UNIVERSITI PUTRA MALAYSIA

CADAVERIC BODY WEIGHT ESTIMATION FROM REGRESSION ANALYSIS OF CORPSE LENGTH AND ANTERIOR ABDOMINAL SUBCUTANEOUS FAT THICKNESS USING POSTMORTEM COMPUTED TOMOGRAPHY

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By

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January 2020

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Forensic pathology has taken an important leap, owing to relatively low maintenance costs, short examination times, and ease of operation make CT a widely used cross-sectional imaging technique in modern postmortem imaging. To determine the regression formula for cadaveric body weight estimation using spine length, anterior abdominal subcutaneous fat thickness (ASCFT) and body weight (BW) of the Malaysian corpse bodies. Retrospectively, 107 corpses were analyzed to assess the correlation between the length of each corpse on PMCT by measuring the topogram length (TL), sternal length (SL) and thoracic column length(TCL) and compared them to the autopsy length (AL) using linear regression analysis. Similarly, we measured the anterior subcutaneous fat thickness (ASCFT) on both sides at the level of the umbilicus and compared them to the autopsy weight (AW). Subsequently, multiple regression analysis techniques were done to assess the correlation and significance between TL, SL, TCL, and ASCFT with AW in order to derive regression equations for cadaveric body weight estimation. The findings of this study confirm and substantially extend earlier observations that PMCT as an accurate method for estimating length and weight of the body, and there is a good linear relationship between topogram length (TL), sternum length (SL) and thoracic column length (TCL) compared to the length of the corpse and its weight. In our study, TL has the best correlation with the coefficient of determination. ASCFT measurements showed a good correlation for both sides with no significant difference but a poor correlation with AW. Multiple regression analysis showed a significant linear relationship using TL, SL, TCL, and ASCFT with AW. PMCT can be used in the estimation of cadaveric height and weight. This is particularly important when dealing with incomplete corpses or mass disaster. The regression equation could also be applied to patients in emergency circumstances.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANGGARAN BERAT BADAN MAYAT DENGAN KAEDAH ANALISIS REGRESI DARIPADA UKURAN PANJANG MAYAT DAN KETEBALAN LEMAK PERUT SUBCUTANEOUS ANTERIOR MENGGUNAKAN TOMOGRAFI BERKOMPUTER POST MORTEM

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Patologi forensik telah mengambil langkah yang drastik, oleh kerana kos penyelenggaraan yang agak rendah, masa pemeriksaan yang singkat, dan kemudahan operasi membuatkan teknik pencitraan keratan rentas CT banyak digunakan dalam pengimejan postmortem moden. Tujuan penyelidikan ini adalah untuk menghasilkan formula regresi menggunakan ukuran panjang tulang belakang dan ketebalan lemak subkutaneus anterior (ASCFT) bagi menentukan berat badan mayat (BW) untuk populasi Malaysia. Secara retrospektif, 107 mayat dianalisa untuk menilai korelasi antara panjang setiap mayat pada PMCT dengan mengukur panjang topogram (TL), panjang tulang sternal (SL) dan panjang tulang torak (TCL)serta membandingkannya dengan ukuran panjang mayat semasa bedah siasat (AL) dengan menggunakan analisis regresi linier. Begitu juga, kami mengukur ketebalan lemak subkutaneus anterior (ASCFT) di kedua-dua belah pada tahap umbilicus dan membandingkannya dengan berat semasa bedah siasat(AW). Selanjutnya, teknik analisa regresi berganda dilakukan untuk menilai korelasi dan kepentingan di antara TL, SL, TCL, dan ASCFT dengan AW untuk mendapatkan persamaan regresi untuk anggaran berat badan simati. Penemuan kajian ini mengesahkan dan memberi perhatian yang mendalam kepada PMCT sebagai kaedah yang tepat untuk menganggarkan panjang dan berat badan, serta terdapat hubungan linear yang baik di antara TL, SL dan TCL berbanding dengan ukuran panjang mayat dan beratnya. Dalam kajian kami, TL mempunyai korelasi terbaik dengan pekali penentuan. Pengukuran ASCFT menunjukkan korelasi yang baik untuk kedua-dua belah pihak tanpa korelasi yang berbeza tetapi rendah bila dibandingkan dengan AW. Analisis regresi berganda menunjukkan hubungan linear yang signifikan menggunakan TL, SL, TCL, dan ASCFT dengan AW. PMCT boleh digunakan dalam perkiraan ketinggian dan berat badan simati. Ini amat penting apabila berhadapan dengan mayat yang tidak lengkap atau bencana besar-besaran. Formula regresi yang sama juga juga boleh digunakan untuk pesakit-pesakit di dalam keadaan kecemasan.

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I certify that a Thesis Examination Committee has met on 9 January 2020 to conduct the final examination of Zyoud Tawfiq Y T on his thesis entitled "Cadaveric Body Weight Estimation from Regression Analysis of Corpse Length and Anterior Abdominal Subcutaneous Fat Thickness using Postmortem Computed Tomography" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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2-D	2-Dimensional
3-D	3-Dimensional
AL	Autopsy length
ASCFT	Abdominal subcutaneous fat thickness
AW	Autopsy weight
BMI	Body mass index
BW	Bodyweight
C	Cervical spine
CT	Computerized tomography
DICOM	Digital imaging and communication in medicine
DNA	Deoxyribonucleic acid
HKL	Hospital Kuala Lumpur
IPFN	Institut Perubatan Forensik Negara
L	Lumbar spine
LW	Lung weight
MDCT	Multidetector computed tomography
MLR	Multiple linear regression
MPR	Multiplanar reconstructions
MRI	Magnetic resonance imaging
MSCT	MultiSlice computed tomography
PET	Positron emission tomography
PMCT	Post-Mortem computed tomography
PMMRI	Postmortem magnetic resonance imaging
PPDN	Pusat Pengimejan Diagnostik Nuklear
r	Pearson correlation coefficients

RIS	Radiological information system
ROI	Region of interest
rTEM	Relative technical error of measurement
SEE	The standard error of estimation
SL	Sternal length
SLR	Simple linear regression
SPSS	Statistical package for social sciences
T	Thoracic spine
TCL	Thoracic column length
TEM	Technical error of measurement
TL	Topogram length
UCS	Upper cervical spine
WBSA	Whole-body surface area

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Cadaveric body weight estimation is nowadays being used in forensic science to explore information related to the dead body, cause of dead and other relevant details that may aid proper investigation especially in detecting what transpired during a crime scene. It is crucial as it involved external inspection of the body before carrying out an autopsy examination(Ferorelli *et al.*, 2017). This procedure has been applied widely especially in this era of frequent mass disasters(Bal *et al.*, 2013; Mitsiopoulos *et al.*, 1998). Anthropologic assessment of skeletal examination may help in the identification process as it has been tested and proven. Numerous studies have been published for the estimation of stature from measuring the long bones, vertebral column, and sternum (Tormey, 2016). As there is some biometric and proportional relationship between every human bone other body segment and the stature of that individual. The skeletal examination may help in identification since bones resist decomposition for a long time (Tormey, 2016). Similarly, there is a relationship between the anterior abdominal subcutaneous fat thickness (ASCFT) with body mass index (BMI) and body weight estimation. The anterior abdominal subcutaneous fat remains stable over time despite the process of decomposition as compared to the other soft tissues of the body(Gitto *et al.*, 2014).

Anterior abdominal subcutaneous fat thickness (ASCFT) has been found to be the key predictor in estimating cadaveric body weight and over the years, post-mortem computed tomography (PMCT) and postmortem magnetic resonance imaging (PMMRI) have been used in clinical and forensic laboratory to investigate, visualize disease and cause of death (Westphal *et al.*, 2012) especially as they serve as a virtual guide for autopsy (Flach *et al.*, 2014). Despite the difficulties in interpreting PMCT findings as it doesn't usually correlate with the clinical results, however, it's still being routinely used in forensic medicine and investigation. It has been reported that the diagnostic yield increases when post-mortem CT (PMCT) is added to the autopsy in both natural and unnatural death (Wichmann *et al.*, 2012). PMCT is being used to specifically detect fractures, hemorrhage, and gas collections in the dead and living body system. The use of PMCT as an alternative to an autopsy was first applied in 1994 but has not been established yet (Jalalzadeh *et al.*, 2015). It can generally be said that PMCT and PMMRI images modalities are key methods applied to autopsy imaging for a better examination of the corpse's body because conventional plain film radiography still tends to be the method of choice amongst most legal pathologists.

1.2 Problem statement

In an emergency clinical setting, obtaining patients' height and weight can be difficult. There are circumstances when the weight of the patient is not known or when the patient's condition is too frail for conventional weight assessment using the weighing scale. Weight needs to be estimated for fluid infusion, drug dosage and contrast media administrations (Gitto *et al.*, 2014). This is particularly important in trauma cases, disaster scenario and especially when dealing with the pediatric age group (Gitto *et al.*, 2014). In addition, there exists a problem in most of the existing techniques that are used in estimating cadaveric body weight and usually not providing complete accurate knowledge about the human body's weight, and height and time are difficult to ascertain the method. Hence, in this study, we used retrospectively collected PMCT scan images and measured the cadaveric body weight using topogram length (TL), sternal length(SL) and thoracic column length(TCL), autopsy length (AL), anterior subcutaneous fat thickness (ASCFT) and autopsy weight (AW) as they seem to be a reliable way in estimating the weight forensically. In addition, no study seems to estimate the bodyweight of the cadaver using CT. It was based on our literature findings that we hypothesized that CT technique may accurately predict the total cadaveric body weight based on the height and ASCFT measured obtained from CT output.

1.3 Significance of the study

Findings from this study will provide useful information to the clinicians, scientists, researchers, and more importantly to the expert's forensic scientists who may use the results in enhancing further security in our society, especially among Malaysian. It will also provide information on the importance of post-mortem CT (PMCT) as its usefulness in accurately determining the length and weight of cadaveric body weight. In a time like this where there is a lot of mass disaster occurring day in day out across the globe, the study will estimate the bodyweight of incomplete corpses. A good linear relationship is provided a linear relationship between topogram length (TL), sternum length (SL) and thoracic column length (TCL) compared to the autopsy length(AL) of the corpse and its weight (AW). These parameters could help biological anthropologists and forensic in furthering the research that will come up with something novel especially when these measurements are correlated with molecular markers found in the dead body. Equally, it can aide to improve in both research and postmortem investigation. The formula derived or predicted using multilinear regression may be applied to estimate the patient's body weight in emergency circumstances and particularly on the Malaysian population.

1.4 Research hypothesis

Based on the literature mining that carried out, it can be said that there is a significant correlation between morphometric length of the cadaveric spine, anterior abdominal subcutaneous fat thickness (ASCFT) and body weight (BW).

1.5 Research objectives

1.5.1 General objective

To determine the regression formula for cadaveric body weight estimation using spine length, anterior abdominal subcutaneous fat thickness (ASCFT) and body weight (BW) of the Malaysian corpse bodies.

1.5.2 Specific objectives

i. To measure the cadaveric spine length (C1-T1, T1-L1, L1-S1, C1-S1 Line, and C1-S1 Ellipse, AL) and determine their differences among the study population.
ii. To determine the relationship between cadaveric spine length and autopsy length (AL) among the Malaysian population.
iii. To measure the level of ASCFT and autopsy weight (AW) and evaluate the differences in morphometry of the right ASCFT, left ASCFT and autopsy weight (AW).
iv. To predict the cadaveric body weight using spine length and anterior abdominal subcutaneous fat thickness (ASCFT).

1.6 Organization of the chapters

This thesis is designed to comprise five (5) main chapters as shown in Figure 1.1, with the following brief explanation for each chapter and it's contained: -

Chapter One: introduces the study background, problems, hypothesis significant of the study and key objectives and the major findings, which summarized the overall contents of the work.

Chapter Two: Here, is a review of literature that involves elaboration on the previous findings that studies and discusses details the development of the post-mortem CT method in body weight estimation and corpse length using CT different theories and models was discussed as general review of the PMCT and of the structure and function of the spine and PMCT versus autopsy, subcutaneous fat, CT scan, analysis of corpse length, analysis of corpse weight, relation to the present study, which outlines the proper procedure to conducting this research.

Chapter Three: Presented the methods which explain the study design, sampling and sampling techniques, sample size estimation, and strategies for data collection, and analysis as well as ethical issues and application.

Chapter Four: The result outlines regression equations for cadaveric body weight estimation, discusses the research objectives and explained the relationship between TL, SL, and TCL compared to the length of the corpse, and its weight.

Chapter Five: discussion, and conclusion then followed by recommendation which summarizes the results. The chapter highlights the contributions of this research in the recent use of forensic medicine and the necessity of PMCT as a compatible, accurate multi-functional imaging tool that can support the autopsy.

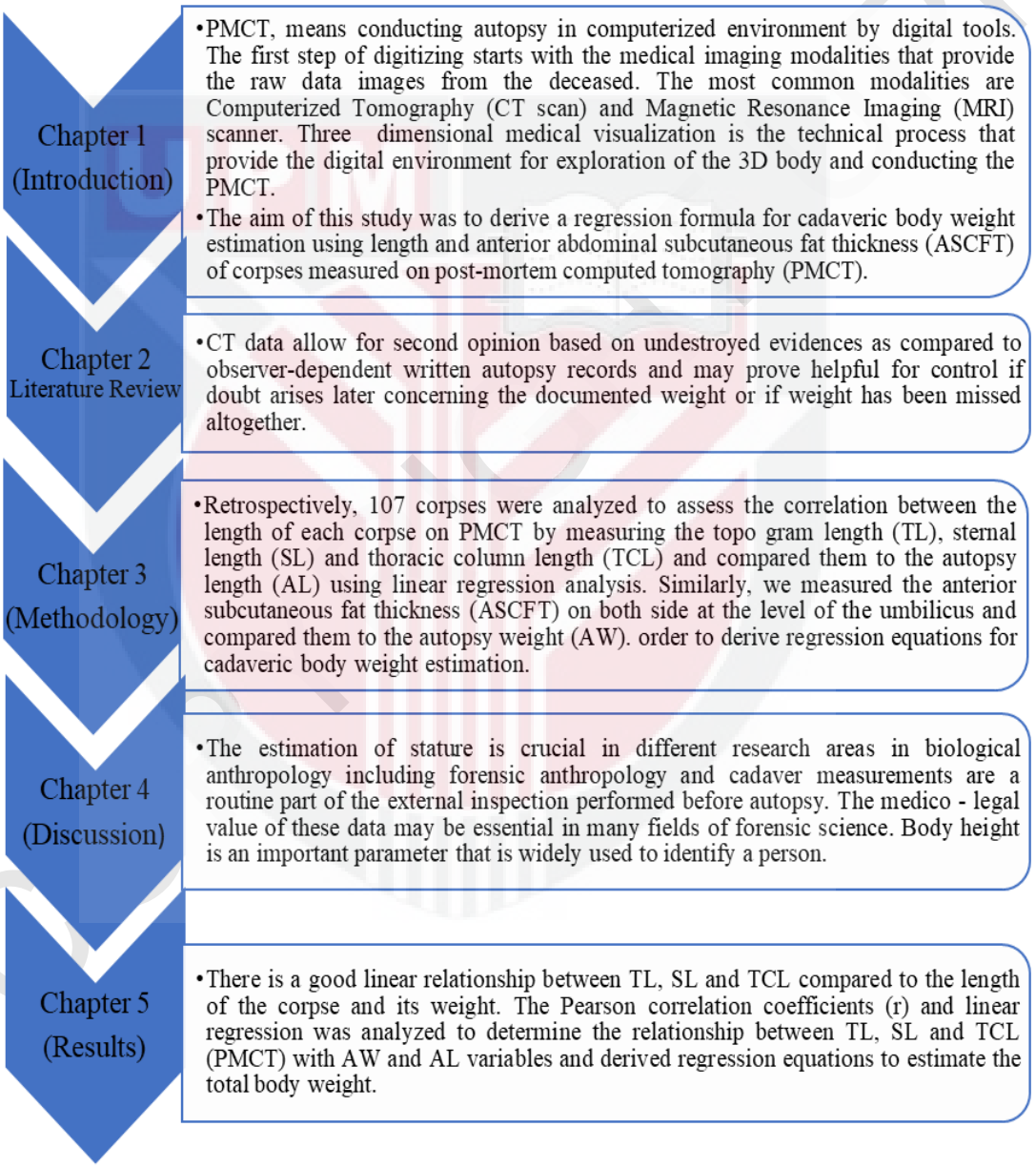

Figure 1.1 : Flow chart showing the study approach by chapter

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LIST OF PUBLICATIONS

Subapriya Suppiah, Tawfiq Y.T Zyoud, Ezamin Abdul Rahim, Ching Siew Mooi, Heamn N. Abduljabr, Rozi Mahmud, Saiful Nizam Abdul Rashid. (2019). Incremental benefits of minimally invasive image-guided virtopsy in improving findings from conventional autopsy: A review of recent literature and sharing of the Malaysian experience. *Journal of Legal Medicine*. (Manuscript submitted).

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