Anaesthetists' accuracy of weight and height estimations in supine adults

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Declaration

I, Shirley Sejabaledi Delina Molepo declare that this research report is my own unaided work. It is being submitted for the degree of Master of Medicine in the branch of Anaesthesiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any University.

Signature of candidate

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Abstract

Weight and height estimations have been shown to be inaccurate in clinical practice. Measuring weight and height pre-operatively may pose a challenge and without measurements, anaesthetists make visual estimations without confirmation. The aim of this study was to describe anaesthetists' accuracy of weight and height estimations in supine adults in the Department of Anaesthesiology at the University of the Witwatersrand.

This was a prospective, contextual, descriptive study with six volunteers representing the general population. Sixty-eight consenting anaesthetists were included in the study and data were collected at the two study hospitals. Comparisons were made using Chi^2 and one sample t-tests.

A total of 408 weight and 408 height estimations were made. Estimations of weight within 10% and height within 5% of the actual values were considered accurate. The overall participants' accuracy for weight estimation was 40% and 67.6% for height. Weight was overestimated for volunteers with a higher Body Mass Index (BMI) and underestimated for those with lower to normal BMIs. Height was consistently overestimated in shorter and underestimated in taller volunteers. Participants with less than 10 years of clinical experience gave better weight and height estimations than their seniors. There was no association between volunteers and participants' gender on weight and height estimation.

Overall weight and height estimation accuracy was low with height more accurately estimated than weight. Given their extensive application in medicine, actual measurements should be preferred over estimations.

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Abbreviations

BMI	Body Mass Index
cm	Centimetre
ED	Emergency Department
ETT	Endotracheal Tube
ICU	Intensive Care Unit
kg	Kilogram
LH	Legs and head weight
MAC	Mid-arm circumference
PBW	Predicted body weight
Wits	University of the Witwatersrand

SECTION 1: Literature review

1.1 Introduction

This section gives an understanding on measurements of weight and height and their estimations. The literature review will discuss the background and then elucidate on the significance of accurate weight and height estimations in anaesthesia. Measuring devices are discussed to give an understanding of the instrumentation used to measure actual weight and height. Factors affecting anaesthetists' ability to accurately estimate weight and height are taken into consideration. Lastly reliability of patients' self-reported and health care workers' estimates of weight and height will be discussed.

1.2 Background

Error is inevitable in the clinical practice. The Institute of Medicine report (1), "To Err Is Human" quantifies between 44 000 and 98 000 patients hospitalised, die each year due to medical errors. It is estimated in the United States of America that medication errors harm at least 1.5 million people and cost billions of dollars per year. It is difficult to ascertain the exact incidence but based on previous data, "it is estimated that per 1000 orders, 0.61 to 53 prescribing errors are made. These comprise errors in weight-based dosing of medications" (2).

The National Confidential Enquiry into Peri-operative Deaths report of 1991/1992 (3), when analysing patients' pre-operative preparation, stated that poor quality of care may be reflected by deficiencies in the recording of patients' weight and height. The basis of the report was information contained in questionnaires obtained from anaesthetists where "1689 index cases (patients on whom a surgical procedure was performed and survived more than 30 days post-operatively) and 1616 deaths were recorded. Weight was recorded for 1313 (77.7%) index cases and 832 (51.5%) deaths. There were no weight recordings for 368 (21.8%) index cases and 772 (47.8%) deaths. Height was recorded for 196 (11.6%) index cases and 215 (13.3%) deaths. There were no height records for 1472 (87.2%) index cases and 1379 (85.3%)

deaths" (3). The absence of pre-operative weight and height records may reflect poor quality of care but measurements are often impractical (4).

1.3 Importance of accurate weight and height estimations in anaesthesia

Weight and height are frequently used in clinical practice. Anaesthetists use weight for reasons such as; fluid and drug infusion rate settings, to calculate drug dosing, mechanical ventilation tidal volume settings, instrument size predictions and physiological state changes like glomerular filtration rate calculations (5, 6). Height is often used for target controlled infusion settings and to calculate predicted body weight (PBW), a critical variable used to calculate the tidal volume during mechanical ventilation (7). A brief discussion of these aspects is presented.

Medication dosing

Coe et al. (8) emphasised the importance of anaesthetists having patients' weight pre-operatively so to give accurate drug dosages as most drugs are calculated on the basis of dose per unit weight. Height is seldom used for medication doses.

The size of error that is reasonable in clinical practice is an important factor when considering the accuracy of weight estimation. A 20% error in adults would possibly not yield significant clinical problems for most drugs. It is of importance to know if higher than actual body weight is consistently estimated, drug dosage in this instance may represent a notable overdose (8). Effects of drugs with narrow therapeutic indices such as anticoagulants and thrombolytics can be crucial when calculated on a 10% weight estimation error (9). Such drugs have a narrow window between their potent dose and the dose where they produce adverse toxic effects.

A national survey of the emergency departments (ED) in Pennsylvania (10) showed that at least 50% of patients admitted to hospitals came through the ED. Follow up of patients in the ED revealed that 12% were admitted to hospital wards and 1.3% were transferred directly to an intensive care unit (ICU) or theatre setting. Therefore, if it is believed that the weight initially estimated and recorded by the ED is accurate, the oversight that occur because of the wrong recorded patient weight may continue throughout a patient's stay in a health care facility (10).

Drugs used in continuous infusions such as vasoactive drugs require an ideal body weight for optimal dosing. The lower commencing dose given by an ideal body weight-based dose provides a safer and rational strategy, due to the frequent and instant titration of these agents to a pre-determined clinical effect. A guidance for optimal weight-based vasoactive dosing strategies remains difficult in obese and underweight patients unfortunately (11).

Fluid management

Peri-operative fluid management must be adapted to the physiological changes and age of the patient in order to compensate for pre-operative fasting, intra-operative fluid losses, optimisation of haemodynamic variables and maintenance of urine output (11).

Intra-operative fluid maintenance for stable paediatric patients is frequently calculated using the 4/2/1 rule:

> *4 ml/kg per hour for the first 10 kg,*
> *2 ml/kg per hour for the second 10 kg and*
> *1 ml/kg per hour for every kg above 20 kg.* (12)

In practice, this has been reduced to a 2:1:1 ratio because of the high incidence of fluid overload with the 4/2/1 rule. In the adult population, the intraoperative fluid management approach is based on the invasiveness of the surgical procedure where the term "goal directed fluid therapy" is used (13). The restrictive (zero balance) approach advocates for replacement of fluid that is lost during surgery for improved clinical outcome (14, 15). Individual responses to trauma, illness and to healing mandate a customised approach to fluid management compared with traditional liberal or fixed volume regimes that predisposed patients to fluid overload (15).

Airway equipment sizes

According to Shih et al. (16) it is imperative to accurately select the correct endotracheal tube (ETT) in general anaesthesia and critical care practice for children. The number of attempts to intubate and prolonged intubation time result from failure to predict a suitable ETT size. Use of an oversized ETT and multiple intubation attempts may cause airway trauma and increase the incidence of post-operative croup (16). This does not apply in adults, because the generalisation of a 7.0 to 7.5 ETT for women and a 7.5 to 8.5 ETT for men is used in clinical practice (17).

The use of laryngeal mask airways is common amongst anaesthetists in the operating room. They are used to secure the patient's airway and maintain ventilation, more often spontaneous, during short surgical procedures. Brimacombe et al. (18) critiqued the study conducted by Voyagis et al. (19) where 300 patients were used to compare the laryngeal mask airway manufacturers' weight-based recommendations "(size 3 for 30 – 70 kg, size 4 for 70 – 90 kg, and size 5 for >90 kg) with a sex-related formula (size 4 for females and size 5 for males)". Brimacombe et al. (18) showed that the sex-related formula was a more efficient approach than the weight-based formula in terms of oro-pharyngeal leak pressure. In practice, the hospitals affiliated to the University of the Witwatersrand use the weight-based recommendation.

The relationship between the airway length and patients' height was established when Cherng et al. (20) conducted a study with 293 American Society of Anesthesiologists I and II patients, requiring general anaesthesia and oro-tracheal intubation. They took length measurements from the carina of the trachea to the vocal cords, from the vocal cords to the right corner of the mouth and from the carina to the right corner of the mouth. Recordings of the patient's height and sternum length were made. The length from 5 cm above the carina was defined as the optimal ETT tip. A formula was derived, by linear regression, to estimate the optimal ETT length in oro-tracheally-intubated patients:

The length from 5 cm above the carina to the right mouth corner (cm) = (body height [cm] / 5) – 13. (20)

This proposed formula provides a guide to verify the optimal ETT tip position (depth of tube position) in patients who require oro-tracheal intubation.

Mechanical ventilation

Mechanical ventilation is often used to maintain patients' ventilation throughout the surgical procedure. According to Linares-Perdomo et al. (21) lung protective mechanical ventilation is focused on the delivery of tidal volumes that target 6 – 8 ml/kg of predicted body weight (PBW). PBW equations use height, age and gender as input variables. For this, anaesthetists need to know their patients' heights.

The PBW of a patient is calculated using the Acute Respiratory Distress Syndrome clinical trial networks formula (22), which is different for both males and females:

Males: PBW (kg) = 50 + 0.91 (height in centimetres – 152.4)

Female: PBW (kg) = 45.5 + 0.91 (height in centimetres – 152.4).

Studies (23, 24) have shown that delivering excessive tidal volumes cause more harm than hypoventilation. Alveolar over distension, with atelectrauma and biotrauma are the main mechanisms for ventilator induced lung injury. Lung injury results in high alveolar permeability, interstitial oedema, haemorrhage, loss of surfactant and alveolar collapse. These changes give a picture of acute respiratory distress syndrome.

Medical air transportation

Air medical transportation has become a well-established part of the emergency medical service system. Medical personnel often have to air-transport patients from one hospital to another or from a remote accident scene to a hospital for medical attention. Crandall et al. (25) issued a case report of an obese patient being transported by air medical transport. They highlighted that most emergency medical service providers and health care facilities have a limited capacity to measure the patients' weight before air transportation, therefore use visual estimations of total body weight. Pertinent decisions like whether the patient can be safely flown, the maximal total aircraft range, the ability to board a full medical crew or family members and fuel capacity are some of the important decisions to be made based on these visual estimates of weight. With overestimation of weight by the health care provider, patients may not be transported by air, when it is otherwise appropriate. With underestimation of the patient's weight comes the risk of negatively affecting aircraft performance (25).

1.4 Methods of measuring and estimating weight

Health care workers use different methods such as analogue (dial), digital, balance beam and chair and sling scales to measure weight (26). Weighing beds have been used for supine patients in ICU. Nasiri and Nasiri (27) assessed the use of the sum of lower limbs and head weights to determine total body weight of anaesthetised patients. The Braselow tape is used to estimate children's weight but it is not recommended for use in adults (28).

Cooper et al. (29) described the bathroom scales to be the most accurate type of scales, with accuracies within 0.4% of a kilogram (29). Numerous factors need to be placed under scrutiny when using these scales. They need to be on a flat surface and are inaccurate on a carpet**.** Every time they are moved they need to be calibrated to zero**.** For the most accurate results, the person needs to stand still on the scale, look straight ahead and count to three before the reading is taken (29).

Yorkin et al. (30) compared the "accuracy and consistency of dial-type versus digital bathroom scales commonly used for self-reported weight". Findings indicated that home bathroom scales were accurate with weights measured. Dial scales were found to be "significantly more imprecise than digital scales at all calibration test loads measured with digital home scale" (30).

Balance beam scales compare the mass of two objects and not the weight. One is a constant, where the object's exact mass is known. The two objects sit on the opposite sides of a long beam. When the two objects balance at the exact same level, they have equilibrium or the same mass. They are operated manually at eye level, calibrated by setting the weight at zero and noting whether the balance beam registers in the middle of the mark. When compared with electronic scales, balance beam scales are primarily for precision (29).

Chair and sling scales are available for patients who are unable to weight-bear. The sling is placed under the patient and connected to the arms of the scale, the patient is then lifted above the bed by a hydraulic devise and the weight is measured on a balance beam scale or a digital display. They are used mostly for the elderly and wheelchair bound patients (29).

According to the manufacturer's recommendations, scales need to be calibrated once or twice a year to ensure accurate weight measurement (31). Multiple calibrations over time can yield various results because different users use diverse calibration methods or different test weight quantities or it could be that they place the weights at different locations on the scale (31). Jarvis (32) recommends measuring weight "to the nearest tenth of a kilogram when using an electronic scale".

Modern ICUs use beds with built-in weighing scales. The manufacturer (33) advises that the accuracy of the bed scale is approximately within 1% of the patient's weight. The repeatability is within 0.3% in patients <75 kg and within 0.1% in patients >75 kg.

Nasiri and Nasiri (27) assessed the accuracy of the sum of legs and head weight (LH) to determine total body weight of anaesthetised patients. LH was measured on the operating table. The hypothesis was that the LH sum might give a better approximation of weight than other methods. The formula used was:

LH sum = 10.8 + (5.1 X legs weight) + (5.5 X head weight).

This method yielded a good correlation coefficient but may not be reliable under more stressful situations or awake patients, because all of the patients in this study were anaesthetised (27).

Darnis et al. (34) conducted a study to examine “the bias and precision of different methods of estimating body weight in immobile adult patients”. The Lorenz formula (35) was used to make estimates incorporating height, waist and hip circumference and the Crandall formula (25) utilises height, arm circumference and visual estimations. The authors found the inaccuracy of body weight estimations by anthropomorphic measures. Recommendations were made for equipment to be made accessible to accurately weigh immobile patients in hospitals (34).

Children’s weight below 25 kg has been shown to be accurately estimated by the Broselow tape. It is a colour coded length-based tape measure that is used for paediatric emergencies (28). In Brazil, Abdel-Rahman et al. (28) evaluated weight estimation methods in children, which were developed for “inaccessibility of sufficiently sensitive, functioning and calibrated scales in remote and resource-constrained regions”. The conclusion made was that weight estimation methods should be withdrawn, even in settings where no consistently dependable alternatives exist to ascertain weight. The tape itself is expensive and should be measured against a supine child, which is limiting in situations where it would be clinically unsuitable for the child to lie supine, such as severe asthma (28). A recent Cape Town study (36) conducted by the Department of Emergency Medicine deduced that “the tape is accurate in the Western Cape population for children aged 10 years and younger” and should be recommended for all medical staff treating children in emergency situations.

Simplicity, rapidity and accuracy were some of the described properties of an ideal method for bedside body weight estimation (37). Efforts to develop more accurate formulas should proceed until “such a time as theatres are equipped with beds enabled to weigh patients, given the likelihood for medication errors and the related risks to patient safety” (37).

1.5 Methods of measuring and estimating height

Height measurement is infrequently required but is needed for calculations requiring body surface area such as cardiac index, body mass index determination and PBW calculation (8).

Height measurement is an acceptable, non-invasive and an inexpensive method of assessing height. Devices such as stadiometers, anthropometers, a vertical ruler attached to the wall or a vertical ruler on a standard platform balance beam scale often measure height but these are not always practical (26).

The use of wall-mounted stadiometers has been advocated. “It is a device consisting of a vertical ruler with a sliding horizontal rod or paddle adjusted to rest on top of the head. The patient should be standing upright on a firm surface, looking straight ahead, arms on the sides, with shoes removed and anything on their head that would inflate height (besides hair) and feet together. The shoulders, buttocks, and heels should be touching the wall. One should consistently report height in either inches, to the nearest quarter inch, or in centimetres, to the nearest tenth“ (31).

The Height Forum (38) advises that to obtain an accurate height measurement, measurements should be taken for three consecutive days, all taken at approximately the same time of the day. “Height varies slightly with spine compression each day therefore the average value of these three measurements would be a more accurate estimation of true height” (38).

Height measurement for individuals who cannot stand upright can be daunting. These could be patients with various physical abnormalities such as spasticity, contractures, paralysis, amputations, osteoporosis, scoliosis or older adults with kyphosis and hospitalised, bedridden patients. There’s unfortunately no standard criteria to measure or estimate height for these patients who cannot stand. Investigators have analysed the validity of the arm span (39-41), demi span (39, 40, 42), half arm span (39, 40) and knee height (39) among others for use as potential height estimates in these groups instead of standing height. A study by Hickson et al. (39) showed a poor agreement between the standing height and all the methods of height estimation. Lahner et al. (40) found that the arm span is acceptable for use in white males and the demi span male equation is acceptable for use in black males. “None of the methods accurately predicted true height in females” (40). Weinbrenner et al. (42) and Brown et al. (43) supported the use of arm span as an option when neither measured height nor self-reported height is available. In the government sector, no standardised height measuring methods have been established in patients who cannot stand upright.

Froehlich-Grobe et al. (44) conducted an analysis assessing measures providing the best estimate for height. Height was obtained from 141 wheelchair users. Estimates included self-reported height and measuring the arm span, recumbent length and knee height. They also assessed the measurement variance of the four height estimates between women and men and whether there were notable differences within each gender. These findings reflected significantly different height estimates and BMI values for men and women. For both genders, the arm span resulted in the greatest over estimation and measured recumbent length the least. “The common variance estimates were excellent for recumbent length (92%) and knee height (>83%) and good for self-report (>75%) while the common variance for arm span was poor (<42%)” (44). The authors concluded “recumbent length gives accurate height estimate for wheelchair users. When practical considerations pose difficulties for obtaining recumbent length, reasonable alternatives may be provided by height estimates based on knee height and self-reported height” (44).

1.6 Factors influencing weight and height estimation

Factors such as obesity, cultural differences and gender of patients can influence anaesthetists’ ability to accurately estimate weight and height.

Obesity

Sixty four per cent of American adults were found to be overweight or obese in 1990 – 2000, an absolute increase of eight percentage points from 1988 – 1994 (45). This further stabilised from 2013 – 2014 with age adjusted percentage for adults aged 20 and over at 37.8%. In 2016, 39% of women and men aged 18 and above were overweight (46). Combined figures for obesity obtained across all ethnic groups in South Africa in 2013 were 12.3% for men and 41% for women (47).

BMI is a "weight-for-height index that is commonly used to classify underweight, normal, overweight and obesity in adults". It is defined by weight in kilograms divided by the square of the height in meters. Obesity has been described as a BMI of >30 (48).

"Obese people have larger absolute lean body masses as well as fat masses than non-obese individuals of the same age, gender and height". However, the percentage of fat per kilogram of total body weight is increased, whereas that of lean tissue is markedly reduced (49).

Estimations of weight (73%) and height (85%) proved to be more accurate for normal weight patients as opposed to the overweight, obese, or severely obese categories (49). Husin et al. (50) attributed the inaccuracy of weight estimation in supine obese patients to visual exposure of the whole body. The individual has to be observed from many angles in order to obtain a better estimation of waist circumference, a task that may be impossible in patients lying supine. This was supported by Hendershot et al. (51) after evaluating the accuracy with which health care providers estimated weight and height and categorised BMI in a sample of trauma patients.

Determann et al. (52) assessed the reliability of weight and height estimates in patients newly admitted to ICU by nurses. They determined the influence of patients' BMI on the estimated values. One hundred consecutive acutely admitted patients from three academic hospital ICUs were included. They found that patients with the highest BMI were more likely to have their weight under-estimated by health care workers (52).

Cultural difference

A study by Jung et al. (53) assessed "the suitability of the knee height calliper in estimating body weight among Chinese elderly persons in Hong Kong". The method used was to take measurements from the mid-arm circumference (MAC) and knee height for the estimation of body weight in the elderly.
Existing equations were used for male and female Caucasians of 60 to 80 years of age:

> *"White males weight (kg) = knee height X 1.10 + MAC (cm) X 3.07 – 75.81*
> *White females weight (kg) = knee height X 1.10 + MAC (cm) X 2.81 – 66.04."*

The results proved the knee height calliper to be a useful, reliable and acceptable tool in estimating the body weight of elderly patients. However the study was limited by the need to adjust to the Caucasian equation for Chinese subjects as the study showed that "the calculated mean estimated body weight from the knee height equation of Caucasian subjects was significantly greater than the mean actual body weight of Chinese subjects" (53). Wang et al. (54) highlighted that the Chinese have "more upper body subcutaneous fat than their Caucasian counterparts" but with lower BMIs and a higher percentage of body fat. A greater MAC value for the Chinese and a resultant higher estimation of body weight will result from this higher upper body subcutaneous tissue.

This weight estimation test has shown that the knee height calliper is useful and valuable since there are few tools available that require the patient to not move. Even though it is a feasible tool, the study addressed the need for an equation for Chinese subjects since there is obvious racial differences (53).

A comparative review by Wagner and Heyward (55) assessed body composition in blacks and whites. They reviewed differences and similarities between the two races in relation to fat-free body mass, fat distribution, body dimensions and proportions. It was apparent that "blacks have a greater bone density and protein content" than do whites, yielding a greater fat-free body density. These results found white male cadavers were used to derive the body density conversion formulas and would systematically underestimate body fat percentage in black men. Differences between races in fat distribution results in errors when body fat percentage or body density is estimated from skin fold thickness or anthropometry as most prediction equations have been established using white populations. The review showed that "blacks deposit less subcutaneous fat on the extremities and front of the body but more on the back than do whites" (55).

Gender

Christensen (56), a Danish psychologist, conducted a study to examine the effect of gender on weight perception where participants were asked to estimate their partner's weight. The survey showed that men showed a clear tendency to over-estimate the weight of their female partners when the women were either underweight or overweight whereas women tend to slightly under-estimate the weight of their male partners. The author attributed this to a preference for a smaller female body in the Danish population by men. Additionally, parents were found to have a tendency to overestimate the weight of their daughters and underestimate that of their sons. The author concluded that "women and men are not rated on the same scale nor expected to adhere to the same body standards" (56).

1.7 Reliability of self-reported weight and height

Studies (57-60) have analysed the accuracy of self-reported weight and height, since the study by Stunkard and Albaum (61) appeared in The American Journal of Clinical Nutrition in 1981.

Schmidt et al. (57) evaluated the "validity of reported personal weight in a survey of 659 adults living in Porto Alegre, southern Brazil". Men and women between 15 and 64 years of age gave their self-reported weight and height before being measured. Measurements were performed to the nearest kilogram using a portable digital scale with individuals without shoes and dressed lightly. Height was assessed to the nearest centimetre using a measuring tape. The difference between measured and self-reported weight was used to calculate error in the reporting of weight. Negative differences represented underestimation and positive differences overestimation. The results yielded similarities for men and women between self-reported and measured weight, with an insignificant tendency for men to over report and for women to under report their actual weight. They attributed these findings of relatively similar accuracy of weight reporting to “widespread use of drug store scales, and to a lesser extent, to frequent medical contact in Port Alegre”.

Pirie et al. (58) investigated both weight and height in subjects aged 20 to 59 years, and found that females under reported their weights, as did heavier males, whereas lighter males overstated their weights. Amongst females, younger women tended to under report weight more than older women, but no age affect was found in men. Height was slightly over reported by males and under reported by females. Kuczmarski et al. (59) compared self-reported to measured weight and height of adults examined in the National Health and Nutrition Examination Survey, where 7772 men and 8801 women 20 years and older were studied. The authors revealed that the mean error for height was statistically significant and larger for the older adults compared to the younger adults. More than half of the sample of adults 60 years of age and older over reported height by approximately 2.5 cm. They further concluded that over estimation of height by older adults occurs because height decreases with age and there is a greater time lapse since height was last measured (59).

Rowland (60) conducted a similar study where 11 284 men and women between the ages of 20 – 74 were analysed. The author found that young men and women aged 20 – 34 years under reported their weight more than older men and women did (55 – 74 years). On average, men and women over reported their height; with adults aged 45 – 74 years over reporting more than adults aged 20 – 44 years.

The agreement in these studies (57-60) was that self-reported weight and height could be used reliably, particularly when impractical to take independent measurements.

1.8 Reliability of weight and height estimation by health care workers

The ability of practitioners to accurately estimate their patients' weight and height has been largely studied in the ED (9, 62-68) and ICU (52, 69) but not much literature has been written on the accuracy of anaesthetists. Coe et al. (8) was the only study that could be identified that focused on anaesthetists' ability to do so.

Coe et al. (8) questioned the conclusion made by the National Confidential Enquiry into Patient Outcome and Death report (70), that anaesthetists' estimation of weight is reasonable. They quantified this by conducting a study with 38 patients undergoing orthopaedic or urology day case surgery. Patients were assessed in the anaesthetic room on trolleys, in the supine position, wearing standard hospital gowns. Four investigators visually assessed the weight and height of each patient: a consultant with at least 18 years of anaesthetic experience, a junior medical officer with nine years of anaesthetic experience, a senior medical officer with five months of anaesthetic experience and a non-medical department assistant with 11 years in the department. Regression analyses were performed and the results were different for each observer. The most accurate weight estimation was by the consultant (most senior) and the department assistant (non-medical) (8). No accuracy values were given but this is a relevant study as it is the only study that worked with anaesthetists.

Height estimation had more scatter in the results. The senior medical officer over estimated shorter heights and under estimated taller heights and the other three investigators all consistently over estimated height (8). This study concluded that height is more difficult to estimate in the supine than upright position. The authors deduced that "supine height is probably estimated in relation to the length of the trolley and this would explain the smaller error margin at heights closer to the trolley length" (8).

The studies that were conducted with staff in the ED (9, 62-68) and ICU (52, 69), reflected the inaccuracy of weight and height estimation by the health care workers. Corbo et al. (62) studied a convenience sample of 458 critically ill patients presenting over a four week period to the ED. “Only half of the nurses and physicians’ estimates were within 10% of the patients’ actual weight” (62). Height estimation was not included in the study.

A prospective study by Maskin et al. (69) determined the “magnitude of errors in the visual estimation of weight and height of critically ill patients”. Forty-two patients were weighed with a calibrated stretcher scale and their length measured in a supine position with a steel measuring tape. Accuracy was defined as an “estimation falling within 10% of patient’s weight and 5% of patient’s height” (69). Overall accuracy of the estimation of actual weight was 58%, with nurses more accurate than physicians (63% versus 53%). Accuracy in the estimation of height was 81% for nurses and 91% amongst attending physicians.

Fernandes et al. (9) conducted a study in a Canadian ED with eleven physicians, 26 nurses and a convenience sample of 117 patients. Patient’s weight was estimated within 10% of the actual weight by 66% of nurses, 66% of physicians and 97% of patients. The study concluded that physicians and nurses’ estimates of weight were unreliable whereas patient’s estimates were far more accurate than nurses and physicians (9).

Khan et al. (63) enrolled 250 mobile patients in an American ED and had their weight estimated by 96 staff members comprising of physicians and nurses. The authors used estimations within 5% of the patient’s actual weight for their accuracy. The staff gave only 33% accuracy of weight estimation. There was significantly less accuracy with underweight and obese patients, but the patients’ gender, ethnicity or years of experience did not have an influence on the accuracy (63).

To examine biases in weight estimation by the ED staff (consultants, medical students, interns, nurses, paramedics and residents), Hall et al. (64) studied a convenience sample of 33 ED staff estimating weight of 15 patients, resulting in a total of 495 individual estimations. Weight estimation within 5 kg of the actual weight was used to define accuracy. Only 28.1% of provider estimations were accurate. Regression analysis showed that paramedics gave significantly less accuracy in patient weight estimations when compared to the rest of the group (19.4%). The Emergency Medicine faculty and paramedics significantly underestimated patients' weight whereas the interns and medical students significantly overestimated patients' weight (64).

Determann et al. (52) concluded after analysing data from intensive care nurses who estimated weight and height from acutely admitted patients. They found that estimation of weight, height and BMI by nurses was accurate. Height was better estimated (96%) than weight (75%). Height was markedly overestimated in the shorter patients whereas weight was overestimated in patients with a low BMI.

Anglemyer et al. (65) concluded that estimation of patients' weight by the ED staff is often inaccurate. Patients inaccurately estimated their weight by greater than 20% only 1.5% of the time when among the ED staff, paramedics were inaccurate by 56% and the nurses by 71% (overall 63.5%). The patient's own estimate can be used over the medical staff estimate, as their actual weight, when available. When the patient is in a critical condition, "no proven method is widely available at this time to avoid this type of error" (65). Table 2.1 reflects a summary of accuracies of weight and height from the various studies mentioned in this chapter.

Table I Accuracies of weight and height estimations from various studies

Authors	Area of study	Weight accuracy	Height accuracy
Corbo et al. (62)	ED	50%	Not included
Fernandes et al. (9)	ED	66%	Not included
Khan et al. (63)	ED	33%	Not included
Hall et al. (64)	ED	28.1%	Not included
Angelmeyer et al. (65)	ED	63.5%	Not included
Determan et al. (52)	ICU	75%	96%
Maskin et al. (69)	ICU	58%	81%
Coe et al. (8)	Anaesthesiology	No value given	No value given

ED = Emergency Department ICU = Intensive Care Unit

1.9 Summary

Health care workers inaccurately estimate weight and height. Actual measurements should be provided over estimates, given their substantial use for therapeutic management. In some circumstances, use of inaccurate estimates could jeopardise application of beneficial evidence based therapies and patient care.

1.10 References

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SECTION 2: Journal guidelines to authors

The formatting of this Research Report complies with the University of the Witwatersrand's Style Guide for Theses, Dissertation and Research Reports. The formatting of the draft article may differ from the rest of the Research Report in order to comply with the author guidelines for the journal to which it is intended to be submitted.

In this section the author guidelines that the researcher followed with regard to formatting the article are included and followed by the draft article. The journal to which this article is intended to be submitted is The South African Journal of Anaesthesia and Analgesia.

Southern African Journal of Anaesthesia and Analgesia guidelines to authors

Article sections and length

The following contributions are accepted (word counts exclude abstracts, tables and references):

Original research (2800 – 3200 words/ 4-5 pages)

FULL AUTHOR GUIDELINES

Title page

All articles must have a title page with the following information and in this particular order: Title of the article; surname, initials, qualifications and affiliation of each author; The name, postal address, e-mail address and telephonic contact details of the corresponding author and at least 5 keywords.

Abstract

All articles should include an abstract. The structured abstract for an Original Research article should be between 200 and 230 words and should consist of four paragraphs labeled Background, Methods, Results, and Conclusions. It should briefly describe the problem or issue being addressed in the study, how the study was performed, the major results, and what the authors conclude from these results. The abstracts for other types of articles should be no longer than 230 words and need not follow the structured abstract format.

Keywords

All articles should include keywords. Up to five words or short phrases should be used. Use terms from the Medical Subject Headings (MeSH) of Index Medicus when available and appropriate. Key words are used to index the article and may be published with the abstract.

Acknowledgements

In a separate section, acknowledge any financial support received or possible conflict of interest. This section may also be used to acknowledge substantial contributions to the research or preparation of the manuscript made by persons other than the authors.

References

Cite references in numerical order in the text, in superscript format (Format> Font> Click superscript). Please do not use brackets or do not use the footnote function of MS Word.

In the References section, references must be typed double-spaced and numbered consecutively in the order in which they are cited, not alphabetically.

The style for references should follow the format set forth in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals (http://www.icmje.org) prepared by the International Committee of Medical Journal Editors. Abbreviations for journal titles should follow Index *Medicus* format. Authors are responsible for the accuracy of all references. Personal communications and unpublished data should not be referenced. If essential, such material should be incorporated in the appropriate place in the text.

List all authors when there are six or fewer; when there are seven or more, list the first three, then ";et al."; When citing URLs to web documents, place in the reference list, and use the following format: Authors of document (if available). Title of document (if available). URL. (Accessed [date]).

<u>The following are sample references:</u>

1 Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH. The analysis of maxillary sinus aeration according to aging process: volume assessment by 3-dimensional reconstruction by high-resolutional CT scanning. Otolaryngol Head Neck Surg. 2005 Mar;132(3):429-34.

2 2. Polgreen PM, Diekema DJ, Vandeberg J, Wiblin RT, Chen YY, David S, et al. Risk factors for groin wound infection after femoral artery catheterization: a case-

control study. Infect Control Hosp Epidemiol [Internet]. 2006 Jan [cited 2007 Jan 5];27(1):34-7. Available from: http://www.journals.uchicago.edu/ICHE/journal/issues/v27n1/2004069/2004069.web.pdf.

More sample references can be found at: http://www.nlm.nih.gov/bsd/uniform_requirements.html"

Tables

Tables should be self-explanatory, clearly organised, and supplemental to the text of the manuscript. Each table should include a clear descriptive title on top and numbered in Roman numerals (I, II, etc.) in order of its appearance as called out in text. Tables must me inserted in the correct position in the text. Authors should place explanatory matter in footnotes, not in the heading. Explain in footnotes all non-standard abbreviations.

For footnotes use the following symbols, in sequence: *,†,‡,§,||,**,††,‡‡

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All figures must be inserted in the appropriate position of the electronic document. Symbols, lettering, and numbering (in Arabic numerals e.g. 1, 2, etc. in order of appearance in the text) should be placed below the figure, clear and large enough to remain legible after the figure has been reduced. Figures must have clear descriptive titles.

Photographs and images

If photographs of patients are used, either the subject should not be identifiable or use of the picture should be authorised by an enclosed written permission from the subject. The position of photographs and images should be clearly indicated in the text. Electronic images should be saved as either jpeg or gif files. All photographs should be scanned at a high resolution (300dpi, print optimised). Please number the images appropriately.

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Manuscripts are initially examined by the editorial staff and are usually sent to independent reviewers who are not informed of the identity of the author(s). When publication in its original form is not recommended, the reviewers' comments (without the identity of the reviewer being disclosed) may be passed to the first author and may include suggested revisions. Manuscripts not approved for publication will not be returned.

Ethical considerations

Papers based on original research must adhere to the Declaration of Helsinki on "Ethical Principles for Medical Research Involving Human Subjects"; and must specify from which recognised ethics committee approval for the research was obtained.

Conflict of interest

Authors must declare all financial contributions to their work or other forms of conflict of interest, which may prevent them from executing and publishing unbiased research. [Conflict of interest exists when an author (or the author's institution), has financial or personal relationships with other persons or organizations that inappropriately influence (bias) his or her opinions or actions.]* *Modified from: Davidoff F, et al. Sponsorship, Authorship, and Accountability. (Editorial) JAMA 2001: 286(10). The following declaration may be used if appropriate: ";I declare that I have no financial or personal relationship(s) which may have inappropriately influenced me in writing this paper."

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1 Please consult the "Uniform requirements for manuscripts submitted to biomedical journals" at www.icmje.org
2 Please consult the guide on Vancouver referencing methods at: http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=citmed.TOC&depth=2
3 The submission must be in UK English, typed in Microsoft Word or RTF with no double spaces after the full stops, double paragraph spacing, font size 10 and font type: Times New Roman.
4 All author details (Full names, Qualifications and affiliation) must be provided.
5 The full contact details of corresponding author (Tel, fax, e-mail, postal address) must be on the manuscript.
6 There must be an abstract and keywords.
7 References must strictly be in Vancouver format. (Reference numbers must be strictly numerical and be typed in superscript, not be in brackets and must be placed AFTER the full stop or comma.)

8 It must be clear where every figure and table should be placed in the text. If possible, tables and figures must be placed in the text where appropriate. If too large or impractical, they may be featured at the end of the manuscript or uploaded as separate supplementary files.

9 All photographs must be at 300dpi and clearly marked according to the figure numbers in the text. (Figure 1, Table II, etc.)

10 All numbers below ten, without percentages or units, must be written in words.

11 Figure numbers: Arabic, table numbers: Roman

12 <="" uk="" in="" proficient="" expert="" a="" by="" reviewed="" be="" must="">

SECTION 3: Draft Article

Anaesthetists' accuracy of weight and height estimations in supine adults

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Keywords: weight estimation, height estimation, anaesthetists, accuracy,

Abstract

Weight and height estimations have been shown to be inaccurate in clinical practice. Measuring weight and height pre-operatively may pose a challenge and without measurements, anaesthetists make visual estimations without confirmation. The aim of this study was to describe anaesthetists' accuracy of weight and height estimations in supine adults in the Department of Anaesthesiology at the University of the Witwatersrand.

This was a prospective, contextual, descriptive study with six volunteers representing the general population. Sixty-eight consenting anaesthetists were included in the study and data were collected at the two study hospitals. Comparisons were made using Chi^2 and one sample t-tests.

A total of 408 weight and 408 height estimations were made. Estimations of weight within 10% and height within 5% of the actual values were considered accurate. The overall participants' accuracy for weight estimation was 40% and 67.6% for height. Weight was overestimated for volunteers with higher BMIs and underestimated for those with lower to normal BMIs. Height was consistently overestimated in shorter and underestimated in taller volunteers. Participants with less than 10 years of clinical experience gave better weight and height estimations than their seniors. There was no association between volunteers and participants' gender on weight and height estimation.

Overall accuracy of estimation of weight and height was low with height more accurately estimated than weight. Given their extensive application in medicine, actual measurements should be preferred over estimations.

Introduction

Weight and height are two of the most commonly used anthropometric measurements in clinical practice. Anaesthetists use weight in theatre not only for drug dosing but also for ventilation settings, infusion rates, instrument size prediction and calculation of physiological state changes like glomerular filtration rate.[1, 2] Height is often needed for target-controlled infusions and to calculate predicted body weight, a critical variable used to calculate the tidal volume during mechanical ventilation.[3]

Studies have showed that up to 18% of avoidable medication errors are due to not having the crucial information at the time of prescribing and giving medications.[4] Patients are not routinely weighed before anaesthesia and often weight and height measurements are not documented on adult patients' charts. Measuring weight and height may be impossible, especially for critically ill patients before anaesthesia. For these reasons, anaesthetists find themselves making visual estimations without confirmation.[5]

Preventable medical errors may be due to incorrect weight estimations.[6] Overestimation can lead to lung barotrauma, drug overdosing, toxicity and increased costs whereas underestimation can lead to hypoventilation and drug under dosing, which potentially results in suboptimal therapeutic effects and ultimately increased costs.[7]

Health care workers use different methods to measure weight and height. Devices such as balance beam scales, electronic scales, spring scales and weighing beds commonly measure weight.[8] Height is often measured by the vertical ruler on a standard platform, stadiometers, balance beam scale or a vertical ruler attached to the wall.[9] Predictions by anthropometry using the knee height, ulna length and demi span; this being the distance from the middle of the sternal notch to the tip of the middle finger on the coronal plane, are also used.[10]

Previous studies examined the accuracy of adult weight and height estimations in the emergency departments (ED) [5, 6, 11-17] and intensive care units (ICU) [7, 18]. All these studies concluded that the physicians and nurses' weight estimations were inaccurate. The anaesthetists' ability to accurately estimate patients' weight has not been well studied.

In 2004 Anglemyer et al.[6] showed that the ED staff estimations of patients' weight is often inaccurate. They suggested that the patients' own estimate of their actual weight can be used as they were found to be more reliable. Should the patient be incapacitated, there's no widely available proven method to avoid dosage error.

Health care workers do not always estimate weight and height but rely on self-reported values by patients. A number of studies assessed the reliability of self-reported weight and height and their impact on the health outcome of patients. These studies[8, 12, 20-27] were consistent in finding high correlations of self-reported weight and height with the actual measurements.

Nasiri and Nasiri, [28] after identifying the need to obtain weight measurements in critically ill patients, conducted a study to determine the accuracy of estimating the total body weight in anaesthetised patients. They took weight measurements of anaesthetised patients' lower limbs and the head separately and developed a formula that gave a good correlation with patients' true total weight and has proven to be helpful in unconscious patients. All the patients in this study were anaesthetised and therefore, the formula may not be reliable in awake patients who may be in a stressful situation.[28]

Patients at the hospitals affiliated to the University of the Witwatersrand (Wits) are not routinely weighed nor do they have their heights measured pre-operatively. Measuring weight and height can be a challenging task for anaesthetist especially in critically ill patients and those with posture disorders.

Anaesthetists frequently have to make weight and height estimations with patients lying supine on the theatre table, however, the accuracy of these estimations is not known. A study was therefore undertaken to describe anaesthetists' accuracy of weight and height estimations in supine adults in the Department of Anaesthesiology at Wits.

Methodology

Approval to conduct the study was obtained from the Human Research Ethics Committee (Medical) at Wits and other relevant authorities. A prospective, contextual and descriptive research design was followed in this study. The study population consisted of all anaesthetists working in the Department of Anaesthesiology. A convenience sampling method was used. A sample size of 60 participants with a power of 89% to detect an accuracy of 40% in estimating volunteers weight with a 95% level of confidence (2 tailed test) was determined in consultation with a biostatistician. Non-consenting anaesthetists, those on annual or sick leave and interns rotating through the department were excluded from the study.

The data were collected on the same day at the two study hospitals, one in the morning and one in the afternoon, in the area where departmental meetings occur. Six volunteers with different body types and ethnicities to represent the general population were used as models. Five of the six volunteers were unknown to the participants who saw them for the first time lying supine. Table II describes the demographics of the volunteers.

Table II Volunteers demographics

Volunteer	Demographics				
	Race	Gender	Weight (kg)	Height (m)	BMI (kg/m^2)
A	Caucasian	Female	61	1.76	19.7
B	Black	Male	91	1.75	29.7
C	Caucasian	Female	51	1.51	22.3
D	Black	Female	119	1.68	42.1
E	Caucasian	Male	102	1.94	27.1
F	Black	Male	61	1.80	18.8

The volunteers were wearing light clothing, with no shoes and lying supine with one pillow. The author (DM), on the same calibrated digital scale weighed the volunteers. The standardised technique for height measurement as described by the BMI Task Force [29] was used and is as follows:

- "For the measurement of height, volunteers are asked to stand with their back against the wall.
- The back, scapulae and buttocks are to be in contact with the wall if possible.
- The weight of the volunteer should be evenly distributed on both feet.
- They are asked to place the legs together, bringing the ankles or knees together.
- If they have knock-knees, the feet are separated so that the medial borders of the knees are in contact, but not overlapping.
- The volunteers are then asked to inhale deeply and hold their breath while maintaining the head and body in the same position.
- They are instructed to stand erect (stand up straight and look straight ahead).
- The upper tip of the tape measure is brought onto the superior point on the head with sufficient pressure to compress the hair." [29]

On the study day, anaesthetists were invited to participate and upon agreement, they were handed an information letter and consent form. Two authors (DM and JS) and an assistant were present during data collection to answer questions and prevent data contamination. No identifying information was requested from participants and completed questionnaires were placed in a sealed box ensuring anonymity and confidentiality.

Data were captured onto a Microsoft Excel spread sheet and analysed using STATA version 13 (StatCorp, USA) in consultation with a biostatistician. Categorical variables were summarised using frequencies and percentages and continuous variables with means and standard deviations, medians and interquartile ranges through a box and whisker diagram. Comparisons were made using Chi^2 and one sample t-tests. A p value of <0.05 was considered statistically significant. Weight estimations within 10% of the actual weight and height estimations within 5% of the actual height were considered accurate. Percentages are rounded off to one decimal place.

Results

Data were collected at the two study hospitals on 23 May 2015. Seventy participants estimated the weights and heights of six volunteers. Two questionnaires were excluded from the study due to being returned blank resulting in 68 usable questionnaires. The 68 participants made 408 weight and 408 height estimations.

The demographics of the participants are shown in Table III.

Table III Participants demographics

	Number (n)	Percentage (%)
Gender		
Males	29	42.6
Females	39	57.4
Professional designation		
Medical officer	10	14.7
Registrar	26	38.2
Consultant	32	47.1
Years of clinical experience		
0-10	54	79.4
>11	14	21

The percentage and number of participants who overestimated, accurately and underestimated the volunteers' weight is reflected in Figure 1.

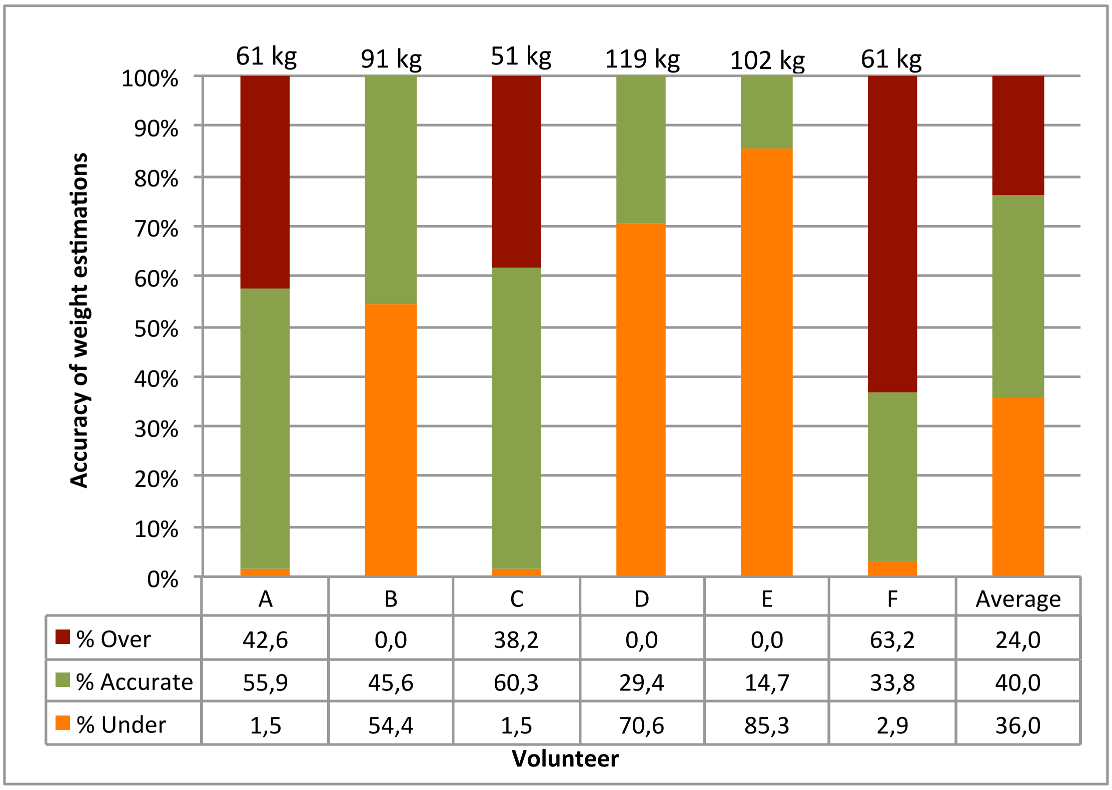


Figure 1 Participants' accuracy of weight estimations

The overall accuracy of weight estimation by participants was 40%. Volunteers with higher BMIs (kg/m^2); volunteer B (29.7), D (42.1) and E (27.1) tended to be underestimated whereas those with lower to normal BMIs; volunteer A (19.7), C (22.3) and F (18.8), were overestimated by the participants.

Figure 2 shows the actual weights of the volunteers and the medians, interquartile ranges (IQRs) and ranges of the participants' weight estimations. The box and whisker diagram for volunteer F has the same value for the median and 3rd quartile and therefore represents overestimation.

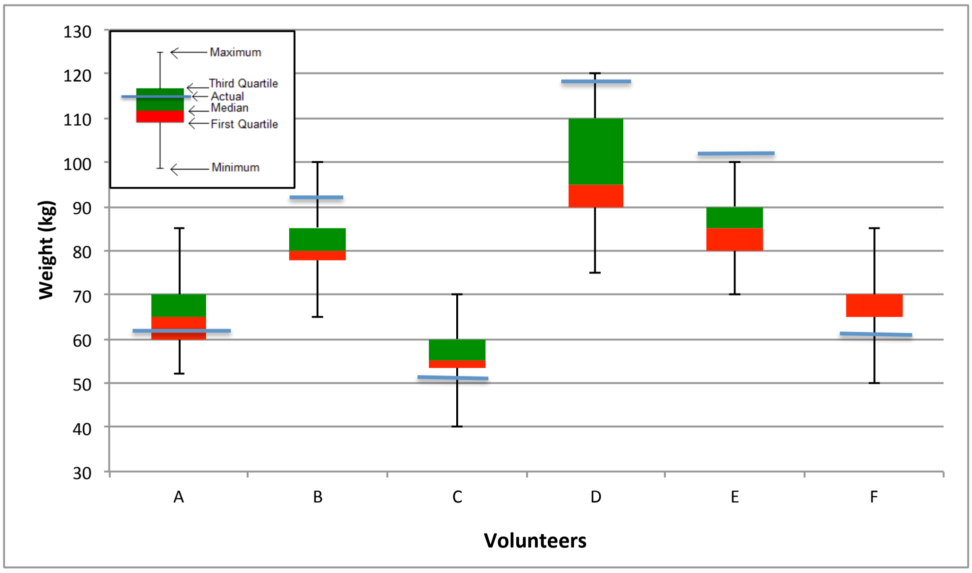


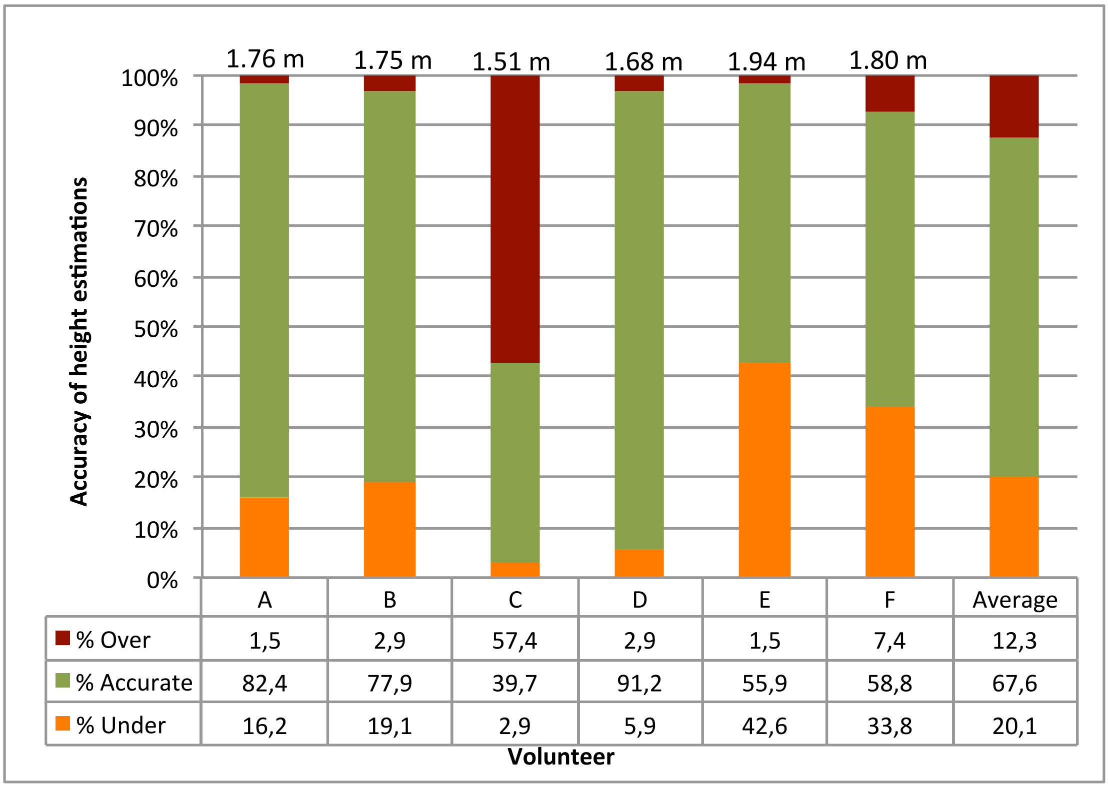
Figure 2 Participants' weight estimations

Table IV displays the highest overestimated, accurately and underestimated weights per volunteer. The most inaccurate estimation was for volunteer D (119 kg) where the highest underestimation was by 44 kg. Volunteer A and F, both 61 kg, had the highest overestimations, which was 24 kg.

Table IV Highest under and overestimations for weight

	Volunteers					
	A	**B**	**C**	**D**	**E**	**F**
	Female 61 kg	**Male** 91 kg	**Female** 51 kg	**Female** 119 kg	**Male** 102 kg	**Male** 61 kg
Highest underestimation (kg)	9	26	11	44	32	11
Highest overestimation (kg)	24	9	19	1	0	24

The percentage and number of participants who overestimated, accurately estimated and underestimated the volunteers' height is reflected in Figure 3.



	A	B	C	D	E	F	Average
% Over	1,5	2,9	57,4	2,9	1,5	7,4	12,3
% Accurate	82,4	77,9	39,7	91,2	55,9	58,8	67,6
% Under	16,2	19,1	2,9	5,9	42,6	33,8	20,1

Figure 3 Participants' accuracy of height estimations

The overall accuracy of height estimation by participants was 67,6%. Volunteers with the more extreme heights were the most inaccurately estimated i.e. the shortest, volunteer C, was overestimated by 39 (57.4%) participants and the two tallest volunteers E and F were underestimated by 29 (42.6%) and 23 (33.8%) participants respectively.

Figure 4 shows the actual heights of the volunteers and medians, IQRs and ranges of the participants' height estimations. Volunteer E (1.9 m) and F (1.8 m), the tallest volunteer had the highest overestimations, which were 26 cm and 30 cm as shown in Table V.

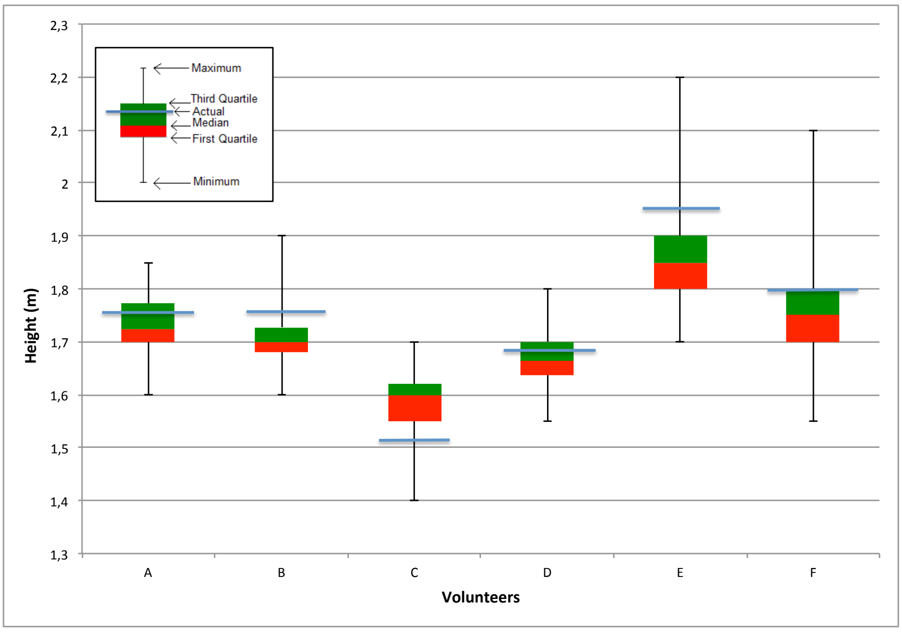


Figure 4 Participants' height estimations

Table V Highest under and overestimation for height

	Volunteers					
	A	**B**	**C**	**D**	**E**	**F**
	Female **1.76 m**	**Male** **1.75 m**	**Female** **1.51 m**	**Female** **1.68 m**	**Male** **1.94 m**	**Male** **1.80 m**
Highest underestimation (cm)	16	15	11	13	24	25
Highest overestimation (cm)	9	15	19	12	26	30

Accuracy of weight estimations per volunteer by participants' years of clinical experience is reflected in Table VI. The majority of participants, 54 (79.4%) had ten years or less of clinical experience and made 324 estimations, with an overall weight accuracy of 135 (41.7%). Participants with more than 11 years of clinical experience 14 (20.6%) made 84 estimations with an overall accuracy of 28 (33.3%).

Table VI Accuracy of weight estimation by years of professional experience

Years of experience	Participants (n)	Volunteers						Total
		A	B	C	D	E	F	
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
0 - 10	54	32 (59.3)	24 (44.4)	35 (64.8)	18 (33.3)	8 (14.8)	18 (33.3)	135 (41.7)
≥ 11	14	6 (42.9)	7 (50)	6 (42.9)	2 (14.3)	2 (14.3)	5 (35.7)	28 (33.3)

Accuracy of height estimations per volunteer by participants' years of clinical experience is reflected in Table VII. Those with 10 years or less of clinical experience 54 (79.4%) made 324 estimations with an overall height accuracy of 222 (68.5%). Participants with more than 11 years of clinical experience 14 (20.6%) made 84 estimations and had an estimation accuracy of 50 (59.5%).

Table VII Accuracy of height estimation by years of professional experience

Years of experience	Participants (n)	Volunteers						Total
		A	B	C	D	E	F	
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
0 - 10	54	45 (83.3)	43 (79.6)	22 (40.7)	48 (88.9)	32 (59.2)	32 (59.2)	222 (68.5)
≥11	14	6 (42.9)	10 (71.4)	5 (35.7)	14(100)	7 (50)	8 (57.1)	50 (59.5)

When determining the relationship between volunteers and participants' gender as an influence towards accuracy of weight estimation, it was shown that both male and female participants estimated the weights for female volunteers better, 40 (58.8%) versus 59 (86.8%), than the male volunteers, 28 (41.2%) versus 34 (50%). There was no association between volunteers and participants' gender on weight estimation (p = 0.5).

When determining the relationship between volunteers and participants' gender as an influence towards accuracy of height estimation, it was shown that male participants were better at estimating height for male volunteers 59 (86.8%), whereas the female participants gave better height estimations for female volunteers 88 (55.7%). There was no association between volunteers and participants' gender on height estimation (p = 0.2).

Estimates by both male and female participants for both male and female volunteers weights were significantly different to the actual weights as shown in Table VIII.

Table VIII Comparison of volunteers' actual weight to mean weight estimations by participants

Participants		Volunteers					
		A 61 kg Female	**B 91 kg Male**	**C 51 kg Female**	**D 119 kg Female**	**E 102 kg Male**	**F 61 kg Male**
Females	**Mean estimation**	64.9	82.1	56.1	99.1	83.4	67.7
	P-value	0.0004	0.000	0.000	0.000	0.000	0.000
Males	**Mean estimation**	65.4	80.6	56.0	96.8	85.5	68.3
	P-value	0.0008	0.000	0.000	0.000	0.000	0.000

Estimates by both male and female participants for both male and female volunteers heights were significantly different to the actual heights except for Volunteers D and F as shown in Table IX.

Table IX Comparison of volunteers' actual height to mean height estimations by participants

Participants		**Volunteers**					
		A 1.76 m	**B 1.75 m**	**C 1.51 m**	**D 1.68 m**	**E 1.94 m**	**F 1.80 m**
Females	**Mean estimation**	1.73	1.70	1.58	1.66	1.85	1.75
	P-value	0.004	0.000	0.000	0.025	0.000	0.003
Males	**Mean estimation**	1.72	1.71	1.57	1.67	1.86	1.76
	P-value	0.004	0.000	0.000	0.229	0.000	0.05

Discussion

Anaesthetists in this study inaccurately estimated weight and height in supine adults with an overall weight accuracy of 40% and height accuracy of 67.6%. Studies by Determann et al. [18] and Maskin et al. [7] found that height estimations (96% and 81% respectively) were more accurate than weight estimations (75% and 58% respectively) in ICU patients. Fernandes et al. [15] and Anglemyer et al. [6] did not include height estimation in their studies but they found that physicians and nurses' weight estimations were unreliable whereas patients' self reported weights were far more accurate and could be used when there is no means to weigh the patients. Kahn et al. [17] and Hall et al. [16] used accuracy as estimations within 5% of the actual weight, a tighter measure than that used in this study and they found that the ED staff gave lower weight estimations at 33% and 28.1% respectively. In this study, participants with less than 10 years of clinical experience gave better weight estimations of 41.7% than their seniors at 33.3%. Conversely, Coe et al. [19] found the most consistently accurate estimators of weight were the seniors.

It was found in this study that volunteers with normal BMIs had their weights accurately estimated. This is in agreement with results from the study by Cheymol [30] who found that estimations of weight proved to be more accurate (73%) for patients who were in the normal weight category as opposed to the overweight, obese, or severely obese categories. In this study volunteers with lower BMIs had their weights overestimated (volunteers A, C, F) whereas those with higher BMIs were underestimated (volunteers B, D, E). These results are in agreement with the results from Determann et al. [18] who found that the weight of patients with lower BMIs were overestimated whereas those with higher BMIs were underestimated. Kahn et al. [15] also found that estimates became significantly less accurate with underweight and obese patients.

The average height estimation accuracy in supine adults was 67.6%. As much as height was better estimated than weight, there were height over-estimations as high as 30 cm. Height was consistently overestimated in shorter participants and underestimated in taller participants in this study. Coe et al. [19] found that height was more difficult to estimate in the supine than in the upright position. Determann et al. [18] found that height was consistently overestimated in the shortest patients and those with a higher BMI. Participants in this study had not met volunteers prior to data collection except for volunteer A, who is a member of the anaesthetic department. This could explain why participants' height accuracy for Volunteer A was 82.3%. Participants overestimated weight in taller volunteers. Both volunteer A (female) and volunteer F (male) weighed 61 kg but because volunteer F was taller than Volunteer A, participants overestimated his weight more. This study reveals that participants with 10 years or less of clinical experience gave better height estimations (68.5%) than their seniors (59.5%). The probable explanation for this could be because the junior anaesthetists are exposed to patients more than their senior counterparts as they carry out pre-operative visits on a daily. Volunteer D has an actual height of 1.7 m (female) and both the groups had an estimation accuracy of 100%.

Gender could also be an influential factor of weight accuracy, as female volunteers were more accurately estimated but no supporting literature could be found. Participants in this study were better at estimating weights of female volunteers (86.8%), with female participants having more accurate weight estimations of female than male volunteers. The association between volunteers and participants' gender on weight estimation was not significant. Gender influence on height estimation reflected that male participants were good at estimating heights of male volunteers (86.8%) and female participants were able to estimate heights of female volunteers (57.7%) more accurately. There was no association between volunteers and participants' gender on height estimation. Christensen [31] showed a gender stereotyping where women tend to under-estimate men's weight and men over-estimated women's weight when the women were either underweight or overweight. The author attributed this to a preference for a smaller female body in the Danish population by men. Additionally, parents were found to have a tendency to overestimate the weight of their daughters and underestimate that of their sons.

This study is not without limitations as it was conducted contextually at CMJAH and CHBAH; the results may not translate to the anaesthetic departments from other institutions. Further research should be considered in order to examine how the participants' own weight and height influence the accuracy of the volunteers' weight and height estimations.

Conclusion

Results from this study and studies conducted in the ED and ICU revealed that weight and height estimations in adults by medical personnel are inaccurate, with height more accurately estimated than weight. This study has given an insight into the inaccuracy with which the anaesthetists estimate their patients' weight and height pre-operatively, which ultimately affect their clinical application of the measurements. Measures to obtain actual pre-operative weights and heights should be put in place where possible.

Conflict of interest

The authors declare that they have no financial or personal relationships, which may have inappropriately influenced them in writing this paper.

Acknowledgements

This study was done in a partial fulfilment of a Master of Medicine degree. The authors want to acknowledge the invaluable contribution of the Faculty of Health Science biostatisticians.

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SECTION 4: Appendices

Appendix A: Participants' information letter and consent form

Dear colleagues

Hello my name is Delina Molepo. I am herewith inviting you to participate in my MMed research: Anaesthetists' accuracy of weight and height estimations in supine adults. Please read this form carefully and ask any questions you may have before agreeing to take part in the study.

My study has been approved by The Human Research Ethics Committee (Medical) (M150110) and the Graduate Studies Committee of the University of the Witwatersrand.

If you agree to be part of this study, we will ask you to sign consent and complete a questionnaire with your demographics and your estimations of six volunteers' weights and heights. This should take approximately 10 minutes of your time.

Your data will be collected anonymously as there will be no identifying information requested from you.

Please be reassured that my supervisors and I will be the only people to see your estimation results. Your participation in this study is totally voluntary: you are under no obligation to participate. There will be no consequences should you choose not to participate.

If you have any questions, you are welcome to contact me on 0761493378 or the Chairperson of the Human Research Ethics Medical on 011 717 1234.

Thank you for taking time to read this letter.

Delina

I have read and fully understand the given information above. I hereby consent to participate in the study.

Signature

Date

Appendix B: Survey form for participants

Please tick where appropriate

What is your gender	Male	Female

What is your professional designation	Medical Officer	Registrar	Consultant

Years of clinical experience	0 – 10	≥ 11

Please move to the stations and write your estimates in the provided spaces

	A	B	C	D	E	F
Supine weight estimation						
Supine height estimation						

Appendix C: Letter for permission to conduct research

6 March 2015

Professor Lundgren

Head of the Department: Anaesthesiology

Request for permission to conduct research

Dear Prof. Lundgren

My name is Delina Molepo and I am a post graduation student at the University of the Witwatersrand Department of Anaesthesia. I wish to conduct a research for my MMed, which involves accuracy of weight and height estimations in supine adults by anaesthetists. This project will be conducted under the supervision of Helen Perrie and Juan Scribante.

I hereby seek your consent to collect data from anaesthetists from all hospitals affiliated with the university.

If you require any further information, please do not hesitate to contact me on sejamlp@yahoo.com or 0761493378.

Thank you for your time and consideration in this matter.

Yours sincerely,

Molepo Delina

University of the Witwatersrand

Approved

D. LINEK. 06/03/2015

PROF. A.C. Lundgren.

16

Appendix D: Ethics approval

R14/49 Dr Shirley Sejabaledi Delina

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M150110

NAME: (Principal Investigator)	Dr Shirley Sejabaledi Delina
DEPARTMENT:	Anaesthesiology Helen Joseph Hospital
PROJECT TITLE:	Anaesthetists Accuracy of Weight and Height Estimations in Supine Adults
DATE CONSIDERED:	30/01/2015
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Helen Perrie and Juan Scribante
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	11/03/2015

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**.

Principal Investigator Signature ______________ Date ______________

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix E: Faculty approval

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Ms Thokozile Nhlapo
E-mail: thokozile.nhlapo@wits.ac.za

04 March 2015
Person No: 1111566
PAG

Dr SSD Molepo
P.O Box 31
Boyne
0782
South Africa

Dear Dr Molepo

Master of Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *Anaesthetists accuracy of weight and height estimations in supine adults* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Appendix F: Turnitin report

Turnitin Originality Report

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SECTION 5: Proposal

Anaesthetists' accuracy of weight and height estimations in supine adults

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5.1 Introduction

Weight and height are two of the most commonly used anthropometric measurements in clinical practice. Anaesthetists use weight in theatre not only for drug dosing but also for ventilation settings, infusion rates, instrument size prediction and calculation of physiological state changes like glomerular filtration rate (1, 2). Height is often needed for target-controlled infusions and to calculate predicted body weight, a critical variable used to set the tidal volume during mechanical ventilation (3).

Research has demonstrated that up to 18% of serious preventable medication errors are the result of not having essential information at the time of prescribing and administering medications (4). Patients are not routinely weighed before anaesthesia and more often weight and height measurements are not documented on adult patients' charts. Measuring weight and height may be impossible, especially for critically ill patients before anaesthesia. For these reasons, anaesthetists find themselves making visual estimations without confirmation (5).

Incorrect weight estimations contribute to preventable medical errors (6). Overestimation can lead to lung barotrauma, drug overdosing, toxicity and increased costs whereas underestimation can lead to hypoventilation and drug under dosing, which potentially results in suboptimal therapeutic effects and ultimately increased costs (7).

Health care workers use different methods to measure weight and height. Devices such as electronic scales, spring scales, balance beam scales and weighing beds commonly measure weight (8-10). Height is often measured by stadiometers, the vertical rule on a standard platform, balance beam scale or a vertical ruler attached to the wall (7). Predictions by anthropometers using the knee height, ulna length and demi span; this being the distance from the middle of the sternal notch to the tip of the middle finger on the coronal plane, are also used (7).

Previous studies examined the accuracy of adult weight and height estimations in the emergency departments (5, 6, 11-12,14-18) and intensive care units (5, 6, 11-18). All of these studies concluded that the physicians and nurses' weight estimations were inaccurate. The ability of anaesthetists to accurately estimate patient's weight has not been well studied.

In 2004 Anglemyer et al. (6) showed that the emergency department staff estimations of patients' weight is often inaccurate. They suggested that the patients' own estimate of their actual weight can be used as they were found to be more reliable. Should the patient be incapacitated, no proven method is widely available to avoid dosage error. Coe et al. (19) found that more experienced health workers gave more accurate estimations.

Health care workers do not always estimate weight and height but rely on self-reported values by patients. A number of studies assessed the reliability of self-reported weight and height and their impact on the health outcome of patients (18, 20-28). These studies were consistent in finding high correlations of self-reported weight and height with the actual measurements.

Nasiri et al. (29) after identifying the need to obtain weight measurements in critically ill patients, conducted a study to determine the accuracy of estimating the total body weight in anaesthetised patients. They took weight measurements of anaesthetised patients' lower limbs and the head separately and developed a formula that gave a good correlation with patients' true total weight and has proven to be helpful in unconscious patients. All the patients in this study were anaesthetised, therefore the formula may not be reliable in awake patients who may be in a stressful situation (29).

5.2 Problem statement

Patients at the hospitals affiliated to the University of the Witwatersrand (Wits) are not routinely weighed or have their heights measured in theatre, nor do they always have these measurements recorded in the files from the wards. Measuring weight and height can be a challenging task for anaesthetist especially in critically ill patients and those with posture disabilities. Anaesthetists in the Department of Anaesthesiology at Wits frequently have to make estimations of weight and height with patients lying supine, however, the accuracy of these estimations is not known.

5.3 Aim

The aim of this study is to describe anaesthetists' accuracy of weight and height estimations in supine adults in the Department of Anaesthesiology at Wits.

5.4 Objectives

The primary objectives of this study are to:

- describe the accuracy of weight estimation in supine adults
- describe the accuracy of height estimation in supine adults.

The secondary objective of this study is to:

- describe the accuracy of weight and height estimations with anaesthetists' years of clinical experience
- compare the relationship between the volunteers and participants' gender as an influence on accuracy of weight and height estimation.

5.5 Research assumptions

The following definitions are used in the study**.**

Anaesthetist: is any qualified doctor working in the Department of Anaesthesiology including medical officers, registrars and consultants**.**

Medical officer: is a qualified doctor practicing in the Department of Anaesthesiology under specialist supervision**.**

Registrar: is a qualified doctor who is registered with the Health Professionals Council of South Africa as a trainee anaesthetist.

Consultant: is a doctor with a specialist qualification in anaesthesiology endorsed by the Health Professionals Council of South Africa. Medical officers with more than 10 years of experience are career medical officers and regarded as consultants.

Volunteer: a person who is used to simulate a pre-operative patient.

Accurate weight estimation: weight of a volunteer estimated by the participants to within 10% of the volunteer's actual weight.

Accurate height estimation: height of a volunteer estimated by the participants to within 5% of the volunteer's actual height.

5.6 Demarcation of study field

The study was conducted in the Department of Anaesthesiology. The staff complement in the department at the time of the study was 27 medical officers, 107 registrars and 74 consultants. The following hospitals are affiliated to Wits:

- Charlotte Maxeke Johannesburg Academic Hospital
- Chris Hani Baragwanath Academic Hospital
- Helen Joseph Hospital
- Rahima Moosa Mother and Child Hospital
- Wits Donald Gordon Medical Centre.

5.7 Ethical considerations

Approval to conduct the study will be obtained from the Human Research Ethics Committee (Medical) and the Graduate Studies Committee at Wits. Further approval was obtained from the Head of Department (Appendix A)

Anaesthetists will be approached and invited to participate in the study. Those agreeing will be given an information letter with a consent form (Appendix B) and a questionnaire (Appendix C).

Anonymity and confidentiality will be ensured, as no identifying data will be requested from the participants. There will be no subordination as the researcher is a registrar in the department and most medical officers are experienced and senior to the researcher. Those medical officers junior to the researcher were not under the researcher's authority. Completed questionnaires will be collected in sealed data collection boxes and only the researcher and supervisors will have access to the raw data.

Data will be stored securely in a locked cupboard for six years after completion of the study.
The study will be conducted according to the principles of the Declaration of Helsinki (30) and the South African Guidelines for Good Clinical Practice (31).

5.8 Research methodology

5.8.1 Research design

A prospective, contextual and descriptive research design will be followed in this study.

According to Brink et al. (32) a prospective study is one in which “data about a presumed cause are first collected and then the effect or outcome is measured.” This study is prospective, as data will be collected at the time the study takes place.

De Vos et al. (33) refers to the context of a study as a “small-scale world”. This study is contextual, as it will take place in the Department of Anaesthesiology.

A descriptive study is concerned with and designed only to describe the existing distribution of variables, without regard to causal or other hypotheses (34). It allows the researcher to organise the data in ways that give meaning and facilitate insight (35). This is a descriptive study as it describes anaesthetists’ accuracy of weight and height estimation.

5.8.2 Study population

The study population will consist of all anaesthetists working in the Department of Anaesthesiology.

5.8.3 Study sample

Sample method

Convenience sampling involves the choice of readily available subjects or objects for the study (34). In this study a convenience sampling method will be used.

Sample size

The sample size will be determined in consultation with a biostatistician. The department at the time of the study will consist of 27 medical officers, 107 registrars and 74 consultants.

A sample size of 60 participants would give a power of 89% to detect an accuracy of 40% in estimating volunteers' weight with a 95% level of confidence (2 tailed test).

5.8.4 Inclusion and exclusion criteria

The inclusion criteria in this study are:

- anaesthetists working in the department
- anaesthetists consenting to participate.

The exclusion criteria are:

- anaesthetists on annual or sick leave
- interns rotating through the department.

5.8.5 Collection of data

Approval will be obtained from the relevant authorities. In consultation with the Head of the Department the most appropriate date will be identified for data collection.

The data will be collected on the same day at the two study hospitals, one in the morning and one in the afternoon, in a private area where departmental meetings occur. Six volunteers with different body types and ethnicities will represent the general population. Five of the six volunteers will be unknown to the participants and the participants will only see them for the first time lying supine. The volunteers will be wearing light clothing, no shoes and lying supine with one pillow. The researcher, on the same calibrated digital scale will weigh them. Their height will be measured with a tape measure using a standardised technique.

The standardised technique for height measurement as described by the BMI Task Force (36) is as follows:

> "For the measurement of height, volunteers are asked to stand with their back against the wall. The back, scapulae and buttocks are to be in contact with the wall if possible. The weight of the volunteer should be evenly distributed on both feet. They are asked to place the legs together, bringing the ankles or knees together. If they have knock-knees, the feet are separated so that the medial borders of the knees are in contact, but not overlapping. The volunteers are then asked to inhale deeply and hold their breath while maintaining the head and body in the same position. They are instructed to stand erect (stand up straight and look straight ahead). The upper tip of the tape measure is brought onto the superior point on the head with sufficient pressure to compress the hair." (36)

On the determined study day, anaesthetists will be invited to participate, upon agreement, they will be handed an information letter and consent form (Appendix B). The researcher and two assistants will be present during data collection to answer any questions and prevent data contamination. Completed questionnaires will be placed in a sealed box.

The questionnaire will request the following information:

- demographics
- o gender
- o professional designation
- o years of anaesthetic experience
- estimation of weight and height of six volunteers.

5.8.6 Data analysis

Data will be captured onto a Microsoft Excel spread sheet and analysed using STATA version 13 in consultations with a biostatistician. Categorical variables will be summarised using frequencies and percentages and continuous variables with means and standard deviations or medians and interquartile ranges depending on the distribution of data. Comparisons will be analysed using Chi^2 and one sample t-tests. A p value of <0.05 will be considered statistically significant.

5.9 Significance of the study

The clinical relevance of inaccurately estimating weight and height may not be the same for all patients (13). Weight is essentially used for drug dosages, ventilation settings and infusion rates of fluids in theatre. Height is used in accurate delivery of drugs during a target-controlled infusion of drugs for intravenous anaesthesia and for predicted body weight calculation. The extent to which anaesthetists make these inaccurate estimations is unknown. This study will give an insight into the accuracy with which the anaesthetists estimate their patients' weight and height pre-operatively.

5.10 Validity and reliability of the study

The following measures will be implemented to ensure validity and reliability in this study:

- using an appropriate study design
- calculating the sample size in consultation with a biostatistician
- the volunteers will be weighed on a calibrated digital scale
- the volunteers will be measured with a tape measure using the standardised technique
- data contamination will be prevented by collecting all the data at both the hospitals on one day and by the presence of the researcher and two assistants
- checking every tenth data entry on excel for accuracy
- data analysis being done in consultation with biostatisticians.

5.11 Potential limitations of the study

Limitations are defined as theoretical or methodological restrictions or weaknesses in a study that may decrease the generalisability of the findings (37).

The following limitations may apply to the study.

- The study will be done contextually i.e. in the Department of Anaesthesiology at Wits and therefore the results will not be able to be generalised to other academic institutions.
- Convenience sampling will be used which may result in selection bias and may therefore not be a true reflection of the study population.

5.12 Project outline

	Oct 2014	Nov 2014	Jan 2015	Apr 2015	Sept 2015	Oct 2015	Nov 2015
Chapter 1-3							
Proposal preparation							
Ethics approval							
Post grad approval							
Data collection							
Data analysis							
Article preparation							
Review with supervisors							
Submission							

5.13 Financial plan

The Department of Anaesthesiology will bear the cost of printing and paper for the proposal, ethics and post graduate approvals.

Proposal	18 pages X 10 copies	R180
Ethics application form	10 pages X 25 copies	R250
Post graduate application form	1 page X 6 copies	R6
Questionnaire forms	1 page X 100 copies	R100
Completed research report	100 pages X 4 copies	R400
Binding	1 book X 3	R450
Total		R1386

5.14 Appendices

Appendix A: Letter for permission to conduct research

6 March 2015

Professor Lundgren

Head of the Department: Anaesthesiology

Request for permission to conduct research

Dear Prof. Lundgren

My name is Delina Molepo and I am a post graduation student at the University of the Witwatersrand Department of Anaesthesia. I wish to conduct a research for my MMed, which involves accuracy of weight and height estimations in supine adults by anaesthetists. This project will be conducted under the supervision of Helen Perrie and Juan Scribante.

I hereby seek your consent to collect data from anaesthetists from all hospitals affiliated with the university.

If you require any further information, please do not hesitate to contact me on sejamlp@yahoo.com or 0761493378.

Thank you for your time and consideration in this matter.

Yours sincerely,

Molepo Delina

University of the Witwatersrand

Approval

D. Lines. 06/03/2015

Prof. A.C. Lundgren.

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Appendix B: Participants' information letter and consent form

Dear colleagues

Hello my name is Delina Molepo. I am herewith inviting you to participate in my MMed research: Anaesthetists' accuracy of weight and height estimations in supine adults. Please read this form carefully and ask any questions you may have before agreeing to take part in the study.

My study has been approved by The Human Research Ethics Committee (Medical) (M150110) and the Graduate Studies Committee of the University of the Witwatersrand.

If you agree to be part of this study, we will ask you to sign consent and complete a questionnaire with your demographics and your estimations of six volunteers' weights and heights. This should take approximately 10 minutes of your time.

Your data will be collected anonymously as there will be no identifying information requested from you.

Please be reassured that my supervisors and I will be the only people to see your estimation results. Your participation in this study is totally voluntary: you are under no obligation to participate. There will be no consequences should you choose not to participate.

If you have any questions, you are welcome to contact me on 0761493378 or the Chairperson of the Human Research Ethics Medical on 011 717 1234.

Thank you for taking time to read this letter.

Delina

I have read and fully understand the given information above. I hereby consent to participate in the study.

Signature

Date

Appendix C: Survey form for participants

Please tick where appropriate

What is your gender	Male	Female

What is your professional designation	Medical Officer	Registrar	Consultant

Years of clinical experience	0 – 10	> 11

Please move to the stations and write your estimates in the provided spaces

	A	B	C	D	E	F
Supine weight estimation						
Supine height estimation						

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