







Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Age	232	19	70	43.08	14.408
RT RA	232	1.02	31.10	10.1049	3.18711
LT RA	232	1.26	16.20	6.0610	3.64083
RA	232	2.71	17.25	8.0829	2.70406
RT TM	232	1.52	11.40	5.1377	2.36142
LT TM	232	1.57	12.30	4.6247	2.13074
TM	232	1.55	11.20	4.8812	2.10147
RT IM	232	1.00	20.90	8.7459	3.15873
LT IM	232	1.55	11.40	4.7450	2.09721
IM	232	2.75	12.25	6.7455	1.93382
RT EO	232	1.89	10.90	5.5919	2.11594
LT EO	232	1.58	11.50	5.1924	2.02724
EO	232	1.74	10.55	5.3922	1.94195
Subcutaneous fatty layer	232	2.66	47.30	21.2023	10.64099
Valid N (list wise)	232				

**Table 3:** ANOVA Test to compare the mean of the measured thickness in (mm) of (Subcutaneous fatty layer) between age groups.

Report				
Subcutaneous fatty layer				
Age group	Mean	N	Std. Deviation	
19-32years	13.2887	62	8.82723	
32-45years	23.5647	72	10.17956	
45-58years	25.9571	55	8.57830	
58-71years	22.5751	43	10.30850	
Total	21.2023	232	10.64099	
p-Value .000				

**Table 4:** ANOVA Test to compare the mean of the measured thickness in (mm) of (Rt.RA &LT.RA& RA) between age groups

Report				
Age group		RT RA	LT RA	TOTAL RA
19-32years	Mean	11.4611	6.6621	9.0616
	N	62	62	62
	Std. Deviation	3.16855	4.05128	2.71541
32-45years	Mean	10.1674	6.0432	8.1053
	N	72	72	72
	Std. Deviation	2.64043	3.49295	2.43498
45-58years	Mean	9.5355	5.5369	7.5362
	N	55	55	55
	Std. Deviation	3.87439	3.33436	2.77347
58-71years	Mean	8.7730	5.8944	7.3337
	N	43	43	43
	Std. Deviation	2.28853	3.63685	2.68567
Total	Mean	10.1049	6.0610	8.0829
	N	232	232	232
	Std. Deviation	3.18711	3.64083	2.70406
P value		.000	.406	.003

**Table 5:** ANOVA Test to compare the mean of the measured thickness in (mm) of (Rt.TA &LT.TA& Total TA) between age groups

Report				
Age group		RT TA	LT TA	TOTAL TA
19-32 years	Mean	5.8905	5.2356	5.5631
	N	62	62	62
	Std. Deviation	2.59040	2.23215	2.20999
32-45years	Mean	5.1693	4.6090	4.8892
	N	72	72	72
	Std. Deviation	2.37698	2.23395	2.15451
45-58years	Mean	4.8189	4.2051	4.5120
	N	55	55	55
	Std. Deviation	2.29289	1.89180	2.02223
58-71years	Mean	4.4072	4.3070	4.3571
	N	43	43	43
	Std. Deviation	1.75943	1.95207	1.71595
Total	Mean	5.1377	4.6247	4.8812
	N	232	232	232
	Std. Deviation	2.36142	2.13074	2.10147
P value		.009	.041	.011

and left side in all four age groups. The RT TA show a mean of 5.89, 5.16, 4.8 and 4.4 respectively with a p value .009. The LT TA show a mean of 5.2, 4.6, 4.2 and 4.3 respectively with a p value of .041. The mean thickness for RT and LT TA in all patients is 5.1 and 4.6 respectively.

As demonstrated in table (6) the total mean thickness of IO in the four age groups 7.8, 6.8, 6.2 and 5.68 respectively and the mean thickness in all patients is 6.7 with a p value .000. The mean thickness of IO muscle was measured in the right and left side in all four age groups. The RT IO show a mean of 10.27, 8.89, 8.1 and 7.05 respectively with a p value .000. The LT IO show a mean of 5.35, 4.78, 4.33 and 4.32 respectively with a p value of .028. The mean thickness for RT and LT IO in all patients is 8.7 and 4.7 respectively.

**Table (7)** shows the total mean thickness of EO in the four age groups is 6.17, 5.48, 4.8 and 4.79 respectively and the mean thickness in all patients is 5.39 with a p value .000. The mean thickness of EO muscle was measured in the right and left side in all four age groups. The RT EO show a mean of 6.3, 5.7, 5.09 and 4.87 respectively with a p value .001. The LT EO show a mean of 6.02, 5.2, 4.59 and 4.7 respectively with a p value of .000. The mean thickness for RT and LT EO in all patients is 5.59 and 5.19 respectively.

**Influence of sex:**

As shown in table (8) the total mean thickness of RA in males and females is 9.1 and 7.03 respectively, with a p value

.000. The mean thickness of RA muscle was measured in the right and left side in both sex. The RT RA show a mean of 11.3 in males and 8.89 in females, with a p value .000. The LT RA show a mean of 6.95 in males and 5.1 in females with a p value of .000.

**Table (9)** demonstrate the total mean thickness of TA in males and females is 5.55 and 4.21 respectively, with a p value .000. The mean thickness of TA muscle was measured in the right and left side in both sex. The RT TA show a mean of 5.8 in males and 4.44 in females, with a p value .000. The LT TA show a mean of 5.27 in males and 3.97 in females with a p value of .000.

**Table (10):** show the total mean thickness of IO in males and females is 7.4 and 6.07 respectively, with a p value .000. The mean thickness of IO muscle was measured in the right and left side in both sex. The RT IO show a mean of 9.47 in males and 8.01 in females, with a p value .000. The LT IO show a mean of 5.3 in males and 4.1 in females with a p value of .000.

**Table (11):** demonstrate the total mean thickness of EO in males and females is 6.16 and 4.61 respectively, with a p value .000. The mean thickness of EO muscle was measured in the right and left side in both sex. The RT EO show a mean of 6.37 in males and 4.8 in females, with a p value .000. The LT EO show a mean of 5.95 in males and 4.42 in females with a p value of .000.

**Table 6:** ANOVA Test to compare the mean of the measured thickness in (mm) of (Rt.IO &LT.IO & Total IO) between age groups

Report				
Age group		RT IO	LT IO	TOTAL IO
19-32 years	Mean	10.2718	5.3508	7.8113
	N	62	62	62
	Std. Deviation	3.34706	2.40568	1.90328
32-45 years	Mean	8.8975	4.7860	6.8417
	N	72	72	72
	Std. Deviation	3.23516	2.15600	2.01891
45-58 years	Mean	8.1498	4.3395	6.2446
	N	55	55	55
	Std. Deviation	2.73779	1.82035	1.60337
58-71 years	Mean	7.0547	4.3214	5.6880
	N	43	43	43
	Std. Deviation	2.09896	1.65019	1.39468
Total	Mean	8.7459	4.7450	6.7455
	N	232	232	232
	Std. Deviation	3.15873	2.09721	1.93382
P value		.000	.028	.000

**Table 7:** ANOVA Test to compare the mean of the measured thickness in (mm) of (Rt. EO &LT.EO ) between age groups

Report				
Age group		RT EO	LT EO	TOTAL EO
19-32years	Mean	6.3356	6.0223	6.1790
	N	62	62	62
	Std. Deviation	2.17086	1.97912	1.93558
32-45years	Mean	5.7589	5.2108	5.4849
	N	72	72	72
	Std. Deviation	2.24903	2.14758	2.07375
45-58years	Mean	5.0976	4.5998	4.8487
	N	55	55	55
	Std. Deviation	2.02199	1.71551	1.76252
58-71years	Mean	4.8723	4.7228	4.7976
	N	43	43	43
	Std. Deviation	1.50282	1.90557	1.53590
Total	Mean	5.5919	5.1924	5.3922
	N	232	232	232
	Std. Deviation	2.11594	2.02724	1.94195
P value		.001	.000	.000

**Table 8:** T- Test to compare the mean of the measured thickness in (mm) of (Rt.RA &LT.RA& RA) between male and female

Group Statistics						P value
	Gender	N	Mean	Std. Deviation	Std. Error Mean	
RT RA	Male	116	11.3173	3.47962	.32307	.000
	Female	116	8.8924	2.30873	.21436	
LT RA	Male	116	6.9544	3.93153	.36503	.000
	Female	116	5.1676	3.09182	.28707	
RA	Male	116	9.1359	2.78555	.25863	.000
	Female	116	7.0300	2.16601	.20111	

**Table 9:** T- Test to compare the mean of the measured thickness in (mm) of (RT TA &LT TA & TA) between male and female

Group Statistics						P value
	Gender	N	Mean	Std. Deviation	Std. Error Mean	
RT TA	Male	116	5.8314	2.63215	.24439	.000
	Female	116	4.4441	1.81718	.16872	
LT TA	Male	116	5.2731	2.38148	.22111	.000
	Female	116	3.9764	1.61247	.14971	
TA	Male	116	5.5522	2.36076	.21919	.000
	Female	116	4.2102	1.54571	.14352	

**Table 10:** T- Test to compare the mean of the measured thickness in (mm) of (RT IO &LT IO & IO) between male and female

Group Statistics						P value
	Gender	N	Mean	Std. Deviation	Std. Error Mean	
RT IO	Male	116	9.4738	3.46729	.32193	.000
	Female	116	8.0181	2.63648	.24479	
LT IO	Male	116	5.3609	2.23235	.20727	.000
	Female	116	4.1290	1.75669	.16310	
IO	Male	116	7.4174	2.01516	.18710	.000
	Female	116	6.0735	1.59378	.14798	

**Table 11:** T-Test to compare the mean of the measured thickness in (mm) of (RT EO &LT EO & EO) between male and female

Group Statistics						P value
	Gender	N	Mean	Std. Deviation	Std. Error Mean	
RT EO	Male	116	6.3736	2.28404	.21207	.000
	Female	116	4.8103	1.59494	.14809	
LT EO	Male	116	5.9590	2.09291	.19432	.000
	Female	116	4.4258	1.63991	.15226	
EO	Male	116	6.1663	2.03786	.18921	.000
	Female	116	4.6180	1.48769	.13813	

**Table 12:** T-Test to compare the mean of the measured thickness in (mm) of Subcutaneous fatty layer between male and female

Group Statistics						P value
	Gender	N	Mean	Std. Deviation	Std. Error Mean	
Subcutaneous fatty layer	Male	116	17.5959	10.37666	.96345	.000
	Female	116	24.8087	9.67119	.89795	

**Table 13:** Correlation between Subcutaneous fatty layer with abdominal muscle wall thickness in mm

Correlations										
		Subcutaneous fatty layer	RT RA	LT RA	RT TA	LT TA	RT IO	LT IO	RT EO	LT EO
Subcutaneous fatty layer	Pearson Correlation	1	-.033	-.090	-.174**	-.117	-.141*	-.218**	-.207**	-.186**
	Sig. (2-tailed)		.620	.171	.008	.075	.032	.001	.002	.005
	N	232	232	232	232	232	232	232	232	232

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

**Table 14:** Correlation between Subcutaneous fatty layer with abdominal muscle wall (RA&TM& &IO & EO) thickness in mm

Correlations		Subcutaneous fatty layer	RA	TM	IO	EO
Subcutaneous fatty layer	Pearson Correlation	1	-.080	-.157*	-.233**	-.210**
	Sig. (2-tailed)		.225	.017	.000	.001
	N	232	232	232	232	232

\*. Correlation is significant at the 0.05 level (2-tailed).  
\*\*. Correlation is significant at the 0.01 level (2-tailed).

**Table (12):** show the mean thickness of subcutaneous fatty layer in males and females is 17.59 and 24.8 respectively, with a p value .000.

**Correlation:**

**Table (13):** show the Pearson correlation test result that was used to test the correlation between the thickness of subcutaneous fatty layer and the muscles. The results show  $r = -.157$  for TM,  $-.233$  for IO, and  $-.210$  for EO.

**Table (14):** demonstrate the Pearson correlation test result that was used to test the correlation between the thickness of fatty layer with abdominal muscle wall (RA&TM& &IO & EO) thickness in mm. The results were insignificant for RT & LT RA and LT TA muscles.

**Muscle Asymmetry:**

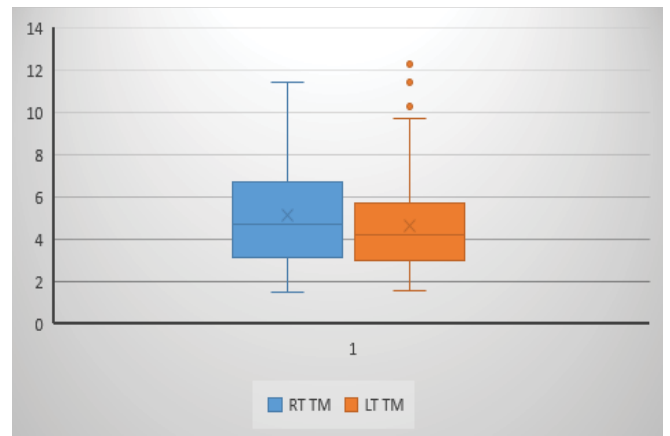
The Figure shows the difference between the mean thickness of right and left RA muscles and the rate of asymmetry.

**Figure (2):** demonstrate the difference between the mean thickness of right and left TA muscles and the rate of asymmetry

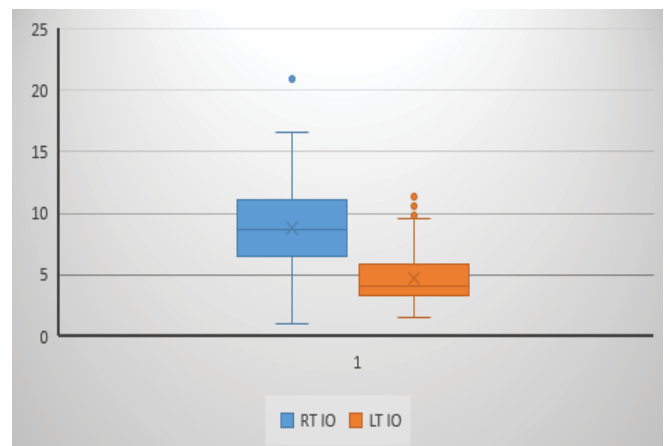
**Figure (3):** show the difference between the mean thickness of right and left IO muscles and the rate of asymmetry

**Figure (4):** show the difference between the mean thickness of right and left EO muscles and the rate of asymmetry

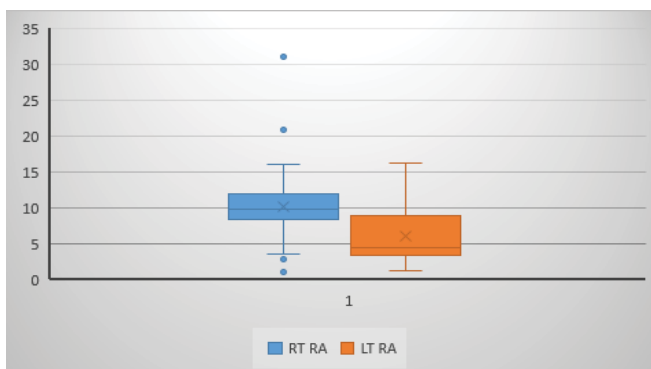
**Figure (5):** show the difference between the mean thickness of the four muscles (RA, TA, IO, EO) and the rate of asymmetry.



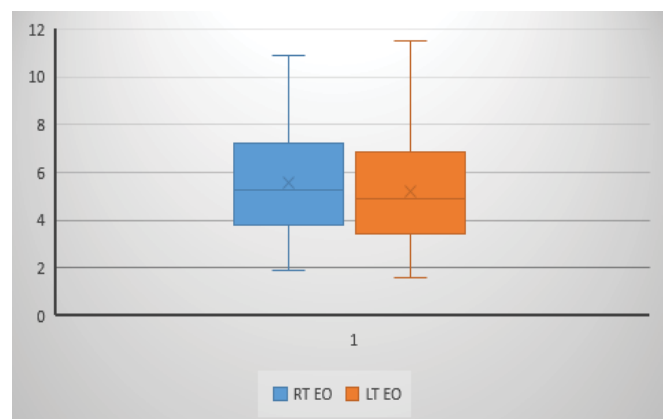
**Figure 2:** Asymmetry rate of (RT&LT TA thickness)



**Figure 3:** Asymmetry rate of (RT&LT IO thickness)



**Figure 1:** Asymmetry rate of (RT&LT RA thickness)



**Figure 4:** Asymmetry rate of (RT&LT EO thickness)



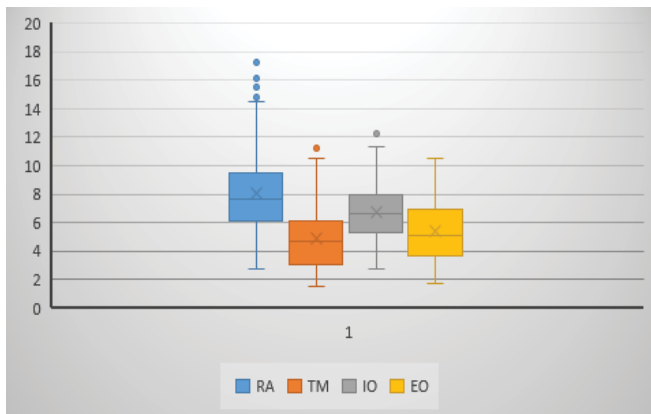


Figure 5: Asymmetry rate of (RA & TA & IO & EO thickness)

## Discussion

After careful literature review, this study is the first of its kind to be done in Sudan, emphasizing the value of the use of CT in measurement of anterior abdominal wall thickness, the uniqueness of this study emerges from its representative study sample and the accuracy of the measurements, in contrast to previous studies where ultrasonography was used for the measurement of thickness which is exposed to more subjectivity and the need for exclusion of intra-abdominal pathologies and gynecological conditions [13,14]. Clearly knowing the normal anterior abdominal wall measurements will have a big role in helping in preparation of abdominal surgeries especially in patients with abnormal abdominal wall. According to what is mentioned before, this data represents a reference value for Sudanese population anterior abdominal wall measurements because it includes four age groups between the age 19 and 71, and the gender is represented equally. Because of the wide range of measurements performed in this work, it is now possible to explain this variability through the influence of age and sex, in contrast to Khan et al where subjects were grouped according to age and obesity, obesity was measured using the help of BMI which later showed little correlation with abdominal muscles thickness [8]. The influence of age on abdominal subcutaneous fatty layer is noted and found to be increased with age, this is consistent with the Jourdan et al, and Khan et al. Jourdan et al show nearly similar results in all four age groups of 21.5, 22.1, 25.1, 21.3 mm respectively. In contrast to muscle, which show a decrease in thickness with age (RA, TA, IO, EO), which is consistent with previous studies [8,10]. This was explained by Khan et al, the slight decrease in abdominal muscle thickness with advancing age is observed by simultaneous increase in intramuscular fat content. Comparing the mean thickness of all muscles of all ages to Jourdan et al, the mean thickness was higher than the mean we found in EO and IO, 8.5 and 8 respectively, and lower than TA and RA, 6.1 and 3.7 respectively. In comparing the right and left abdominal musculatures, we used the

thickness in mm unlike Jourdan et al in which the asymmetry was evaluated with the muscle area. In contrast to Mannion et al., which suggests no significant differences between left and right sides, the RT side show more thickness that is more obvious in RA ( 10.1 mm for right and 6 mm for left )and IO ( 8.7 mm for right and 4.7 mm for left ). Although this could be explained by hand dominance, the lack of asymmetry based on hand dominance was not supported in previous studies [14]. The influence of sex on abdominal subcutaneous fatty layer is showing female predilection and this is in accordance with previous work. The thickness of subcutaneous fatty layer in female in our study is 24.8 mm which is consistent with Jourdan et al which show 24.2 mm and Kim et al study which show subcutaneous fat thicknesses of 24.31 mm (right) and 23.39 mm (left). However, a slight difference in male was found, 17.6 mm and 20.8 mm respectively. In contrast, the muscles in males have more thickness compared to females. Using ultrasound image Springer et. al. illustrated the thickness of TA in male and female and found out similar values 5+/-0.9 and 4.2 +/- 0.7 respectively. Tahan et al. also used ultrasound imaging to evaluate EO, IO, TA and RA thickness in healthy adult male and female subjects and found similar values to ours (Rt EO 5.7 mm, Lt EO 5.4 Rt IO 8.9 mm, Lt IO 8.5, Rt TA 4.5 mm, Lt TA 3.8 mm, Rt RA 10.3, Lt RA 10.4 for males and 4.8, 4.8, 6.1, 5.8, 3.5, 3.3, 8.7, 8.3 for females respectively). A Pearson correlation show weak negative correlation between the thickness of subcutaneous fatty layer and the muscles  $r = -.157$  for TM,  $-.233$  for IO, and  $-.210$  for EO. The correlation is insignificant between RM and subcutaneous fatty layer, in contrast to Kim et al study which demonstrate positive correlation, clear association was found between age and wall thickness, and the influence of sex was also significant, in relevance to Mannion et al which showed that the main effect of gender was significant for all the OI parameters, OE change in thickness from rest to hollowing, and the sum of all lateral parameters during hollowing, but in contrast the differences were mainly significant to left side [13]. This study is not devoid of certain limitations. All measurements were taken on single slice which could limit the accuracy of the results. Additionally, human error could happen during measurements.

## Conclusion

The study was performed among 232 patients who underwent CT KUB scan in Ibn Sina Specialized Hospital in the second half of 2021 with equal number of male and female. It demonstrates the mean thickness of subcutaneous fatty layer and anterior abdominal wall muscles in both right and left group. The muscle thickness is decreasing with age, in contrast to subcutaneous fatty layer thickness which increases with age. Males have thicker muscles than female however, females have thicker subcutaneous fat. The asymmetry is present between all muscles with right group dominance. The

RT RA has the highest mean thickness followed by IO then EO and then TA. The correlation between abdominal wall muscles and fatty layer is weakly negative.

## Recommendation

The study gives reference measurements which can be useful to surgeons in different conditions like when they are dealing with ventral hernia, abdominal wall flaps. Because it can improve the outcome, increasing the awareness of this muscles measurements and variations is one of our recommendations. Additionally, we recommend further researches to assess the abdominal wall muscles in relation to BMI. Furthermore, more focus on subcutaneous fatty layer to study its accuracy in diagnosing obesity instead of BMI. Additionally further studies regarding the correlation between hand dominance and muscle wall thickness could be of a value, finally we recommend studying the effects of various conditions on abdominal wall muscle thickness.

## Statements and Declarations

Authors declare that they have no competing interests.

## Funding

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