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Quantification of fat deposition in the testis and epididymis using mDIXON Quant sequence: correlation with age and ejaculation

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Abstract

Purpose The objective of this study was to quantitatively assess fat deposition in the testis and epididymis by measuring the fat/water signal ratios with mDIXON Quant and to investigate its correlation with age and ejaculation.

Materials and methods Routine pelvic magnetic resonance imaging and mDIXON Quant were performed on 120 subjects. The fat/water signal ratios of the testis and epididymis were measured based on the fat/water signal intensity on mDIXON Quant.

Results The fat/water signal ratio values of the testis and epididymis in the early adulthood group (0.952–3.550%, $p < 0.05$, and 5.182–12.725%, $p < 0.05$, respectively) were significantly higher than those in the late childhood group (0.611–2.198% and 1.310–4.520%) and in the youth group (0.659–2.360% and 1.568–4.469%), and they were lower than those in the middle adulthood group (1.538–4.249%, $p < 0.05$, and 5.830–19.002%, $p < 0.05$). The fat deposition decreased in the testis of the youth group, who ejaculated more than ten times per month (0.750–2.022%, $p < 0.05$), and the fat/water signal ratios of the epididymis decreased in one subject in the early adulthood group who had three ejaculations within 12 h.

Conclusion The findings of this study suggest that mDIXON Quant may be useful as a noninvasive, quantitative, and objective method for evaluating the fat deposition of the testis and epididymis. This method can provide guidance for fat deposition in the testis and epididymis in different age groups with varying ejaculation experiences. Additionally, our findings may facilitate more accurate diagnosis and monitoring of the reproductive function of the testis and epididymis by quantitatively measuring their fat deposition with age.

Keywords Magnetic resonance imaging · Testis · Epididymis · Fat deposition

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Introduction

The testis and epididymis are important male reproductive and endocrine organs. Previous studies have reported that these organs contain a small amount of fat [1–3] and that fat deposition was associated with their physiological function [4, 5]. Therefore, it is helpful to understand the fat deposition of the testis and epididymis, and biopsy and medical imaging can be used to determine their fat content. A biopsy is not only invasive, but the results vary with the sampling point [6, 7]. The common medical imaging modalities are based on qualitative analysis and semi-quantitative measurement of the fat content, which may not be as accurate as quantitative measurements [8]. The standard qualitative analysis of magnetic resonance imaging (MRI) data may be insufficient to fully characterize physiological changes of the testis and epididymis. Therefore, new imaging techniques that quantitatively assess the fat deposition in the testis and epididymis are necessary for further investigation.

Currently, a noninvasive quantitative MRI technique called proton density fat fraction (PDFF) measurements, such as IDEAL IQ for GE Healthcare and mDIXON Quant for Philips Healthcare, is used to help accurately detect and quantify the adipose deposition in various organs [9–12]. IDEAL IQ and mDIXON Quant are different names for similar techniques in different instruments [12]. Because contiguous axial images are acquired, it is possible to calculate the fat fraction (FF) at any site within the scanning field. Our aim in this study was to determine the fat deposition of the testis and epididymis using mDIXON Quant sequence as well as to investigate its correlation with age and ejaculation.

Materials and methods

Subjects

The study was approved by the local research and ethics committee, and written informed consent was obtained from all the study participants. One hundred and twenty consecutive male subjects who had undergone pelvic MR study for physical examination or abdominal discomfort (Table 1), including mDIXON Quant from June 2016 to March 2018, were prospectively evaluated. All the subjects were divided into four groups according to age as follows: late childhood group (7–14 years, 28 people), youth group (15–22 years, 28 people), early adulthood group (23–40 years, 32 people), and middle adulthood group (41–65 years, 32 people). People younger than 7 years and older than 65 years were not included in the study because some of them did not cooperate well with the MRI process. Participants with malignant tumors, hematopoietic disease, obesity, anemia, hyperglycemia, hyperlipidemia, or autoimmune disease and those with severe liver and renal function as well as any history of disease in the testis or epididymis were excluded from this study. We measured the fat deposition of the testis and epididymis in each age group, and we compared the men who ejaculated (sex or masturbation) more than ten times a month with those who had no experience of ejaculation in the youth group. In addition, we remeasured the fat deposition of the testis and epididymis in three subjects in the early adulthood group after they ejaculated three times within 12 h.

MRI exploration

All the axial images were produced by a 1.5 T MRI system (Achieva, Philips Healthcare, Best, the Netherlands) and a 32-channel, phased-array torso coil. Prior to mDIXON Quant, the routine sequences, including fast spin echo T1-weighted sequences [repetition time (TR)/echo time (TE) = 450 ms/12 ms] and fast spin echo T2-weighted images (T2WI) of the perineum (TR/TE = 3800 ms/100 ms), were recorded (matrix = 512 × 512, field of view [FOV] = 40 × 40 cm, and section thickness/gap = 3 mm/1 mm; 32 sections covering the perineum).

The mDIXON Quant technique was used on the perineum in the axial plane with the following scan parameters: TR = 5.7 ms, first TE = 1 ms, delta TE = 0.7 ms; flip angle = 5°; acceleration: SENSE, acceleration factor = 2; number of signals averaged (NSA) = 1; matrix 128 × 128; 32 sections at a thickness of 3 mm; and scan time = 16 s. The following types of images were obtained automatically once the mDIXON Quant sequence was scanned without off-line processing: in phase image, out of phase image, pure water image, pure fat image, FF map, and R2* relaxation rate image. The adipose contents of the testis and epididymis were directly measured using the FF map, and the measurements represent the percentage of fat deposition in the local testicular and epididymal tissue.

Image processing

Two abdominal MRI-trained radiologists with image post-processing experience independently retrospectively evaluated the MRI imaging studies. The radiologists were blinded to the clinical information, clinical examination, and the original MRI imaging report. One of the radiologists also reviewed the MRI imaging studies twice, 2 months apart. The mDIXON Quant datasets were transferred to the workstation and processed using image processing software. The maximum circular regions of interest

Table 1 Clinical characteristics of the participants enrolled

	Late childhood group (n = 28)	Youth group (n = 28)	Early adulthood group (n = 32)	Middle adulthood group (n = 32)
Physical examination	0	0	10	12
Abdominal pain	12	11	10	12
Abdominal distention	6	8	5	2
Diarrhea	8	5	4	1
Abdominal tightness	1	1	0	2
Abdominal bulge	0	1	2	3
Other discomfort	1	2	1	0

(ROIs) were defined as the average of five replicates each at the largest level of testis and epididymis on the FF map by each radiologist in succession, and T1-weighted and T2-weighted axial images were used for the reference (Fig. 1). The ROI sizes varied slightly owing to different thicknesses and shapes of the testis and epididymis among the subjects, but they were similar and specific for the anatomic structure. The same location-matched fat/water signal ratios were quantitatively measured in all the subjects.

Statistical analysis

Statistical analyses were performed using the SPSS statistical package (SPSS 21.0 software for Windows). All the data were expressed as the mean ± SD, and $p < 0.05$ was considered statistically significant. The fat/water signal ratios were compared between the childhood, juvenile, youth, and middle-aged groups and between two time points (with or without ejaculation) using Bonferroni's test. The averages of the testis and epididymis measurements were calculated. The reliability of the fat/water signal ratio measurements that were independently performed by two radiologists was evaluated with the intraclass correlation coefficient (ICC) [13].

Results

All the sequences, including mDIXON Quant, were successfully performed without technical issues, and detailed MRI data were available for all the subjects. The fat/water signal ratios of testis and epididymis were 0.611–2.198%

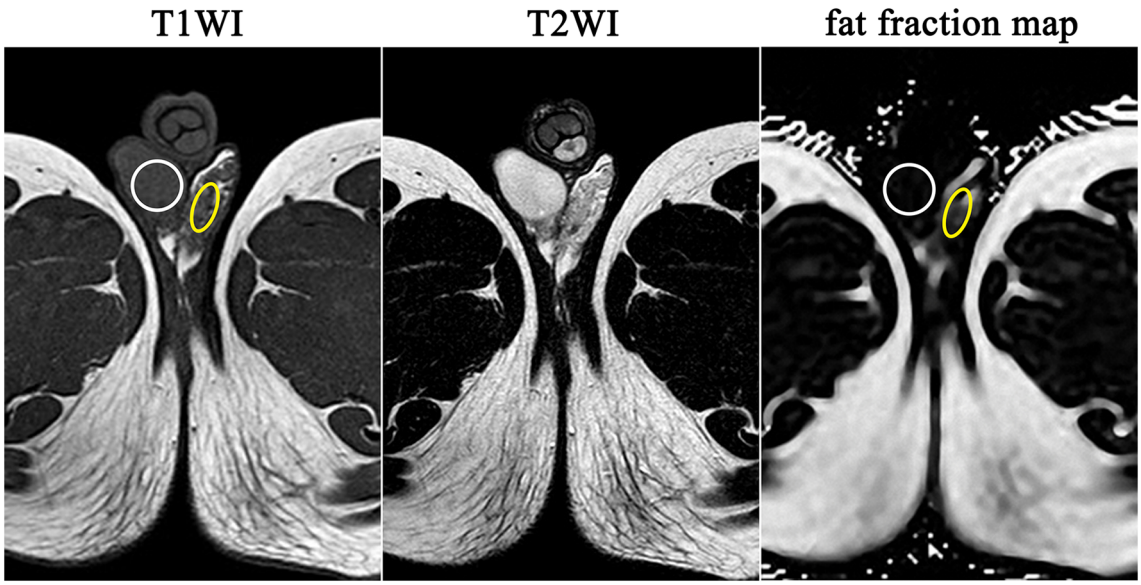

Fig. 1 Maximum circular regions of interest were drawn on the testis (white circular) and epididymis (yellow circular) to measure the fat fraction using mDIXON Quant sequence images

and 1.310–4.520% in the late childhood group, 0.659–2.360% and 1.568–4.469% in the youth group, 0.952–3.550% and 5.182–12.725% in the early adulthood group, and 1.538–4.249% and 5.830–19.002% in the middle adulthood group (Fig. 2). There was no significant difference in the fat/water signal ratios of the testis and epididymis between the late childhood and youth groups ($p > 0.05$), but there were obvious differences among the youth group, early adulthood group, and middle adulthood group ($p < 0.05$).

The fat/water signal ratios of the testis were 0.806–2.360% in the youth group, without the experience of ejaculation, and the fat/water signal ratio values were significantly higher than those of men who had ejaculated more than ten times a month (0.750–2.022%, $p < 0.05$) (Fig. 3a). There was no difference in the fat/water signal ratios of the epididymis between the men without experience of ejaculation (1.568%–4.469%) and with experience of ejaculation (1.562–4.453%, $p > 0.05$) (Fig. 3a).

Two of the three subjects in the early adulthood group who had ejaculated three times within 12 h had no significant decrease in the fat/water signal ratios of the testis and epididymis (Fig. 3b). While the fat/water signal ratios of the third subject decreased significantly in the epididymis, there was no significant change in the testis (Fig. 3b). The decrease in the epididymal fat deposition after ejaculation was observed as decreased signal intensity on the FF map, but signal changes are not obvious on conventional T1 and T2 sequences (Fig. 4). In the measurement of the fat deposition on the FF map from the mDIXON Quant sequence, interobserver agreement was high [ICC = 0.972; 95% confidence interval (CI) 0.951–0.979], and intraobserver agreement was also high [ICC = 0.969; 95% confidence interval (CI) 0.948–0.975].

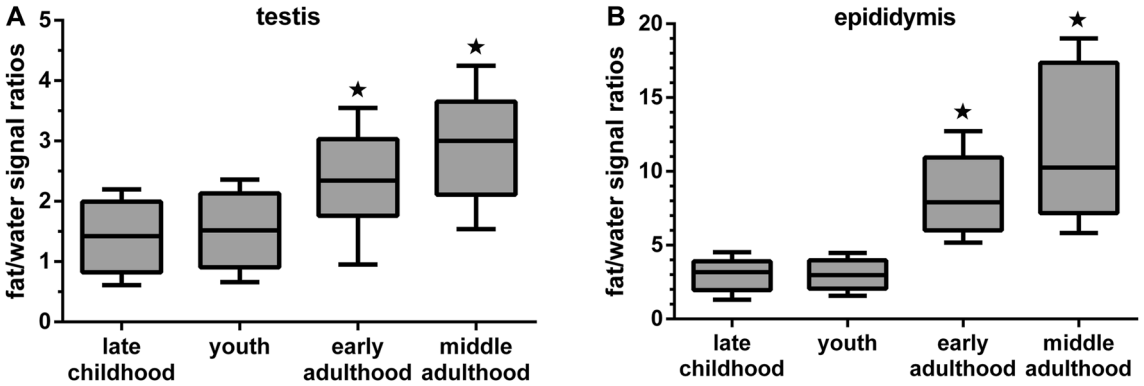

Fig. 2 The fat/water signal ratios of the testis (**a**) and epididymis (**b**) in the late childhood, youth, early adulthood, and middle adulthood groups were quantitatively measured in the fat fraction map of the mDIXON Quant sequence. The fat/water signal ratios of the testis and epididymis in the early adulthood group were significantly higher than those in the late childhood and youth groups, and they were lower than those in the middle adulthood group. *$p < 0.05$ compared with the fat/water signal ratios in the early adulthood group or middle adulthood group

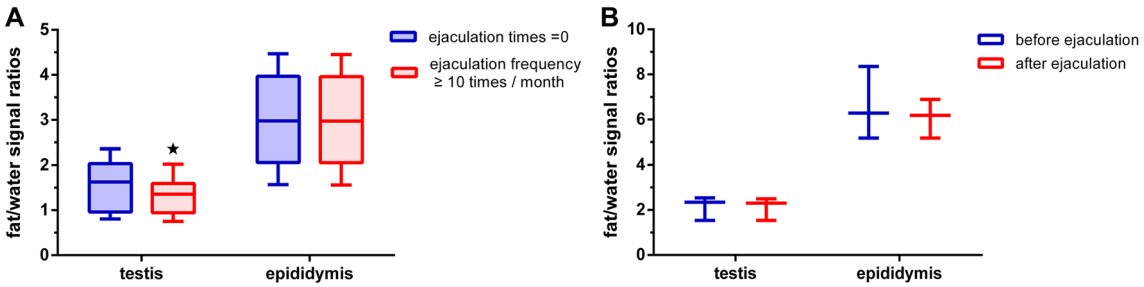

Fig. 3 The fat/water signal ratios of the testis and epididymis in the youth group who lacked ejaculation experience vs experience of more than ten ejaculations in a month (**a**) as well as in three subjects in the early adulthood group who ejaculated three times within 12 h (**b**) were quantitatively measured in the fat fraction map of the mDIXON Quant sequence. The fat/water signal ratios of the testis in the group without ejaculation experience were significantly higher than those with more than ten ejaculations in a month; the fat/water signal ratios were not different in the epididymis (**a**). The fat/water signal ratios of one subject in the early adulthood group who ejaculated three times within 12 h were significantly decreased in the epididymis, while there was no significant change in the testis; the fat/water signal ratios of the testis and epididymis were not changed in the other two subjects (**b**). *$p < 0.05$ compared with the fat/water signal ratios of the testis in the group with more than ten ejaculations in a month

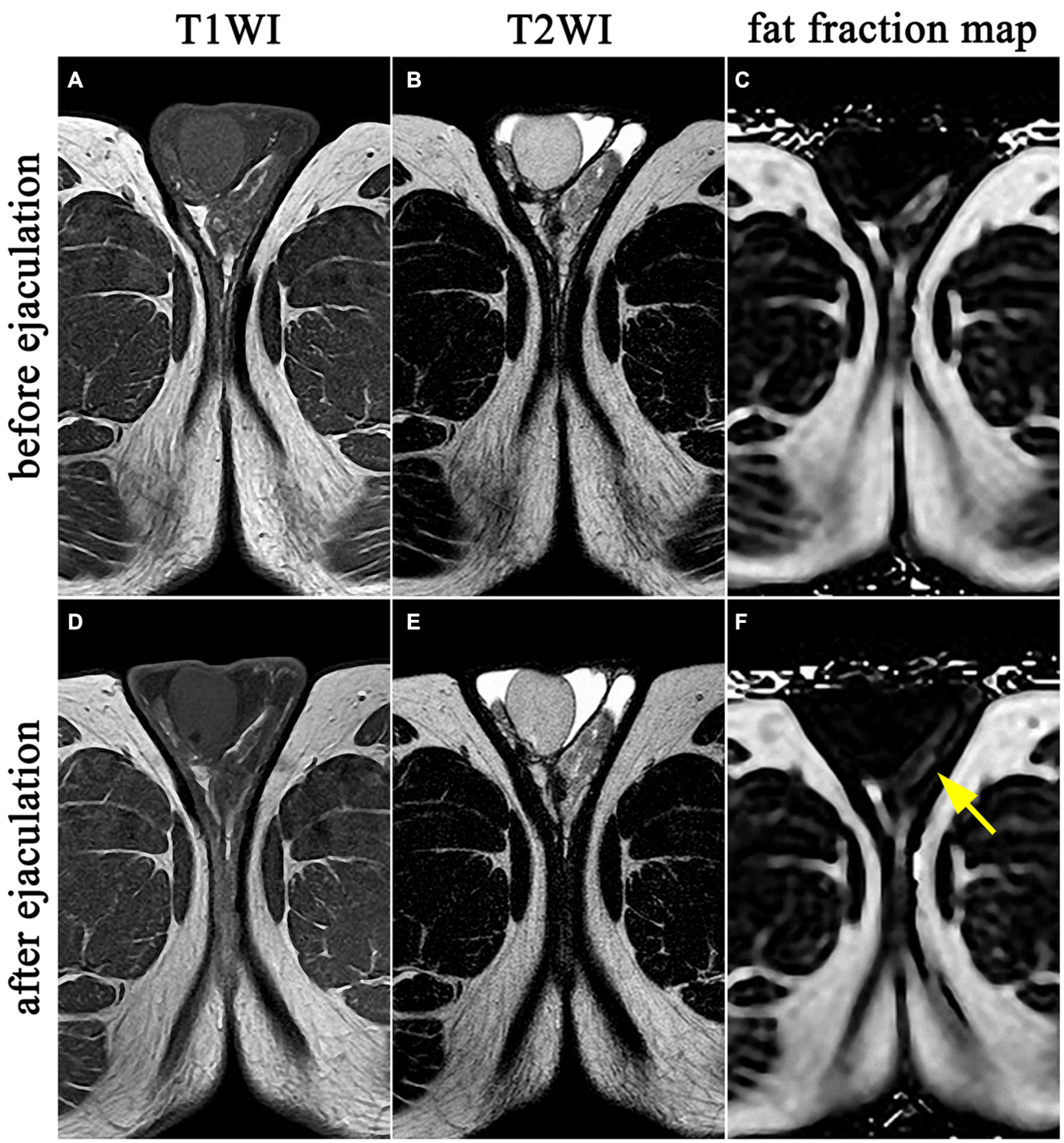

Fig. 4 A 32-year-old male with three ejaculations within 12 h. Axial T1-weighted image (**a**, **d**), T2-weighted image (**b**, **e**), and fat fraction map of the mDIXON Quant sequence (**c**, **f**) show that asymmetric fat deposition decreased (yellow arrow) after three ejaculations within 12 h, and the changes in the fat deposition in the testis and epididymis were not obvious in routine T1-weighted and T2-weighted images

Discussion

The testis and epididymis contain a certain amount of fat. Previous studies [1–3] have measured the fat deposition in the testis and epididymis by analyzing the tissue, which not only introduces sampling errors but also cannot be widely performed on patients because of invasiveness. Recently, noninvasive quantitative MRI PDFF measurements have been shown to help accurately detect and quantify the fat deposition of the parenchymal organs [9–12], and our study

confirmed that the mDIXON Quant, the name of PDFF in Philips Healthcare instruments, can quantitatively measure fat deposition in the testis and epididymis.

Some studies showed that obesity and age affect male fertility potential [14, 15], and Sertoli-cell function is impaired with increasing age. Our study confirmed that the proportion of fat in the testis and epididymis changed with age according to the MRI mDIXON Quant sequence. The fat/water signal ratio values of the testis and epididymis in the early adulthood group were significantly higher than those in the late childhood and youth groups, and they were lower than those in the middle adulthood group. Therefore, we speculate that fat deposition of the testis and epididymis may weaken the reproductive function and that young people (15–22 years) have better fertility than adults (older than 22 years).

This study also found that the fat deposition decreased in the testis of the youth group, who ejaculated more than ten times per month, while it did not change significantly in the epididymis. The fat deposition in the testicle is more likely to decrease with semen elimination. We believe that a stable ejaculation experience can reduce fat deposition in the testis, which may be beneficial to reproductive function.

In addition, the fat/water signal ratios of the epididymis decreased in one subject in the early adulthood group who had three ejaculations within 12 h. Due to the small number of subjects in this study, we speculate that multiple ejaculations reduce epididymal fat deposition in a short period of time as a result of an individual difference or that the synthesis of lipid-containing secretions in the epididymis cannot compensate for the ejaculations. This observation merits further study.

PDFF technology has been used in the brain, abdomen, spine, and sacroiliac joint [9, 10, 16, 17], but there are limited reports on its use in the testis and epididymis. In this study, we used the mDIXON Quant approach to study the fat deposition in the testis and epididymis and to compare the fat/water signal ratios measured in multiple age groups as well as groups with or without ejaculation experience. Compared with the qualitative and semi-quantitative diagnosis of the fat deposition in previous reports [18, 19], the mDIXON Quant sequence not only enables a qualitative diagnosis but also quantitatively measures the degree of fat deposition and provides guidance for the fat deposition of the testis and epididymis in different age groups as well as groups with varying ejaculation experiences. Furthermore, we can speculate on reproductive function according to fat deposition in the testis and epididymis.

Our study has a few limitations. First, the sample size was small and lack of testis biopsy, and a study with a larger sample size and biopsy result is needed to confirm our results. Second, there was lack of quantitative correlation between the mDIXON Quant sequence and other inspection methods (i.e., MR spectroscopy). Third, the selection bias of different consecutive patients needs to be further discussed.

In conclusion, the mDIXON Quant is a novel tool for noninvasive, quantitative, and objective evaluation of the fat deposition in the testis and epididymis. This tool can provide guidance on fat deposition in the testis and epididymis in different age groups and for individuals with varying ejaculation experiences. Fat deposition in the testis and epididymis increases with age, and ejaculation may reduce fat deposition in the testis or epididymis. Furthermore, our findings may facilitate more accurate diagnosis and monitoring of the reproductive function of the testis and epididymis by quantitatively measuring their fat deposition with age.

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Compliance with ethical standards

Conflict of interest We or our institution have no conflicts of interest.

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