Anthropometric and computed tomography scan exposure measurements among adult patients, a hospital-based study

Geoffrey Erem1,2*, Samuel Bugeza1, Faith Ameda1, Caroline Otike3, William K Olwit1, Aloysius Gonzaga Mubuuke1, Cyril Scandhorf6, Akisophel Kisolo5 and Michael G Kowooya1,6

Abstract: Medical exposures to ionizing radiation constitute nearly half of the total radiation exposures from all sources. The higher utilization of imaging services is happening all over the world, Uganda inclusive. We sought to establish the relationship between adult patient anthropometric measurements and computed tomography scan exposure variables. This was a hospital-based cross-sectional study conducted in three selected hospitals performing adult CT scan examinations. A total of 176 adult patients who presented for head, abdominal, cardiac CT—calcium score and cardiac angiogram were recruited in the study. Data was collected using a piloted standardized research protocol for establishing diagnostic reference values. The data collected were weight, height, age and sex with CT scan variables. Data were analyzed using Spearman’s rank correlation coefficient and Wilcoxon rank-sum tests. This study was also approved by the ethics committee. The key findings showed that the examination, reference and total mAs were associated with significant positive associations with the anthropometric characteristics namely; weight, height and BMI as opposed to sex and age. The findings also revealed that males were generally exposed to higher doses for Head and...
Cardiac CT studies with females receiving higher doses for abdominal examinations only.

**Subjects:** Medicine; Dentistry; Allied Health

**Keywords:** Anthropometric characteristics; CT scan; exposure variables

1. Introduction

Computed Tomography (CT) scan is an invaluable diagnostic tool in patient management and the number of CT examinations has grown tremendously over the years (2012; Linton, 2014). This has been partly due to the rapid technological developments, resulting in the continued expansion of CT applications and clinical practices (Brenner & Hall, 2007). However, despite the accelerated use of CT, caution needs to be taken because an ionizing radiation-based imaging investigation, there are associated potentially harmful health risks. Therefore, to address this problem, there should be a careful balance of the patients and machine parameters for the optimization of radiation dose and image quality.

For example, the patients’ characteristics associated with differences in radiation exposures for the abdominal-pelvis CT studies include; older age, female gender, obesity, and multi-phase or repeat scanning (Cooper et al., 2017). The x-ray transmission data and effective photon energy data are used to determine CT image noise and image contrast, respectively, information on patient size and composition can be used to determine patient doses (Huda et al., 2004).

Huda et al in their study found that the adult male heads are 5% larger than females, with a corresponding 20% x-ray attenuation. In this study; the adult examinations were performed at 120 kV, typical values were 32 mGy for the mean section dose, 105 mJ for the total energy imparted, and 0.64 mSv for the effective dose. They also found out that increasing the x-ray tube voltage from 80 to 140 kV increased patient doses by a factor of five. Due to the potentially harmful effects of CT radiation scan doses, there is a need to take into account the patient age, head size, and composition as well as the selected x-ray technique factors (Huda et al., 2004).

In a study conducted in Germany, the mean size-specific dose estimate (SSDE) and Volume computed tomography dose index (CTDIcon) for chest and abdominopelvic CT protocols were lower than the updated 2017 ACR DRLs. In this study, size-specific sub-group analysis revealed a wide variability of SSDE and CTDIcon across CT protocols and patient size groups in non-contrast abdominopelvic CT of large patients (Klosterkemper et al., 2018).

With CT, particularly in countries without well-established guidelines and DRLs, there remains a risk of inappropriately optimized CT radiation control. A pilot study in a paediatric population in Sudan demonstrated that imaging protocols were not adapted to the patient’s weight in some CT machines resulting in unnecessary radiation doses to the children. In addition, the established DRLs were higher than those available in other countries. From this study, one can realize the need for harmonization of CT practice as well as optimization of radiation doses (Sulieman, 2015).

The need for continuous evaluation and control of CT radiation policies and the tools that aid in this has also become necessary with the ever-changing technologies. In a study conducted by Kim et al, CT Dosimetry Computer Codes, their influence on radiation dose estimates and the necessity for their revision under the new ICRP Radiation Protection Standards were looked at, the study found out that the radiation doses varied with patient age and sex (Kim et al., 2011). The younger patients and adult females received a higher radiation dose in general compared with adult males for the same CT technique factors. It also emerged that there were several limitations in the current CT dosimetry computer codes. The codes had unrealistic modelling of the human anatomy,
a limited number of organs and tissues for dose calculation, inability to alter the patient height and weight, and non-applicability to new CT technologies (Kim et al., 2011).

In addition, Tsapaki et al examined several variables in their investigation of the measure of radiation doses for CT scans of the head, chest and abdomen. These included: patient height, weight, sex, and age; tube voltage and tube current-time product settings; pitch; section thickness; the number of sections; weighted or volumetric CT dose index; and dose-length product (DLP). In this study, they compared the results with the DRLs. It was concluded from this study that there was a need for revisions, partly because the newer CT scanners tend to have improved technology that facilitates lower patient doses (Tsapaki et al., 2006).

CT usage is dependent both on adequate radiation control and correlation with patient factors. The relationship between the exposure settings, the resulting image quality and the patient dose is dependent on the size of the patient, it is, therefore important to adjust the exposure settings to the size of the patient (2014). CT is associated with relatively high radiation doses, with a corresponding increased risk of carcinogenesis (Protection Ar, 2008), therefore, the use of CT requires strict adherence to the tenets of radiation protection, justification and optimization to ensure that the risk to patients doesn’t outweigh the benefit gained from the technique (Commission E, 1999).

Despite some literature on CT dose optimization with the patient characteristics, there is a dearth of published empirical studies on this subject from sub-Saharan Africa whose population anthropometric characteristics might be different parts of the world, thus the need for this study. The purpose of this study was therefore to determine the relationship between the patients' anthropometric characteristics and the various CT scan exposure variables in clinical radiology practices from selected hospitals in Uganda.

2. Methods and materials
Study design: This was a cross-sectional, descriptive quantitative study.

Study setting: Hospitals with CT scan machines that had automated computation of radiation dose indices were selected for this study. The hospitals were purposively drawn from the private and private not for profit (PPF and PNFP) hospitals respectively. For the sake of anonymity, the facilities were designated A, B and C. The machines from facilities A, B and C were all siemens machines of various models namely; siemens perspective 128 slice scanner, Siemens 16 slice and Siemens Somatom emotion 8 slice scanner respectively. Additionally, the protocols used by the various facilities were as follows: facility A used helical scanning with machine pre-set protocols that had automatic dose reduction software in place, facilities B and C used sequential scanning using operator adjusted scan parameters.

3. Participants, sampling and sample size determination
Adults who met the recruitment criteria were included in this study by systematic random sampling. Every third patient was recruited in this study namely for head and abdominal CT scans and every second patient for cardiac CT scans. International Atomic Energy Agency (IAEA) survey form adopted from International Commission for Radiological Protection (ICRP) 135 for participant recruitment recommends a minimum of 10 patients and a maximum of 20 patients per radiation room to describe CT dose characteristics (Vanhó et al., 2017).

4. Recruitment table
Data collection: Data was collected using the aid of a piloted standardized research protocol. This was adopted from the tested and validated IAEA survey form for establishing diagnostic reference levels. Weight was measured using a calibrated SECA 762 weighing scale and height was measured using a wall fitted Stadiometer stature meter 206. The CT scan variables were extracted from
the CT computer console. The quantitative data were entered into the Epi-Info database and then analyzed using Stata.

**Study variables:** The variables of interest were patient anthropometry and CT scan technical variables, independent variables were age, sex, weight, height and BMI while dependent variables included kV, total mAs, examination mAs, effective mAs, slice thickness, scan length and scan time.

5. Data analysis
The data were analyzed using Stata version 11.2 software. Frequency tables were generated for patients’ anthropometric characteristics and CT scan variables. Spearman’s rank correlation was used to determine the relationship between continuous variables and Wilcoxon Ranks Sum analysis was used to determine the relationship between the categorical variables and continuous outcomes.

6. Ethical considerations
Approval to conduct this study was granted by the Makerere University School of Medicine Research and Ethics Committee (REC REF 2015–150). Further administrative clearance was obtained from each of the hospitals that participated in the study. Before data collection, informed consent was obtained from each participant. Privacy, anonymity and confidentiality of the participant information were guaranteed by making sure that no participant was identified by name and all collected data was kept on a computer secured by a password only accessible to the researcher. The selected hospitals were also de-identified and only given letter codes to maintain anonymity.

7. Results
The purpose of this study was to determine the relationship between the anthropometric measurements and the CT scan variables in adult patients who presented to selected facilities for the head, abdominal and Cardiac CT scan examinations. A total of 176 patients were recruited from three health facilities designated A, B and C.

While the majority of the patients for head CT scans were male, most of the patients for cardiac and abdominal CT scans were female. The highest BMI was noted in patients for calcium score and the lowest was noted in patients for abdomen CT scan (Table 1).

Whereas in facility A, the majority of the participants for head CT scans were male, for cardiac and abdominal CT scans the majority of the participants were female. However, in facilities B and facility C, most of the participants were males except for the abdomen in facility B. (Table 2).

In the Spearman’s rank correlation coefficient to evaluate the relationship between the continuous anthropometric variables and CT scan exposure variables; for facility A, there was a moderate positive relationship between the patient’s weight with total mAs ($r_s = 0.48$, $p$-value $= 0.0263$), exam mAs ($r_s = 0.59$, $p$-value $= 0.0048$) and reference mAs ($r_s = 0.45$, $p$-value $= 0.0048$) for head CT scans. There was a strong positive relationship between the patient’s weight with examination mAs ($r_s = 0.87$, $p$-value $= 0.0244$) and a strong positive relationship between the height and reference mAs ($r_s = 0.89$, $p$-value $= 0.0171$) for CT calcium score and a weak negative significant relationship between BMI and total mAs ($r_s = −0.50$, $p$-value $= 0.0255$) for CT coronary angiogram. This thus means that generally the higher the patient weight, the higher the total, reference and exam mAs, however for cardiac CT scan the higher the BMI, the less the total mAs (Table 3a).

Regarding abdominal CT scan, there was a moderate positive relationship between the patient’s weight and BMI with total mAs ($r_s = 0.55$, $P$-value $= 0.0093$), ($r_s = 0.54$, $P$-value $= 0.0119$)) and a moderate positive relationship between weight and BMI with examination mAs ($r_s = 0.56$, $P$-value $= 0.0083$), ($r_s = 0.73$, $0.0002$) respectively. This therefore implies that for abdominal CT scans, the higher the patient’s weight and BMI, the higher the total and exam mAs (Table 3a).
Table 1. Social demographic characteristics of 176 patients doing head, abdomen and cardiac CT scans

| Characteristics | Head (n = 68) | Cardiac Calcium (n = 30) | Cardiac angiogram (n = 22) | Abdomen (n = 56) | Total (N = 176) |
|-----------------|--------------|-------------------------|---------------------------|-----------------|----------------|
| Age             | 32 (24, 45.5) | 55.7 (6.7)              | 53.9 (7.1)                | 47.5 (30.5, 57.5)| 48 (30.5, 55.5)|
| Weight (Kgs)    | 71.5 (60.81.3) | 79 (68, 89)             | 72.8 (10.3)              | 69 (59, 86.5) | 72.7 (15.5) |
| Height (cms)    | 172.6 (164.5, 187.3) | 159.5 (154, 172)       | 163.3 (161, 168.5)       | 168.3 (161.5, 190) | 168 (161.4, 183) |
| BMI             | 23.8 (6.8)    | 30 (10.0)               | 27 (4.2)                 | 22.7 (19.4, 29.3) | 25.8 (9.8) |
| Sex n (%)       | Female 22 (32.4) | 18 (60.0)               | 15 (68.2)                | 28 (50.0)       | 83 (47.2) |
|                 | Males 46 (67.6) | 12 (40.0)               | 7 (31.8)                 | 28 (50.0)       | 93 (52.8) |
Table 2. Social demographic characteristics were analyzed and disaggregated by facilities for the 176 patients doing head, abdomen and cardiac CT scans in facilities A, B and C

| Measure                      | Facility A          | Facility B          | Facility C          |
|------------------------------|---------------------|---------------------|---------------------|
| **Characteristics**          | **Facility A**      | **Facility B**      | **Facility C**      |
| Head (n = 21)                | Calcium score (n = 30) | Cardiac angiogram (n = 22) | Abdomen (n = 21) |
| Age                          | 32 (18, 53) **      | 55.8 (6.7)          | 53.9 (7.1)          |
| Weight (kgs)                 | 68.5 (10.8)         | 77.9 (19.5)         | 72.8 (10.3)         |
| Height (cms)                 | 194.9 (186.5,199) **| 159.5 (154, 172) **| 164.6 (7.0)         |
| BMI                          | 17.7 (15.7,19.8) ** | 30.3 (10.0)         | 27.0 (4.2)          |
| Sex n (%)                    | Male                | Female              | Male                |
| Female                       | 5 (23.8)            | 18 (60.0)           | 15 (68.2)           |
| Males                        | 16 (76.2)           | 12 (40.0)           | 7 (31.8)            |

** median (25th percentile, 75th percentile)
| Facility | Block | Total mAs | Age | Weight | Height | BMI |
|----------|-------|-----------|-----|--------|--------|-----|
| A Head   | Total mAs | 0.31 (0.1776) | 0.48 (0.0263) ** | 0.09 (0.6908) | 0.20 (0.3816) |
|          | Examination mAs | 0.38 (0.0932) | 0.59 (0.0048) ** | −0.04 (0.8490) | 0.41 (0.0661) |
|          | Reference mAs | 0.34 (0.1298) | 0.45 (0.0048) ** | −0.18 (0.4352) | 0.36 (0.1094) |
|          | Scan length (mm) | 0.13 (0.5698) | 0.09 (0.7111) | 8.31 (0.1706) | −0.15 (0.5182) |
|          | Scan time | −0.05 (0.8230) | 0.09 (0.7027) | 0.16 (0.4961) | −0.04 (0.8580) |
| A Cardiac calcium | Total mAs | −0.37 (0.4685) | 0.41 (0.4247) | 0.64 (0.1731) | 0.41 (0.4247) |
|          | Examination mAs | −0.26 (0.6228) | 0.86 (0.0244) ** | 0.75 (0.0835) | 0.46 (0.3542) |
|          | Reference mAs | −0.29 (0.5734) | 0.69 (0.1268) | 0.89 (0.0171) ** | 0.30 (0.5675) |
|          | Scan length (mm) | 0.06 (0.9131) | −0.18 (0.7380) | 0.29 (0.5715) | 0.09 (0.8680) |
|          | Scan time | 0.09 (0.8717) | 0.03 (0.9565) | 0.55 (0.2574) | 0.03 (0.9565) |
| A Cardiac | Total mAs | 0.06 (0.8174) | −0.27 (0.2488) | 0.40 (0.0842) | −0.50 (0.0255) ** |
|          | Scan length (mm) | 0.12 (0.6203) | 0.0004 (0.9987) | 0.21 (0.3816) | −0.13 (0.5777) |
|          | Scan time | 0.23 (0.3229) | 0.07 (0.7615) | 0.12 (0.6009) | −0.10 (0.6785) |
| A Abdomen | kVp | 0.14 (0.5469) | −0.21 (0.3630) | −0.09 (0.7074) | −0.14 (0.5471) |
|          | Total mAs | −0.01 (0.9510) | 0.55 (0.0093) ** | −0.13 (0.5822) | 0.54 (0.0119) ** |
|          | Examination mAs | 0.22 (0.3297) | 0.56 (0.0083) ** | −0.42 (0.0557) | 0.73 (0.0002) ** |
|          | Reference mAs | 0.33 (0.1457) | −0.37 (0.1018) | 0.01 (0.9718) | −0.32 (0.1519) |
|          | Scan length (mm) | 0.24 (0.3006) | 0.27 (0.2370) | 0.15 (0.5033) | 0.12 (0.5981) |
|          | Scan time | 0.29 (0.2088) | 0.35 (0.1238) | 0.03 (0.8822) | 0.26 (0.2566) |

(b) Spearman’s rank correlation coefficients for the relationship between continuous predictors and CT scan exposure variables.
| Facility | Examination | Scan length (mm) | Scan time | Reference |
|----------|-------------|-----------------|-----------|-----------|
| B Head Total mAs | -0.35 (0.0992) | 0.06 (0.7999) | -0.12 (0.5900) | 0.15 (0.4904) |
| | Examination mAs | 0.03 (0.8841) | 0.35 (0.0977) | -0.23 (0.3016) | 0.35 (0.0978) |
| | Scan length (mm) | -0.35 (0.1027) | 0.02 (0.9134) | -0.10 (0.6636) | 0.13 (0.5584) |
| | Scan time | -0.39 (0.0654) | -0.17 (0.4257) | 0.02 (0.9365) | -0.08 (0.7178) |
| Abdomen Examination mAs | 0.10 (0.7980) | 0.90 (0.0009) ** | 0.15 (0.7001) | 0.87 (0.0025) ** |
| | Reference mAs | -0.41 (0.2679) | 0.00 (1.0000) | 0.41 (0.2679) | -0.10 (0.7910) |
| | Scan time | 0.05 (0.8984) | 0.33 (0.3807) | -0.42 (0.2646) | 0.30 (0.4328) |
| C Head Total mAs | -0.12 (0.6799) | 0.36 (0.2080) | -0.28 (0.3338) | 0.37 (0.1910) |
| | Examination mAs | -0.22 (0.4448) | -0.04 (0.9000) | -0.43 (0.1295) | 0.02 (0.9500) |
| | Reference mAs | 0.04 (0.9015) | 0.37 (0.1903) | -0.21 (0.4771) | 0.43 (0.1228) |
| | Scan length (mm) | 0.22 (0.4487) | 0.08 (0.7760) | 0.39 (0.1713) | -0.02 (0.9583) |
| | Scan time | -0.25 (0.3860) | -0.004 (0.9881) | -0.11 (0.6969) | -0.03 (0.9227) |
| Abdomen Total mAs | 0.25 (0.3519) | 0.78 (0.0004) ** | 0.14 (0.5941) | 0.60 (0.0140) ** |
| | Examination mAs | -0.36 (0.2017) | 0.36 (0.1650) | 0.03 (0.9179) | 0.31 (0.2457) |
| | Reference mAs | 0.01 (0.9568) | 0.95 (<0.001) ** | 0.16 (0.5566) | 0.80 (0.0002) ** |
| | Scan length (mm) | 0.10 (0.7237) | 0.20 (0.4483) | 0.17 (0.5379) | 0.15 (0.5790) |
| | Scan time | -0.09 (0.7355) | 0.53 (0.0328) ** | 0.26 (0.3341) | 0.44 (0.0909) |
Table 4. Facility A: Wilcoxon Rank sum test for the relationship between sex and CT scan exposure variables

| Outcome variables | Head | Calcium score | Cardiac angiogram | Abdomen | p-value |
|-------------------|------|---------------|-------------------|---------|---------|
|                   | Median (25th and 75th percentile) | p-value | Median (25th and 75th percentile) | p-value | Median (25th and 75th percentile) | p-value |
| kVp               | -    | -             | -                 | 0.8927  |         |         |
| Female            | 130 (130, 130) | 130 (130, 130) | 130 (130, 130) | 130 (110, 130) |         |         |
| Male              | 130 (130, 130) | 130 (130, 130) | 130 (130, 130) | 130 (110, 130) |         |         |
| Total mAs         | 0.3218 | 0.3302 | 0.4378 | 0.2908  |         |         |
| Female            | 1102 (919, 1176) | 419 (314, 505) | 2350 (2305, 2561) | 5084 (3753, 6399) |         |         |
| Male              | 1191.5 (1082, 1287) | 386.5 (271.5, 430.5) | 2360 (2344, 2376) | 4310.5 (3488, 5912) |         |         |
| Examination mAs   | 0.8362 | 0.1684 | - | 0.0074 ** |         |         |
| Female            | 160 (141, 168) | 62.5 (44, 88) | 400 (400, 400) | 126 (106, 150) |         |         |
| Male              | 156 (150, 172.5) | 47.5 (32.5, 61) | 400 (400, 400) | 89.5 (84, 103) |         |         |
| Reference mAs     | 0.6831 | 0.5826 | - | 0.5437  |         |         |
| Female            | 190 (190, 190) | 75 (75, 75) | - | 150 (130, 150) |         |         |
| Male              | 190 (190, 190) | 75 (52.5, 75) | - | 150 (130, 150) |         |         |
| Slice thickness   | - | - | - | - |         |         |
| Female            | 5 (5, 5) | 3 (3, 3) | 3 (3, 3) | 5 (5, 5) |         |         |
| Male              | 5 (5, 5) | 3 (3, 3) | 3 (3, 3) | 5 (5, 5) |         |         |
| Scan length (mm)  | 0.0693 | 0.0248 ** | 0.9418 | 5 (5, 5) | 0.2599  |         |
| Female            | 193 (175, 204.5) | 104.3 (100.3, 115.5) | 142.5 (136, 142.5) | 422 (246.5, 452.5) |         |         |
| Male              | 222.3 (204, 248.5) | 121.3 (110.3, 132.6) | 142.5 (7) | 434.3 (358.5, 498) |         |         |
| Scan time         | 0.1864 | 0.1432 | 0.5531 | 0.4179  |         |         |
| Female            | 14.9 (14.8, 15.8) | 5.4 (5.4, 5.4) | 8.77 (8.77, 8.77) | 12.2 (8.06, 13.03) |         |         |
| Male              | 15.9 (14.8, 20.2) | 7.9 (7.9, 8.2) | 8.77 (8.45, 8.77) | 12.4 (10.4, 13.9) |         |         |

**significant p-value
For facilities B and C concerning head CT scans, there was no significant relationship between anthropometric characteristics and the CT scan variables (Table 3b).

However, for abdominal CT in facility B, there was a strong positive relationship between the patient's weight and reference mAs ($r_s = 0.90$, P-value = 0.0009), and a strong positive relationship between the patient's BMI and reference mAs ($r_s = 0.87$, P-value = 0.0025). In facility C, there was a strong and moderate relationship between patients' weight, BMI with the total mAs ($r_s = 0.78$, P-value = 0.0004), ($r_s = 0.60$, P-value = 0.0140) and a strong relationship between weight and BMI with reference mAs ($r_s = 0.95$, P-value <0.001), ($r_s = 0.80$, P-value = 0.0002) (Table 3b). There was also a moderate positive relationship between patient weight and scan time ($r_s = 0.53$, P-value = 0.0328).

In the Wilcoxon Rank-sum test for facilities A, B and C; kVp and slice thickness were constant across all variables and examination mAs were constant for cardiac CT in facility A; hence they have no relationship with the patient's sex (Tables 4–6).

For cardiac calcium score and abdomen CT, there is a significant relationship between patients’ sex with the median scan length (p = 0.0248) and examination mAs (p = 0.0074) (Table 4).

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**Table 5. Facility B; Wilcoxon Rank sum test for the relationship between sex and CT scan exposure variables**

| Outcome variable | Head | Abdomen |
|------------------|------|---------|
| KvP              | -    | -       |
| Female           | 130 (130, 130) | 130 (130, 130) |
| Male             | 130 (130, 130) | 130 (130, 130) |
| Total mAs        | 4626 (4287, 4809) | 13,098.5 (6194, 19,329) |
| Female           | 4631 (4589.5, 4727) | 7731 (6037, 12,180) |
| Male             | 220 (220, 220) | 83.5 (63, 133) |
| Exam mAs         | 220 (220, 220) | 97 (76, 106) |
| Reference mAs    | 220 (220, 220) | 120 (120, 120) |
| Slice thickness  | 4 (4, 4) | 5 (5, 5) |
| Scan length (mm) | 229 (210.5, 236.2) | 371.8 (252.5, 400) |
| Scan times       | 229.3 (227, 234.5) | 364.5 (217.5, 410.5) |

For facilities B and C concerning head CT scans, there was no significant relationship between anthropometric characteristics and the CT scan variables (Table 3b).
In facilities B, there was no significant relationship between patients’ sex and CT scan variables (Table 5).

For head CT in facility C, there is a significant relationship between the patient’s sex with the median total mAs and reference mAs (p = 0.0192 and 0.0030) respectively and for abdomen CT, there is no significant relationship between the CT scan variables (Table 6).

8. Discussions

This study set out to determine the relationship between the patients’ anthropometric measurements and CT scan exposure variables whereby a total of 176 patients were recruited from three selected health facilities to examine this relationship.

There were more males in this study across the various facilities, this is comparable with the previous studies (Vañó et al., 2017). Whereas there are more women in the workforce (51%), the median monthly wedge for their male counterparts was twice that of the females (UBOS, 2020). The males were also more prone to head injury as per the study of Erem et al. in 2017 that understudied the clinical and cranial computed tomography findings in Uganda (Erem et al., 2017).

**Table 6. Facility C; Wilcoxon Rank sum test for the relationship between sex and CT scan exposure variables**

| Outcome variable | Head | | Abdomen | |
|------------------|------|-----------------|-----------------|
| **Median (25th and 75th percentile)** | **p-value** | **Median (25th and 75th percentile)** | **p-value** |
| kVp | - | - |
| Female | 130 (130, 130) | 130 (130, 130) | |
| Male | 130 (130, 130) | 130 (130, 130) | |
| Total mAs | 0.0192** | 0.2429 |
| Female | 2969 (2700, 3901) | 7565 (4605, 10,236) | |
| Male | 3844 (3546, 4420) | 5113 (3670, 9659) | |
| Examination mAs | 0.4777 | 0.3997 |
| Female | 180 (180, 190) | 98 (98, 98) | |
| Male | 185 (180, 190) | 98 (98, 98) | |
| Reference mAs | 0.0030** | 0.1460 |
| Female | 145 (133, 156) | 62 (59, 89) | |
| Male | 175.5 (158, 195) | 57 (44, 73) | |
| Slice thickness | - | - |
| Female | 5 (5, 5) | 1 (1, 1) | |
| Male | 5 (5, 5) | 1 (1, 1) | |
| Scan length (mm) | 0.8748 | 0.4361 |
| Female | 275 (161, 285) | 672 (600, 722) | |
| Male | 217.5 (166, 313) | 633 (612, 680) | |
| Scan times | 0.1381 | 0.4259 |
| Female | 37.2 (34.8, 38.1) | 41.5 (39.1, 44.7) | |
| Male | 39 (38.1, 39.4) | 40.4 (39.3, 41.4) | |

**significant p-value**
The key findings from this study show that while the patient's weight, height, BMI and sex had a significant relationship with CT scan exposure variables, the patient's age did not show any significant relationship with the CT scan exposure variables. The average weight was 72.7kgs, this was lower than the average weight from other studies. In Saudi Arabia, the average weight was 10 kgs more than in our study (Alkhorayef et al., 2021).

There was generally moderate to a strong positive significant relationship between the patient weight and the CT scan exposure characteristics namely; total, examination and reference mAs for the various study areas namely; head, abdominal and cardiac CT scans in the different hospitals. However, some of the facilities demonstrated no relationship between patient weight and CT dose characteristics namely total mAs, examination mAs for head CT examinations in Facilities B and C and total mAs, scan length and scan time for cardiac CT—coronary angiogram examination. Facilities B and C were 8 slice Siemens CT scanners compared to the 128 slice Siemens CT scanner for facility A. The study sites also did not have documented CT standard radiation dose characteristics influencing the choice of the CT dosimetric characteristics and this could account for non-consistency in the CT dose exposure characteristics.

CT scan is a major source of diagnostic radiation exposure to the general population accessing radiological services, this therefore necessitates the need to optimize the exposure parameters to ensure that the radiation doses delivered are consistent across the various facilities and examinations (Adam, 2016; Aliasgharzadeh et al., 2018; Chau, 2019). The study however found no significant relationship between patient weight with kVp, slice thickness and scan length.

The average height in this study was 168cms, this profile is similar to the adult patient characteristics in other settings, these findings agree with the Uganda Bureau of Statistics (UBOS) studies of 2020 (UBOS, 2020). There was generally no significant relationship between the patients' height and the radiation dose characteristics for head and abdominal CT scan examinations. However, when it came to cardiac CT scan—calcium score, there was a strong positive correlation between the patient height and reference mAs, implying that the higher the height of the patient, the higher the reference mAs.

The overall average BMI in this study was 24.5 which is categorized as healthy according to WHO, this is however lower than the average BMI reported in other studies (Vanø et al., 2017). There was a strong positive relationship between BMI with some CT scan parameters namely total, examination and reference mAs for abdominal CT scan examinations. For cardiac CT scans, there was a weak negative relationship between BMI and total mAs. This thus implies that when BMI increases, the total mAs should decrease.

However, for head CT scans, there was no significant relationship between the patient’s BMI and the CT scan variables across all the facilities. Huda et al in their study however used A-P and Lateral measurements for head size as opposed to weight and height in our study with eventual determination of BMI (Huda et al., 2004).

Although the BMI was lower in our study, this was still an important contributor to the radiation dose. The study also found increased weight to be associated with higher radiation doses. It is therefore imperative that key attention should be given to the anthropometric characteristic of weight which in turn determines the BMI of the patients (2014).

The median scores for the exposure characteristics namely the reference, total and exam mAs for males were generally higher across most of the hospitals, however for abdominal CT scans, the females had a higher median exposure characteristic score. This is in keeping with findings from previous studies demonstrating that females generally receive higher radiation doses (Kim et al., 2011). Considering that the females had a higher BMI especially for abdominal CT scans, this, in turn, translates into higher radiation dose characteristics to attain an optimal image quality.
The kVp and the slice thickness were constant across all the facilities, hence no relationship was elicited with the patients' sex (Cooper et al., 2017; Kim et al., 2011). The CT scan facilities usually have pre-set kVp and slice thickness parameters in the CT scan machines. This is usually done to reduce variability in the exposure parameters. There are however many other exposure characteristics that determine the eventual CT radiation dose, so these pre-set parameters alone may not optimize the radiation dose.

There was no significant relationship between the sex of the patient and all CT scan exposure variables in facility B, head and coronary angiogram in facility A and abdomen in facility C. This study therefore found out that sex generally did not have a significant relationship with the CT scan exposure characteristics, this is similar to the study by Huda et al. (2004).

This study in the adult participants found no significant relationship between age and any CT scan variable, hence as opposed to children whereby exposure characteristics increased with patient age in the adult population, there was no relationship between patient age and CT dose characteristics. This study generally is in agreement with the previous studies (Cooper et al., 2017; Kim et al., 2011).

This study overall demonstrates significant findings that could have implications for clinical practice and patient care. According to the study, the weight of the adult patient was an important parameter, but to a greater extent for abdominal CT scan examinations. The patients' sex was generally not important for CT scans of the head and abdomen.

The key strength of the study is that it was conducted in an African population whose social anthropometric characteristics could be different from those in other parts of the world. The dearth of literature on this particular subject was also a great motivator to contribute to this discussion, thus, the findings from this study will contribute to the overall discourse in this area. The fact that three different hospitals were used for purposes of comparison adds rigour to this study.

A limitation in this study was that the patients' weight and height were not taken routinely for CT examinations and the appropriate scales had to be procured to achieve this goal. There were also challenges of frequent machine breakdown significantly slowing down data collection.

This study however still yields significant empirical data that offers more understanding into the relationships between anthropometric patient characteristics and CT scan exposure variables that can guide to improve clinical practice.

9. Conclusion
This study found that the examination, reference and total mAs had a significant positive association with the patient characteristics namely; weight, height and BMI across the various facilities.

There was, however, no significant relationship between patients' age with the CT scan characteristics across all facilities. It also went ahead to demonstrate that the males were generally associated with higher exposure characteristics for head and cardiac CT scans whereas the female had a significant relationship with the CT parameters for abdominal CT scans.

The kVp and scan length was uniform for most of the examinations across the different facilities.

10. Recommendations
(1) The patients' weight and BMI, as opposed to the age and sex, should be considered when choosing the CT technical parameters for head, cardiac and abdominal CT scan examinations.

(2) There is a need for a conversation with different radiation users and facilities to harmonize the CT scan examination parameters to optimize the radiation exposure to the patients.
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Author details
Geoffrey Erem1,2
E-mail: deremgeoffrey@gmail.com
ORCID ID: http://orcid.org/0000-0002-1667-5219

1 Department of Radiology, School of Medicine, Makerere University.
2 Department of Radiology, St. Francis Hospital Nsambya.

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