Original Article

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A Study of Physicochemical Properties of Subcutaneous Fat of the Abdomen and its Implication in Abdominal Obesity

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ABSTRACT

Introduction: The lower abdominal obesity is more resistant to absorption as compared to that of upper abdomen. Differences in the physicochemical properties of the subcutaneous fat of the upper and lower abdomen may be responsible for this variation. There is paucity of the scientific literature on the physicochemical properties of the subcutaneous fat of abdomen.

Aim: The present study was undertaken to create a database of physicochemical properties of abdominal subcutaneous fat.

Materials and Methods: The samples of subcutaneous fat from upper and lower abdomen were collected from 40 fresh autopsied bodies (males 33, females 7). The samples were prepared for physicochemical analysis using organic and inorganic solvents. Various physicochemical properties of the fat samples analysed were surface tension, viscosity, specific gravity, specific conductivity, iodine value and thermal properties. Data was analysed by paired and independent sample t-tests.

Results: There was a statistically significant difference in all the physicochemical parameters between males and females except surface tension (organic) and surface tension (inorganic) of upper abdominal fat, and surface tension (organic) of lower abdominal fat. In males, viscosity of upper abdominal fat was more compared to that of lower abdomen (both organic and inorganic) unlike the specific conductivity that was higher for the lower abdominal fat as compared to that of the upper abdomen. In females there were statistically significant higher values of surface tension (inorganic) and specific gravity (organic) of the upper abdomen fat as compared to that of lower abdomen. The initial and final weight loss of the lower abdominal fat as indicated by Thermo Gravimetric Analysis was significantly more in males than in female

Conclusion: The difference in the physicochemical properties of subcutaneous fat between upper and lower abdomen and between males and females could be responsible for the variant behaviour of subcutaneous abdominal fat towards resorption.

Keywords: Specific conductivity, Specific gravity, Surface tension, Thermal properties, Viscosity

INTRODUCTION

A strong relationship exists between the abdominal obesity, insulin resistance and cardio-metabolic risk factors [1-3]. Localized Fat Deposits (LFDs) over abdomen are relatively more resistant to absorption and shows strong correlation with cardiovascular disease [4].

A study conducted to ascertain the gross anatomy of superficial fascia and the localized fat deposits of abdomen in adult cadavers indicated that Localized Fat Deposits (LFD) in the central region of the abdomen corresponds to the area of multilayered fascia with smaller fat lobules.

The anatomy of the fat lobule was variable in the different areas of the abdomen [5]. In yet another study in fetuses, the gross anatomy and the attachment and of the superficial fascia was similar to that in adults. The future LFD areas were represented by brownish white blubbery tissue with ill-defined fat lobules [6]. Additionally a study on the morphology of subcutaneous fat lobules of upper and lower abdomen indicated that there was a significant difference in the superficial and deep subcutaneous fat based on location and gender of the individual [7].

The deposition of subcutaneous fat in lower abdomen is difficult to lose by dieting and exercises as compared to upper abdomen [8]. Various physicochemical properties like surface tension, viscosity, specific gravity, iodine value, conductivity and thermal property of subcutaneous fat may be responsible for this difference. However, the studies on physicochemical properties are scanty in the available literature to verify the same. Available studies that could relate the physicochemical properties to the absorption/deposition of fat have been discussed further:

According to Gibbs-Thomsom's principle, substances (surfactants) which lower the surface tension become concentrated on the surface, whereas substances which increase surface tension are concentrated within the interior of the liquid than on the surface (soluble in liquid). This principle has importance pertaining to adsorption process [9,10].

As the temperature increases, the molecular motion increases at the expenses of cohesive forces causing resistance to flow. Therefore, the viscosity of liquid is found to decrease by 1-2 % for each degree rise of temperature [10]. Several studies have indicated a strong relationship between specific gravity of subcutaneous fat and obesity in the human body. Low values for specific gravity indicate obesity while high values signify leanness [11-15].

The mobility of an ion responsible for conductivity is affected by factors such as charge, size, mass and extent of solvation. The conductivity of an electrolyte rises with temperature causing alteration of the mobility of the ions [8,15].

Iodine value is an indicator of degree of saturation and unsaturation of fat. Unsaturation varies in parallel with the iodine value and the melting point is inversely proportional to it. Lipolysis of dietary triglycerides decreases linearly with the increase in the degree of saturation of fat [16,17].

Thermo gravimetric analysis is the study of the change in mass of a sample as the temperature is varied. It helps in analysis of qualitative and quantitative properties, volatilizations, adsorptions and decompositions of wide range of sample types. Hence, the thermal analysis is important to know the response of fat to the internal and external heat [16,18].

Paucity of the scientific literature on the physicochemical properties of the subcutaneous fat of abdomen instigated to take up the present study to create a database of physicochemical properties of abdominal subcutaneous fat.

MATERIALS AND METHODS

Method of sample collection

The samples of subcutaneous fat for the present study were collected from 40 fresh autopsied bodies (33 males and 7 females) from the Department of Forensic Medicine, Kasturba Medical College, Manipal. The sample size was calculated after consulting the statistician. The study was conducted over a period of four years from November 2009 to April 2013. Samples measuring 2cm x 2cm of subcutaneous fat were procured from upper and lower abdomen (3cm above and below the umbilicus respectively) at the mid-clavicular line within six to ten hours after death. The collected samples were cut in to small pieces and were repetitively washed with normal saline to free from blood.

Preparation of the sample for physicochemical analysis

1. By using organic solvent: 3g tissue containing fat was homogenized using 45ml of chloroform methanol (2:1).
2. By using inorganic solvent: 1gm tissue containing fat was homogenized using 50ml of 10% triton in saline to get its suspension on homogenization.

Both organic and inorganic fat samples were then used to study the surface tension, viscosity, specific gravity and conductivity [9,18,19]. Iodine value and TGA were analysed from the fat samples directly [20].

Physicochemical study

Surface tension of fat was measured by using capillary rise method, viscosity by Ostwald's viscometer, specific gravity by specific gravity bottle method, specific conductivity by conductivity meter (model no.304, Systronics), iodine value by iodine monochloride method (Wijsmethod) and estimation of weight loss (TGA) by thermal analyser (DTG-60, Shimadzu, Japan) [9,18-20].

Statistical analysis was performed using the SPSS 15 package. Data was expressed as mean ± Standard Deviation (SD) and 95% Confidence Interval (CI). Paired sample t-test was applied for comparing upper abdomen and lower abdomen parameters for each sex. Independent sample t-test was applied to compare the physicochemical parameters between males and females. A p-value < 0.05 was considered statistically significant.

RESULTS

Surface Tension

In males, statistically there was no significant difference in surface tension (both organic and inorganic) for fat between lower and upper abdomen. In females, surface tension (inorganic) was significantly more (p=0.035) in the upper abdomen than in the lower abdomen. There was no statistically significant difference in the mean values of surface tension between males and females [Table/Fig-1].

Viscosity

In males, viscosity (organic) was significantly higher (p<0.001) in the upper abdomen than in the lower abdomen. In females, there was no significant difference in viscosity (both organic and inorganic) of fat between lower and upper abdomen. The means of viscosity values of males and females were compared. In females, the viscosity (organic) of both upper abdomen (p = 0.012) and lower abdomen (p=0.001) were statitically significant [Table/Fig-1].

Specific Gravity

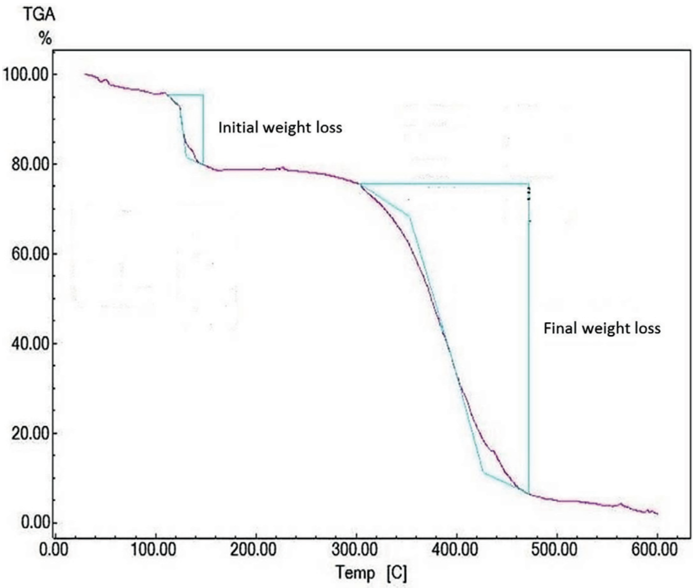
In males, there was no significant difference in specific gravity (both organic and inorganic) of fat between lower and upper abdomen. In females, specific gravity (organic) of subcutaneous fat of upper abdomen was significantly higher (p = 0.030) in the upper abdomen than in the lower abdomen. When the means of specific gravity of males and females were compared, all the values were significantly higher in males than in females:specific gravity (organic) of upper abdomen (p=0.024), specific gravity (organic) of lower abdomen (p =0.014), specific gravity (inorganic) of upper abdomen (p = 0.017), specific gravity (inorganic) of lower abdomen (p = 0.027) [Table/Fig-1].

Specific Conductivity

In males, specific conductivity (organic) of subcutaneous fat of lower abdomen was significantly greater than upper abdomen (p=0.003). In females, there was no significant difference in specific conductivity (both organic and inorganic) of fat between lower and upper abdomen. Comparision between the means of specific conductivity of males and females revealed that all the values were significantly higher in females than in males: specific conductivity (organic) of upper abdomen (p<0.001), specific conductivity (organic) of lower abdomen (p=0.016) specific conductivity (inorganic) of upper abdomen (p=0.039) and specific conductivity (inorganic) of lower abdomen (p=0.045) [Table/Fig-1].

Parameters	Lower Abdomen			Upper Abdomen		
	Male (n=33) Mean ± SD	Female (n=7) Mean ± SD	p-value	Male (n=33) Mean ± SD	Female (n=7) Mean ± SD	p-value
1. Surface Tension(Organic) (N/m)	0.068 ± 0.038	0.030 ± 0.012	<0.001*	0.059 ± 0.033	0.033 ± 0.007	0.045*
2. Surface Tension (Inorganic) (N/m)	0.043 ± 0.019	0.041 ± 0.004	0.763	0.045 ± 0.015	0.043 ± 0.006	0.777
3. Viscosity (Organic) (mp)	11.115 ± 2.110	14.797 ± 3.465	0.001*	12.427 ± 1.873	16.922 ± 9.386	0.012*
4. Viscosity (Inorganic) (mp)	51.688 ± 20.749	72.998 ± 33.628	0.402	40.627 ± 17.771	39.212± 15.637	0.894
5. Sp. Gravity (Organic) (μS/m)	1.27 ± 0.102	1.17 ± 0.021	0.014*	1.27 ± 0.104	1.18 ± 0.023	0.024*
6. Sp. Gravity (Inorganic) (mS/m)	1.09 ± 0.091	1.01 ± 0.004	0.027*	1.10 ± 0.093	1.012 ± 0.004	0.017*
7. Sp. Conduct. (Organic) (μS/m)	29.64 ± 9.323	44.29 ± 27.657	0.016*	26.27 ± 6.625	43.43 ± 20.566	<0.001*
8. Sp. conduct. (Inorganic) (mS/m)	9.75 ± 1.779	11.50 ± 3.019	0.045	8.95 ± 2.284	11.08 ± 2.929	0.039*
9. Iodine value	54.68 ± 8.259	45.90 ± 6.417	0.012*	56.64 ± 6.464	47.28 ± 4.730	0.001*
10. Initial weight loss (%)	3.866 ± 1.78	0.710 ± 0.459	<0.001*	2.725 ± 1.242	1.98 ± 1.62	0.55
11. Final weight loss (%)	80.62 ± 10.64	45.412 ± 27.881	0.0188*	77.72 ± 12.62	57.584 ± 29.605	0.14

[Table/Fig-1]: Comparison of physicochemical properties of subcutaneous fat in males and females.
*p-value <0.05 is considered as significant.



[Table/Fig-2]: Graphical representation of TGA of abdominal subcutaneous fat showing initial and final weight loss

Iodine Value

In both males and females, there was no significant difference in iodine values of fat between lower and upper abdomen. Iodine values of both upper and lower abdomen of males were significantly higher than females (upper abdomen, p= 0.001; lower abdomen, p=0.012) [Table/Fig-1].

Thermo Gravimetric Analysis (TGA)

In both males and females, there was no significant difference in findings of TGA of fat between lower and upper abdomen. The means of values of TGA of males and females when compared indicated that both the initial and final weight loss of the lower abdominal fat on heating was significantly more in males than in females (p<0.001) [Table/Fig-1,2].

DISCUSSION

Physicochemical properties such as surface tension, viscosity, specific gravity, iodine value, conductivity and thermal property of subcutaneous fat determines the behaviour of the fat and is important in understanding the properties like deposition, tissue adherence, flow (mobilization), thermal stability and absorption of subcutaneous fat.

Surface tension (inorganic) of upper abdomen was significantly more than lower abdomen in females. This indicates that there are some inorganic substances that would increase the hydrophobic property between fat cell in upper abdomen [9,10]. No similar study was available in the literature for comparison.

In the present study, in males, viscosity (organic) of upper abdomen was statistically more than lower abdomen. The viscosity (organic) of upper abdomen and lower abdomen and viscosity (inorganic) of lower abdomen were statistically more in females than males. This difference in flow property of fat may indicate an asymmetrical fat distribution over abdomen especially in females. There were no similar studies available in the literature for comparison.

Low values for specific gravity is seen in obesity while high values in leanness. Weight loss due to exercise and a restricted diet is closely related to increase in specific gravity [13,15].

In the present study, all the values of specific gravity were found to be higher in males than females indicating leaner appearance and firmer feel of the fat in males.

Specific gravity (organic) of subcutaneous fat of upper abdomen was significantly more than lower abdomen in females. Relatively less specific gravity of subcutaneous fat in the lower abdomen in females may be one of the reasons for phenotypically more common lower abdomen obesity. Our study supports the findings of previous studies [11-15].

In males, the specific conductivity (organic) of subcutaneous fat of lower abdomen was more than that of the upper abdomen and was statistically significant. All specific conductivity values were higher in females than males. Higher values could be due to more electrolyte contents in the lower abdomen fat. No similar study was available in the literature for comparison.

The iodine values of both upper and lower abdomen of males were significantly more than females. Therefore, melting point of lower abdominal fat of females will be higher [16,17]. This may be responsible for difficult absorption and hence, more lower abdominal obesity in females. Also, in females lower iodine value indicated more saturated fat than males. Unlike saturated fat, unsaturated fat is liquid at room temperature and may have bearing on absorption of fat in females [16,17,21].

The weight loss on heating indicates evaporation of volatile constituents (initial heating) and water content (longer heating) inside and outside the fat tissues. The values of TGA of males and females when compared indicated that both the initial and final weight loss of the lower abdominal fat on heating was significantly more in males than in females indicating more volatile material and water content in the fat of males leading to phenotypically obvious bulge. Less volatile substance and water content in female abdominal fat could be responsible for resistant nature of fat towards absorption [21].

LIMITATION

Though the sample size was adequate, the number of female samples were less due to unavailability of female cadavers. A study including more number of female samples could provide more relevant results.

CONCLUSION

There was a difference in the physicochemical properties of subcutaneous fat of upper and lower abdomen and between males and females. The present study attempts to build a normal database for the different physicochemical properties of subcutaneous fat of upper and lower abdomen.

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