Int. J. Morphol.,
40(5):1219-1227, 2022.

A Comprehensive Morphometric Study of Visceral and Subcutaneous Adipose Tissue Depots in Mice, Hamsters and Rats

Un Estudio Morfométrico Completo de los Depósitos de Tejido Adiposo Visceral y Subcutáneo en Ratones, Hámsters y Ratas

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MILJKOVIC, D.; DRLJACA, J.; LOVRENSKI, A. & GAJIC, M. A comprehensive morphometric study of visceral and subcutaneous adipose tissue depots in mice, hamsters and rats. *Int. J. Morphol., 40(5)*:1219-1227, 2022.

SUMMARY: Adipose tissue morphology of different fat tissue depots can be described using the number of adipocytes and cell surface of adipocytes. This study deals with characteristics and morphometric analysis of white and brown adipose tissue depots in healthy adult laboratory mice, hamsters and rats of both sexes. The number of unilocular adipocytes in white adipose tissue differs from one adipose tissue depot to another, with the largest number of adipocytes in mice and a similar number in hamsters and rats. The smallest surface area and the largest percentage of small unilocular adipocytes were found in mice. White adipose tissue in hamsters and rats was predominantly made out of a larger percentage of medium-sized adipocytes and a smaller percentage of small and medium-sized adipocytes. Uncoupling protein 1 positive multilocular adipocytes were found in classic brown adipose tissue depots with larger percentages in mice (93.20 %) and hamsters (91.30 %), while rats had a smaller percentage (78.10 %). In white and brown adipose tissue, significant differences between species and both sexes within the same species were found, indicating the influence of sexual dimorphism. The presented morphometric results could serve as a basis for further studies concerning experimental animal models of metabolic disorders and obesity.

KEY WORDS: Mouse; Hamster; Rat; White adipose tissue; Brown adipose tissue.

INTRODUCTION

Fat tissue or adipose tissue (AT) is a term for loose connective tissue composed of adipocytes, preadipocytes and a stromal vascular fraction consisting of fibroblasts, pericytes, endothelial cells, monocytes, and mast cells (Thiagarajan & Reizes, 2016). As a metabolically very active tissue, adipose tissue is highly vascularized and well innervated, responding to nervous and humoral stimuli, releasing hormones and other significant substances. Investigations into the function of fat cells concluded that adipocytes have three primary functions, they represent cells sensitive to insulin, store lipids, and secrete hormones that act in distant tissues (Stephens, 2012).

Various types of AT have been documented in mammals, the two widely known distinct types - white adipose tissue (WAT) and brown adipose tissue (BAT). The third type, called the beige adipose tissue, has been shown to develop from the WAT due to various activators (Chabowska-Kita & Kozak, 2016). WAT is typically localized in the peritoneal cavity and subcutaneously. Adipocytes in WAT have a single, large lipid droplet and variable amounts of mitochondria. In addition to its energy storage function in the form of triglycerides, this fat tissue also plays a structural role, providing mechanical support and protection for certain parts of the body. BAT is located in different anatomic regions (e.g. axillary, cervical, interscapular and subscapular regions). Adipocytes in BAT have a multilocular morphology and abundant mitochondria. Their primary function is thermogenesis orchestrated by the inner mitochondrial membrane uncoupling protein 1 (UCP1)

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This study was supported by the Republic of Serbia, Autonomous Province of Vojvodina, Provincial Secretariat for High Education and Scientific Research, Grant No. 142-451-2626/2021-01/2 and Grant No. 142-451-2676/2021-01/2.

Received: 2022-06-22 Accepted: 2022-07-06

specifically expressed in these cells (Nicholls, 2021). Beige adipose tissue is located subcutaneously and comprises, among others, the brachial, periovarial and inguinal depots. Beige adipocytes are morphologically indistinguishable from their neighbouring white adipocytes in the basal or unstimulated state. However, upon stimulation by chronic cold exposure or mechanisms that mimic beta-adrenergic stimulation, they become multilocular and begin expressing UCP1 (Gallerand *et al*., 2021).

Adipose tissue is widely distributed in the body, and it is generally regarded as connective tissue without specific anatomy. However, all the data from the literature support the idea that AT in humans and animals is organized to form a large organ made up of multiple adipose tissue depots (ATD) with specific vascular and nerve supplies, complex cytology, and high physiological plasticity (Cinti, 2012). Like humans, rodents have three main types of ATDs classified according to the anatomical regions in which they are located: intra-abdominal or visceral ATD and two subcutaneous ATDs. The main difference between these two species is that humans have abdominal and gluteofemoral subcutaneous ATD, while rodents have anterior and posterior subcutaneous ATDs. In rodents, the visceral ATDs include perigonadal (epididymal in male and periovarial in female), retroperitoneal, renal, retroperitoneal and mesenteric ATD. There are three separate depots within the anterior subcutaneous depot: axillary, cervical, interscapular, and subscapular ATD. The posterior subcutaneous depot consists of inguinal ATD that extends from the dorsolumbar to the gluteal region in rodents (Chusyd *et al*., 2016; Mandarim-de-Lacerda *et al*., 2021).

The heterogeneity among various ATDs lies primarily in their intrinsic differences in cellular and physiological properties. Additional factors that influence adipose tissue heterogeneity are genetic predisposition, environment, sex and age (Kwok *et al*., 2016). Adipose tissue deposition can be divergent within different species so that adipocytes and numbers in these depots also display metabolic heterogeneity. Therefore, this study can provide insight into specific attributes and morphometric parameters of ATDs in three rodent species of both sexes and help lay the foundation for further developing adipose tissue studies that include animal models.

MATERIAL AND METHOD

Animals and experimental design. The study was approved by the Ethics Committee of the University of Novi Sad and the Serbian Ministry of Agriculture, Forestry and Water Economic (Approval No. 323-07-01030/2020-05). This study was conducted in strict accordance with the recommendations of the National Institutes of Health's Guide for the Care and Use of Laboratory Animals. The experiment included 18 animals, which were divided into three different groups of 6 individuals: the group of albino laboratory mice, strain NMRI (M), the group of Syrian golden hamsters (Mesocricetus auratus) (H) and the group of albino laboratory rats of the Wistar strain (R). Each group included healthy adult animals (three males and three females) of approximate age (12-15 weeks) and body weight. The animals were kept in the vivarium of the Pasteur Institute in Novi Sad, in standard cages at room temperature (20-25°C,) on a 12 h light/dark period, with free access to food (standard chow diet) and water.

Experimental animals were anaesthetized with an intraperitoneally administered mixture of an analgesic solution consisting of 10 % Ketamidor (Richter Pharma AG, Austria) and 20 mg/mL Xylased (Bioveta, A.S., Czech Republic). All sedated animals were attached to a workstation, and transcardiac perfusion fixation was performed in a two-step procedure. After puncturing the left heart ventricle, the first step was the infusion of 50 mL of saline, followed by the second step - the infusion of 50 mL of fixative (4 % paraformaldehyde diluted in 0.1M phosphate buffer, pH 7.4) to fixate the tissues of the whole organism, including the adipose tissue.

Each animal was dissected individually, and specimens of adipose tissue were excised from the different ATDs: axillary ATD (aATD), interscapular ATD (iATD), subscapular ATD (sATD), renal ATD (rATD), retroperitoneal ATD (rpATD), mesenteric ATD (mATD), inguinal ATD (ingATD), epididymal ATD (eATD) in males, and periovarial ATD (poATD) in females. To obtain the distribution of isolated fat depots, all ATDs were macroscopically photographed on the outlines of each animal species.

Adipose tissue processing and immunohistochemistry. For histochemical and immunohistochemical analysis, adipose tissue of each fat depot was dehydrated in increasing concentrations of ethyl alcohol (70 %, 80 %, 96 %, 100 %) and 100 % chloroform. After dehydration, different fat depots were embedded in paraffin. Paraffin blocks were cut into 5 μm thin sections with a rotary microtome (Leica, Wetzlar, Germany). Half of the tissue sections were used for hematoxylin-eosin stain (H&E), while the other half was used for immunohistochemistry. Slides with sections for immunohistochemical staining required antigen retrieval using citrate buffer (pH 6.0) in a microwave oven at 850 W for 25 minutes. A primary anti-UCP1 antibody (Abcam, 23841) with 1:200 dilution and goat polyclonal secondary

anti-rabbit antibody conjugated with horseradish peroxidase (Abcam, ab97051) were used in further process of staining. The visualization was performed using DAB Substrate Kit (Abcam, ab64238). Mayer's hematoxylin was used as a counterstain.

Morphometric analysis. The slides were analyzed with a Leica DMLB 100T microscope and photographed with a Leica MC 190 camera. For quantitative analysis, within each H&E and UCP1 stained AT slide, eight randomly selected high-power fields (400x) were photographed. Each photograph of histological slides that contained ingATD, eATD/poATD, mATD and rpATD was processed in Fiji image software before any morphometric measurements. Image processing involved calibration, subtraction of background, removal of excess noise (Despeckle tool), converting images to a binary format, thresholding images, and enhancing adipocytes' margins (Dilate tool). After initial image processing, "Measure and Label Macro" for ImageJ (http://rsbweb.nih.gov/ij/plugins/measure-label.html) was used for better visualizing and measuring the number and area of each adipocyte that was selected by using the Wand tool. The adipocytes that did not touch the image margins were not counted in the final number of adipocytes. UCP1 immunohistochemical marker was used for qualitative/quantitative differentiation of WAT from BAT. The percentage of white and UCP1 positive brown adipose tissue in aATD, iATD, rATD and sATD was determined using two tools (Grid and Cell Counter) within the Fiji software program.

Statistical analysis. The collected data were analyzed using the statistical program IBM SPSS Statistics 23.0. The unique adipocyte number, respective surface area (Sa) of adipocytes, size-frequency distribution of adipocytes, and the percentage of BAT and WAT, were exported for statistical analysis. One-Way ANOVA parametric test with post hoc Tukey test was used to compare the mean adipocyte number between different species and sexes. For other parameters that don't follow a normal distribution, comparisons between different species and both sexes were made using the Kruskal Wallis non-parametric test followed by Mann Whitney post hoc analysis. A $p<0.05$ value was considered statistically significant.

RESULTS

Gross, histological and immunohistochemical characteristics of adipose tissues. The gross anatomy of all three species shows the characteristic multi-depot organization of adipose tissue. The color of inguinal, epididymal/periovarial, mesenteric and retroperitoneal ATDs is white, while axillary, interscapular, renal and subscapular ATDs are predominantly brownish, with a few white areas (Fig. 1A).

Our study's qualitative analysis of standard histological sections showed that inguinal, epididymal/periovarial, mesenteric and retroperitoneal ATDs consist of WAT only. WAT has large unilocular white adipocytes with almost the same structure in all three species. However, unilocular adipocytes in mice seem to be smaller in almost all ATDs, compared to hamsters and rats (Figs. 1B-D). BAT with classic small multilocular brown adipocytes is found only in axillary, interscapular, renal and subscapular ATDs (Figs. 1E-G). To distinguish WAT from BAT in this study, we used UCP1 immunohistochemical marker found only in BAT. Characteristic cytoplasmic positivity of UCP1 marker is found in multilocular brown adipocytes of all three species (Figs. 1H-J). Besides predominantly multilocular, some unilocular adipocytes were found in adipocytes within axillary, interscapular, renal and subscapular ATDs of mice, hamsters and rats (Figs. 1K-M). In these fat depots, unilocular adipocytes were UCP1 negative, while surrounding multilocular adipocytes were UCP1 positive.

Morphometric analysis of WAT in different adipose tissue depots. The mean number of unilocular adipocytes was significantly different between all three species within inguinal ($F=290.25$, $df=2$, $p<0.001$), epididymal/periovarial ($F=310.92$, $df=2$, $p<0.001$), mesenteric ($F=207.59$, $df=2$, $p<0.001$) and retroperitoneal ($F=231.12$, $df=2$, $p<0.001$) ATDs. Post hoc test showed that within inguinal, epididymal/periovarial and retroperitoneal ATDs, mice had a statistically larger number of adipocytes than hamsters and rats. The number of adipocytes within mesenteric ATD differed significantly between all three species (Fig. 2).

As shown in Table I, morphometric analysis of WAT in inguinal, epididymal/periovarial, mesenteric and retroperitoneal ATDs of all three species revealed that the surface area (Sa) of unilocular adipocytes was significantly different in almost all fat depots. However, the Sa of unilocular adipocytes found in retroperitoneal ATDs of hamsters and rats were similar ($U=11.52$, $p=0.12$).

Results of One-Way ANOVA showed that there was a significant difference between male's and female's mean number of unilocular adipocytes within inguinal ($F=146.85$, $df=5$, $p<0.001$), epididymal/periovarial ($F=278.89$, $df=5$, $p<0.001$), mesenteric ($F=177.22$, $df=5$, $p<0.001$) and retroperitoneal ($F=608.65$, $df=5$, $p<0.001$) ATDs. Post hoc test showed that within inguinal, epididymal/periovarial, and

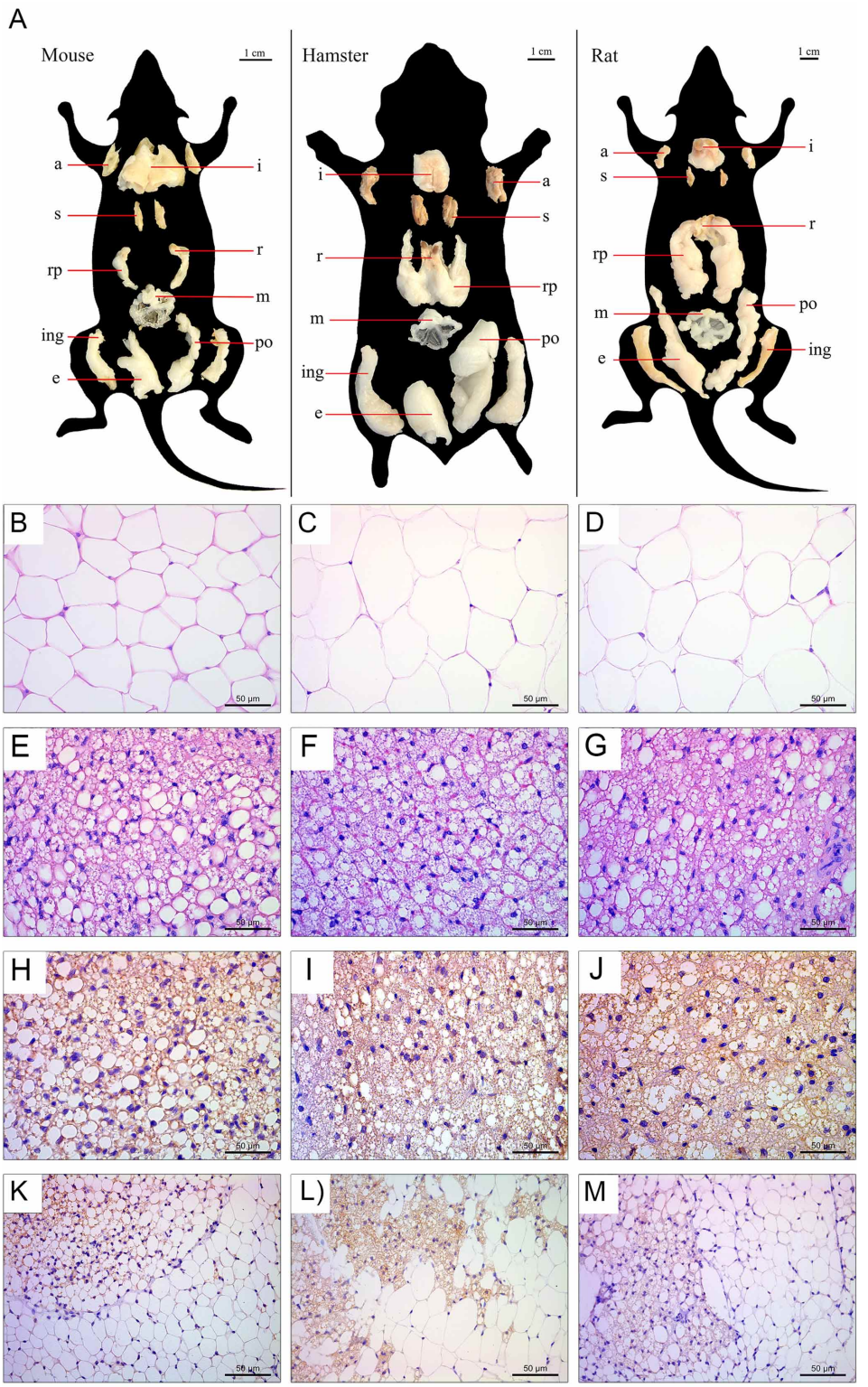


Fig. 1. Gross anatomy and histological features of the ATDs in healthy adult mice, hamsters and rats. The subcutaneous and visceral ATDs were dissected and positioned on templates of all three species to show their respective body locations, scale bars: 1 cm (A); H&E staining of retroperitoneal ATD: mouse (B), hamster (C), rat (D); H&E staining of subscapular ATD: mouse (E), hamster (F), rat (G); UCP1 immunohistochemical staining of subscapular ATD: mouse (H), hamster (I), rat (J); UCP1 immunohistochemical staining of renal ATD: mouse (K), hamster (L), rat (M); scale bars: 50 µm.

Abbreviations: ATD, adipose tissue depot; a, axillary; i, interscapular; s, subscapular; r, renal; ing, inguinal; e/po, epididymal/periovarial; m, mesenteric; rp, retroperitoneal; UCP1, uncoupling protein 1.

retroperitoneal ATDs, female mice had a statistically more significant number of adipocytes than male mice. Male hamsters had a larger number of adipocytes than female hamsters within inguinal ATD. In contrast, in periovarial ATD, female hamsters had a more significant number of adipocytes than male hamsters had in epididymal ATD. Within mesenteric ATD, male mice had a more significant number of unilocular adipocytes (Fig. 3).

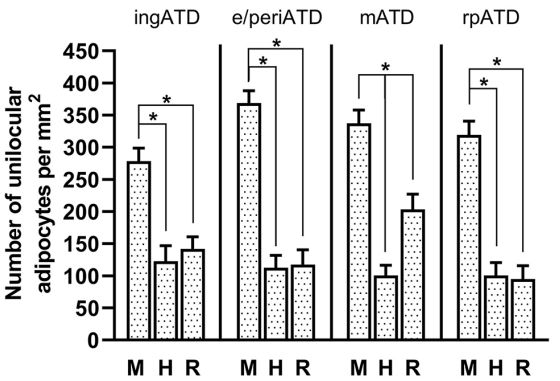


Fig. 2. The mean number of unilocular adipocytes in various ATDs of mice, hamsters and rats. All values were analyzed by One-Way ANOVA with the post hoc Tukey test, * $p<0.05$. Abbreviations: ATD, adipose tissue depot; ing, inguinal; e/po, epididymal/periovarial; m, mesenteric; rp, retroperitoneal; M, mice; H, hamsters; R, rats.

Table I. Mean unilocular adipocyte surface area values and standard deviations of various adipose tissue depots in mice, hamsters and rats.

	S_a - ingATD (μm^2) (n=6)	S_a - e/poATD (μm^2) (n=6)	S_a - mATD (μm^2) (n=6)	S_a - rpATD (μm^2) (n=6)
M	1121.27±17.31*	891.16±19.26*	874.09±14.99*	915.91±16.84*
H	3344.77±88.68*	2938.89±77.55*	3272.65±86.33*	3143.39±82.54
R	2006.19±45.51*	2573.28±77.26*	1483.12±29.05*	3091.71±87.44

* $p<0.05$ All values are analyzed by Kruskal Wallis with the post hoc Mann Whitney test. Abbreviations: S_a, surface area; ATD, adipose tissue depot; ing, inguinal; e/po, epididymal/periovarial; m, mesenteric; rp, retroperitoneal; M, mice; H, hamsters; R, rats.

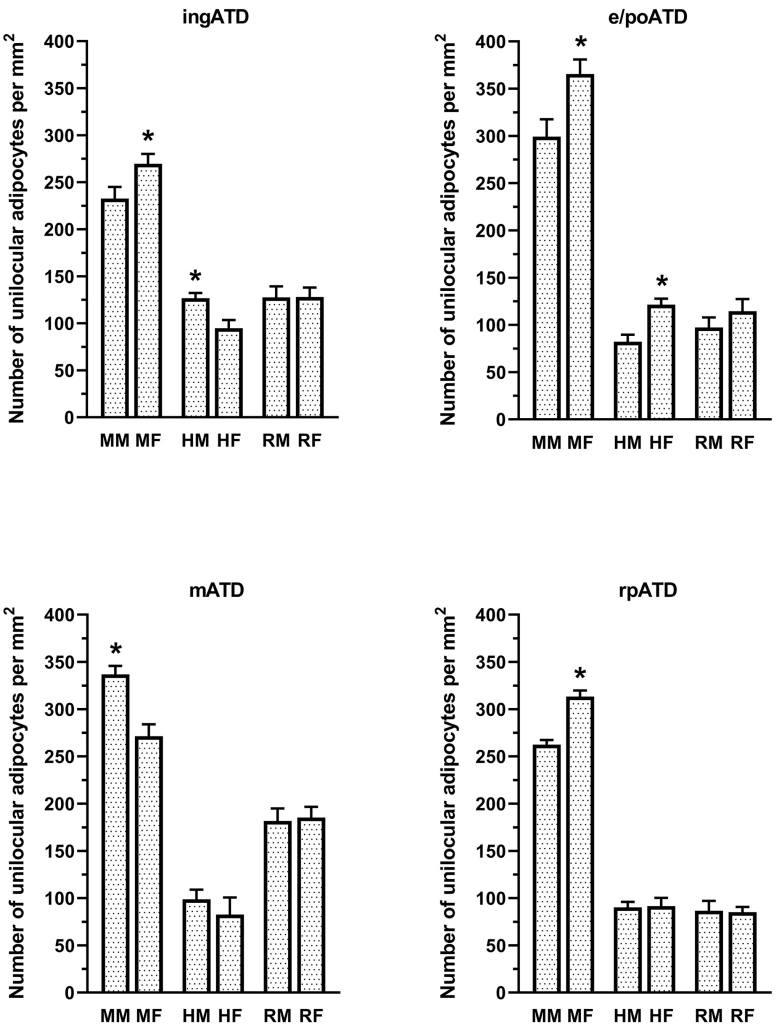


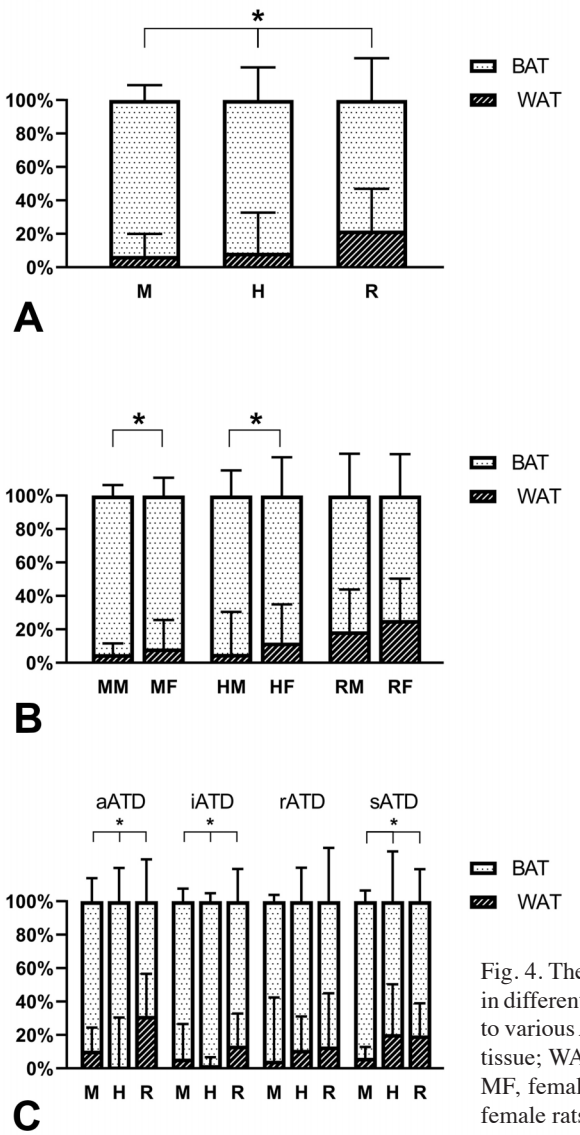
Fig. 3. The mean number of unilocular adipocytes in various ATDs of mice, hamsters and rats of both sexes. All values are analyzed by One-Way ANOVA with the post hoc Tukey test, * $p<0.05$. Abbreviations: ATD, adipose tissue depot; ing, inguinal; e/po, epididymal/periovarial; m, mesenteric; rp, retroperitoneal; MM, male mice; MF, female mice; HM, male hamsters; HF, female hamsters; RM, male rats; RF, female rats.

When comparing S_a values of unilocular adipocytes found in different WAT depots in mice, hamsters and rats according to sex, a significant difference was found across male and female mice. There was no significant difference in S_a between male and female hamsters whitin inguinal, mesenteric and retroperitoneal ATDs. The difference in S_a between male and female hamsters was found only in epididymal/periovarial ATDs. In rats, a significant difference was found between males and females in almost all ATDs, except in retroperitoneal ATD (Table II).

Table II. Mean unilocular adipocyte surface area values and standard deviations of various adipose tissue depots in mice, hamsters and rats of both sexes.

	S_a - ingATD (μm^2) (n=3)	S_a - e/poATD (μm^2) (n=3)	S_a - mATD (μm^2) (n=3)	S_a - rpATD (μm^2) (n=3)
MM	1073.96±28.33*	1080.28±21.71*	896.62±18.68*	1297.82±24.04*
MF	1162.09±20.91*	736.31±29.09*	846.15±24.29*	596.12±15.14*
HM	3443.29±124.09	3503.19±137.04*	3209.73±117.56	3032.49±116.25
HF	3212.93±123.95	2557.09±83.67*	3347.94±127.31	3252.66±116.96
RM	1928.50±65.18*	2881.27±103.06*	1652.49±46.46*	2966.73±125.64
RF	2083.60±63.32*	2311.36±110.50*	1317.05±33.22*	3218.67±121.22

* p<0.05 All values are analyzed by Kruskal Wallis with the post hoc Mann Whitney test. Abbreviations: Sa, surface area; ATD, adipose tissue depot; ing, inguinal; e/po, epididymal/periovarial; m, mesenteric; rp, retroperitoneal; MM, male mice; MF, female mice; HM, male hamsters; HF, female hamsters; RM, male rats; RF, female rats.



Morphometric analysis of BAT in different adipose tissue depots. Since predominantly BAT and some WAT were histologically confirmed only in axillary, interscapular, renal, and subscapular ATDs of all three species, we analyzed the ratio between these two tissues within given fat depots. There was a statistically significant difference in the percentages of BAT between mice (93.20 %), hamsters (91.30 %) and rats (78.10 %) (x^2=42.35, df=2, p<0.001) (Fig. 4A).

Within each species, the percentage of BAT was compared to the sex of the experimental animals. Male mice had 94.80 % of BAT, which is statistically larger than the percentage of BAT in female mice (91.50 %) (U=1530.00, df=1, p=0.013). The percentage of BAT in male hamsters (94.70 %) was significantly higher than the percentage in female hamsters (88.0 %) (U=1379.00, df=1, p=0.001). There was no difference in the percentage of BAT between male and female rats (U=1682.00, df=1, p=0.08) (Fig. 4B).

Also, a comparison was made within each ATD concerning the animal species. In axillary ATD, all three experimental animals differ in the percentage of BAT (x^2=49.73; df=2; p<0.001). The hamsters had the largest percentage of BAT (98.90 %), mice had 89.50 % of BAT, and rats had the smallest percentage of BAT (68.60 %). Mice, hamsters and rats had 94.20 %, 98,10 % and 86.40 % of

Fig. 4. The ratio of brown and white adipose tissue: in different animal species (A); in different animal species according to sex (B); in different animal species according to various ATDs (C). Abbreviations: ATD, adipose tissue depot; BAT, brown adipose tissue; WAT, white adipose tissue; M, mice; H, hamsters; R, rats; MM, male mice; MF, female mice; HM, male hamsters; HF, female hamsters; RM, male rats; RF, female rats; a, axillary; i, interscapular; s, subscapular; r, renal.

BAT within interscapular ATD, respectively. Kruskal-Wallis test showed that these percentages are statistically different (x^2=22.23; df=2; p<0,001). Mice had 95.40 %, hamsters had 89 %, and rats had 87 % BAT within renal ATD. There was no difference in the percentage of BAT within renal ATD among all three species (x^2=0.13; df=2; p=0.937). As it is for subscapular ATD, all three experimental animals differ in the percentage of BAT (x^2=6.53; df=2; p=0.043). The mice had the largest percentage of BAT (93.70 %), rats had 85.30 % of BAT, and hamsters had the smallest percentage of BAT (79.40 %) (Fig. 4C).

DISCUSSION

Laboratory animals in our study showed multi-depot organization of adipose tissue with characteristics specific for rodents. Retroperitoneal, mesenteric, inguinal, epididymal and periovarial fat depots were purely made by unilocular white adipocytes, and therefore adipose tissue was white. BAT with predominantly UCP1 positive multilocular brown adipocytes was found in axillary, interscapular, renal and subscapular fat depots. These brown adipocytes were mixed with white adipocytes without expression of UCP1 marker, so clear anatomical boundaries between BAT and WAT didn't exist. Similar results were found in other studies with mice and rats where UCP1 negative white adipocytes and UCP1 positive brown adipocytes were distributed in the same manner as in fat depots of our laboratory animals (Chusyd *et al*., 2016). These relative amounts of mixed white and brown parts are genetically determined and depend on several factors (mainly species, age, sex, environmental temperature, and nutritional status) (Zhang *et al*., 2018; Shinde *et al*., 2021). In a study by Cousin *et al*. (1992), some multilocular brown adipocytes were found within several ATDs considered as typical white fat in rodents. These cells varied in different ATDs and were most numerous in rodents' periovarial and inguinal fat depot. Compared to this study, in our research, we didn't find any multilocular brown adipocytes in typical white ATDs of all three roedent species.

Morphometric analysis of WAT within inguinal, epididymal/periovarial and retroperitoneal ATDs showed more unilocular adipocytes in mice than in hamsters and rats. However, the number of adipocytes within mesenteric ATD was statistically different between mice, hamsters and rats. The S_a of unilocular adipocytes was significantly different between all three species in all ATDs, except in retroperitoneal ATDs of hamsters and rats, where unilocular adipocytes were similar in size. Such diversity in the number and size of adipocytes can be attributed to different species with distinct genetics and, therefore, unique fat tissue metabolisms.

Sex differences in the morphology of fat tissue in rodents are manifested by differences in the number and size of fat cells in lower/truncal subcutaneous fat depots. For example, some differences in fat pads like inguinal, epididymal or periovarial WAT were associated with sex hormones (Macotela *et al*., 2009; Chusyd *et al*., 2016). Our research also showed that the number of adipocytes within epididymal and periovarial ATDs differed between mice and hamsters. All female laboratory animals had smaller unilocular adipocytes within periovarial ATD than those within epididymal ATD in males. By observing the size of adipocytes in inguinal ATD, male mice and rats had smaller unilocular adipocytes than female counterparts. There was no statistical difference in the size of adipocytes between male and female hamsters within inguinal ATD. These data are inconsistent with previous findings in which female mice and rats had larger unilocular adipocytes (Macotela *et al*., 2009).

Besides a detailed morphometrical analysis of classic WAT depots, we also analyzed classic BAT depots. Our study showed that axillary, interscapular, renal and subscapular ATDs were made of mixed BAT and WAT, although these depots are considered classic BAT depots. Multilocular brown adipocytes with UCP1-mediated non-shivering thermogenesis within these BAT depots are crucial in maintaining core body temperature in endothermic animals (Wu *et al*., 2013). To maintain constant body temperature in challenging environmental conditions such as cold and unpredictable decreases in food availability, endothermic animals evolved in such ways to enter hypometabolic states called hibernation and daily torpor (Nowack *et al*., 2017; Huang *et al*., 2021). Unlike animals in hibernation that lasts a few weeks to months, a certain number of small animals may employ daily torpor. Daily torpor represents a suppression of metabolic rate to as low as 30 % of basal metabolic rate and a fall of animals' core temperature lasting for several hours. Such animals are called daily heterotherms animals, and they tend to be small, typically 5–50 g, and include shrews, gerbils, hummingbirds, and numerous marsupials (Solymár *et al*., 2015). Besides wild animals, some studies showed that specific laboratory animals could also enter daily torpor, such as mice (Sunagawa & Takahashi, 2016) and rats (Nowack & Turbill, 2022). On the contrary, laboratory animals like Syrian hamsters are proven to be facultative hibernators, and their hibernation may be induced in any season by exposure to a short-day photoperiod and cold ambient temperatures (Trefna *et al*., 2017; Chayama *et al*., 2019). Our research showed that all three laboratory animals had a large percentage of BAT within typical BAT depots. Mice had 93.20 %, hamsters had 91.30 %, and rats had only 78.10 % of BAT. These data suggest that mice and rats also have the capabilities for the hypometabolic state

such as daily torpor, except for hamsters that could enter either daily torpor or deep hibernation. Indeed, because of hamsters being facultative hibernators, it was expected that they had a considerable percentage of BAT. Nevertheless, that percentage in our study was slightly lower than the percentage of BAT in mice. Analysis of BAT percentage between all three species in our study showed a significant difference in axillary, interscapular and subscapular ATDs. Despite differences in their genetics, size and adipose tissue metabolism, the percentage of BAT in renal ATD was similar. By observing the percentage of BAT between sexes within each species of laboratory animals, we found a statistically significant difference only between male and female mice and hamsters, which can be attributed to the aforementioned sexual dimorphism.

In summary, our data provide a more comprehensive view of characteristics, localization and morphometric analysis of ATDs in three rodent species of both sexes. Various ATDs mature and grow with specific cellular characteristics of certain fat depots within a given rodent species and their unique adipose tissue metabolism. In addition to species of laboratory animals, there is also a sexual dimorphism in this study that showed significant influence on different numbers and sizes of unilocular adipocytes in male and female laboratory animals. Sex also had repercussions on diverse percentages of BAT within ATDs, especially in mice and hamsters. Findings of large percentages of BAT in our laboratory animals favor great potential for entering hypometabolic states such as daily torpor and hibernation. These findings must be included in the overall picture when conducting adipose tissue studies, especially animal model studies of metabolic disorders and obesity.

ACKNOWLEDGEMENTS

This study was supported by the Republic of Serbia, Autonomous Province of Vojvodina, Provincial Secretariat for High Education and Scientific Research, Grant No. 142-451-2626/2021-01/2 and Grant No. 142-451-2676/2021-01/2.

MILJKOVIC, D.; DRLJACA, J.; LOVRENSKI, A. & GAJIC, M. Un estudio morfométrico completo de los depósitos de tejido adiposo visceral y subcutáneo en ratones, hámsteres y ratas. *Int. J. Morphol., 40(5)*:1219-1227, 2022.

RESUMEN: La morfología del tejido adiposo de diferentes depósitos de tejido graso se puede describir utilizando el número de adipocitos y la superficie celular de los adipocitos. Este estudio analiza las características y el análisis morfométrico de los depósitos de tejido adiposo blanco y marrón en ratones, hámsteres y ratas de laboratorio, adultos sanos de ambos sexos. El número de adipocitos uniloculares en el tejido adiposo blanco difiere de un depósito de tejido adiposo a otro, con el mayor número de adipocitos en ratones y un número similar en hámsteres y ratas. La superficie más pequeña y el mayor porcentaje de adipocitos uniloculares pequeños se encontraron en ratones. El tejido adiposo blanco en hámsteres y ratas estaba compuesto predominantemente por un mayor porcentaje de adipocitos de tamaño mediano y un porcentaje menor de adipocitos de tamaño pequeño y mediano. Los adipocitos multiloculares positivos para la proteína desacopladora 1 se encontraron en depósitos de tejido adiposo marrón clásico con mayores porcentajes en ratones (93,20 %) y hámsters (91,30 %), mientras que las ratas tenían un porcentaje menor (78,10 %). En el tejido adiposo blanco y pardo se encontraron diferencias significativas entre especies y entre ambos sexos dentro de una misma especie, lo que indica la influencia del dimorfismo sexual. Los resultados morfométricos presentados podrían servir como base para futuros estudios sobre modelos animales experimentales de trastornos metabólicos y obesidad.

PALABRAS CLAVE: Ratón; Hámster; Rata; Tejido adiposo blanco; Tejido adiposo marrón.

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