 and 3 can be seen in tables 3 and 4. Intra-class correlation (ICC) scores from 0.70 to 0.90 between data collectors 1 and 3 and from 0.69 to 0.85 between data collectors 2 and 3 demonstrated high reliability.

Table 3: ANOVA results for inter-observer correlation for 6MWD test (n = 18).

	Data Collectors 1 & 3					
	HRpre6	**RRpre6**	**HRpost6**	**RRpost6**	**HR2mins**	**RR2mins**
ICC	0.85	0.70	0.74	0.90	0.84	0.90
CI	0.68 – 1.03	0.36 – 1.04	0.43 – 1.04	0.77 – 1.02	0.65 – 1.03	0.78 – 1.02

HRpre6 = heart rate prior to 6MWD; RRpre6 = respiratory rate prior to 6MWD; HRpost6 = heart rate immediately after 6MWD; RRpost6 = respiratory rate immediately after 6MWD; HR2mins = heart rate after 2-minute rest period; RR2mins = respiratory rate after 2-minute rest period; ICC = intra-class correlation; CI = 95% confidence interval.

Table 4: ANOVA results for inter-observer correlation for 6MWD test (n = 18).

	Data Collectors 2 & 3					
	HRpre6	**RRpre6**	**HRpost6**	**Rrpost6**	**HR2mins**	**RR2mins**
ICC	0.75	0.79	0.84	0.69	0.85	0.85
CI	0.46 – 1.04	0.54 – 1.04	0.65 – 1.03	0.34 – 1.04	0.67 – 1.03	0.68 – 1.03

HRpre6 = heart rate prior to 6MWD; RRpre6 = respiratory rate prior to 6MWD; HRpost6 = heart rate immediately after 6MWD; RRpost6 = respiratory rate immediately after 6MWD; HR2mins = heart rate after 2-minute rest period; RR2mins = respiratory rate after 2-minute rest period; ICC = intra-class correlation; CI = 95% confidence interval.

The ICC scores in tables 3 and 4 showed a high inter-observer correlation between data collectors with ICC scores ranging from 0.69 to 0.90.

Pearson product moment correlation coefficient results for dynamometry measurements of the right quadriceps muscles and left triceps muscles of the nine volunteers are presented in Table 5.

Table 5: Pearson product moment correlation coefficient results for dynamometry (df = 7).

Data Collectors	Week 1		Week 2	
	Quadriceps Right	Triceps Left	Quadriceps Right	Triceps Left
1 & 2	r = 0.07 p = NS	r = 0.48 p = NS	r = 0.62 p < 0.05	r = 0.64 p < 0.05
1 & 3	r = 0.48 p = NS	r = 0.85 p < 0.005	r = 0.80 p < 0.005	r = 0.85 p < 0.005
2 & 3	r = 0.30 p = NS	r = 0.54 p = NS	r = 0.29 p = NS	r = 0.67 p < 0.025

NS = not significant

A strongly positive correlation existed for right quadriceps and left triceps measurements between data collectors at the second testing session as r ranged from 0.62 to 0.85 with the p-value < 0.05 to 0.005. However a weak correlation existed between data collectors for these measurements during the first testing session as r ranged from 0.07 to 0.54 and p-values were mostly insignificant.

The ANOVA results for intra-observer reliability for dynamometry measurements are presented in Table 6.

Table 6: ANOVA results for intra-observer correlation for dynamometry (n = 18).

	Data Collector 1		Data Collector 2		Data Collector 3	
	Quadriceps Right	Triceps Left	Quadriceps Right	Triceps Left	Quadriceps Right	Triceps Left
ICC	0.37	0.71	0.43	0.59	0.11	0.62
CI	0.00 – 0.95	0.38 – 1.04	0.00 – 0.97	0.15 – 1.02	0.00 – 0.77	0.21 – 1.03

ICC = intra-class correlation; CI = 95% confidence interval

ICC scores ranging from 0.59 to 0.71 demonstrated a moderate to high intra-observer reliability for left triceps measurements. ICC scores ranging from 0.11 to 0.43 demonstrated weak intra-observer reliability for right quadriceps measurements.

DISCUSSION

The Pearson product moment correlation coefficient is a parametric test and can be used for correlation study designs as long as the data is of an interval/ratio nature (Hicks 2004). This design looks for the degree of association between sets of data (Hicks 2004). A correlation coefficient close to +1 indicates a strong positive relationship; a value closer to –1 indicates a strong negative relationship. A value closer to 0 indicates a weak relationship between data sets (Hicks 2004).

Six minute walk distance test

Each volunteer in this study was given a 30 minute rest period in-between the 6MWD measurements to allow recovery time prior to the execution of the next test. This decision was supported by the research of Opasich et al in 1998 in which these researchers investigated the reproducibility of 6MWD test results in 233 patients by performing 2 tests on the same day and on 2 consecutive days. They showed that the data collected on the same day (provided that there was a 30-minute rest between tests) was equivalent to that collected over 2 consecutive days.

Demers and colleagues (2001) performed the 6MWD test on 60 patients with stable heart failure 3 times during the course of their study and produced ICC scores ranging from 0.88 to 0.91. O'Keefe and colleagues (1998) tested 24 elderly heart failure patients in whom the ICC score for reproducibility was > 0.75. Pankoff et al (2000) tested the reliability of 6MWD in 26 people with fibromyalgia in whom ICC scores were 0.91 to 0.98. Although the current study was performed on healthy subjects, the intra-class correlation coefficient results were similar to those found in the above-mentioned studies.

Positive inter-observer correlations existed for data collected by all three data collectors during the performance of the 6MWD. The hypothesis that the 6MWD is reproducible is confirmed and that the high inter-observer reliability found between the data collectors for measurement of heart rate, respiratory rate and distance walked is likely to be similar for measurements of blood pressure, oxygen saturation and level of perceived exertion during the execution of the 6MWD in the subsequent study.

Dynamometry

Burns et al (2005) compared the make and break techniques for hand-held dynamometry on elbow flexor and extensor muscles of 19 people with upper limb weakness due to tetraplegia. They used two novice testers for their study and the testing sessions were separated by 10-minutes. The inter-observer and intra-observer reliability was strong with ICC scores exceeding 0.9 for both make and break tests. Roy et al (2004) investigated the reliability of hand-held dynamometry in the assessment of knee extensor strength after hip fracture in 16 subjects. These researchers showed high test-retest ICC scores of 0.91 for the fractured leg and 0.90 for the unfractured leg.

In our study the Pearson product moment correlation coefficient showed a weak correlation between data sets collected for left triceps and right quadriceps muscles at the first testing session in this study. The Pearson correlation coefficient showed a stronger positive correlation between data collected at the second test session. The ICC scores obtained for left triceps muscles ranged from 0.59 to 0.71, which constitute a fair degree of intra-observer correlation. However, the ICC scores for right quadriceps muscles ranged from 0.11 to 0.43, a low intra-observer correlation. On these grounds, the one-way hypothesis for dynamometry would have to be rejected. Possible explanations for poor reproducibility of this test within data collectors could be the difference in strength between the data collector and the volunteer. The volunteers were young, healthy and strong. It is possible that as a consequence some data collectors might not have been able to apply sufficient vertical resistance to the muscle contractions of some of the volunteers. Mulroy found that female examiners' maximal push force with a hand-held dynamometer was not significantly different when measuring quadriceps strength in male and female patients but was only 60% and 40% of quadriceps strength force generated in a group of normal women and men (Mulroy et al 1997). The planned study will involve muscle testing of patients who suffered penetrating trunk trauma, mechanical ventilation and prolonged bed rest. This group of patients frequently suffer from muscle weakness for a prolonged time period after hospital discharge (Bruton, Conway & Holgate 2002; Convertino, Broomfield & Greenleaf 1997; Lewis 2003;Winkelman 2004). If the strength of the volunteers contributed to the discrepancies seen in the current study, these may not be present in the main study.

The time frame between the two testing sessions was a limitation to the study as this might have influenced the performance of the volunteers. If a day or two separated the two testing

sessions, less variation in data might have been seen especially for the dynamometry measurements. Another limitation was the level of inexperience in using the hand-held dynamometer amongst the data collectors. In accordance with this it is interesting that a learning effect was seen between the results of the first and second testing sessions for dynamometry. It is possible that further experience with this device may dramatically improve intra-observer reliability. Based on the above results, data collector 2 will be used for dynamometry measurements and data collectors 1 and 3 will be used for the 6MWD measurements during the main study.

CONCLUSION

A strong inter-observer reliability was established between data collectors for the 6MWD. A fair intra-observer correlation was established for the dynamometry measurements in this study which may improve over time. A possibility exists that the patients in the main study might find the prone position uncomfortable for triceps strength measurement postoperatively. If this is found, triceps muscle strength will be assessed in supine.

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APPENDIX II

SUBJECT INFORMATION SHEET AND CONSENT FORM

SUBJECT INFORMATION SHEET

Dear Patient

I, Heleen van Aswegen, am registered as a postgraduate student at the University of the Witwatersrand. I am investigating the effects of penetrating chest/abdominal trauma (gun shot/ stab wounds) and mechanical ventilation on the recovery of the adult survivor on discharge from the intensive care unit up to 6 months after hospital discharge, as part of a Doctor of Philosophy degree.

Recent studies in the medical literature have shown that patients, who have been in the Intensive Care Unit due to illness, suffer from generalised muscle weakness that may take between 3 – 5 months to recover to the normal level. Mechanical ventilation has also been shown to reduce a person's lung capacity and this may lead to difficulties when performing activities of daily living after discharge from the hospital.

The aim of this study is to establish the initial levels/values of your lung function, exercise ability and quality of life before your hospital admission and on discharge from the ICU. These tests as well as muscle strength tests will be repeated at 1, 3 and 6 months after your discharge from the hospital. With these results I aim to find out if there is a need for a formal exercise programme intervention for patients that have survived penetrating trunk trauma and mechanical ventilation like you. There is currently no research available in South Africa about this topic. If you decide to participate in this study, you'll be making a big contribution to the knowledge of medical and rehabilitation professionals in South Africa. The knowledge obtained from this study will help us to put in place the most effective treatment programmes for people that have sustained similar injuries to yours.

The physiotherapist and surgeon, who were responsible for your care during your stay in the intensive care unit, referred you to me for possible participation in this study.

If you choose to participate in this study, you are ensured that all the information obtained about your condition during this study, will remain confidential. This means that a specific code and number will be assigned to your name if you participate in this study. All the data collected from your tests will be entered into the computer under your code and number so that your name remains unknown to the researchers. You will also need to sign this letter to indicate whether you want to participate in this study.

The duration of this study will be 6 months from the time that you are discharged from the hospital. The lung function tests will be conducted at Johannesburg Hospital. The exercise tests, muscle strength tests and quality of life questionnaire will be conducted at the Centre for Exercise Science and Sports Medicine, Wits Education Campus (across the road from Johannesburg Hospital). These tests will not cost you anything because you are participating in a research project.

Your transport costs to and from Johannesburg Hospital and the Wits Education Campus will be reimbursed to you, at a fixed amount, during the duration of this study. You are free to withdraw from this study at any time without penalty or loss of normal treatment benefits.

If you require any further information about the study or if any of the above information is unclear to you, please do not hesitate to contact me.

Contact person: Heleen van Aswegen

Contact number: (011) 717 3702/6 or 082 560 6076

CONSENT

I fully understand the nature of this study investigating the effects of penetrating chest/abdominal trauma and mechanical ventilation on the recovery of adult survivors from ICU discharge until 6 months after hospital discharge.

I agree to participate in this study and to come in for testing 3 times during the 6-month period after my discharge from the hospital.

Name: _____

Signature: _____

Date: _____

APPENDIX III

UNIVERSITY OF THE WITWATERSRAND

PHYSIOTHERAPY RESEARCH STUDY (PENETRATING TRUNK TRAUMA)

DEMOGRAPHIC QUESTIONNAIRE

PERSONAL INFORMATION

Name & Surname: _____ Age: _____

Gender: M/F (circle) Telephone nr: _____(H)
_____(Cell)

Address: _____
_____

Do you have any support at home? Yes/No

Who provides this support? _____

What type of support is given to you? _____

What is your occupation (job)? _____

Approximate income per month:
< R1 000 ☐
R1 000 – R 5 000 ☐
R5 000 – R10 000 ☐
> R10 000 ☐

Are you the sole income provider for your family? Yes/No

How did you get injured and admitted to hospital? _____

_____

Have you been able to return to your job since discharge from hospital? Yes/No

If yes, please supply date of return to work: _____

GENERAL HEALTH

A) Do you suffer from any of the following diseases (circle your answer)?

- ✡ High blood pressure Yes/No
- ✡ Diabetes Yes/No
- ✡ Epilepsy Yes/No
- ✡ Heart Disease Yes/No
- ✡ Asthma Yes/No
- ✡ Chronic lung disease Yes/No
- ✡ Stroke Yes/No
- ✡ Emotional disorders Yes/No
- ✡ High cholesterol Yes/No
- ✡ HIV/Aids Yes/No

B) Do you smoke? Yes/No

If yes, please state how many cigarettes per day: _____

How many years have you smoked? _____

C) Are you taking any medication at the moment? Yes/No

If yes, please state which medications you are using:

_____

_____

PHYSICAL ACTIVITY

A) Did you do any sport/exercise before you were admitted to the hospital?
Yes/No

If yes, what type of sport/exercise did you do? _____

How often did you do sport/exercise per week? _____

B) Do you participate in any sport/exercise after your discharge from hospital?Yes/No

If yes, what type of sport/exercise do you do? _____

When did you return to your sport/exercise? Date: _____

How often do you do sport/exercise per week? _____

PHYSIOTHERAPY TREATMENT

A) Did you receive any physiotherapy treatment while you were in the hospital ward?
Yes/No

If yes, please describe the type of physiotherapy treatment that you received:

B) Have you received any physiotherapy treatment after your discharge from the hospital?
Yes/No

If yes, please describe the type of physiotherapy treatment that you received:

How many physiotherapy treatment sessions did you receive after your discharge from the hospital? _____

Subject signature: _____

Date: _____

APPENDIX IV

TRUNK TRAUMA RESEARCH PROJECT

Outcome Measures for Subjects

Subject Code: _____

WARD TESTS (AFTER ICU D/C)		
Peak flow	**Resting HR**	**30-meter walk test**
1		
2		
3		HR response:

Date (dd/mm/yy)			
	1 month	3 months	6 months
Lung Function Tests			
FVC			
FEV 1			
FEV1/FVC			
TLC			
RV			
DLCO			
O2 Uptake Test			
Max HR			
RQ			
Peak VO2			
Distance walked			
Dynamometry (mean)	**Left/Right**	**Left/Right**	**Left/Right**
Strength: Deltoid			
Strength: Biceps			
Strength: Triceps			
Strength: Abdominal			
Strength: Quadriceps			
Strength: Hamstrings			
6-min walk test	**Pre-test/Post-test**	**Pre-test/Post-test**	**Pre-test/Post-test**
Distance			
Rest Periods			
Heart Rate			
SaO2			
Blood Pressure			
Resp Rate			
Mod Borg Score			
Post-test HR (2 mins)			

APPENDIX V

ETHICS CLEARANCE CERTIFICATE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

COMMITTEE FOR RESEARCH ON HUMAN SUBJECTS (MEDICAL)
Ref: R14/49 van Aswegen

CLEARANCE CERTIFICATE **PROTOCOL NUMBER** M03-05-83

PROJECT Exercise Therapy in Adult Survivors of Acute Respiratory Distress Syndrome After Hospital Discharge

INVESTIGATORS Miss H van Aswegen

DEPARTMENT School of Therapeutic Sci, Wits Medical School

DATE CONSIDERED 03-05-30

DECISION OF THE COMMITTEE Approved unconditionally

Unless otherwise specified the ethical clearance is valid for 5 years but may be renewed upon application
This ethical clearance will expire on 1 January 2008.

DATE 03-07-04 CHAIRMAN ..... pp 9/7/03
(Professor P E Cleaton-Jones)

* Guidelines for written "informed consent" attached where applicable.

c c Supervisor: Prof C Eales
Dept of School of Therpaeutic Sci, Wits Medical School
Works2\Iain0015\HumEth97.wdb\M 03-05-83

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DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10001, 10th Floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. I agree to a completion of a yearly progress form. I/we agree to inform the Committee once the study is completed.

DATE 16/7/2003 SIGNATURE .....

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX VI

Figure 1: Schematic representation of the response to trauma

