DEVELOPMENT OF A REGRESSION EQUATION FOR ESTIMATING THE WEIGHT OF MALE BLACK SOUTH AFRICAN ADULTS WITH PARAPLEGIA USING ANTHROPOMETRIC MEASUREMENTS

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DECLARATION OF AUTHENTICITY

Hereby I, Hildegard Snyman, declare that this thesis is my own original work and that all sources have been accurately reported and acknowledged and that this document has not previously in its entirety or in part been submitted at any university in order to obtain an academic qualification.

H Snyman December 2005

ABSTRACT

Introduction: The objective of this study was to develop a regression equation to estimate weight of black male paraplegic South African subjects. Very few institutions in South Africa have wheel chair scales and very few paraplegic persons know what their weight is. People with spinal cord injury (SCI) are reported to have an increased risk to develop obesity and diseases of lifestyle. It is therefore important to monitor the nutritional status of these patients to prevent and treat the above diseases effectively. The aim was to develop an equation that incorporates variables or measurements that do not require a high level of skill and experience to be determined. The equipment needed for the determination of the measurements should also be easily accessible, for example a tape measure rather than a skin-fold caliper.

Method: The study design was cross-sectional. A convenience sample was selected from a population of black adult male paraplegics at the outpatient clinic of Kalafong Hospital, Tshwane. The following measurements were obtained from the subjects when they came for follow-up: waist circumference, calf circumference, chest circumference, neck circumference, mid upper-arm circumference, supine length, upper- arm length and wrist circumference. The age of the subject, time elapsed since injury, level of injury and level of spasticity were also recorded. This made up the 12 possible independent variables that could be used in the regression equation with body weight as the dependent variable. The subjects were weighed in their wheel chairs on a wheel chair scale. The wheel chair was then weighed separately and subtracted from the subject-plus-chair weight in order to determine the weight of the subject.

Results: Forty-three subjects complied with the inclusion and exclusion criteria of the study. Of the twelve variables included in the study, five variables individually have had a good correlation with weight. The body weight correlated significantly with waist circumference, calf circumference, chest circumference, mid upper-arm circumference and neck circumference with respective correlation coefficient values (R) of 0.85 or higher and Pearson correlations of $p < 0.0001$. A regression equation to estimate weight was chosen on the basis of strength and practicality and included the following variables: circumferences of the calf, chest, and neck as well as the supine length. The equation had a significant value ($p < 0.0001$) for body weight estimation.

Conclusion: A regression equation with a statistical significant estimation value was developed which can be reliably used to estimate the weight of black, adult male South African paraplegic persons.

OPSOMMING

Inleiding: Die doel van die studie was om ‘n regressieformule te ontwikkel wat gebruik kan word om die gewig van volwasse manlike swart Suid-Afrikaanse parapleë te beraam. Baie min Suid Afrikaanse instansies besit rolstoelskale en min parapleë weet wat hulle gewig is. Persone met spinale beserings het ‘n verhoogde risiko om oormassa en lewenstylsiektes te ontwikkel. Dit is dus belangrik om die voedingstatus van hierdie persone te monitor ten einde bogenoemde siektes te voorkom en effektief te behandel. Die doel was om ‘n formule te ontwikkel wat veranderlikes of metings gebruik wat nie moeilik is om te meet of waarvoor nie baie ervaring vereis word om korrek te meet nie. Die toerusting wat benodig word om die metings te neem moes ook geredelik toeganklik wees byvoorbeeld ‘n maatband, eerder as ‘n velvou kalliper.

Metode: Die dwars-snit studiemetode is gevolg. ‘n Gerieflikheid-steekproef is gekies uit die populasie van volwasse swart paraplegiese mans van die spinale buite pasiënte kliniek van Kalafong Hospitaal, Tshwane. Die volgende metings is van pasiënte geneem tydens hulle besoek aan die kliniek: middelomtrek, kuitomtrek, borsomtrek, mid bo-armomtrek, nekomtrek, liggende lengte, bo-armlengte en polsomtrek. Die pasiënte se ouderdom, tydsduur sedert hul besering, vlak van hul besering en die graad van spastisiteit wat hulle ervaar, is ook genoteer. Hierdie inligting vorm die 12 moontlike onafhanklike veranderlikes wat gebruik kan word om die regressieformule saam te stel met liggaamsgewig as die afhanklike veranderlike. Die pasiënte is op ‘n rolstoelskaal geweeg saam met hul rolstoele. Die rolstoel is dan alleen geweeg en die gewig daarvan afgetrek van die pasiënt-plus-rolstoel gewig om sodoende die pasiënt se gewig te bepaal.

Resultate: Drie-en-veertig pasiënte het aan die insluitings- en uitsluitingskriteria van die studie voldoen. Vyf van die twaalf veranderlikes ingesluit in die studie, het individueel ‘n redelik goeie korrelasie met gewig gehad. Die gewig het betekenisvol gekorreleer met middel-, kuit-, bors-, mid bo arm- en nekomtrek respektiewelik met ‘n korrelasiekwosiënt (R) van 0.85 en hoër en Pearson korrelasies van $p < 0.0001$. ‘n Regressieformule om gewig te bereken, is gekies op grond van praktiese uitvoerbaarheid en statistiese betekenisvolheid en het die volgende metings ingesluit: kuit-, bors- en nekomtrek asook liggende lengte. Hierdie formule het ‘n uitstekende vlak van betekenisvolheid gehad ($p < 0.0001$).

Gevolgtrekking: ‘n Regressieformule met ‘n statistiese betekenisvolle beramingswaarde is ontwikkel wat betroubaar gebruik kan word om die gewig van swart, volwasse manlike Suid-Afrikaanse parapleë te beraam.

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All the spinal cord injured patients of Kalafong Hospital, I would like to thank you for your voluntary participation in this study and your continuous enthusiasm for life in spite of your disability. Thank you to all the staff of the spinal clinic at Kalafong Hospital for your assistance during the period of my study, especially Dr Maree and Emily for your assistance with the evaluation of level of spasticity. Prof Labadarios and Prof Herselman, my two study leaders, it has been a privilege to work with you. Thank you for your valuable input and quick response to all my queries. Prof Nel, thank you for your statistical advice and help with the data analysis.

LIST OF ABREVIATIONS

BMI:	Body Mass Index
C1 to C7:	Cervical neurological segment 1 to cervical neurological segment 7
T1 to T12:	Thoracic neurological segment 1 to thoracic neurological segment 12
L1 to L5:	Lumbar neurological segment 1 to lumbar neurological segment 5
MUAC:	Mid upper-arm circumference
LBM:	Lean body mass
SCI:	Spinal cord injury
TEM:	Technical error of measurement
WHO:	World Health Organisation

LIST OF DEFINITIONS

spinal cord injury: The term emerges many types of injuries to the spine, raging from stable fractures to catastrophic transaction of the spinal cord

cervical region: The region of the neck

thoracic region: The region of the chest

lumbar region: The region between the thorax and the pelvis

creatinine/height index: The actual 24 hour urinary creatinine excretion is divided by the ideal creatinine excretion for a person of the same height to determine the creatinine/ height index. This index can be used to estimate skeletal muscle breakdown.

spasticity/spasms: This is involuntary muscle contraction below the level of injury that results from lack of inhibition from the higher central nervous system.

Frankfort plane: A plane is formed by a line between the lowest point on the margin of the orbit (the bony socket of the eye) and the tragion (the notch above the tragus, the cartilaginous projection just anterior to the external opening of the ear). With the head in line with the spine, this plane should be in line with the spine.

intermittent catheterisation: This refers to the drainage of the bladder several times a day by catheterisation with a narrow qauge rubber or plastic tube. The tube does not stay in the bladder between catheterisations.

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CHAPTER 1

INTRODUCTION

1.1 Spinal cord injury: the magnitude of the problem and its causes

It is estimated that between 400-500 South Africans sustain spinal cord injuries (SCI) every year.[1] For every female injured, there are five males.[1] Currently there is no documented information on the total number of people living with SCI in South Africa.[1] The majority of injuries are incurred by young people. The life expectancy of persons living with SCI is almost as long as persons without SCI.[1,2] This implies that an increasing number of people with SCI are ageing with their disability.[1,2]

The causes of SCI fall into two main categories: traumatic and non-traumatic. Table 1.1 indicates the most common traumatic causes of SCI in the United States of America and elsewhere[1]:

Table1.1: Causes of SCI

Causes of SCI	Percentage of total incidence
Road accidents involving motor vehicle, motor cycles and pedestrian accidents	51.1
Falls	19.8
Water sport	13.0
Crush injury	5.3
Violence	3.1
Rugby	2.5
Other sport	1.2
Equestrian related accidents	0.6
Other trauma	3.4

Non-traumatic causes of spinal cord injury are much less common and include viral infections, spinal cord cysts and tumors.[1]

Reports from hospitals and rehabilitation clinics suggested that the causes of SCI in South Africa are similar to the above, except for physical violence (including gun shot and stabbing injuries), which is suspected to influence the statistics in South Africa.[1]

1.2 Classification of SCI

SCI are referred to in terms of the regions (cervical, thoracic or lumbar) of the spinal cord in which they occur and the numerical order of the neurological segments.[3] The cervical region includes seven neurological segments, the thoracic region twelve neurological segments and the lumbar region five neurological segments (Figure 1.1).[3] The level of SCI designates the last fully functioning neurological segment of the cord, for example C6 refers to the sixth neurological segment of the cervical region of the spinal cord as the last fully intact neurological segment.[3]

SCI generally causes quadriplegia or paraplegia. Quadriplegia refers to loss of motor and/or sensory function in the cervical segments of the spinal cord due to damage of neural elements within the spinal canal.[3] It refers to impairment of function in the arms, trunk, legs and pelvic organs.[3] Paraplegia refers to impairment or loss of motor and/or sensory function in the thoracic or lumbar segments due to damage of neural elements within the spinal canal.[13] Depending on the level of injury, the trunk, legs and pelvic organs may be involved.

The type of SCI can further be classified as a complete or incomplete injury. The term complete injury is used when there is a total absence of sensory and motor function below the neurological level of injury.[3] An incomplete injury indicates that there is partial preservation of sensory and/or motor functions below the neurological level and includes the lowest sacral segment.[3]

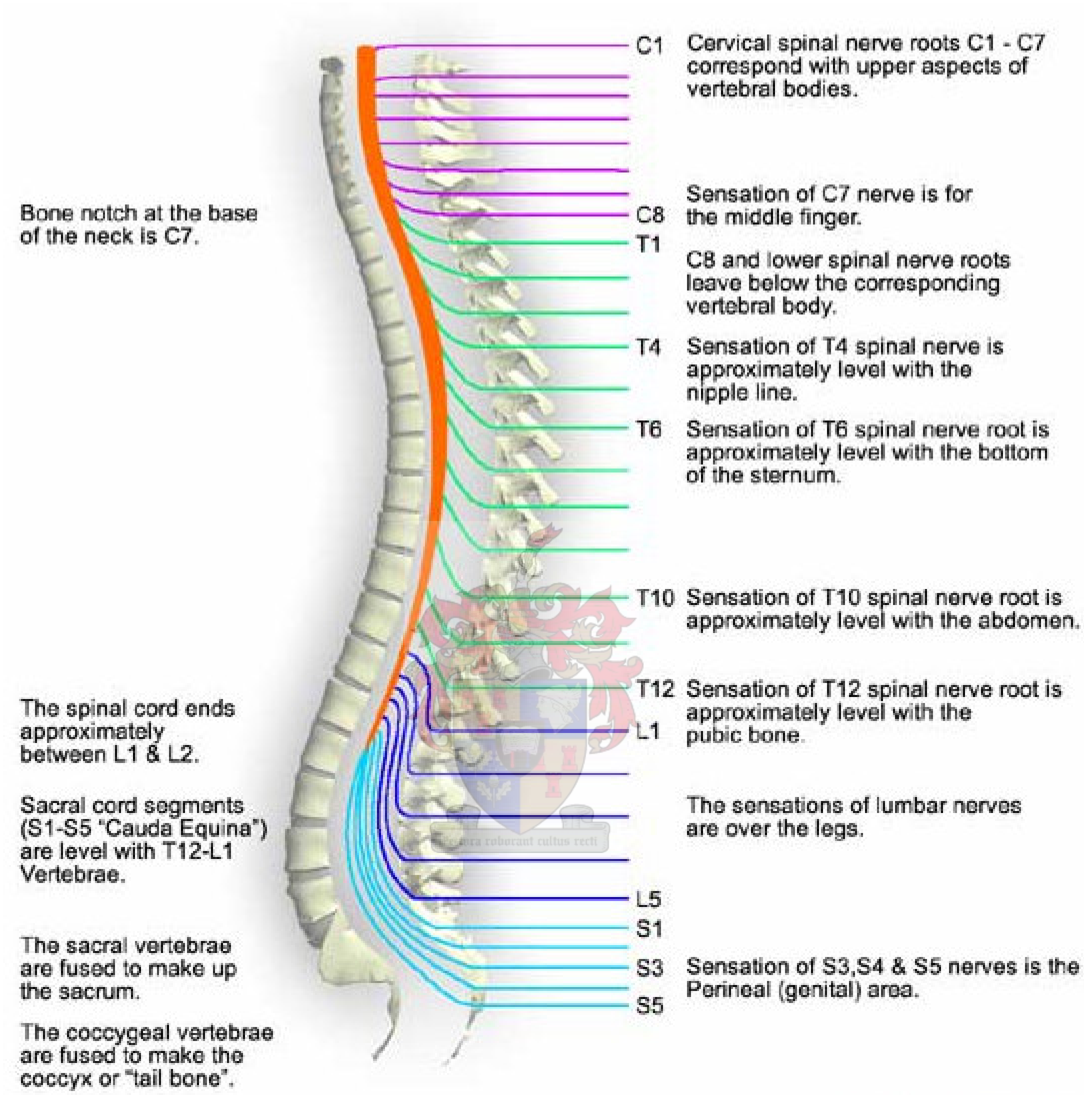

Figure 1.1: Diagram showing the relationship between spinal nerve roots and vertebrae

Source: http://www.qasa.co.za/info.htm

1.3 Nutritional risks of the SCI person

1.3.1 Over-nutrition in SCI

SCI gives rise to certain nutritional consequences. People with SCI have lower basal metabolic rates than able-bodied persons.[4] Their metabolic rates are proportional to the amount of denervated muscle that results from the loss of motor function.[4] The lower metabolic rate and general immobility may result in over-nutrition.[4] It is reported that SCI is associated with an increased incidence of coronary heart disease and type II diabetes.[5] This occurs in a younger age group than in the able-bodied population. The mortality rate for cardiovascular disease is 228% higher than for able-bodied individuals.[5] Post prandial glucose uptake is achieved primarily through the muscle mass. The loss of lean tissue mass in people with SCI may contribute to the greater risk of developing diabetes.[2] In people with SCI, there is a positive correlation between body mass index (BMI) and serum levels of uric acid; BMI and body fat percentage; BMI and basal, peak and sum glucose; and BMI and leptin. An inverse relationship exist between BMI and high density lipoprotein cholesterol.[6,7]

Men with body fat content > 25% and women with levels > 32% are classified as obese.[5] Many SCI people have levels of fat beyond these cut-off points. In addition to the risk of diseases of lifestyle, obesity increases the risk for developing pressure ulcers and reduces independence in transfer activities.[5]

There is evidence that the World Health Organisation (WHO) BMI cut-off point of 25kg/m² for overweight and 30kg/m² for obesity are not suitable for predicting disease risk in various ethnic populations and that lower cut-offs may be needed in some populations. SCI individuals is one of the population groups that may benefit from lower BMI cut-offs to describe overweight and obesity.[6] Several studies on people with SCI reported a mean BMI of 21.4 – 24.8kg/m², which is classified as normal according to the WHO classification, but a fat percentage of 23% - 30% which indicates obesity.[7]

1.3.2 Under-nutrition in SCI

Although it seems that over-nutrition is a bigger problem than under-nutrition in the SCI patient,[2,5,6] under-nutrition should not be overlooked. SCI patients are particularly susceptible to pressure ulcers.[8] Patients with pressure ulcers have increased protein and energy needs due to the increased need for wound healing and tissue epithelialization.[8] Energy needs can be as high as 40 kCal/kg and protein needs as high as 2 g/kg for pressure ulcers to heal.[8] This severely catabolic condition can easily result in under-nutrition.[8] Other causes of under-nutrition could be depression and physical difficulties in preparation and eating of food.[9]

1.4 The importance of weight in terms of morbidity and mortality

As weight goes up, life expectancy goes down.[10] Obesity is associated with increased morbidity and mortality. Many health problems are either caused or exacerbated by overweight and obesity.[10] Most clear-cut links have been observed between obesity and cardiovascular risk factors such as type II diabetes, dyslipidaemia and hypertension.[10] Obesity is also associated with an increased risk of stroke, gall bladder disease, osteoarthritis, sleep apnea and certain forms of cancer.[10] BMI of less than 18.5 is associated with an increased risk for mortality due to digestive and pulmonary diseases.[4,11] Malnutrition (over- and under-nutrition) is a major risk factor for the development of pressure ulcers.[8]

Keeping in mind the above-mentioned risks for over- and under-nutrition and the consequences thereof, it is clear that the monitoring of the nutritional status of the SCI person is essential.

1.5 Difficulties in monitoring the nutritional status of the SCI person

Anthropometric data plays an important role in the evaluation of nutritional status. It characterises persons with unusual properties of stature, weight, body fat and muscle percentage.[12] With all anthropometric measurements it is assumed that a subject is able to co-operate and can be positioned such that the measurements can be taken accurately and according to the prescribed methodology.[12] This is unfortunately not the case for people with SCI.

SCI patients can for instance not be weighed while standing. Specialised equipment is needed to weigh a paraplegic or quadriplegic person.[11] A sitting scale, platform wheelchair scale or bed scale is needed to weigh these people.[11] Specialised equipment may not be available in the health care setting in the developing world, including South Africa. This increases the difficulty of monitoring nutritional status in this population group. Alternative methods to measure and monitor relevant anthropometry in the SCI patient clearly need to be established.

1.6 Weight estimating formulas

With the lack of equipment to weigh SCI people in South Africa, it would be helpful to use alternative anthropometrical measurements to estimate weight. Equations for weight estimation have been developed for able-bodied adults and the elderly.[11] Equations for estimating the weight of SCI persons are however still lacking. Standard regression equation formulas cannot be used for SCI people as they have been validated for able-bodied population and it cannot be assumed that the hydration and composition of muscle, bone and fat tissue of able-bodied persons are the same as for persons with SCI.[13]

1.7 Changes in body composition in the SCI person.

1.7.1 Muscle wasting and SCI

It is known that enforced inactivity, immobilisation of limbs and muscle denervation are factors that lead to compositional changes in the body or affected limbs.[13] Persons with spinal cord injury have a reduced physical capacity which lead to changes in their body composition.[6] The lesion of the spinal cord leads to denervation of the muscles below the lesion and this leads to disuse atrophy and to loss of lean body mass (LBM).[13] Disuse atrophy takes place independently of the metabolic rate of the subject.[13]

Skeletal muscle and organs form the major part of the intra-cellular water compartment of the body. In the stable paraplegic person disuse atrophy of the skeletal muscle leads to a depressed intra-cellular water compartment.[7] Extra-cellular water and extra-cellular mass do not change after a SCI.[13] The ratio of extra-cellular water to total body water therefore increases. The ratio increases as the level of the injury increases.[13] It is clear that body fluid compartments of people with SCI are different from those of able-bodied persons.

The creatinine/ height index can be used as an indicator of muscle mass.[13] The creatinine/ height index was much lower in quadriplegics than in paraplegics due to the larger muscle wasting that took place in quadriplegics. This index was also lower in paraplegics than in able-bodied people.[13] The mid upper-arm circumference values were lower in subjects with higher spinal cord lesions (quadriplegics) than in those with lower lesions (paraplegics).[13] This confirms that muscle wasting takes place below the lesion of the spinal cord.

Some SCI patients develop spasticity.[14] Spasticity patterns change over the first year after injury. It increases in the first 6 months after the injury and reaches a plateau one year after the injury.[14] Lean mass is better maintained in patients with spasms when compared to flaccid patients.[15] Spasticity is more common in the acute paraplegic patient, but can still be present in the stable paraplegic person.[15]

1.7.2 Changes in body fat

The loss or gain of body fat takes place proportionally to the metabolic rate of a person with a SCI.[13] In previous studies on people with SCI the lower body muscle mass was accompanied by an increase in body fat.[13] It would seem that the loss in LBM was a result of inactivity due to the SCI and the increase in body fat the result of an over-supply of energy relative to the requirements for energy expenditure.[13] Many paraplegic patients do not look overweight, even though they have a very high percentage of body fat. The reason is that lean tissue has been replaced by fat.[2]

1.7.3 Changes in bone mineral content

Spinal cord injury is well known to cause multiple system dysfunctions.[16] Atrophy of the appendicular skeleton with loss in bone mineral content is one of the dysfunctions.[16] Osteoporosis below the level of the SCI exceeds the normal loss of bone mass seen in able-bodied people and the development of bone mineral loss is dependent on the level of the lesion.[17] The aetiology of the reduction in bone mineral density is immobilisation and disuse due to paralysis.[18] Paraplegic patients experience a decrease in bone mineral content which also impacts on their weight.[7,15]

There is a rapid decrease in bone mineral content in the paralysed areas of paraplegic persons. During the first year after injury it decreases with ~4% per month in trabecular bone and with ~2% per month in compact bone.[15] Bone loss is the greatest in the first 3 –– 6 months following injury and stabilises at a level close to fracture threshold in the period between 12 and 16 months.[2] Although the lean mass is better preserved in patients with spasticity, the bone mineral content decreases at the same rate as in flaccid patients.[15]

1.8 Significance of the study

People with SCI have an increased risk for over-nutrition as well as under-nutrition.[2,5,6,7] It is therefore important to monitor the nutritional status of these patients to prevent malnutrition and to intervene effectively. Specialised equipment is needed to weigh a SCI person. The availability of such equipment in developing countries is limited and this increases the difficulty of monitoring nutritional status in SCI persons. If a specialised scale is not available to weigh a person with a SCI, it is possible to estimate weight by using a regression equation. Surrogate anthropometric measurements then act as the independent variables and weight is estimated by submission of the values of the measurements into the equation. Similar equations have been developed for able-bodied adults but not yet for paraplegic or quadriplegic persons.[11]

The development of a regression equation to estimate the weight of paraplegic persons will assist in monitoring of the nutritional status of these people. The aim of this research was to develop such an equation and to make it available to institutions that lodge paraplegic persons or institutions to which they come for follow-up treatment.

CHAPTER 2

METHODS

2.1 Study aims

2.1.1 Main aim

The main purpose of the research was to develop a multiple regression formula to estimate the weight of adult male black South African persons with paraplegia using anthropometric measurements.

2.1.2 Sub-goals

In order to achieve the main aim of the study, two secondary aims first of all had to be achieved, namely:

- Firstly to determine which of the following anthropometric measurements have an influence on the estimation of weight of paraplegic persons, and to what extent:
  - supine length
  - upper-arm length
  - mid upper-arm circumference (MUAC)
  - waist circumference
  - chest circumference
  - neck circumference
  - wrist circumference
  - calf circumference
- Secondly to determine to which extent, if at all, the following characteristics play a role in the weight of persons with paraplegia:

- age
- level of spasticity
- level of injury
- time since injury

2.2 Study plan

2.2.1 Study type

The type of study can be classified as cross-sectional and analytical.

2.2.2 Study population

The study population included black adult males with paraplegia, who attended the spinal outpatient clinic of Kalafong Hospital, Tshwane, South Africa. There were inadequate patient numbers from the other ethnic groups, women and quadriplegics to get any representative data.

2.2.3 Inclusion criteria

The following criteria were selected for persons to be included in the data set for the investigation:

- Black males, 18 to 60 years of age
- Paraplegics with a level of injury of T2 – L3
- Paraplegics with a complete lesion
- The injury should have occurred more than 1 year prior to the day of investigation. This time span is chosen as the most significant changes in body composition (see section 1.7) would have taken place after a year has elapsed since injury.[13] Changes

in body composition follow a log curve which levels off between one to three years after injury.[19] No upper limit for time since injury was used to exclude subjects in this study.

2.2.4 Exclusion criteria

Criteria to exclude persons from the data set were the following:

- Subjects with a level of injury above T2
- Subjects with an incomplete lesion
- White, coloured and Indian subjects
- Subjects with amputations
- Subjects with oedema
- Subjects with contractures that prevent proper measurement of one or more of the parameters listed in section 2.1.2
- Children (<18 years of age)
- Females

2.2.5 Sample selection

The sampling method was convenience sampling. All subjects who attended the spinal clinic during the study period from November 2004 to March 2005 and who complied with the inclusion criteria, were included in the study.

2.3 Method of data collection

2.3.1 Implementation

2.3.1.1 The examination room

The research was done at the outpatient clinic for spinal patients at Kalafong Hospital. An empty examination room next to the clinic was used to measure and weigh the subjects. The examination bed in the room was used to measure supine length of the subjects. Electricity supply was available in the room in order to operate the electronic platform wheelchair scale (refer to section 2.3.1.3 for specifications of the scale).

2.3.1.2 Time of research

The clinic took place every Tuesday. The anthropometric measurements of the subjects were taken from the time they arrived at the clinic (about 7:00) till all subjects acceptable for inclusion in the data set were measured. Patients were supposed to come for follow-up scrutiny every three months and the study had to continue for at least three months in order to be able to include in the study all eligible subjects attending the clinic. The duration of the study was five months. Some of the subjects attended the spinal clinic more than once during the study period. These subjects were measured only during their first visit.

2.3.1.3 Equipment

The aim of the study was to develop an equation that can be used by people who do not have access to equipment such as a knee height caliper or a skin-fold caliper. Furthermore the taking of the proposed measurements should require less advanced technical skills. Personnel from institutions who care for paraplegics should be able to measure the paraplegics and to calculate estimated weight.

Errors in measurement, due to intra- and/or inter-observer variation, had to be small when circumferences and lengths were being measured.[20,21] It is preferable to do circumferential measurements rather than skin-fold measurements, especially when measuring obese clients.[11,21] The caliper might not be able to open wide enough and the accuracy of the measurement is less with increased skin folds.[11,21] There is a tendency in SCI patients towards obesity[7] and circumferences would therefore be the measurement method of choice in this population.

Equipment used:

- A flexible non-stretch tape measure with 1 mm increments[21] was used to measure supine length, upper-arm length, MUAC, waist circumference, chest circumference, neck circumference, wrist circumference and calf circumference.
- A marking pen was used to apply marks on the bed (to measure length) and to mark the anatomical landmarks[11] needed to take the anthropometric measurements of the subject.
- A platform electronic wheel chair scale from SCALES 2000 was used to weigh subjects in their wheelchairs and the wheel chairs separately (Electronic digital wheel chair platform scale, Model WCS, manufactured by Scales 2000, Durban, South Africa). The wheelchair scale was moved from the spinal ward to the outpatient clinic every Tuesday morning and returned to the ward after the measurements where done. Transportation of the scale was done using a battery powered cart. According to the chief technician of the scale, there should not have been a problem with the calibration of the scale if it was moved carefully (Appendix 1).

A container filled with water, which weighed 5.0 kg, was used to calibrate the scale. The container was weighed on an electronic digital scale (Electronic digital physician scale, Model PSWHS, manufactured by Scales 2000). The electronic digital scale was bought less than a year ago and had never been moved and was therefore accurate. The container with the known weight was placed on the wheel chair scale before every subject was weighed. If the reading on the wheel chair scale differed from the reference weight with more than 0.2 kg (the resolution of the scale), the four foot rests of the scale were checked and adjusted to level the scale.

- A plank was used to assist in measuring supine length (refer to section 2.3.2.7).
- A towel was used to assist in measuring MUAC (refer to section 2.3.2.8).

2.3.2 Obtaining anthropometrical data

Both the upper and lower body of the paraplegic subject differs from that of an able-bodied person due to changes in body composition. Measurements of the upper and lower body parameters as described in the section below were included in the study.

2.3.2.1 Weight

Paraplegic subjects are taught to perform intermittent catheterisation every two hours. Subjects were asked whether they have performed catheterisation during the past two hours. If not, they were asked to empty their bladders before their weight could be measured. Consequently all subjects were weighed after emptying their bladders.[21]

The platform wheelchair scale was plugged in at the examination room. The subject was helped to remove excess clothing and shoes. The subject-plus-the-wheelchair was weighed to the nearest 0.2 kg as this was the resolution of the scale. Once the subject had transferred himself to the examination bed to measure length, the weight of the wheelchair was measured. This was subtracted from the weight of the subject-plus-the-wheelchair to get the weight of the subject.[22]

2.3.2.2 Upper-arm length

Upper-arm length correlates well with body height and can be used as a proxy for body height.[23] This measurement was taken with the subject's right elbow flexed 90 degrees. The distance was then measured from the inferolateral acromium to the lateral epicondyle of the humerus. If arm length correlates just as well as length with weight in this population, it may be an easier measurement to take and more practical than supine length. The measurement was taken to the nearest 0.1 cm.[11]

2.3.2.3 Chest circumference

This measurement was included due to possible increase in muscle mass in this area and the effect that it would have on weight. This circumference was taken at the level of the mesosternale (Figure 2.1). The subject was asked to slightly abduct his arms allowing the tape to be passed around the chest in a near horisontal plane. The measurement was taken at the end of normal expiration with the arms relaxed at the sides.[24]

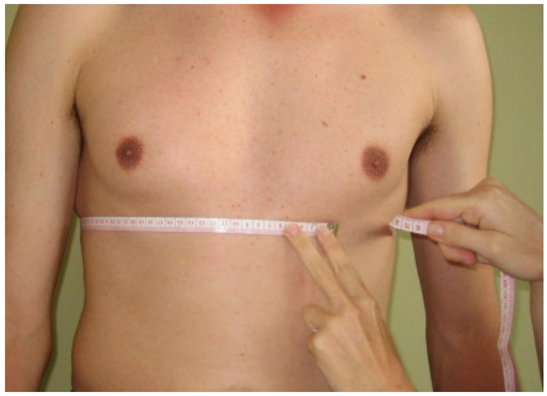

Figure 2.1: Measurement of the chest circumference

2.3.2.4 Neck circumference

Increased upper body muscle mass (including the neck) will have an influence on weight and this is the reason why neck circumference was included in this study. It was measured superior to the thyroid cartilage (Adam's apple). The subject had to maintain the head in the Frankfort plane. The tape was held perpendicular to the long axis of the neck (Figure 2.2).[24]

Figure 2.2: Measurement of the neck circumference

2.3.2.5 Wrist circumference

Frame size influences weight and wrist circumference gives an indication of frame size.[11] The wrist circumference was measured on the right arm with the elbow flexed 90 degrees. The measuring tape was placed distal to the styloid process and the reading was taken to the nearest 0.1 cm.[11]

2.3.2.6 Calf circumference

The calf circumference (a measurement of the lower body) of paraplegics would have a correlation with weight different from that for able-bodied persons due to muscle wasting in lower extremities.[13,] This measurement was also included as some subjects with spasms may have bigger calf circumferences due to involuntary muscle contraction than those without spasms.[14] Calf circumference was measured while the subject was sitting in a wheel chair with the foot resting on the foot rest of the chair. A non-stretchable tape measure was looped horisontally around the right calf and moved up and down to find the greatest calf circumference. The tape was tightened around the skin without compressing the soft tissue. The circumference was recorded to the nearest 0.1 cm.[11]

2.3.2.7 Supine length

Body length has a direct effect on weight and supine length would therefore be included in the study.[11] Supine length was used for this population group as they cannot stand erect to measure height. The subject was asked to transfer himself to the examination bed. The subject was aligned so that the lower extremities, trunk, shoulder, and head were in a straight line.[11] A 1 cm thick wooden plank was used to flex the feet of the subjects with their toes pointing straight up. A mark was made on the bed at the base of the heels.[22] The top of the crown was also marked on the bed by placing the plank on the head while the head was in the Frankfort position. The inside of the plank was used as the reference. The distance between the two marks was measured.[22] The marks were erased by using water, before the next subject was measured. The measurement was taken on the left side of the subject.[22] Measurements were taken to the nearest 0.1 cm.[11]

2.3.2.8 MUAC

Due to increased activity, arm muscle area in paraplegics is suspected to be higher than for able-bodied people. MUAC was measured while the patient was in the supine position. The right arm was measured. The subject was asked to place his fore-arm, palm down, across the middle of the body with the elbow bent 90 degrees and the upper-arm approximately parallel to the body. The midpoint between the acromium process and the olecranon was located and marked. The arm was then returned to the side of the subject with the palm facing up. A folded towel was placed under the subjects elbow to raise his arm. A tape measure was placed around the subject's arm at the level of the marked midpoint and perpendicular to the long axis of the arm. Measurements were taken to the nearest 0.1 cm.[11]

2.3.2.9 Waist circumference

An increased waist circumference is known to be an indicator of risk for cardiovascular disease.[25] Total body fat is suspected to be increased in paraplegics.[7] This is the reason for including this measurement in the study. This measurement was taken while the subject was in the supine position. The measure was taken at the narrowest point between the lower costal border and the iliac crest. If there was no obvious narrowing, then the measurement was taken at the mid point between these two landmarks. The tape was snug against the skin but not too tight so that it compressed the tissue. The reading was taken at the end of a normal expiration to the nearest 0.1 cm.[24]

2.3.3 Order of measurements

The measurements with the subject in his wheelchair were taken first (Table 2.1). These measurements were taken in rotational order and repeated three times.[21] The average of the three measurements were taken.[21] The subject was then asked to transfer himself to the bed for the remainder of the measurements (Table 2.1). These measurements were also taken in rotational order, repeated three times and the average of the three measurements was recorded. It took 30 minutes per patient to perform all the measurements.

Table 2.1: The various measurements taken in the sitting and the supine position

Measurements taken in the sitting position	Measurements taken in the supine position
Upper-arm length	Supine length
Chest circumference	Waist circumference
Neck circumference	MUAC
Wrist circumference	Weight of wheel chair
Calf circumference	
Weight of subject-plus-wheelchair	

2.3.4 Other information needed

- Date of injury. The date of injury was found in the file of the subject.
- Spinal cord level of injury. The level of injury was found in the file of the subject.
- Age. There is an age-related increase in body fat mass and decrease in fat-free mass which could affect the weight of a subject.[20] The date of birth was found in the file of the subject.

- Ankle oedema. Hydration status can affect weight. Subjects were assessed for ankle oedema by applying firm pressure over the tibia with the examiner's thumb for a few seconds.[27] This was done while subjects were sitting in their wheel chairs.
- Level of spasticity. The modified Ashworth scale was used to classify spasticity (Appendix 2).[26] This is the most frequently used scale to classify spasticity at Kalafong Hospital. The scale has an inter-rater correlation of 0.847 (Kendall's r correlation).[14] The clinician and the occupational therapist were asked to train the researcher in classifying the degree of spasticity of a subject. It was demonstrated to the researcher how the level of spasticity is evaluated in the following way: The level of spasticity was assessed while the subject was lying in a comfortable supine position. The right knee was bent and extended to evaluate the resistance to combined knee and hip extension.[26] A score was allocated according to the modified Ashworth scale. The spasticity of one subject of each of the six levels of spasticity was evaluated and demonstrated by the occupational therapist. Subjects of the spinal ward of the hospital were chosen for the evaluations. The researcher then had the chance to repeat the evaluation of spasticity on the six subjects to experience how each level of spasticity feels. The demonstrated method was used by the researcher to classify the level of spasticity of the subjects of the study.

All the information mentioned above was listed in the recording form (Appendix 3)

2.3.5 Validation of anthropometric measurements

For each parameter the average of three measurements was taken to ensure accuracy of measurements. The guidelines on how to perform the measurements were carefully followed.[21]

Repeatability was evaluated by calculating the technical error of measurement (TEM).[28] This is the most commonly used measure of imprecision.[28] The TEM was obtained by carrying out two repeat measurements on the same subject and doing this for 10 subjects. The differences between the measurement were calculated and this was used to calculate the square root of measurement error variance.[28] Black, adult male subjects using a wheel chair and who could transfer themselves from the chair to the bed, attending the outpatient clinic, were used for the repeatability study. Only subjects who did not comply with the inclusion and exclusion criteria of the study were used for the repeatability study. All the subjects who complied with the inclusion and exclusion criteria, were used for the actual study due to the limited population size. Examples of subjects who were used for the repeatability study are paraplegics with incomplete lesions or subjects with an injury level of C7. The repeatability study was completed before the research project started (Appendix 3).

2.4 Data analysis

The data was collected from all the subjects. Multiple stepwise linear regression was used to analyse the relationship between weight, as the dependent variable and age, time since injury, level of injury, level of spasticity, supine length, upper-arm length, MUAC, chest circumference, wrist circumference, neck circumference, waist circumference and calf circumference as the independent variables. The level of significance was set at $p < 0.05$ and applied to all tests. Thus if a p-value of less than 0.05 was observed, the corresponding correlation was considered significant.

The software program *Statistica*[29] was used to develop the estimation formula and to evaluate its accuracy. Descriptive statistics were used to describe the characteristics of the population.

The statistical analysis was done by the researcher in consultation with a statistician, appointed by the Faculty of Health Science, University of Stellenbosch.

2.5 Ethics

2.5.1 General

Taking of the measurements held no risk for the patient. No incentives were given to the subjects. This specific population group may not benefit from the research, as they have access to a scale, but other paraplegics from other institutions or hospitals may benefit from the research.

All the costs of the study were covered by the researcher.

2.5.2 Ethics committee

The study protocol was submitted to and approved by the *Committee for Human Research of the Faculty of Health Sciences,* Stellenbosch University.

2.5.3 Informed consent

The aim of the study was explained to each subject as well as which measurements were to be taken and how the measurements were to be taken. The researcher provided each subject with an informed consent form and read through it with the subject. The subjects were required to sign the consent form. An adapted informed consent form of the University of Stellenbosch was used (Appendix 4). All of the subjects could write and were able to sign the document. A translator (the nurse in charge of the clinic) was available to explain the consent form if a subject did not understand Afrikaans or English. All the subjects could understand either Afrikaans or English. The subjects received a copy of the signed consent form.

2.5.4 Patient confidentiality

The information collected, was included in the thesis without disclosing the identity of a person. Each subject received an identification number, which was used in the study material and documentation. Each subject was told that the information collected by the researcher is regarded as confidential. This is also stated in the consent form.

CHAPTER 3

RESULTS

3.1 Repeatability study

A repeatability study was done before the actual study to evaluate the intra-individual technical error of measurement (TEM). Of the 10 subjects that were used for the repeatability study, 5 have had incomplete lesions, 2 subjects had an injury level of C6, 2 an injury level of C7 and 1 subject had had his injury for less than one year. The R value (coefficient of reliability) of the two repeated measurements was calculated and was 1 for measuring the weight of subject-plus-wheelchair and also for the weight of the wheel chair alone (Table 3.1). This indicates that the repeatability of the scale to measure the same weight twice was excellent. The R values for all the other measurements were 0.999 or higher, which is also an excellent correlation.

Table 3.1: Results of the repeatability study

Measurement	Technical error of measurement	Coefficient of reliability (R value)
Weight: subject-plus-chair (kg)	0.012 (kg)	1.000
Weight: chair (kg)	0.002 (kg)	1.000
Upper-arm length (cm)	0.026 (cm)	0.999
Waist circumference (cm)	0.153 (cm)	0.999
Calf circumference (cm)	0.046 (cm)	0.999
Chest circumference (cm)	0.125 (cm)	0.999
Neck circumference (cm)	0.112 (cm)	0.999
Wrist circumference (cm)	0.017 (cm)	0.999
Supine length (cm)	0.121 (cm)	0.999
MUAC (cm)	0.049 (cm)	0.999

3.2 Characteristics of the study population

A total of 43 subjects conformed to the inclusion criteria and were included in the study. The ages of the 43 subjects in the sample ranged from 18 years to 60 years (Figure 3.1). There were 62 black male paraplegics who attended the clinic at the time of the study. Of these, 3 subjects chose not to partake in the study due to other appointments they had previously arranged. There were 4 subjects who had to be excluded from the study due to amputations and 5 subjects who had had their injuries for less than a year. Of the 62 possible subjects, 7 did not keep their appointments at the clinic during the time of research. Due to lack of contact details, these subjects could not be contacted to be reminded to attend the clinic. None of the subjects was excluded from the study due to oedema. None of the subjects had contractions which could have hindered the measuring of one or more of the measurements. Only 3 subjects had to empty their bladders before they could be weighed.

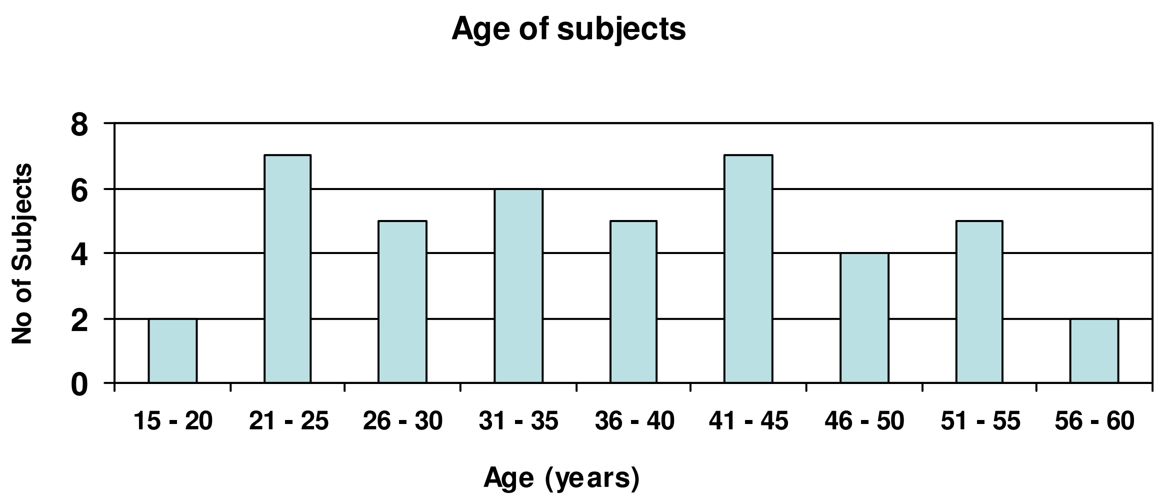

Figure 3.1: Age distribution of the subjects

The subjects had had their SCI for a period ranging from 1 year to 27 years prior to this project. (Figure 3.2).

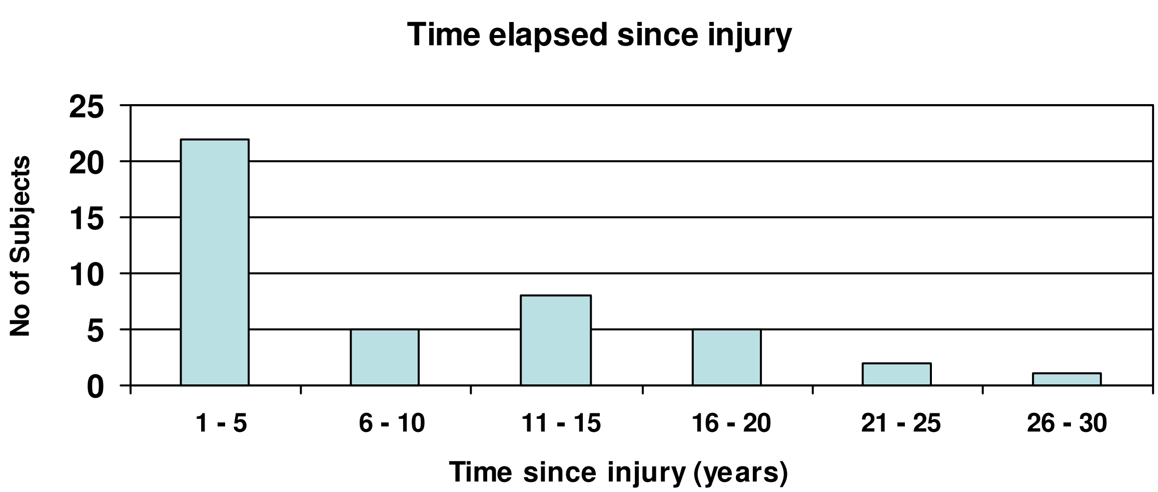

Figure 3.2: Distribution of time elapsed since injury of the subjects

Subjects with an injury level of T2 to L3 were included in the study (Table 3.2). No subjects had an injury level of L3 or T3. The highest number of subjects with the same level of injury was 7, for levels T12 and T4.

Table 3.2: Distribution of level of injury of the subjects

Level of injury	Number of subjects
L3	0
L2	4
L1	3
T12	7
T11	1
T10	1
T9	1
T8	5
T7	3
T6	4
T5	1
T4	7
T3	0
T2	6

Many of the subjects (n = 15, 35%) of this study did not have spasms. Some subjects did have spasms of level 1, level 1+, level 2 and level 3 on the modified Ashworth scale (Figure 3.4).[14]

Table 3.3: Distribution of level of spasticity of the subjects

Level of spasticity	Number of subjects
0	15
1	11
1+	4
2	6
3	7
4	0

The descriptive statistics of the anthropometrical data were calculated (Table 3.4).

Table 3.4: The mean, standard deviation (SD), confidence interval, minimum and maximum values and the median of the anthropometrical variables assessed during the study.

Variables	Mean (SD)	Confidence -95.000%	Confidence +95.000%	Minimum Value	Maximum Value	Median
Weight (kg)	61.5 (15.1)	56.8	66.1	35.0	93.5	59.7
Waist circumference (cm)	79.2 (15.7)	74.4	84.1	58.6	111.3	74.2
Calf circumference (cm)	29.2 (4.4)	27.9	30.6	20.2	37.9	29.5
Chest circumference(cm)	85.5 (9.2)	82.7	88.3	71.7	110.5	82.3
MUAC (cm)	30.2 (4.9)	28.7	31.7	20.6	39.5	30.0
Neck circumference (cm)	37.8 (3.7)	36.7	38.9	31.9	45.3	37.3
Supine length (cm)	170.9 (7.9)	168.5	173.4	146.9	186.4	171.9
Upper-arm length (cm)	32.3 (2.3)	31.6	33.0	26.6	36.9	32.1
Wrist circumference (cm)	16.5 (0.8)	16.2	16.7	15.0	19.0	16.5

3.3 Correlation between different variables and the weight of the subjects

The correlations between the twelve variables, assessed in this study, and the weight of patients, were in the range of 0.89 to a negative correlation of -0.09. Waist circumference had the strongest correlation with weight ($R = 0.89$). Calf-, chest-, arm- and neck circumferences all had a correlation of 0.85 and higher. The level of injury, level of spasticity, time since injury and age did not have a good correlation with weight. The R values of these variables were less than 0.26 (Table 3.3). The following variables were significantly correlated with weight ($p < 0.05$): circumferences of the calf, chest, arm, neck and wrist as well as supine length and upper-arm length.

Table 3.5: The proportion of variation in weight explained and the Pearson correlation coefficients of various variables with weight

Variable	R Square value	Pearson correlation coefficient (R value)	p value
Waist circumference (cm)	0.794	0.89	< 0.0001
Calf circumference (cm)	0.786	0.88	< 0.0001
Chest circumference (cm)	0.756	0.87	< 0.0001
MUAC (cm)	0.748	0.86	< 0.0001
Neck circumference (cm)	0.735	0.85	< 0.0001
Wrist circumference (cm)	0.564	0.75	< 0.0001
Supine length (cm)	0.314	0.56	< 0.0001
Upper-arm length (cm)	0.140	0.37	0.0135
Age (years)	0.069	0.26	0.0879
Level of injury	0.066	-0.25	0.0953
Time since injury (years)	0.012	0.10	0.4927
Level of spasticity	0.009	-0.09	0.5493

The scatter plots demonstrate the correlation between weight and the four variables with the highest correlation with weight (Figures 3.3 -- 3.6). A linear correlation can be seen between body weight and circumferences of the waist, calf, chest and arm.

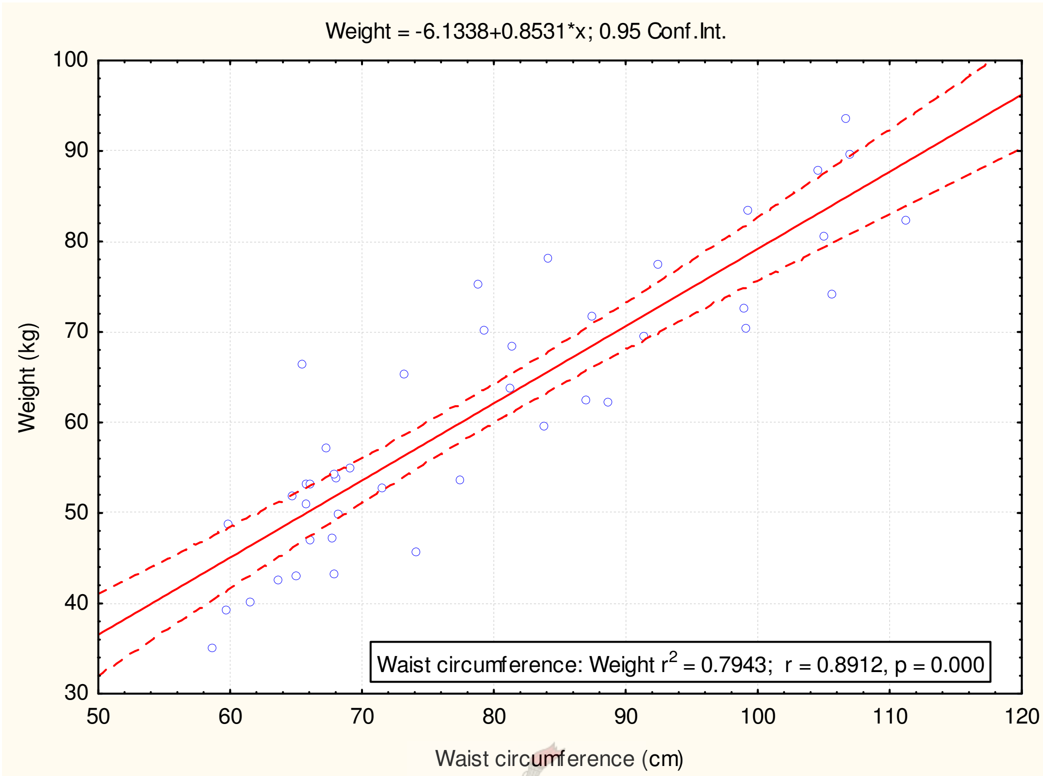

Figure 3.3: The regression relation between weight and waist circumference

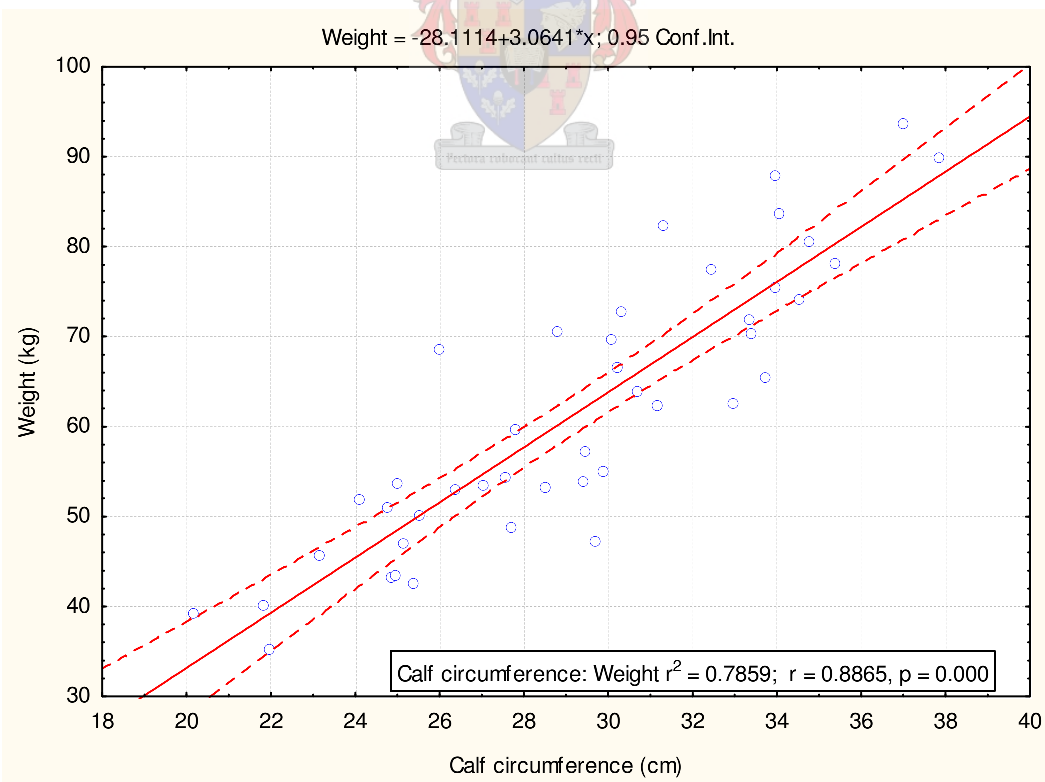

Figure 3.4: The regression relation between weight and calf circumference

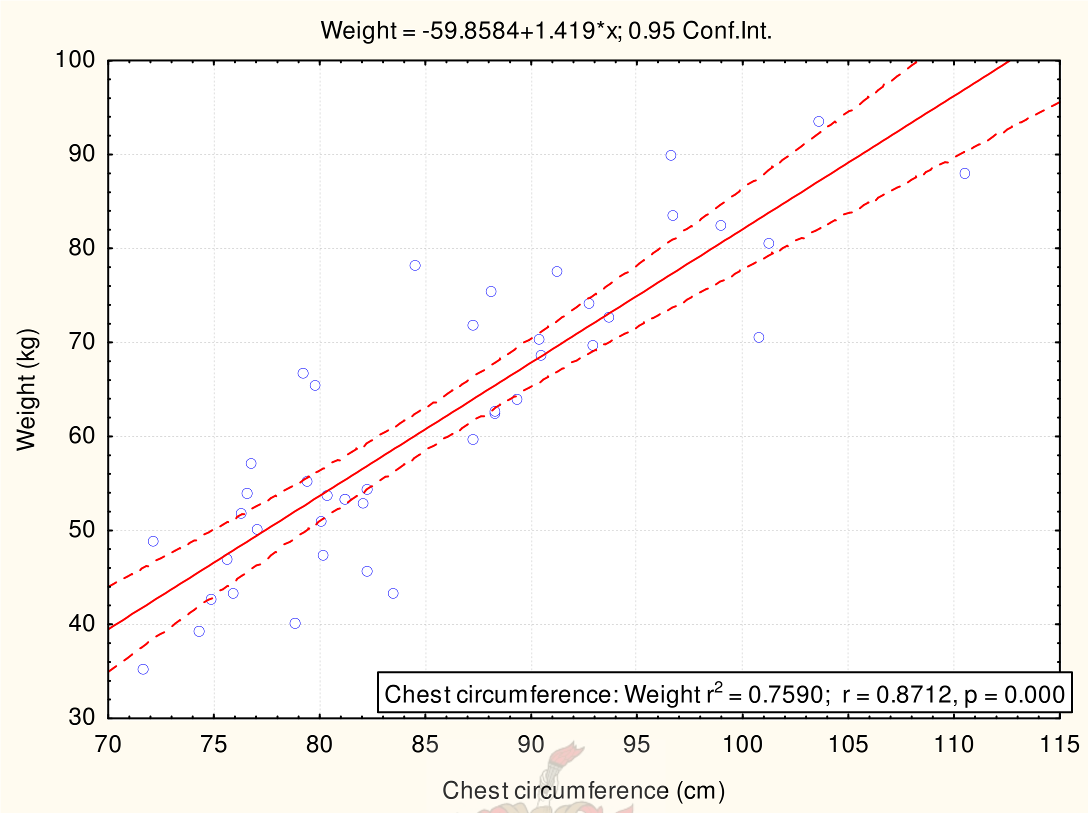

Figure 3.5: The regression relation between weight and chest circumference

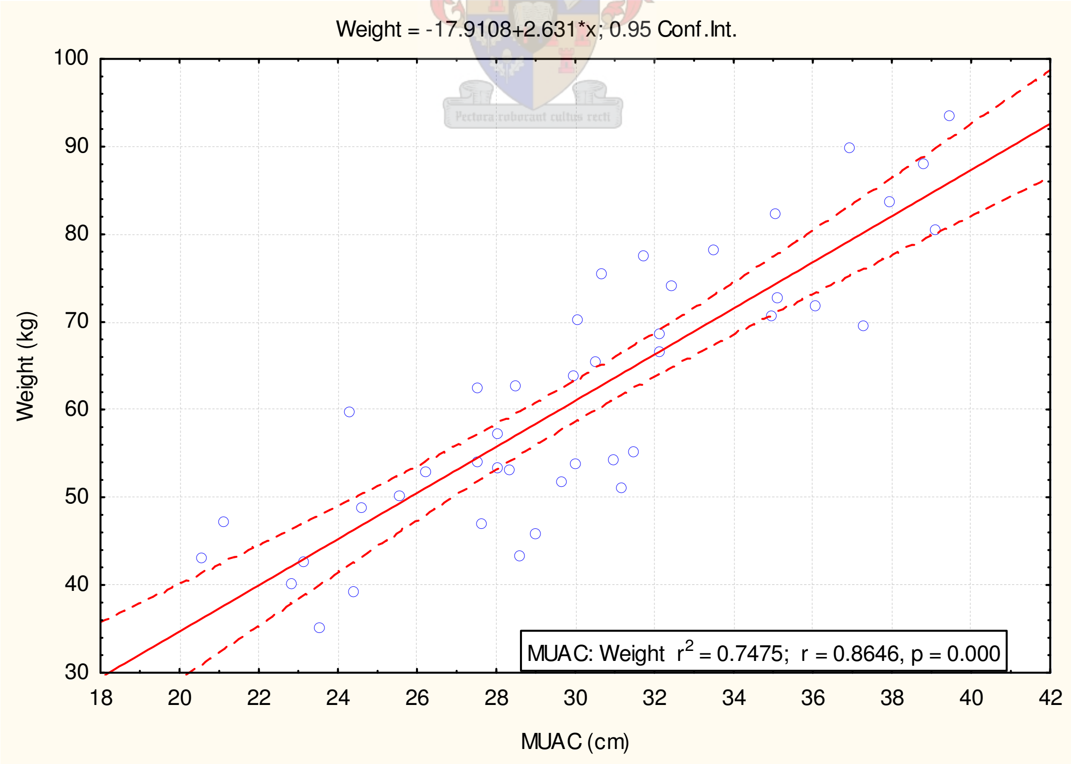

Figure 3.6: The regression relation between weight and MUAC

3.4 Data analysis

The factors discussed below were considered when choosing the ideal regression equation to estimate weight:

3.4.1 Practicability

The more variables there are in a regression equation, the more complex the equation and the more impractical to use. It is also time consuming to carry out all the measurements and to collect the data. The equation should be chosen with the least number of variables but at the same time showing acceptable accuracy.

3.4.2 Strength of relationship

The strength of the relationship between the equation as a whole and the actual weight of the subjects was evaluated by the R square value. The closer to one, the more the variation of weight was explained by the equation. The R square value of the regression equation, using all twelve variables, was 0.977, which is a fairly good value. If only one variable was to be used to develop a regression equation, the equation using waist circumference had the best R square value, which was 0.794. For each equation with a different number of variables (from 1 to 12), there was a different R square value (Table 3.6). Note that for the number of variables being used in an equation for example five variables, there were many different combinations of five variables that could be combined in one equation. Only the equation with five variables, with the best R square value was used in the table. The R square values of all the other options of combinations of five variables were less than the one mentioned in Table 3.6.

Table 3.6: Statistical analysis of regression equations, using different numbers of variables in each equation

Number of variables per equation	Which variables were used	R square value	Adjusted R square value*	Difference between R square and adjusted R square value	Standard error of estimate (kg)
1	Waist Circumference	0.794	0.789	0.005	6.91
2	Circumferences (Calf, Chest)	0.916	0.912	0.004	4.46
3	Circumferences (Calf, Chest), Supine length	0.954	0.950	0.004	3.35
4	Circumferences (Calf, Chest, Neck), Supine length	0.965	0.961	0.004	2.97
5	Circumferences (Waist, Calf, Chest, Upper-arm) Supine length	0.968	0.964	0.004	2.84
6	Circumferences (Waist, Calf, Chest, Upper-arm) Supine length, Upper-arm length,	0.972	0.967	0.005	2.72
7	Circumferences (Waist, Calf, Chest, Upper-arm). Supine length, Age, Level of injury	0.975	0.970	0.005	2.61
8	Circumferences (Waist, Calf, Chest, Upper-arm, Wrist), Supine length, Age, Level of injury	0.977	0.971	0.006	2.56
9	Circumferences (Waist, Calf, Chest, Wrist, Upper-arm), Supine length, Age, Level of injury, Time since injury	0.977	0.971	0.006	2.56
10	Circumferences (Waist, Calf, Chest, Neck, Wrist, Upper-arm), Supine length, Age, Level of injury, Time since injury	0.977	0.970	0.007	2.60
11	Circumferences (Waist, Calf, Chest, Neck, Upper-arm, Wrist),Supine length, Age, Upper-arm length, Level of injury, Time since injury	0.977	0.969	0.008	2.64
12	Circumferences (Waist, Calf, Chest, Neck, Upper-arm, Wrist), Supine length Age, Upper-arm length, Level of injury, Time since injury, Level of spasticity	0.977	0.968	0.009	2.68

*This value was adjusted for the number of variables

From Table 3.6 it is clear that the strength of the relationship between the estimated and the actual weight of the subject did not improve by using an equation with more than 8 variables in the equation. The increase in the R square value from using an equation with 4 variables to using an equation with 8 variables, was 0.012, which was not a meaningful improvement in the strength of relationship. The increase in R square value from using an equation with only 1 variable to an equation with 3 variables was 0.160. If the strength of relationship was taken into account, a regression equation with between 4 to 8 variables would be appropriate to estimate weight in this population group.

3.4.3 Adjusted R square value

Another criterion that needs to be considered, when choosing the number of variables in a regression equation, is adjusted R square. The adjusted R square value takes into account how much of the variation in weight is explained through the equation, but it adjusts this for the number of variables used. As the number of variables in the equation increases, the gap between R square and adjusted R square value will also increase. This is another reason why the equation with all 12 variables was not necessarily the better equation to use even if it had the highest R square value. The differences in R square and adjusted R square values started to increase for equations with 8 or more variables (Table 3.6). If adjusted R square values were taken into account, it would be a better option to use an equation with 7 or less variables in the equation.

3.4.4 Standard error of estimate

The standard error of estimate is a measure of the accuracy of estimations made with a regression equation (Table 3.6). The clinical significance of the error should be weighed against the effort to carry out more measurements and the risk to measure incorrectly.

The standard error of estimate decreased from 6.91 kg, using an equation with 1 variable, to 2.97 kg, using an equation with 4 variables. The standard error of the one-variable equation was 2.3 times that of the four-variable equation. The ratio of error of estimate between the four-variable equation and the twelve-variable equation was only 1.1. If the clinical significance of the standard error of estimate was taken into account, an equation with 4 variables gave a result with a fairly acceptable standard error of estimate.

3.4.5 The equation chosen as the most suitable to estimate weight

If the strength of relationship between the estimated and actual weight of the regression equations were considered, based on the adjusted R square value, the standard error of estimate and the practicability of the equation, the equation using 4 variables, was considered the best and most practical equation to use for this study. This equation involved the following variables: calf circumference, chest circumference, neck circumference and supine length. The coefficients of the respective variables as well as the intercept (-129.914) as they appear in the regression equation are given in Table 3.7.

Table 3.7: The intercept and coefficients of the variables of the four-variable equation

	Variable number	Coefficient
Intercept		– 129.914
Neck circumference (cm)	X_1	0.803
Chest circumference (cm)	X_2	0.651
Calf circumference (cm)	X_3	1.284
Supine length (cm)	X_4	0.397

The regression equation is as follows:

$$Y = WEIGHT = - 129.914 + 0.803\ X_1 + 0.651\ X_2 + 1.284\ X_3 + 0.397\ X_4$$

The F-value is the test for significance of the regression coefficients used in the equation. In this case the F-value is 260.86. For a p-value of 0.005 the F-value is 4.53. Thus for an F-value of 260.86 the p-value would be much smaller ($p < 0.0001$) which indicates a high level of significance.

The Mallows Cp criterion gives an indication of how small the bias of the chosen equation is.[30] A value close to p+1 indicates that the equation bias is small (p is the number of variables in the equation). Values near or below p+1 are generally desirable. In this case a value of 5 or less would be desirable.[30] The Mallow CP criterion for this four-variable equation is 5.000, which indicates that the equation has a very small level of bias.

3.4.6 Actual weight versus estimated weight

The four-variable equation was used to calculate the estimated weights of the subjects in this study which were then compared to their actual weights (Figure 3.9). The line, indicated on the graph is where estimated weight equals actual weight (x = y). The closer to the line the points are, the more accurate the weight was estimated.

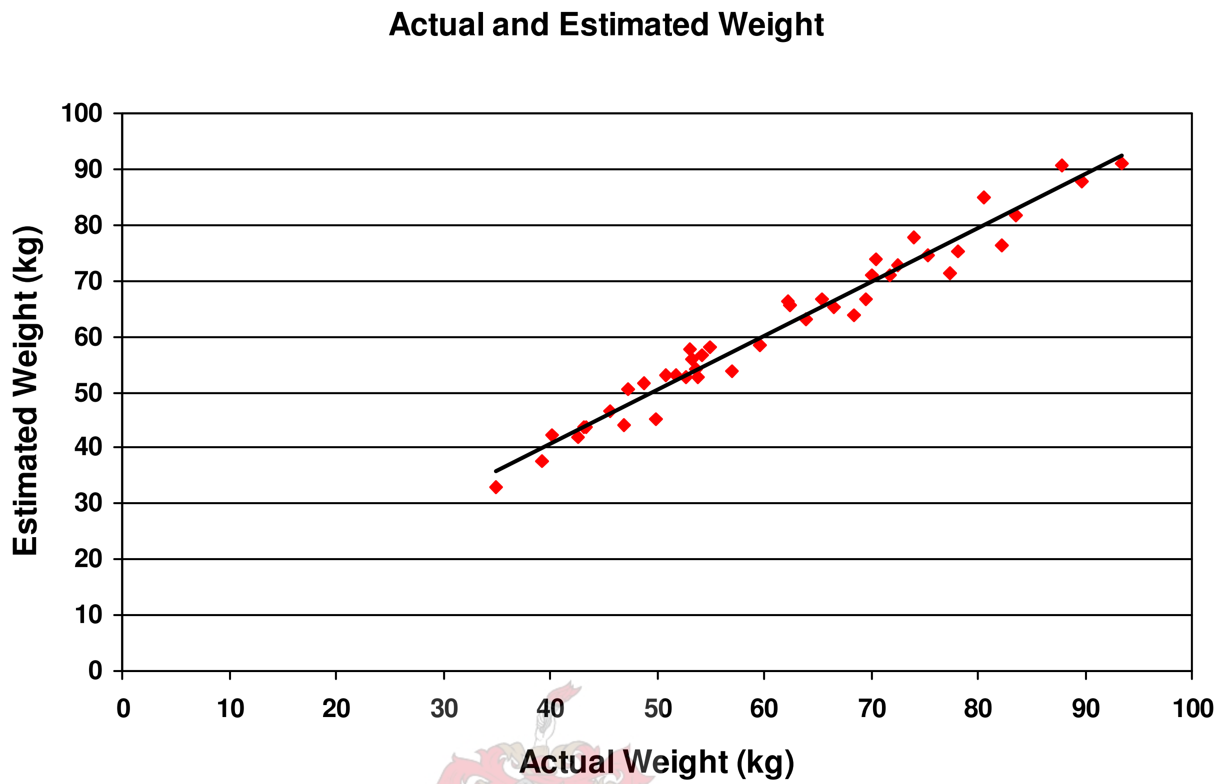

Figure 3.7: The comparison between the estimated weight and the actual weight of the subjects of the study

3.4.7 Accuracy of the estimate

By calculating the 90% estimation limit of an equation, subjects who fall outside this interval can be identified and regarded as exceptional. When the 90% estimation limit was applied in this sample, 5 subjects fell outside of this interval. These 5 subjects had the biggest differences between their actual weight and estimated weight (Table 3.8). The biggest difference between actual weight and estimated weight was 6.04 kg, seen in subject 38.

Table 3.8: Subjects with highest variance between actual and estimated weight

Subject number	Actual weight (kg)	Estimated weight (kg)	Difference between actual and estimated weight (kg)
15	82.3	76.3	-5.97
21	53.1	57.74	4.61
24	68.5	63.68	-4.81
38	77.4	71.36	-6.04
40	49.96	45.29	-4.67

CHAPTER 4

DISCUSSION

4.1 Introduction

A regression equation with a high degree of predictability has been formulated to be used in black male paraplegics. Such an estimate has not been established before for South African black paraplegic subjects and will be useful for the nutritional support of such persons. This equation obviates the use of specialised equipment which may not be available in the health care setting in the developing world and it is the first time such an equation has been developed and proposed to be used for the benefit of male black South African paraplegics.

4.2 The characteristics of a good estimation equation

According to Heyward and Stolaczyk, good estimation equations have several characteristics[21]:

- Use of acceptable reference methods to obtain criterion measures of body composition
- Use of large randomly selected samples (n > 100)
- High multiple correlation between the reference measure and estimated scores (R > 0.80)
- Small prediction of standard error of estimate
- Cross-validation of the equation on additional, independent samples from the population

In this study acceptable reference methods were used to obtain the actual weight of the subjects. The regression relation between actual and estimated weight was higher than 0.80.

The standard error of estimate was small (2.97 kg). The equation has two limitations: the sample size was far less than 100 and the equation was not cross-validated in an independent sample of the population. This is an area for future studies.

4.3 The consequences of incorrect weight estimation

The aim of weight estimation is to assess and monitor nutritional status. If weight is incorrectly estimated, invalid conclusions will be drawn from the assessment. The BMI of subject 38 (Table 3.8), using his actual weight, was 24.6 opposed to a BMI of 24.0 when the estimated weight was used to calculate BMI. The difference of 6.04 kg made a difference of 0.6 when the BMI was calculated. Subjects could be misclassified as having a normal weight, when they are actually under- or over-weight. A difference in BMI of 0.6 is clinically not that significant and the option to estimate weight is still better than not having any idea of the subject's weight in the absence of a wheel chair scale. Using the estimated weight in stead of actual weight should not impair the planning and implementation of nutritional support.

4.4 Factors that affect the equation adversely

One variable that was not included in the equation was the level of spasticity. Lean mass is better maintained in subjects with spasticity when compared to flaccid subjects.[20] This could partly explain why the estimated weights of some of the subjects with spasms were less than their actual weight.

The level of injury was also not taken into account when estimating the weight of the subjects. The lesion of the spinal cord leads to denervation of the muscles below the lesion. The higher the lesion, the more muscle wasting there is.[3] The latter could partly explain why the weight of some of the subjects with lower lesions were under-estimated.

When the length (cm) of a subject is divided by his wrist circumference (cm), it gives an indication of the bone structure of the patient.[17] It could be possible that the weight of a subject with a heavy bone structure could be under-estimated because wrist circumference was not included in the equation.

Aging is marked by a 2% to 3% loss of lean body mass per decade.[7] The loss of lean mass due to aging could lead to an over-estimation of weight in older subjects, as age was not one of the variables of the equation.

Time since injury was not included in the equation. Although most of the changes in body composition occur during the first year after injury, the changes follow a log curve which levels off between one to three years after injury.[25] It could be expected that subjects with a recent injury (less than 3 years ago) may have more bone and muscle mass than subjects who carried their injury for a longer period and that the equation would under-estimate their weight.

The hydration status of the subjects could have affected their weight. Dehydration could have lead to under-estimation of weight. Subjects were assessed for oedema but skin turgor was not assessed for dehydration.[17]

4.5 Advantages an disadvantages of the four-variable equation

The simplicity of taking the 4 measurements to estimate weight is a definite advantage. Only a tape measure is needed to carry out the measurements. Neck, chest and calf circumference can be taken while the subject is seated in the wheel chair. The subject will however have to transfer himself to a bed to measure supine length.

The level of spasticity was not included in the equation and no clinician or other therapist was needed to classify the subject according to the modified Ashworth scale. Neither was the level of injury included in the equation. If a paraplegic person does not know his level of injury, or his file cannot be found, it is still possible to estimate the weight of the person. Even if the person does not know his age or for how long he has been a paraplegic, the equation can still be used to estimate weight. The person estimating the weight can collect all the information needed to use the regression equation.

No obvious disadvantages can be linked to the utilisation of the proposed regression equation.

4.6 Involvement of the subjects in their nutritional status

None of the 43 subjects involved in this study had an idea what their weight was. In general, the subjects wanted to know what their weights were and whether they were well nourished. Many of the subjects who were under- or over-weight requested dietary advice. During the study period some subjects returned to the clinic and were eager to weigh themselves again to determine whether their nutritional status has improved. This gives an indication of the need for anthropometrical assessment of paraplegic people and their eagerness to know and improve their nutritional status.

4.7 Limitations of the study

Factors which could have had an influence on the weight of the subjects and which were not taken into account in this study, are weight of the trousers of a subject, dehydration and the presence of possible faecal mass.[17] Due to logistical problems subjects could not be weighed just after they have had evacuated. The subjects only attended the spinal clinic on Tuesday mornings and they followed a bowel regimen on Mondays, Wednesdays and Fridays. A bowel regimen refers to the regimen which is followed to empty the bowel of faecal mass and takes place during the mornings of these three days. At Kalafong Hospital patients are taught to take Depuran capsules the night before, and a Dulcolex suppository is inserted in the morning so that the bowel can be evacuated.

Physical exercise was also not taken into account in this study. Physical exercise increases muscle mass and LBM is denser than the same volume of fat mass.[4] Subjects who exercise and have stronger upper bodies might have their weight under-estimated if the equation was used.

The level of spasticity was evaluated by the researcher who did receive adequate, but not formal, training to do the assessment. The assessment of this variable by a clinician or occupational therapist could yield different results and a possible better regression relation between weight and level of spasticity.

Supine length was measured in this study in-stead of height due to the inability of the subjects to stand. When the ideal body weight of an adult is calculated, height and not length is used to do the calculations.[17] In a study by Gray, there was a significant difference of 2% between standing height and supine length.[31] In that study the supine length of the subjects were on average 3.68 cm longer than their standing height.[31] The compression of the spinal vertebrae in the standing position is the reason for the difference between the two measurements.[29] This small but systematic error may result in the misinterpretation of the nutritional status of an individual.

The study was only done on adult black male South African paraplegics. Other age groups, ethnic groups, nationalities, women and quadriplegics have the same need for regression equations such as the ones developed for the population represented in this study.[12,13,18,24] The results of this study can only be used to estimate weight in populations with the same characteristics as in this study. The study was done on outpatients of a hospital. It is unknown whether the regression equation will yield the same results if paraplegic athletes for instance were used to develop the equation, since such subjects have a much more developed upper body musculature which might influence the correlation between different measurements and weight.

The statistical analysis indicated that the developed equation has a high level of significance. The small sample size of 43 still remains a concern

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Standards have been set for ideal body weight for able-bodied persons in the form of body mass index.[4,11] The ideal body weight of a paraplegic person is 4.5 kg to 6.5 kg below the ideal body weight of an able-bodied person of the same height due to disuse atrophy.[9] The standards that exist for ideal body weight of paraplegic people is of little value if their weight can not be accurately determined. Due to the lack of availability of suitable equipment to determine the weight of paraplegic persons, the study was embarked upon to obtain an alternative way to estimate the weight of these subjects.

Regression analysis is a widely used method to estimate the value of a dependent variable from various independent variables.[11,12,20,23] Regression analysis has often been used to estimate a measurement where it is not possible to take the measurement directly. Regression equations have been developed to estimate various measurements of paraplegic persons, due to their inability to stand or walk.[11,23,32,33] There is however limited data available on the anthropometry of paraplegic persons and, as far as could be determined, no other studies have attempted to develop a regression equation to estimate weight of paraplegics.

The question was asked whether a suitable regression equation could be developed to estimate weight of male, black South African paraplegics. The data of the 43 subjects included in the study, indicated that certain variables had a very good correlation with weight and that a statistically significant regression equation was definitely possible. The development of the four-variable regression equation of this study added to the limited body of knowledge on the anthropometry of paraplegic people.

It can be concluded that the chosen four-variable regression equation can be implemented in institutions to estimate the weight of a paraplegic person with the same characteristics as the sample in this study.

5.2 Recommendations

It is recommended that the results of this study should only be used to estimate the weight of subjects with the same characteristics as the sample of the study. Measurements should be taken as prescribed in the study. The accuracy of any regression equation depends on the accuracy with which the measurements are carried out.

Further studies are needed to explore the relationship between anthropometrical measurements and the weight of SCI persons. Studies should be done on quadriplegic persons, women, people of other races and ages and sub-populations such as paraplegic athletes. A multi-center approach with a large sample size will certainly add value to the results of this study.

Waist circumference had the strongest correlation with weight in this study. It would be interesting to know whether the same cut-off points for waist circumference for paraplegics could be used as indicators for risk for cardiovascular diseases such as the ones applied for able-bodied persons.[25] Further research on anthropometry and lifestyle diseases could also give more insight into what the ideal body mass index for this population group is.[6] Body circumferences and diameters have been used to assess body composition in able-bodied people.[21] No estimation equations have yet been developed to estimate body composition of paraplegics. This could be another interesting area of research.

REFERENCES

1. Seielis A. Incidence and causes of spinal cord injury. Spinal cord injury information. [Online] Available: http://www.qasa.co.za/info.htm. 2002. Accessed: 18 June 2005.

2. Jones LM, Goulding A and Gerrard DF. DEXA: A practical and accurate tool to demonstrate total and regional bone loss, lean tissue loss and fat mass gain in paraplegia. Spinal Cord 1998; 36: 637 -- 640

3. Maynhard FM, Bracken MB, Creasy G, Ditunno JF, Donovan WH, Ducker TW, Garber SL, Marino RJ, Stover SL, Tator CH, Waters RL, Wilberger JE, Young W. International standards for neurological and functional classification of spinal cord injury. Spinal Cord 1997; 35: 266 -- 274

4. Hammond KA. Dietary and clinical examination. In: Mahan K, Escott-Stump S, eds. *Food, nutrition and diet therapy.* 11*th ed.* Washington: Saunders, 2004: 421 -— 427, 580 -- 581

5. Kocina P. Body composition of spinal cord injured adults. Sports Medicine 1997; 23 (1): 48 -— 60

6. Jones LM, Legge M Goulding A. Healthy body mass index values often underestimate body fat in men with spinal cord injury. Arch Phys Med Rehabil 2003; 84: 1068 -— 1070

7. Buchholz AC, McGillivray CF, Pencharz PB. The use of bioelectrical impedance analysis to measure fluid compartments in subjects with chronic paraplegia. Arch Phys Med Rehabil 2003; 84: 854 -— 860

8. Breslow RA, Bergstorm N. Nutritional prediction of pressure ulcers. J Am Diet Assoc 1994; 94: 1301 -— 1304

9. Rodwell WS. The physically disabled. In: Thomas B, eds. *Manual of dietetic practice.* 2nd ed. London: Blackwell Scientific Publishers, 1988: 318 — 320

10. Pi-Sunyer FX. Medical hazards of obesity. Ann Intern Med 1993; 119: 655 -- 662

11. Lee RD, Nieman DC. Anthropometry. In: *Nutritional assessment*. 3rd ed. London: McGraw Hill, 2003:164 --165, 182 -– 183, 223 -- 225

12. Chumlea CWM, Guo SS, Steinbaugh MI. Prediction of stature from knee height for black and white adults and children with application to mobility-impaired or handicapped persons. J Am Diet Assoc 1994; 94: 1385 -– 1388, 1391

13. Nuhlick RDN, Spurr GB, Barboriak JJ, Booney CB, Elghatit AZ, Bongard RD. Body composition of patients with spinal cord injury. Eur J Clin Nutr 1988; 42: 765 -– 773

14. Mathiowetz H, Haugen JB. Evaluation of motor behaviour: traditional and contemporary views. In: Trombly CA, eds. *Occupational therapy for physical dysfunction*. 4th ed. Baltimore: Williams & Wilkins, 1995: 167 -– 170

15. Wilmet E, Ismail AA, Heilporn A, Welreads D, Bergmann P. Longitudinal study of bone mineral content and soft tissue composition after spinal cord section. Paraplegia 1995; 33: 674 –- 677

16. Szollar SM, Martin EME, Parthemore JG, Sartoris DJ, Deftos LJ. Demineralization in tetraplegic and paraplegic man over time. Spinal Cord 1997; 35: 223 -– 228

17. Frey- Rindova P, De Bruin ED, Stussi E, Dambacher MA, Dietz V. Bone mineral density in upper and lower extremities during 12 months after spinal cord injury measured by peripheral quantitative computed tomography. Spinal Cord 2000; 38: 26 -- 32

18. Tsuzuku S, Ikegami Y, Yabe K. Bone mineral density differences between paraplegic and quadriplegic patients: a cross-sectional study. Spinal Cord 1999; 37: 358 -– 361

19. Zehner Y, Luthi M, Michel D, Knecht H, Perellet R, Neto I, Kraenzlin M, Zach G, Lippuner K. Long-term changes in bone metabolism, bone mineral density, quantitative ultrasound parameters, and fracture incidence after spinal cord injury. Osteoporosis Int 2004; 15(3): 180 -– 189

20. Deurenberg P, Westrate JA, Seiden JC. Body mass index as a measure of body fatness: age- and sex- specific prediction equation formulas. Br J Nutr 1991; 65: 105 — 114

21. Heyward VH. Practical body composition assessment for children, adults, and older adults. Int J Sport Nutr 1998; 8: 285 -— 307

22. Skipper, A. *Anthropometric data in nutrition support, policies, procedures, forms and formulas.* Maryland: Aspen publishers, 1995: 47 -- 87

23. Jarzem PF, Gledhill RB. Predicting height from arm measurements. J Peadiatr Orthop 1993; 13(6): 761 -- 765

24. Ross WD, Marfell-Jones MT. Kinanthropometry. In: MacDougall JD, Wenger HA, Green HJ,eds*. Physiological testing of the high-performance athlete.* 2nd ed. Champaign: Illionois, 1991: 223 -- 308

25. Lean MEJ, Han TS, Morrison CE. Waist circumference as a measure for indicating need for weight management. Br Med J 1995; 311: 158 -— 161

26 Priebe MM, Sherwood AM, Thornby JI, Kharas NF, Markowski J. Clinical assessment of spasticity in spinal cord injury: a multidimentional problem. Arch Phys Med Rehab 1996; 77: 713 -- 716

27. Anderson EDC, Campbell IW, Hunter JAA. General examination and the external features of disease. In: Muno JF, Campbell IW, eds. *Macleod's clinical examination.* 10th ed. Churchill Livingston, Philadelphia, 2000: 23 -- 70

28. Ulijaszek SJ, Kerr DA. Anthropometric measurement error and the assessment of nutritional status. Br J Nutr 1999; 82: 165 -- 177

29. Statsoft Inc. (2004), *STATISTICA* data analysis software system, version 7. www.statsoft.com

30. Neter J, Kutner MH, Nachtsheim CJ, Wasserman W, eds. *Applied linear models*. 4th ed. Irwin, Chicacgo, 1996: 341 -- 345

31. Gray DS, Crider JB, Kelley C, Dickinson L C. Accuracy of recumbent height measurement. J Parenter Ent Nutr 1985; 9: 712 -– 715

32. Chen C, Yeung K, Bih L, Wang C, Chen M, Chien J. The relationship between sitting stability and functional performance in patients with paraplegia. Arch Phys Med Rehabil 2003; 84: 1276 -- 1281

33. Vinet A, Le Gallias D, Bouges S, Bernard P-L, Varray A, Micallef J-P. Prediction of VO2 peak in wheelchair-dependent athletes from the adapted Leger and Boucher test. Spinal Cord 2002; 40: 507 -– 512

APPENDICES

Appendix 1

From: MARCELLINE SIMONOTTI [simonoti@mweb.co.za]
Sent: 06 07 2004 08:22
To: Hildegard Snyman
Subject: Re: Calibration of scale
Dear Hildegard,

Your scale should not be affected by moving it to a new position as long as the floor is flat and level. If the scale is moved around carefully there should be no problems with moving it. We recomend that the scale should be calibrated every year if it is used a lot and in adverse conditions.
Regards Trevor Holroyd Chief technician
----- Original Message -----
From: Hildegard Snyman
To: scales2000@mweb.co.za
Sent: Monday, July 05, 2004 7:59 PM
Subject: Calibration of scale

Marcelline

I am a dietician, working at Kalafong Hospital. We bought an electronic digital wheelchair platform scale from you in 2003. I have been using the scale in our spinal unit with great success. I am planning to do a research project on the body composition of people with paraplegia. I am going to use your scale to weigh the patients. I have a few questions on the calibration of the scale and would appreciate it if you could answer them for me:

- The scale was placed on one spot and never moved after that. Does it need calibration before my study (hopefully starting in September) ?
- The clinic where the patients come for follow up is at a different place than where the scale is standing at the moment. Can I move the scale or would it need recalibration after every time I move it?
- How would it affect the calibration of the scale if I move it once a week to the clinic and then back to the ward again?

I would appreciate it if you could answer my questions in writing so that I can attach it to my protocol.
Thank you so much

Regards

Hildegard Snyman

Appendix 2

The modified Ashworth scale

Subjects were graded as follow:

0 If there is no increase in muscle tone.

1 If there is a slight increase in muscle tone, manifested by minimal resistance at the end of the range of motion (ROM) when the affected part(s) is moved in flexion or extension.

1+ If there is a slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM.

2 If there is a more marked increase in muscle tone through most of the ROM, but affected part(s) is easily moved.

3 If there is a considerable increase in muscle tone and passive movement is difficult.

4 If the effected part(s) is rigid in flexion or extension.[8]

Appendix 3

DATA RECORDING FORM

DATA RECORDING FORM NUMBER: 0001

KALAFONG HOSPITAL (GAUTENG NORTH)

ANTHROPOMETRIC STUDY

Date: Day / Month / Year

Patient name: ______________________________

Hospital number : ____________

Date of birth : Day / Month / Year

Age at time of investigation : ________ yrs ________ mnths

Date of injury : Day / Month / Year

Time elapsed from date of injury to date of investigation: ________ yrs ________ mnths

Level of injury: ______________________

Level of spasticity:

0	1	1+	2	3	4

ANTHROPOMETRY

	Site of measurement	Measurement 1	Measurement 2	Measurement 3
1	Weight: subject plus wheelchair	kg	kg	kg
2	Weight: wheelchair	kg	kg	kg
3	1 minus 2	kg	kg	kg
4	Upper arm length	cm	cm	cm
5	Wrist circumference	cm	cm	cm
6	Calf circumference	cm	cm	cm
7	Chest circumference	cm	cm	cm
8	Neck circumference	cm	cm	cm
9	Waist circumference	cm	cm	cm
10	Supine length	cm	cm	cm
11	Arm circumference	cm	cm	cm

Recorded by: ____________________

Appendix 4

Repeatability study

Subject no	Weight Subject + w/chair		Upper arm length		Waist circumference		Calf circumference		Chest circumference		Neck circumference		Wrist circumference		Weight Wheelchair		Supine length		Arm circumference	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

Appendix 5

INFORMATION AND INFORMED CONSENT DOCUMENT

TITLE OF THE RESEARCH PROJECT: Development of a regression equation for estimating the weight in black South African adults with chronic paraplegia using anthropometric measurements

REFERENCE NUMBER: …………………………………………….…………………….

PRINCIPAL INVESTIGATOR: Hildegard Snyman

Address: Kalafong Hospital
Attridgeville
Gauteng

DECLARATION BY OR ON BEHALF OF PATIENT/*PARTICIPANT:

I, the undersigned, ………………………………………………………………….. *(name)*

[ID No: …………………..…………] the participant

of……………………………………………………………………………………………………..

……………………………………..………………………….……………………..…………*(address)*.

A. HEREBY CONFIRM AS FOLLOWS:

1. I (the participant) was invited to participate in the abovementioned research project which is being undertaken by the Department of Nutrition, Faculty of Health Sciences, Stellenbosch University.
2. The following aspects have been explained to me (the participant):
   - 2.1 **Aim:** To develop a tool (a formula) that can be used to estimate weight in people with paraplegia where there is no scale available
   - 2.2 **Procedures:** Every paraplegic patient attending the spinal clinic will be measured once at the date he comes for follow up. Measurements will include weight, arm length, arm circumference, chest, neck, wrist, waist and calf circumference and supine length.
   - 2.3 **Possible benefits:** The research will be used to the benefit of other paraplegics who do not have access to a scale.
   - 2.4 **Confidentiality:** The information collected, will be treated as confidential. When it is published, the names of the subjects will not be disclosed.
   - 2.5 **Access to findings:** The measurement values will be disclosed to the patient if he requests such information.

2.6 **Voluntary participation/refusal/discontinuation:** Participation is voluntary and if the subject does not want to be measured he is welcome to refuse to participate.

3. The information above was explained to me (the participant) by Hildegard Snyman in Afrikaans / English ……….…………………………… and I am in command of this language / it was satisfactorily translated to me by ………………………………… *(name of translator).* I was given the opportunity to ask questions and all these questions were answered satisfactorily.
4. No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without any penalisation.
5. Participation in this study will not result in any additional costs to my self.

HEREBY CONSENT VOLUNTARILY TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT THAT THE POTENTIAL PARTICIPANT MAY PARTICIPATE IN THE ABOVEMENTIONED STUDY.

Signed/confirmed at Kalafong Hospital on …………….……………20 …...
(date)

……………………………………………………… ……………………………….............
Signature or right thumb print of participant *Signature of witness*

STATEMENT BY THE INVESTIGATOR:

I, ………………………………………………………………….……………………, declare that

- I explained the information given in this document to …………………………………….
  (name of participant)
- He was encouraged and given ample time to ask me any questions;
- This conversation was conducted in Afrikaans / English and no translator was used OR this conversation was translated into ……………………..*(language)* by …………...…………………………...…………………………………… *(name).*

Signed at Kalafong Hospital on …………………….………...20 ….
(date)

……………………………………………………… …………………………………………..
Signature of investigator *Signature of witness*

DECLARATION BY TRANSLATOR:

I, ……………………………………..…..……………………………………*(name)*, confirm that I

- translated the contents of this document from English into ……………………..(*indicate the relevant language)* to the participant;
- explained the contents of this document to the participant
- also translated the questions posed by ….………………….………………*(name),* as well as the answers given by the investigator; and
- conveyed a factually correct version of what was related to me
- Signed at Kalafong Hospital on ………………………………..20……
(date)

……………………………………………………… ……………………………………………..

Signature of translator *Signature of witness*