

Establishing reference values and evaluating diagnostic utility of scrotal ultrasound for azoospermia subtypes: A cross-sectional study in Guangdong, China

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ABSTRACT

Background: Male infertility is a significant health issue in East Asia, affecting over 12 million men, primarily due to non-obstructive and obstructive azoospermia. Although scrotal color Doppler ultrasonography is widely used to assess male reproductive health, existing diagnostic standards derived from European populations remain unvalidated for Chinese men. This study aimed to establish population-specific reference values and evaluate the diagnostic utility of ultrasonographic parameters in differentiating azoospermia subtypes.

Methods: We enrolled 424 men aged 20–45 years, including 245 normozoospermic controls, 135 with non-obstructive azoospermia, and 44 with obstructive azoospermia from Guangdong Province, China. All participants underwent scrotal ultrasound following standardized protocols to measure testicular volume, epididymal dimensions, and hemodynamic parameters. Semen analysis and hormonal profiling were also performed.

Results: Results showed that testicular volumes in fertile men from Guangdong Province, China were significantly smaller than European reference values. Testicular volume was inversely correlated with follicle-stimulating hormone and luteinizing hormone levels and positively correlated with sperm count and concentration, but not with



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motility or morphology. Men with non-obstructive azoospermia had significantly smaller testicular volumes, while those with obstructive azoospermia showed significant dilation of the epididymal caput.

Conclusions: This study provides the first scrotal ultrasound reference standards for men from Guangdong Province, China and suggests that a two-parameter approach based on testicular volume and epididymal caput diameter may aid in non-invasive differentiation of azoospermia subtypes, potentially reducing the need for invasive biopsies.

Key words: Scrotal color Doppler ultrasonography, Non-obstructive azoospermia, Obstructive azoospermia

Background

Male infertility represents a growing global health challenge, affecting tens of millions worldwide with rising prevalence rates. In the East Asian context, the condition impacts over 12 million men, reflecting a significant burden on couples' reproductive health (1), with Non-obstructive Azoospermia (NOA) and Obstructive Azoospermia (OA) being the primary contributing factors (2, 3). Color Doppler ultrasonography (CDUS) serves as a valuable diagnostic tool by providing real-time visualization of scrotal structures and blood flow dynamics, which facilitates precise anatomical and hemodynamic assessments. This capability allows it to accurately differentiate pathological conditions, thereby reducing unnecessary surgical interventions and enhancing diagnostic reliability when physical or biochemical examinations yield inconclusive results (4). Furthermore, the recent EAA multicenter study established standardized reference baselines for fertile males, advancing CDUS into a quantifiable framework for evaluating male reproductive health (5). However, these standards are predominantly derived from European cohorts, resulting in a persistent deficiency of testicular morphological benchmarks for Chinese. Furthermore, discriminatory CDUS features distinguishing OA from NOA remain incompletely characterized.

Our study established CDUS reference ranges for testicular and epididymal parameters in normozoospermic men from Guangdong Province of China, following standardized EAA protocols (5). We

systematically investigated the correlations between CDUS-derived metrics and seminal parameters, as well as hypothalamic-pituitary-testicular (HPT) axis hormonal profiles. Furthermore, we conducted comparative CDUS analyses among normozoospermic, NOA, and OA cohorts to identify discriminative imaging features. These findings establish locally adapted, diagnostic standards for assessing male infertility in populations from Guangdong Province, China, demonstrate the utility of scrotal CDUS as a non-invasive tool for differentiating between OA and NOA, and provide novel insights into the regulation of the testicular microenvironment.

Methods

Study design

This single center cross-sectional study consecutively recruited 424 male participants aged 20-45 years, who were categorized into three groups based on semen analysis and clinical diagnosis: Group 1 consisted of 245 community-derived controls with proven fertility, defined by normal semen parameters according to the WHO 2021 criteria and a partner's time-to-pregnancy (TTP) of ≤ 12 months. Group 2 included 135 patients with non-obstructive azoospermia (NOA), confirmed via testicular biopsy or open histological examination showing conditions such as Sertoli cell-only syndrome or spermatogenic maturation arrest; Group 3 comprised 44 patients with obstructive

azoospermia (OA), diagnosed via surgical or imaging evidence of genital tract obstruction and confirmed normal spermatogenesis through testicular biopsy. The participant screening, grouping, and subsequent analytical pathways are summarized in Figure 1. Briefly, all eligible normozoospermic men constituted the fertile reference cohort (n=245). This single cohort served a dual purpose: (i) to establish the population-specific reference intervals for scrotal CDUS parameters, and (ii) to serve as the control group for comparison with azoospermic patients. A total of 179 patients with azoospermia were enrolled and further subclassified into non-obstructive (NOA, n=135) and obstructive (OA, n=44) groups. The CDUS parameters of the fertile reference cohort and the two azoospermia groups were then compared.

Research subjects and inclusion criteria

This study enrolled three categories of participants: men with normal semen parameters, OA, and NOA. The inclusion criteria of normal semen parameters were: age 20–45 years, residence in the local area, meeting the WHO 2021 criteria for standard semen parameters, and most importantly, having a partner with a documented time-to-pregnancy (TTP) of ≤ 12 months, confirming natural conception without medical assistance, while excluding those with clinical grade II or higher varicocele, genital tract infections, abnormal karyotype or AZF microdeletions, or a history of cryptorchidism. To enhance the phenotypic specificity of the OA cohort while maintaining clinical relevance, we applied a conservative exclusion criterion of a

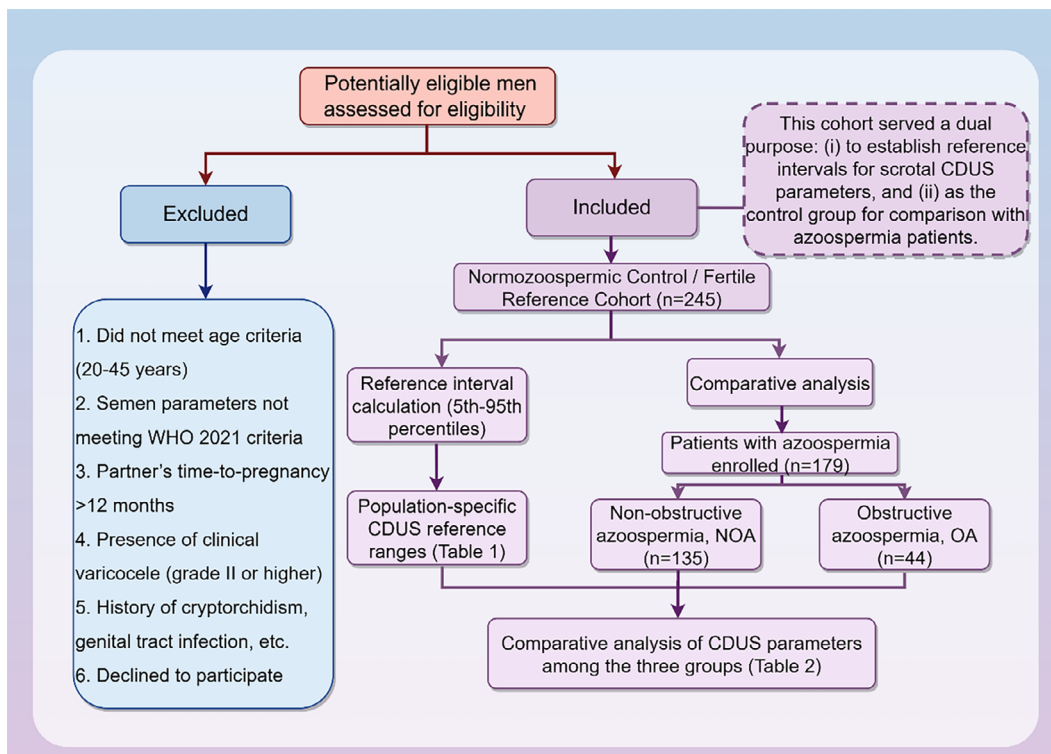


Figure 1. Flowchart of study participant recruitment and analysis. Potentially eligible men were assessed based on the following key exclusion criteria: 1) age outside 20–45 years, 2) semen parameters not meeting WHO 2021 criteria, 3) partner's time-to-pregnancy >12 months, 4) presence of clinical varicocele (grade II or higher), 5) history of cryptorchidism or genital tract infection, and 6) declined to participate. Men who met all criteria formed the normozoospermic control / fertile reference cohort (n=245). This cohort was used to calculate reference intervals (5th–95th percentiles) for scrotal CDUS parameters, establishing the population-specific reference ranges. The same cohort also served as the control group for comparative analysis against patients with azoospermia (n=179), who were subclassified into non-obstructive (NOA, n=135) and obstructive (OA, n=44) groups. The final comparative analysis evaluated CDUS parameters across these three groups.

testicular volume <7 mL in either testis. This threshold lies within the established normal reference interval (5.4–12.3 mL) for our population but helps minimize the inclusion of cases with probable severe concomitant spermatogenic impairment. The NOA group was diagnosed based on the absence of sperm in at least two semen analyses and testicular pathology showing spermatogenic failure such as Sertoli cell-only syndrome or maturation arrest, while excluding any evidence of obstruction or prior androgen or gonadotropin therapy.

Data acquisition and ultrasound imaging protocol

Scrotal color Doppler ultrasound (CDUS) was performed using a GE Voluson E8 system equipped with a 4–16 MHz linear transducer, following standardized protocols aligned with the European Academy of Andrology (EAA) recommendations. All examinations were conducted with participants in the supine position after even application of coupling gel to the scrotal skin; the probe was placed gently to avoid tissue deformation.

The imaging protocol included comprehensive assessment of testicular and epididymal parameters. Testicular measurements encompassed three orthogonal dimensions: length (L), width (W), and height (H), all recorded in centimeters (cm). Testicular volume (V, in milliliters) was calculated using the following formulas: The Ellipsoid formula: $V = L \times W \times H \times 0.52$; The Lambert formula: $V = L \times W \times H \times 0.71$; The Hansen formula: $V = L \times W \times H \times 0.52$ (The Hansen formula, as implemented in our study, used the maximal dimensions and a constant of 0.52). Epididymal evaluation followed a segmental measurement protocol: the caput was assessed by measuring the head-to-base distance in the maximal longitudinal section, while the corpus and cauda were evaluated on the same longitudinal plane by recording their anteroposterior diameters. Hemodynamic parameters, including peak systolic velocity and resistive index, were also systematically recorded. To ensure measurement consistency and diagnostic reliability, all examinations were conducted by two experienced sonographers blinded to group assignment. Prior to study commencement, both operators underwent joint training sessions on standardized EAA operating procedures. Throughout

the data collection period, they performed periodic simultaneous scans and measurement comparisons on initial cases to calibrate techniques and establish consensus on anatomical landmarks. All images were independently analyzed, with any discrepancies resolved through consensus review or consultation with a senior andrologist.

Complementary assessments included semen analysis performed according to WHO 2021 guidelines (evaluating volume, pH, concentration, motility, and morphology) and serum hormone measurements (FSH, LH, and testosterone) via electrochemiluminescence immunoassay, ensuring comprehensive multimodal evaluation of reproductive parameters.

Statistical analysis

Normative reference ranges were defined as the 5th and 95th percentiles according to CLSI guidelines. The distribution of all key parameters was visually assessed using violin diagram. The uncertainty of the percentile estimates was quantified by calculating their 95% confidence intervals (CIs) using the bootstrap method with 1,000 resamples. No pre-specified outliers were excluded from the reference range calculation to ensure the results represent the natural variation within the defined fertile population, as per the principle of establishing reference intervals. Correlations between CDUS features and both seminal and hormonal parameters were evaluated using Pearson or Spearman tests based on data distribution. Group comparisons (normozoospermic vs. NOA vs. OA) for continuous variables were performed using one-way ANOVA with Tukey's post-hoc test. All analyses were conducted using SPSS version 26.0, with a two-sided $p < 0.05$ considered statistically significant.

Results

Scrotal CDUS and Morphometric Reference Ranges in Fertile Men from Guangdong Province, China

Our study established testicular color Doppler ultrasound (CDUS) reference ranges for 245 fertile men from Guangdong Province, China using three

volumetric formulas, revealing significantly lower values than European counterparts. The mean testicular volume, calculated using the ellipsoid formula, was 8.4 ± 2.3 mL, with 5th and 95th percentiles (reference interval) of 5.4 mL (95% CI: 4.9–5.6) and 12.3 mL (95% CI: 11.9–13.5), respectively. Corresponding values derived from the Lambert formula were 7.4 mL (95% CI: 6.8–7.6) and 16.8 mL (95% CI: 15.9–18.4) for the 5th and 95th percentiles, respectively, and from the Hansen formula were 6.2 mL (95% CI: 5.1–6.0) and 14.3 mL (95% CI: 14.6–15.9), respectively. All these population-specific reference values are substantially lower than those reported in the European Academy of Andrology (EAA) standards (mean volumes: 17.2 ± 4.1 mL, 23.5 ± 5.6 mL, and 20.4 ± 5.0 mL for the ellipsoid, Lambert, and Hansen formulas, respectively; $P < 0.001$). The distributions of testicular volume (ellipsoid formula) and epididymal head diameter in the reference cohort are visually summarized in Figure S1. Testicular dimensions similarly demonstrated reduced metrics: left/right testicular lengths measured 37.2 ± 3.5 mm/ 37.8 ± 3.5 mm, widths 19.0 ± 2.0 mm/ 19.0 ± 2.3 mm, and heights 22.0 ± 2.4 mm/ 22.2 ± 2.7 mm. In addition, standardized ultrasonographic assessment of the epididymis was performed. The normal epididymal caput exhibited a characteristic triangular shape in longitudinal scans, while both the corpus and cauda appeared homogeneous. Morphometric evaluation included the longitudinal diameter (length), anterior–posterior diameter (height), and transverse diameter (width) obtained in orthogonal planes (Figure 2). Our study also provides the first comprehensive dataset on accessory gland dimensions in Asian populations, including seminal vesicle diameters (left: 9.5 ± 2.4 mm; right: 9.8 ± 2.3 mm) and prostatic urethral parameters (length: 41.7 ± 3.0 mm; height: 21.0 ± 1.8 mm; width: 30.8 ± 1.9 mm) (Table 1 and Table S1). This comprehensive dataset establishes the first population-specific CDUS reference standards for testicular development and epididymal morphology assessment in Chinese fertility evaluations.

Correlation between CDUS-derived testicular volume and hormonal levels

Building upon established CDUS reference ranges for testicular volume (TV) in fertile men from

Guangdong Province, China, we investigated the relationship between ultrasonographic parameters and hypothalamic–pituitary–testicular (HPT) axis function. Testicular volume demonstrated significant inverse correlations with gonadotropin levels—specifically with follicle-stimulating hormone (Figure 3A) and luteinizing hormone (Figure 3B). These associations indicate progressively elevated gonadotropin secretion at smaller testicular volumes, consistent with compensatory HPT axis activation. Conversely, TV showed no statistically significant relationship with testosterone levels (Figure 3C). This evidence supports the utility of CDUS-measured testicular volume as an indirect biomarker for evaluating functional integrity of the reproductive endocrine axis.

Predictive utility of sonographic testicular volume for semen characteristics

We further evaluated the clinical relevance of CDUS parameters to seminal quality, identifying significant associations between testicular volume and sperm production metrics. Mean testicular volume demonstrated statistically significant positive correlations with both total sperm count (Figure 4A) and sperm concentration (Figure 4B), indicating enhanced spermatogenesis efficiency with larger testicular dimensions. Conversely, no statistically significant relationships were observed between TV and sperm kinematic quality, including progressive motility (Figure 4C) or normal morphology rate (Figure 4D). These findings establish CDUS-derived testicular volume as a predictor of sperm production capacity, while demonstrating its limited predictive utility for functional sperm parameters related to motility and morphological integrity.

CDUS-based differentiation of non-obstructive vs. obstructive azoospermia

We conducted a tripartite CDUS comparison among men with normal semen parameters, non-obstructive azoospermia (NOA), and obstructive azoospermia (OA) cohorts to identify the key morphological differences. NOA patients exhibited significantly reduced testicular volumes compared to fertile

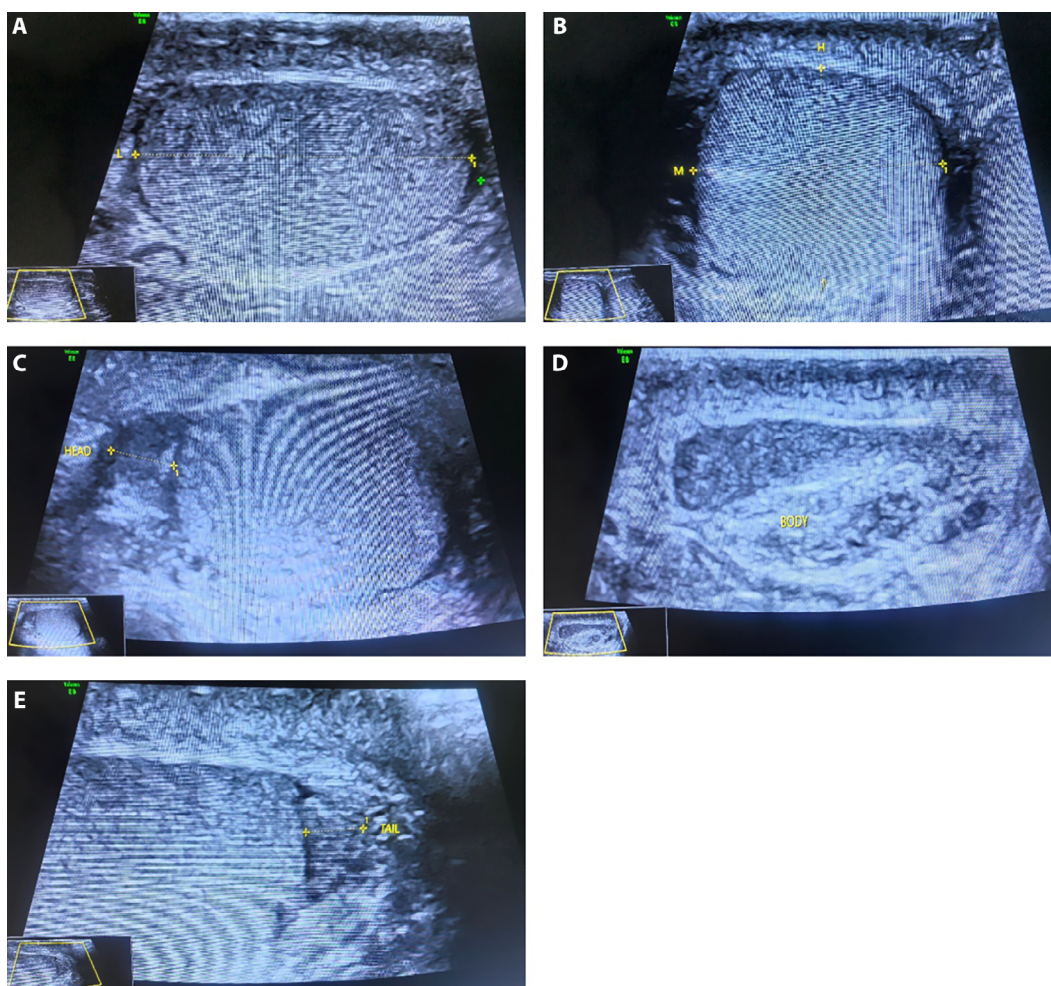


Figure 2. Ultrasonographic visualization and anatomical landmarks of the testis and epididymis. (A) longitudinal diameter (length [L]) in longitudinal scan. (B) anterior-posterior diameter (height [H]) and transverse diameter (width [W]) in transverse scan. (C) Normal epididymal head with triangular shape in a longitudinal scan. (D) Homogeneous epididymal body in a longitudinal scan. (E) Homogeneous epididymal tail in a longitudinal scan.

controls, with ellipsoid formula measurements declining from 8.4 ± 2.3 mL to 4.7 ± 2.8 mL ($P < 0.001$). Lambert formula volumes similarly decreased from 11.4 ± 3.2 mL to 6.4 ± 3.8 mL ($P < 0.001$). Conversely, OA patients maintained testicular volumes comparable to fertile men (ellipsoid: 8.3 ± 2.3 mL, Lambert: 11.4 ± 3.2 mL; $P > 0.05$ for both). Epididymal architecture demonstrated diagnostic divergence: while NOA subjects showed caput diameters similar to controls (8.0 ± 1.6 mm vs. 7.8 ± 1.9 mm; $P = \text{NS}$), OA patients exhibited significant cephalic dilation (9.2 ± 1.9 mm; $P < 0.001$ vs. both groups) (Table 2). These results establish CDUS-defined testicular volume reduction as

a primary discriminator for NOA diagnosis, whereas epididymal head dilation serves as a key sonographic marker for OA. Collectively, sonographic metrics provide clinically actionable morphological criteria for non-invasive differentiation of azoospermia subtypes.

Diagnostic performance of ultrasound parameters

To quantify the discriminative ability of CDUS parameters between OA and NOA, receiver operating characteristic (ROC) curve analysis was performed for individual parameters (Figure 5A). Testicular

Table 1. Reference range and mean values of the testicular color Doppler ultrasound (CDUS) parameters in fertile men.

Testis US parameters	Our study		EAA study	
	Mean±SD	Reference range	Mean±SD	Reference range
Testicular volume (ml)				
“Ellipsoid” formula				
Left	8.2±2.3	5.4-12.6	16.5 ± 4.1	11.0-24.1
Right	8.5±2.4	5.4-12.9	17.9 ± 4.4	12.0-25.7
Mean	8.4±2.3	5.4-12.3	17.2 ± 4.1	11.8-24.4
“Lambert” formula				
Left	11.2±3.1	7.4-17.1	22.6 ± 5.6	15.1-32.9
Right	11.6±3.3	7.3-17.7	24.4 ± 6.0	16.4-35.1
Mean	11.4±3.2	7.4-16.8	23.5 ± 5.6	16.0-33.0
“Hansen” formula				
Left	10.0±2.9	6.0-14.6	19.7 ± 5.2	12.5-28.6
Right	10.4±3.1	6.2-15.3	21.2 ± 5.5	13.2-30.6
Mean	10.2±2.8	6.2-14.3	20.4 ± 5.0	13.5-29.4
Testicular diameters (mm)				
Left testis length	37.2±3.5	32.5-44.0	44.7 ± 4.5	37.0-52.0
Left testis width	19.0±2.0	19.0-26.0	28.8 ± 2.8	24.0-34.0
Left testis height	22.0±2.4	15.5-23.0	24.4 ± 2.8	20.0-29.0
Right testis length	37.8±3.5	32.8-43.0	45.7 ± 4.3	38.5-52.0
Right testis width	19±2.3	18.1-27.0	29.6 ± 2.8	25.0-34.0
Right testis height	22.2±2.7	16.0-22.9	25.1 ± 2.9	20.0-30.0
Epididymal				
Left epididymal head diameter	8.1±1.5	6.2-9.8		
Left epididymal body diameter	2.5±0.4	1.9-3.0		
Left epididymal tail diameter	5.5±1.2	4.0-7.1		
Right epididymal head diameter	7.9±1.7	6.0-9.7		
Right epididymal body diameter	2.4±0.5	1.8-2.9		
Right epididymal tail diameter	5.3±1.0	3.7-7.0		
Mean epididymal head diameter	8.0±1.6	6.3-9.7	9.0 ± 1.5	7.0-11.5
Mean epididymal body diameter	2.5±0.5	2.0-2.9	3.8 ± 0.8	2.5-5.0
Mean epididymal tail diameter	5.4±1.1	4.0-6.5	4.8 ± 0.7	4.0-6.0

volume demonstrated excellent discriminatory ability with an area under the curve (AUC) of 0.844 (95% CI: 0.787–0.902). The AUC for epididymal head diameter was 0.760 (95% CI: 0.685–0.835), indicating fair discrimination, which was significantly lower than

that of testicular volume (DeLong test, $p = 0.048$). Patient age showed no significant discriminatory value (AUC: 0.539, 95% CI: 0.431–0.647). To integrate the two key sonographic parameters into a composite diagnostic tool, a multivariable logistic regression model

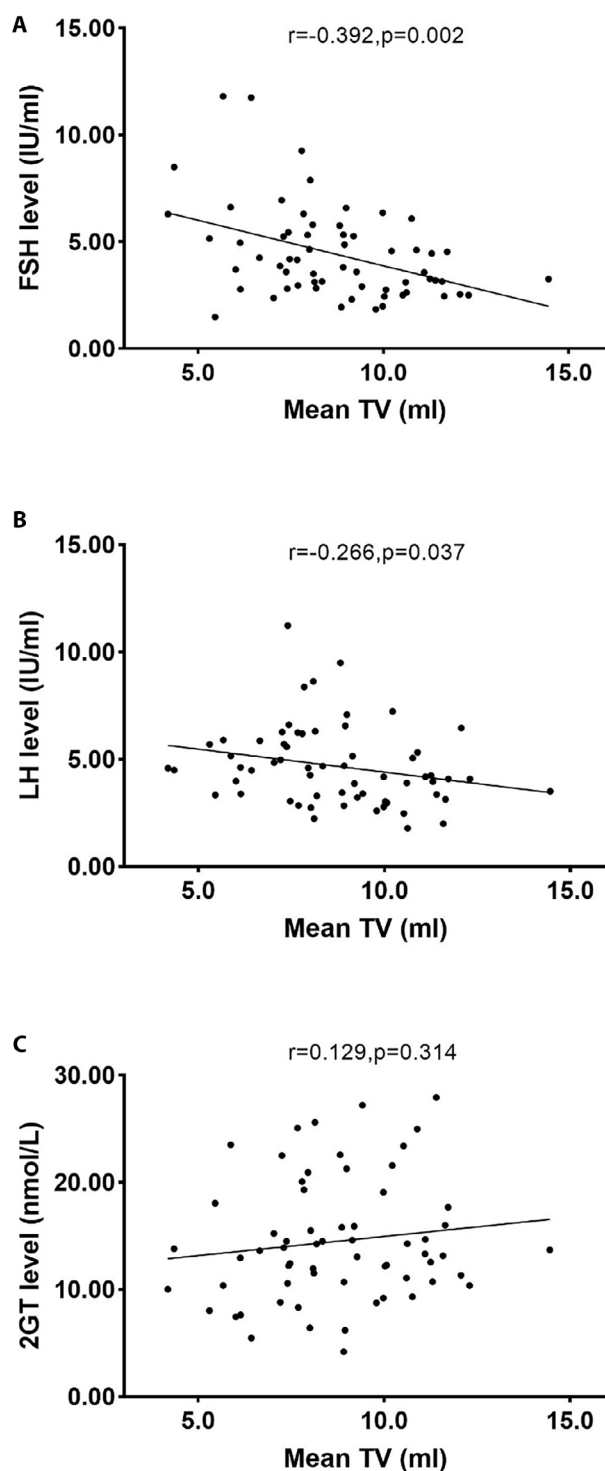


Figure 3. Correlation analysis between mean testicular volume and serum hormone levels. (A) Significant negative correlation between mean testicular volume and FSH ($r = -0.392$, $P = 0.002$). (B) Negative correlation between mean testicular volume and LH ($r = -0.266$, $P = 0.037$). (C) No significant correlation between mean testicular volume and testosterone ($r = 0.129$, $P = 0.314$) ($n = 245$).

was constructed, with OA as the outcome and age as a covariate. The model was statistically significant (Likelihood Ratio test: $p < 0.001$; Pseudo $R^2 = 0.262$). As detailed in Table 3, both sonographic parameters were independent predictors after adjusting for age: testicular volume was the strongest predictor (adjusted Odds Ratio [aOR] = 1.54, 95% CI: 1.29–1.83; $p < 0.001$), and epididymal head diameter was also significant (aOR = 1.30, 95% CI: 1.03–1.63; $p = 0.025$). Age was not a significant predictor (aOR = 1.04, 95% CI: 0.96–1.12; $p = 0.313$). The combined predicted probability generated by this model effectively discriminated between the groups, with a significantly higher mean probability in the OA group (0.465 ± 0.233) than in the NOA group (0.174 ± 0.186 ; $p < 0.001$, t-test). The ROC curve for this combined probability is presented in Figure 5B, showing high overall diagnostic accuracy (AUC: 0.866, 95% CI: 0.808–0.917). The model's performance at the optimal probability cutoff of 0.210 (determined by Youden's index) is summarized in Table 4, yielding a sensitivity of 86.36%, specificity of 74.81%, a positive predictive value of 52.78%, and a negative predictive value of 94.39%.

Discussion

Validation of population differences and consideration of potential biases

The notably smaller testicular volumes observed in our community-based cohort of proven fertile men from Guangdong Province, China, compared to European standards, raise the crucial question of whether this reflects a genuine biological difference or methodological artifacts. Firstly, regarding selection bias, our control group was specifically recruited from the community with a stringent criterion of proven fertility (partner's time-to-pregnancy ≤ 12 months), ensuring they represent a true fertile reference population rather than a clinically selected group. This design effectively minimizes the risk of selection bias associated with hospital-based infertility studies. Secondly, concerning measurement bias, our strict adherence to standardized EAA ultrasound protocols, using a single ultrasound platform and implemented by sonographers who underwent

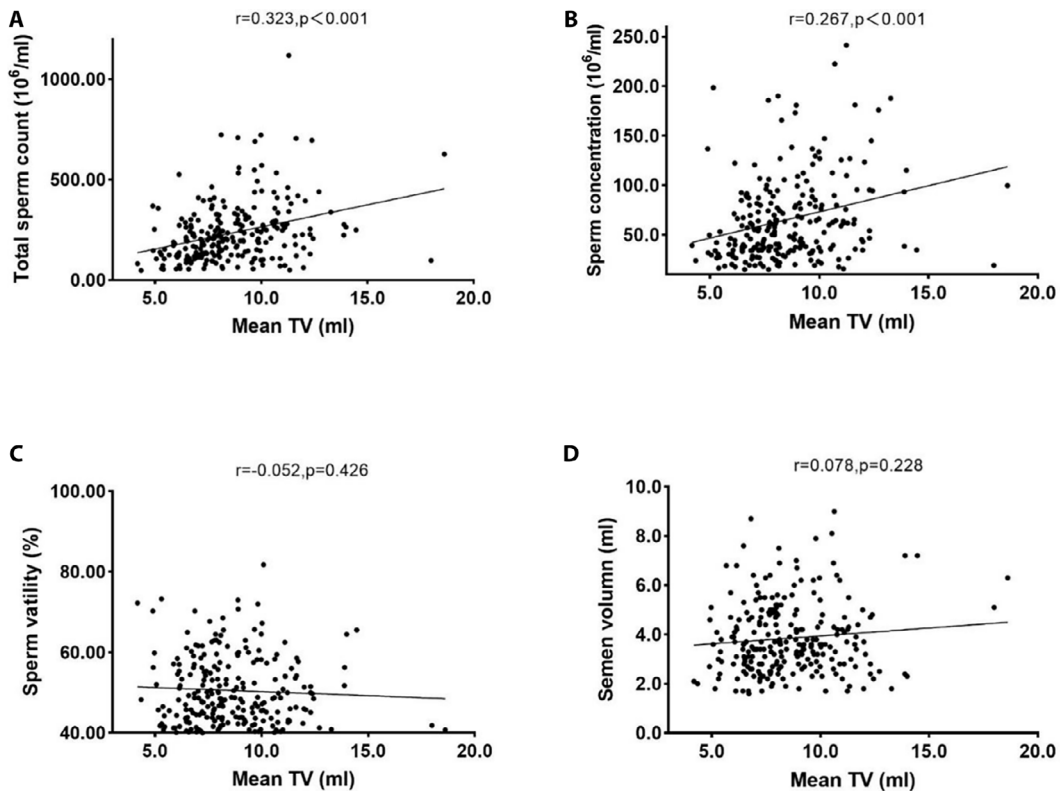


Figure 4. Correlation Analysis Between Mean Testicular Volume and Seminal Parameters. (A) Pronounced positive correlation between testicular volume and total sperm count ($r=0.323, P<0.001$). (B) Significant positive association with sperm concentration ($r=0.267, P<0.001$). (C) No statistically significant correlation with progressive motility ($r=-0.052, P=0.426$). (D) Absence of significant association with normal morphology rate ($r=0.078, P=0.228$) ($n=245$).

joint training, robustly minimizes inter-observer and inter-machine variability. Lastly, to address the potential confounding effect of anthropometrics, although detailed data on height and BMI were not available for direct adjustment, the magnitude of the observed difference (~50% smaller) is disproportionately large compared to known variations in body habitus. Although a significant height difference exists between Chinese and European males (6), the study revealed only a weak positive correlation between stature and testicular volume, with correlation coefficients of $r=0.162$ for the left testis and $r=0.276$ for the right testis (7). Thus, body size alone seems insufficient to plausibly explain the substantial disparity in testicular volume. Therefore, we propose that the observed difference is likely an authentic population-level characteristic.

Establishment of population-specific reference ranges and hypotheses for observed disparities

The European Academy of Andrology (EAA) US study is the first to systematically evaluate the entire human male genital tract (MGT) using standardized operating procedures (SOPs) and color Doppler ultrasound (CDUS). Based on a reference cohort of healthy and fertile men, this study established reference ranges, echotexture features, and vascular characteristics for organs within the scrotal, prostatic, and seminal vesicular regions (5, 8, 9). In China, CDUS has been clinically applied in the diagnosis of breast cancer (10), bone tumors (11), focal nodular hyperplasia (12), hepatocellular adenoma (12), and erectile dysfunction (13), as well as in the detection of deep

Table 2. Compare of the testicular color Doppler ultrasound (CDUS) parameters in fertile men, NOA and OA.

	Fertile men (n=245)	NOA (n=135)	OA (n=44)
Testis US parameters	Mean±SD	Mean±SD	Mean±SD
Testicular volume(ml)			
“Ellipsoid” formula			
Left	8.2 ± 2.3	4.6 ± 2.8**	8.1 ± 2.6
Right	8.5 ± 2.4	4.7 ± 2.8**	8.6 ± 2.0
Mean	8.4 ± 2.3	4.7 ± 2.8**	8.3 ± 2.3
“Lambert” formula			
Left	11.2 ± 3.1	6.3 ± 3.8**	11.0 ± 3.5
Right	11.6 ± 3.3	6.4 ± 3.8**	11.8 ± 2.7
Mean	11.4 ± 3.2	6.4 ± 3.8**	11.4 ± 3.2
Epididymal			
Left epididymal head diameter	8.1 ± 1.5	8.0 ± 1.9	9.0 ± 1.9**
Right epididymal head diameter	7.9 ± 1.7	7.7 ± 1.9	9.3 ± 1.9**
Mean epididymal head diameter	8.0 ± 1.6	7.8 ± 1.9	9.2 ± 1.9**

NOA and OA compared with fertile men group separately;

** : P<0.001; #: P>0.05

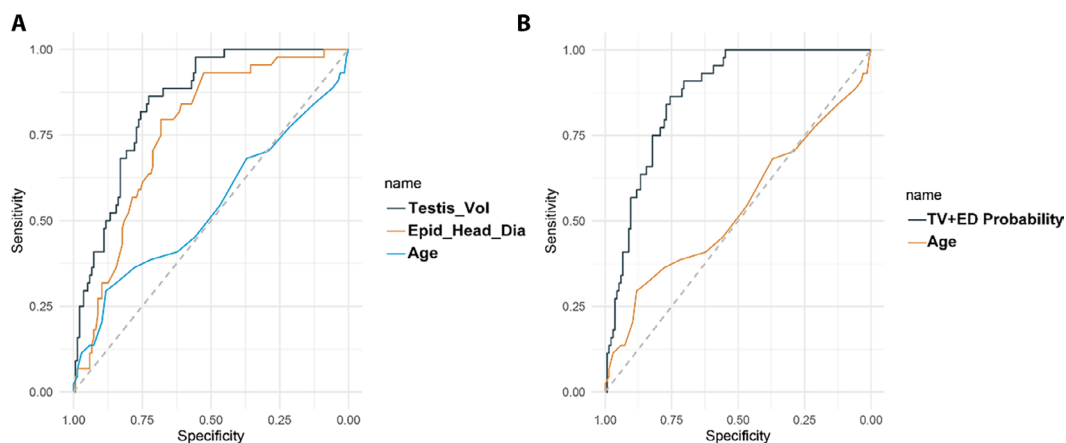


Figure 5. Diagnostic performance of individual parameters and the combined model for differentiating azoospermia subtypes. (A) Receiver operating characteristic (ROC) curves for the univariate analysis of testicular volume (TV), epididymal head diameter (EHD), and patient age. (B) ROC curves for the multivariate logistic regression model combining TV and EHD (TV+ED Probability) compared to age alone. The diagonal dashed line represents the line of no discrimination (AUC = 0.5). Areas under the curve (AUC) with 95% confidence intervals are displayed in the legends. The combined TV+ED model demonstrated superior diagnostic performance compared to any single parameter or age.

vein thrombosis in patients with acute intracerebral hemorrhage (14). It also serves as an auxiliary tool for the differential diagnosis of benign and malignant pelvic tumors in women of childbearing age (15) and

for predicting sentinel lymph node metastasis in breast cancer (16). However, standardized systematic assessment of the male reproductive system based on CDUS remains lacking in China. To address this gap, this

Table 3. Results of the multivariable logistic regression analysis for predicting obstructive azoospermia.

Variant	RC	standard error	Wald χ^2	p value	OR value	OR 95%CI	Significance
Y-intercept	-7.277	1.700	18.32	<0.001	0.001	[0.000, 0.019]	**
Average testicular volume	0.431	0.089	23.14	<0.001	1.538	[1.291, 1.833]	**
Average epididymal head diameter	0.262	0.117	4.99	0.025	1.299	[1.033, 1.634]	*
Age	0.040	0.039	1.02	0.313	1.041	[0.963, 1.124]	n.s.

** $P < 0.001$; * $P < 0.05$

Abbreviations: n.s. non-significant; RC: Regression coefficient

Table 4. Diagnostic performance and predicted probability distribution of the combined two-parameter model for differentiating obstructive azoospermia.

Diagnostic Metric / Group	Value (95% CI)	Clinical Interpretation
Diagnostic Performance at Optimal Cut-off (0.210)		
Sensitivity	86.36% (73.29 – 93.60)	Correctly identified 86.36% of OA patients.
Specificity	74.81% (66.88 – 81.38)	Correctly excluded 74.81% of NOA patients.
Positive Predictive Value (PPV)	52.78% (41.40 – 63.87)	52.78% of predicted OA cases were true OA.
Negative Predictive Value (NPV)	94.39% (88.30 – 97.40)	94.39% of predicted NOA cases were true NOA.
Area Under the Curve (AUC)	0.866 (0.808 – 0.917)*	Overall discriminatory accuracy.
Distribution of Predicted Probability	Sample Size (n)	MeanW \pm SD
NOA Group	135	0.174 \pm 0.186
OA Group	44	0.465 \pm 0.233

Note: The optimal cut-off probability of 0.210 was determined by maximizing Youden's index. The confusion matrix at this threshold was: True Positive = 38, False Negative = 6, False Positive = 34, True Negative = 101.

Abbreviations: OA: obstructive azoospermia; NOA: non-obstructive azoospermia; CI: confidence interval; SD: standard deviation.

**The AUC value is presented as a summary metric from Figure 5B for reader convenience. A detailed breakdown is available in the main text.

study established CDUS reference ranges for the testes in 245 fertile men from Guangdong Province, China. The present study reports ultrasound-derived testicular volume (TV) reference ranges based on the most commonly used mathematical formulas (the Ellipsoid, Lambert, and Hansen formulas) (8, 17). The results demonstrated significantly smaller measurements compared to European data: the mean testicular volume in fertile men from Guangdong Province, China (8.6 mL) was only 50% of that reported in European populations (17.2 mL), and the epididymal caput diameter (7.9 mm) was 12% smaller than the European reference (9.0 mm). These findings indicate a significant difference in testicular volume between males from Guangdong, China, and European populations.

The reasons for this disparity are likely multifactorial and warrant further investigation. Several hypotheses can be proposed based on existing literature. Genetic factors are one plausible avenue. Differences in the AR gene CAG repeat length, which has been correlated with testicular size in some studies (18) and shown to vary between European and Asian populations (19), could represent one contributing factor. Environmental influences, such as the hot and humid climate of Guangdong, might also play a role. Experimental data from other mammalian species suggest that sustained heat exposure can adversely affect testicular size (20–23); however, direct evidence in human populations is limited. Similarly, regional variations in nutrition and dietary patterns are known to influence reproductive

physiology (24, 25) and could potentially contribute to the observed morphological differences. Therefore, establishing a CDUS-based standardized systematic evaluation for the male reproductive system in Guangdong populations is imperative, as the direct application of European standards may lead to the misdiagnosis of testicular underdevelopment in men from this region.

Clinical significance of testicular volume in reproductive assessment

The EAA Multicenter Consortium has established SOPs for the assessment of qualitative and quantitative parameters in scrotal color Doppler ultrasound (9). These protocols have been described in detail on the EAA website (<http://www.andrologyacademy.net/studies12>) (8). Testicular volume is a crucial parameter in clinical practice, as it reflects not only an individual's semen quality and hormonal status but also indicates the potential presence of congenital or acquired, previous or current testicular and systemic disorders (17, 26). Previous studies have demonstrated that testicular volume can serve as a predictor in patients with varicocele (27–29). A study in the Guangdong population showed that testicular volume was negatively correlated with FSH and LH levels, which aligns with previous reports (30, 31). Furthermore, studies involving infertile Japanese males revealed a significant positive correlation between testicular volume and semen quality parameters, particularly sperm density (32). Our findings also indicate a positive correlation between testicular volume and sperm concentration, but no significant association with sperm morphology or motility, suggesting that testicular volume primarily reflects the number of spermatogenic cells rather than sperm function.

Development and clinical implication of the CDUS two-parameter diagnostic model

More importantly, this study systematically evaluated the discriminatory value of CDUS parameters in the etiological classification of azoospermia. Our analysis demonstrated that a significantly reduced testicular volume is a characteristic feature of NOA, which

is consistent with the findings reported by Luca Boeri et al. in an infertile population (33), reflecting severe impairment of spermatogenic function. In contrast, OA patients maintained testicular volumes comparable to those of the fertile control group, a finding that aligns with the descriptions in the EAA standards (5). Notably, this study is the first to reveal, through standardized measurements, that a significantly enlarged epididymal caput diameter is a valuable indicator for identifying OA, with an AUC of 0.760. This observation is consistent with the pathophysiological understanding that obstruction leads to passive dilatation of the epididymal tubules (34), and our study provides objective quantitative evidence for this phenomenon. It is important to note that while epididymal head dilation is a predictor of OA in our model, it is not entirely specific. Other conditions such as epididymitis (35) or spermatocele (36) can also present with epididymal enlargement, necessitating integration with clinical context and other sonographic features for accurate differential diagnosis. The strength of our approach lies in combining this parameter with testicular volume, which significantly improves diagnostic specificity and overall accuracy (AUC 0.866), as demonstrated by our multivariable model. These two parameters form complementary diagnostic markers: testicular volume reflects the spermatogenic functional reserve, while epididymal caput diameter indicates the patency of the seminal tract. Our quantitative analysis substantiates this complementary relationship. The multivariable logistic regression model confirmed that both parameters are independent predictors for OA. The integration of these two parameters into a combined model yielded a superior discriminative ability, as evidenced by an area under the receiver operating characteristic curve (AUC) of 0.866 (95% CI: 0.808–0.917), which was significantly higher than that of testicular volume (AUC: 0.844) or epididymal head diameter (AUC: 0.760) alone. At the optimal probability cut-off of 0.210, the model demonstrated a sensitivity of 86.36% and a negative predictive value (NPV) of 94.39%. This high NPV is clinically crucial, as it implies that a patient classified as “low probability” for OA by the model has a very high likelihood of being a true NOA case, potentially avoiding unnecessary surgical exploration for obstruction. Conversely,

the model's specificity (74.81%) and positive predictive value (52.78%) indicate that a "positive" result should be interpreted as identifying a high-risk group warranting further confirmatory tests (e.g., vasography or diagnostic surgery), rather than providing a definitive diagnosis. Traditional diagnosis of azoospermia relies on invasive procedures such as testicular biopsy (37, 38), whereas the CDUS two-parameter model offers a reliable non-invasive alternative. Particularly for OA patients, it can avoid unnecessary testicular biopsies; for NOA patients, it can provide an early indication of the degree of spermatogenic dysfunction. Therefore, initial diagnostic workup could begin with CDUS evaluation, using testicular volume and epididymal caput diameter for preliminary classification, followed by targeted selection of subsequent examination protocols. This optimized workflow not only reduces the risks and costs associated with invasive procedures but also offers patients a more comfortable and convenient diagnostic experience.

Conclusion

Our study established standardized scrotal CDUS reference ranges for testicular and epididymal parameters in a well-defined cohort of fertile Chinese men from Guangdong Province. The results revealed significantly smaller testicular volumes and epididymal dimensions in this population compared to existing European standards, underscoring the necessity of developing population-specific diagnostic criteria to prevent misclassification. The significant inverse correlation between testicular volume and serum FSH/LH levels further supports its role as a reliable, non-invasive biomarker for assessing seminiferous tubular function and hypothalamic-pituitary-testicular axis integrity. Moreover, this study identified an association between testicular volume and epididymal caput diameter in differentiating azoospermia subtypes, with notably reduced testicular volume in NOA and significant epididymal caput dilation in OA. These CDUS-based findings may help reduce the reliance on invasive diagnostic procedures such as testicular biopsy, offering potential clinical value particularly in avoiding unnecessary interventions for OA patients. This work provides

valuable population-specific benchmarks for refining the assessment of male infertility in Chinese populations from Guangdong Province and demonstrates the evolving utility of CDUS in andrological practice.

Research limitations and prospects

Several methodological considerations regarding sample size warrant discussion. First, concerning the establishment of reference intervals, our cohort of fertile men comprised 245 individuals with confirmed fertility. While this sample size is comparable to some published multicenter studies (5, 39), we ensured the robustness of the reference interval estimates by calculating 95% confidence intervals for the percentiles using the bootstrap resampling method. We must acknowledge the limitations of this study. The relatively modest sample size of the obstructive azoospermia (OA) subgroup (n=44) may affect the stability of the derived diagnostic thresholds. Compared to the large-sample study by Boeri et al. (33), the confidence intervals for our diagnostic indices are wider, suggesting that these cut-off values should be applied with caution when extrapolating to different populations. Therefore, we explicitly recommend that these diagnostic thresholds be considered preliminary and require further validation in larger-scale, multicenter prospective studies.

Several methodological considerations and limitations warrant discussion. First, a potential selection bias must be acknowledged. To refine the OA cohort phenotypically, we excluded patients with a testicular volume <7 mL. While clinically reasoned, this criterion may enrich the group with OA patients having better-preserved testicular size, potentially amplifying the contrast with the NOA group and leading to an overestimation of the diagnostic performance of testicular volume as a standalone parameter. The strength of our approach lies in the combined two-parameter model, which likely offers greater robustness against this form of spectrum bias. Future validation in consecutive, unselected patient series is needed to confirm the generalizability of the proposed sonographic thresholds. Second, regarding sample size, our cohort of fertile men (n=245) is substantial for a single-center study, and we ensured the robustness of reference intervals by reporting bootstrap confidence intervals.

However, the sample size of the OA subgroup remains modest. Compared to large-sample studies, the confidence intervals for our diagnostic indices are wider, suggesting that these cut-off values should be applied with caution. Therefore, we explicitly recommend that these diagnostic thresholds be considered preliminary and require validation in larger, multi-center cohorts. In terms of diagnostic performance, while epididymal head dilation is a valuable indicator for OA, its use alone carries a non-negligible risk of misclassification. Notably, epididymal enlargement is not pathognomonic and can also occur in conditions such as epididymitis, necessitating integration with other clinical and sonographic features. Although our single-center design ensured exceptional measurement consistency, it may limit the immediate generalizability of the results. Future studies should aim to expand sample sizes through multicenter collaborations, particularly for rarer subtypes, to establish more universally applicable diagnostic criteria. The development of models that incorporate additional sonographic features and clinical variables holds promise for improving diagnostic accuracy. Furthermore, as noted above, validation of the current model in less selected, consecutive patient populations is essential.

List of abbreviations

CDUS: Color Doppler ultrasonography
 NOA: Non-obstructive Azoospermia
 OA: Obstructive Azoospermia
 HPT: hypothalamic-pituitary-testicular
 FSH: follicle-stimulating hormone
 LH: luteinizing hormone
 T: testosterone
 EAA: European Academy of Andrology
 TV: testicular volume
 ICC: intraclass correlation coefficient
 MGT: male genital tract
 SOPs: standardized operating procedures

Author's Contributions: WBQ. conceived the research idea and supervised the study. HRC. and WBQ. designed the study, conducted the literature search and drafted the manuscript. ZXZ. drafted the manuscript and participated in the planning and coordination of the study. LH., HN., and XHL. reviewed and critically revised the manuscript. All authors read and approved the final manuscript.

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Availability of Data and Material: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate: The study protocol was approved by the Research Ethics Committee of the Guangdong Institute of Family Planning and Science and Technology (No: 2020-026), and all participants provided written informed consent prior to enrollment in accordance with the principles of the Declaration of Helsinki.

Consent for Publication: Informed consent was obtained from all subjects involved in this study.

Competing Interests: The authors declare that they have no competing interests.

Declaration on the Use of AI: The authors declared that generative AI was not used in the creation of this manuscript.

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Appendix – Supplementary files

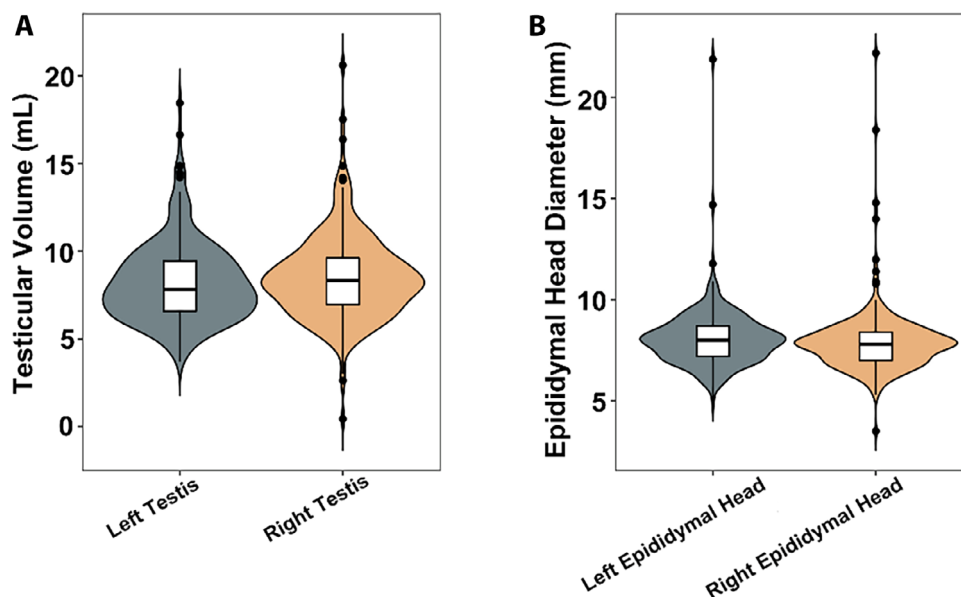


Figure S1. Distribution of Testicular Volume and Epididymal Head Diameter in the Fertile Reference Cohort.

(A) testicular volume (calculated using the ellipsoid formula) and (B) epididymal head diameter in the population-based fertile reference cohort from Guangdong Province, China (n=245).

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Table S1. Individual-level data for the fertile reference cohort

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	46	29.4	59.3	39	19	24	39	20	21	8.4	2.5	5.2	8.5	2.4	5	9.24768	8.5176	12.62664	11.6298	
male	25	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19.4	16.2	36.3	39	19	24	41	19	23	6.6	2.4	4.3	6.8	2.9	4.4	9.24768	9.31684	12.62664	12.72107	
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	68.7	24.57	61.2	36	20	28	34	19	24	8.7	3.9	8.6	7.8	0	8.6	10.4832	8.06208	14.3136	11.00784	
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	33.2	11.04	37.8	40	20	23	39	20	26	7	2.9	4.7	7.9	2.2	4.8	9.568	10.5456	13.064	14.3988	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	36.7	29.24	58.4	40	19	25	42	20	26	8.1	2.5	5.6	8.7	2.3	4.6	9.88	11.3568	13.49	15.5064	

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	55.3	68.48	40.4	39	20	25	41	18	24	7.4	2	4.6	8.1	2.5	5.1	10.14	9.21024	13.845	12.57552
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	74.8	12.56	58.3	39	19	24	38	19	26	7.6	2.4	4.8	7.3	2.2	4.9	9.24768	9.76144	12.62664	13.32812
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	46.5	40.8	62.6	37	18	20	38	17	25	7.1	1.7	5.9	6.8	2.5	4.7	6.9264	8.398	9.4572	11.4665
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.4	14.28	45.5	33	15	21	34	16	21	7.7	2.9	6.2	6.4	2.7	6.7	5.4054	5.94048	7.38045	8.11104
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	50.1	23.1	47.2	39	19	20	39	18	21	7.1	2.2	5	7.8	2.5	4.9	7.7064	7.66584	10.5222	10.46682

male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	35.3	14.58	43	35	18	21	40	19	22	8.3	2.6	5.6	8	2.6	4.6	6.8796	8.6944	9.3933	11.8712	
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	34.5	24.84	60.3	38	17	21	36	17	20	7.6	2	4.2	8	2.3	3.3	7.05432	6.3648	9.63186	8.6904	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	24.1	23.52	40.8	44	20	24	42	21	24	7.1	2.5	5.5	8	2.3	4.6	10.9824	11.00736	14.9952	15.02928	
male	24	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	47.8	76.61	39.4	42	21	28	41	21	26	9.3	2.4	3.9	7.4	2.1	4.5	12.84192	11.64072	17.53416	15.89406	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	10.8	17.34	38.1	45	19	19	41	18	22	7.8	2.4	8.6	7.1	2.3	5.5	8.4474	8.44272	11.53395	11.52756	

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	6.9	9.86	33.2	35	16	22	34	19	22	7	2.6	4.8	7.7	2.7	4.7	6.4064	7.39024	8.7472	10.09052	
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	16.6	6.08	63.1	40	20	23	33	18	20	8.6	2.4	4.3	8.1	2	4.4	9.568	6.1776	13.064	8.4348	
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	17.4	4.8	81.8	41	20	23	42	19	25	8.5	2.4	6.1	8	2.2	4.9	9.8072	10.374	13.3906	14.1645	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	74.2	11.27	64.5	46	25	24	42	24	26	6.8	2.5	5.2	8.5	0	5.2	14.352	13.62816	19.596	18.60768	
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	41.4	38.7	34.1	40	20	23	41	19	25	7	2.4	4.6	6.3	2	3.5	9.568	10.127	13.064	13.82725	

male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	48	17	34	37	17	21	39	19	23	5.9	2.5	4.1	6.1	2	4.5	6.86868	8.86236	9.37839	12.10053
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14.3	22.5	34.5	37	18	22	39	18	23	7.4	2.1	3.8	7.2	2.4	5.3	7.61904	8.39592	10.40292	11.46366
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	9.2	18.7	34.9	36	19	22	39	20	23	7.6	2.5	5.3	8.1	2.6	5.6	7.82496	9.3288	10.68408	12.7374
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	50.4	50	50.2	39	19	23.5	40.3	18.1	20.3	8.9	2.4	5.1	7.3	2.3	5	9.05502	7.69986308	12.363585	10.51327459
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	30.4	13.05	56.2	35	19	19	38	18	22	6.9	2.2	4.6	8.2	2.8	3.9	6.5702	7.82496	8.97085	10.68408

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19.5	13.94	38.6	32	16	21	38	19	20	7.1	2.1	6.2	8.5	2.6	4.7	5.59104	7.5088	7.63392	10.2524	
male	23	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	21.2	53.1	53.3	42	23	25	38	21	21	8.3	2.4	5.1	6.9	2.3	5.7	12.558	8.71416	17.1465	11.89818	
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8	2.64	58.3	37	18	21	36	19	21	9.4	2.3	5.5	8.5	4.5	6.8	7.27272	7.46928	9.93006	10.19844	
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	26.3	14.4	36.2	41	22	27	42	23	27	7.1	2.6	5.1	8.6	2.4	4.8	12.66408	13.56264	17.29134	18.51822	
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13.7	5.06	51.8	35.5	15.8	20.4	36	16.7	20.5	8.1	2.7	4.4	6	2.8	4	5.9500272	6.408792	8.1240756	8.750466	

male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	6.1	5.55	40.3	35.6	18.1	19	38.2	19.1	17.9	7.1	2.6	4.3	6.8	2.1	4.4	6.3662768	6.79130296	8.6924164	9.27274058
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	20.4	11.78	61.1	38.9	21.6	23.6	27.6	12.9	14.3	8.9	2.7	7.1	6.4	1.9	5.3	10.31142528	2.64751344	14.07906144	3.61487412
male	38	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	9.9	5.2	37.3	39.2	21.9	19.9	34.9	19.5	22.6	8.1	2.9	5.6	8.2	2.7	5.5	8.88355104	7.9978236	12.12946392	10.9201053
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	15	12.6	39.4	35.7	17.3	21.7	39.5	20	18.9	7.7	2.3	4.8	7.2	2.6	4.9	6.96911124	7.76412	9.51551727	10.60101
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	10.7	13.64	35.9	39.4	20.7	22.6	37.8	21.5	22.3	9.5	1.4	7	8.9	2.9	4.9	9.58469616	9.4240692	13.08679668	12.8674791

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	24	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	5.5	2.48	51.7	34.7	16.8	20.1	37	17.1	20.6	8	3.4	5.9	7.6	3.6	7.8	6.09309792	6.7774824	8.31942216	9.2538702	
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	122.7	118.9	70.8	36.1	20.5	23.7	37.2	21.8	20.6	8.5	3.2	5.9	7.2	4.2	5.4	9.1203762	8.68700352	12.45282135	11.86110096	
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	30.5	14.7	47.6	37.4	18.1	21.7	34.7	18.7	20.1	7.8	2.6	5.2	7.4	2.1	5.1	7.63859096	6.78219828	10.42961458	9.26030919	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	39	13.52	62.5	36.6	19.7	20.5	37.9	19.5	21.7	6.8	2.4	6.3	7.3	2.4	4.9	7.6860732	8.3394402	10.4944461	11.38654335	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	16	13.72	35.2	34.3	16.3	20.3	36.3	15.6	20.9	6.3	2.7	5.1	6.9	2.3	4.2	5.90175404	6.15433104	8.05816417	8.40302892	

male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	10.1	14.8	35.3	35.1	20	23.4	40.4	20	24.8	7.4	2.9	4.9	8.9	2.6	6.7	8.541936	10.419968	11.663028	14.227264
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	9.2	7.25	34.2	36.1	15.7	19.5	35.1	15.5	19.4	8	2	4.5	7.7	2.4	4.6	5.7470478	5.4883764	7.84693065	7.4937447
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	20.8	25.42	47.6	41.2	19.9	23.2	36.3	19.6	22.5	7.9	2	6.1	8	2.3	5.5	9.89103232	8.324316	13.50506336	11.365893
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	37.3	44.65	53.4	36.4	19.2	19.3	41.5	20.2	20.3	8.5	2.8	4.8	6.8	2	5.3	7.01395968	8.8490948	9.57675264	12.0824179
male	23	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	27	20.72	42.5	36.8	18.3	24.3	37.3	19.8	21.7	6.9	2.9	6.8	6.6	2.8	7.3	8.50958784	8.33368536	11.61886032	11.37868578

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	16.5	11.89	58.5	34.9	14.8	22.1	34.1	17.8	19.5	8	2.8	4.8	9	2.6	5.6	5.93584784	6.1547772	8.10471532	8.4036381	
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	15.9	13.44	61.9	33.6	17.6	20.3	35.9	18.3	22.2	7.1	2	4.5	6.3	1.9	5.4	6.24239616	7.58406168	8.52327168	10.35516114	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	18.1	21.76	32.1	33	19.1	22.7	38.2	20.2	23.6	8.9	2	5.7	7.6	2.7	5.6	7.4400612	9.46956608	10.1585451	12.92959984	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	2.8	2.04	41.2	29.5	16.7	20.6	38.6	18.4	21.4	7.7	5.7	6.3	8	2.6	5.3	5.2772668	7.90355072	7.2054989	10.79138656	
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	20.8	21.6	44	38.8	20.4	22	37.3	19.7	22.3	9.3	3.5	5.8	8.1	3.3	3.9	9.0549888	8.52085676	12.3635424	11.63424673	

male	38	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	42.6	26.03	45.6	36.9	16.5	29.3	35.9	15.2	21.9	9.5	2.2	8.2	9.3	2.4	7.4	9.2764386	6.21420384	12.66590655	8.48477832
male	39	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	58	78.28	36.2	39.4	18.3	18.7	42.4	22.3	25.9	10.5	2.4	5.9	10.9	3	7.6	7.01119848	12.73426336	9.57298254	17.38716728
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	27.6	29.4	50.6	39.3	18.7	17.6	35.9	18.7	24.4	7.1	3	5.5	8.8	2.8	6.3	6.72589632	8.51783504	9.18343536	11.63012092
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	168.3	50.26	32.7	37.1	19.5	22.2	38.1	20.7	26	6.6	2.3	5.5	6.6	2.3	5.2	8.3515068	10.6628184	11.4030189	14.5588482
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	15.1	49.4	43.6	36	18	21	37	16	19	7.1	2.5	5.4	7	2.1	5.7	7.07616	5.84896	9.66168	7.98608

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	1.7	3.96	44.4	33.2	17.7	22.8	36	17.3	19.8	9	4.2	16.3	9	2.4	7.7	6.96705984	6.4123488	9.51271632	8.7553224	
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	22.1	9.57	41.5	33.2	16.5	20.7	31	15.6	19.9	7	2.1	5.6	6	1.9	5.1	5.8965192	5.0042928	8.0510166	6.8327844	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	6.8	3.63	40.8	33.6	17.2	18.4	33.4	17.3	17.5	6.2	2	5.3	6.1	2.3	5.6	5.52953856	5.258162	7.54994688	7.1794135	
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	41.6	25.23	48.9	41	20	23	41	20	23	6.7	2.4	4.1	6.3	2.4	5.2	9.8072	9.8072	13.3906	13.3906	
male	24	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	47.6	15.3	59.5	34.8	18.7	22.3	33.9	18.6	21.5	7.6	2.7	4.6	7.7	2.7	5.1	7.54621296	7.0494372	10.30348308	9.6251931	

male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.1	12.24	41.9	48.3	23.7	31	47.6	23.3	30.4	8.8	2.5	5.6	8	2.3	6.3	18.4527252	17.53233664	25.1950671	23.93838272
male	41	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	57.4	105.45	47.3	36.5	20.1	25.5	38.6	20.6	23.4	9	2	5.2	7	2.4	5.3	9.728199	9.67550688	13.28273325	13.21078824
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14.8	11.84	43.6	41	22	22	40	19	23	8.8	2.7	6.6	6.7	2.6	6.1	10.31888	9.0896	14.08924	12.4108
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.5	3.76	54	42.6	20.5	25.7	39.8	20.8	24.5	10.7	2.1	6.5	9.4	2	4.3	11.6707812	10.5466816	15.9351051	14.4002768
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	18	15.18	56.3	31	16	20	31.6	17	16.7	7.9	2.3	4.5	9.5	2	4.9	5.1584	4.6650448	7.0432	6.3695804

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	86.5	104.76	64.6	39	21	25	41	19	23	8.6	2.6	5	7.8	2.7	5.4	10.647	9.31684	14.53725	12.72107	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	42.3	37.92	32.9	33.7	16.9	19.1	37	19	25.4	6	2.1	5.2	6.6	2.3	5	5.65657196	9.285224	7.72339633	12.677902	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13.2	11	35.3	35.8	19.8	19.1	34.1	18.5	19.5	8.6	2.6	5.7	9.6	2.4	5.7	7.04019888	6.396819	9.61257924	8.73411825	
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	10.1	6.16	40.4	41.6	21.2	23.6	41.5	20	25.4	9.2	2.7	5.2	7.4	2.3	4.2	10.82292224	10.96264	14.77745152	14.96822	
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14.4	15.58	41.2	36.3	20.6	22.3	36.9	20.3	18.9	7.4	2.5	5.7	7.8	0	5.7	8.67125688	7.36185996	11.83960074	10.05177033	

male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	1.1	1.65	37.2	35.4	18	19.2	36.5	16.2	21.3	8.4	2.9	6.3	7.9	2.4	5.7	6.3618048	6.5492388	8.6863104	8.9422299
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	11.2	9.48	58.2	38	20	23	40	21	24	14.7	3.5	6.8	8.4	3.4	6.2	9.0896	10.4832	12.4108	14.3136
male	41	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	5.1	0.75	57.9	33	15	19	35	17	20	11.8	4.2	7.1	8.8	2	5.2	4.8906	6.188	6.67755	8.449
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	47.1	19	34.4	39	18	23	38	16	20	7.6	2.5	5.2	6.8	2.4	4	8.39592	6.3232	11.46366	8.6336
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13	12.22	47.6	35	17	23	38	17	22	8	2.5	4.8	7.9	2.3	7	7.1162	7.39024	9.71635	10.09052

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	55.1	57.2	57.7	47	22	24	41	19	26	7.2	2.3	5.8	14.8	2.3	6.8	12.90432	10.53208	17.61936	14.38034	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	72.4	75.36	49.8	42	23	25	43	21	26	7.1	2.9	6.1	6.6	2.3	5.6	12.558	12.20856	17.1465	16.66938	
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	5.7	2.61	45.8	39	19	23	38	19	23	8.1	1.7	3.3	7.7	1.8	4.8	8.86236	8.63512	12.10053	11.79026	
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	18.1	33.39	49	35	16	22	38	18	24	8.1	2.3	5.8	8	2.4	6.1	6.4064	8.53632	8.7472	11.65536	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	64	31.02	50.9	40	22	22	42	21	26	8.7	2.1	7.8	7.5	2.5	6.7	10.0672	11.92464	13.7456	16.28172	

male	43	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	7.9	8.74	33.7	39	18	21	38	18	24	8.6	2.3	6.6	8.3	2.5	5.4	7.66584	8.53632	10.46682	11.65536
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	2.1	2.08	36.4	38	18	21	36	16	23	7	2.4	4.7	6.5	2.9	6.2	7.46928	6.88896	10.19844	9.40608
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	51.1	35.67	38.5	41	19	21	40	19	22	7.2	2.3	5.1	7.6	2	5.8	8.50668	8.6944	11.61489	11.8712
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	11.2	5.83	39.1	35	17	22	35	17	21	8	2.4	6.2	7.9	2.9	4.8	6.8068	6.4974	9.2939	8.87145
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	26.7	12.88	43.9	36	18	23	38	18	23	8	2.2	6.5	7.1	2.3	5.3	7.75008	8.18064	10.58184	11.16972

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	15.8	10.8	34.7	38	19	22	39	17	20	7.6	2.8	5.4	7.5	2	6.3	8.25968	6.8952	11.27764	9.4146	
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	26.1	21.12	56.3	40	17	22	38	18	23	8.9	2.2	4.9	7.2	2.7	5.3	7.7792	8.18064	10.6216	11.16972	
male	40	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	47.8	75.04	60	42	18	24	39	18	23	8.2	2	4.5	7.3	2.2	4.6	9.43488	8.39592	12.88224	11.46366	
male	39	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	9.7	10.64	34.1	33	16	20	35	18	21	8	2.5	6.1	8.4	2.7	7.3	5.4912	6.8796	7.4976	9.3933	
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	40.3	24.14	43.6	34	17	21	35	18	20	6.2	2.6	6.6	7	1.9	5.3	6.31176	6.552	8.61798	8.946	

male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14.5	11.76	32.6	37	18	21	38	17	23	9.2	2.9	4.9	8.6	2.7	5.2	7.27272	7.72616	9.93006	10.54918
male	25	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	37.9	23.31	50	44	20	25	44	20	24	7.1	2.4	4.6	6.8	2	6.4	11.44	10.9824	15.62	14.9952
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	32.8	38.52	43	40	21	25	39	19	24	6.9	1.9	3.3	6.9	2.1	4.4	10.92	9.24768	14.91	12.62664
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	9.1	9.69	33.7	46	23	27	45	25	28	7.9	2.8	7.6	8.7	2.9	5.2	14.85432	16.38	20.28186	22.365
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	21.7	15.12	56.3	44	23	27	42	23	27	7.6	2.9	5.9	9.3	2.9	4.8	14.20848	13.56264	19.40004	18.51822

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	15.7	15.95	53.3	36	19	22	39	19	23	8.2	2.9	4.7	7.8	2.5	4.4	7.82496	8.86236	10.68408	12.10053	
male	38	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	23.6	16.12	40.7	37	18	21	38	19	23	9.1	2.3	5.2	7.5	2.5	5.7	7.27272	8.63512	9.93006	11.79026	
male	42	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	40.6	8.82	40.8	46	24	29	50	24	33	8.2	2.8	5.8	8.6	1.8	4.4	16.64832	20.592	22.73136	28.116	
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	96.3	11.88	70.3	32	15	19	34	15	19	7.1	2	4.6	6.9	2.4	5.1	4.7424	5.0388	6.4752	6.8799	
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	22.8	14.4	65.6	44	25	26	47	23	25	7.8	2	4.7	6.5	2.1	5.2	14.872	14.053	20.306	19.18775	

male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	7.9	3.06	36.2	40	18	21	37	19	22	6.2	2.8	6	7.8	2.7	5.6	7.8624	8.04232	10.7352	10.98086
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13.1	4.05	53.3	41	19	22	44	20	23	8.2	2.9	6.5	7	2	5.6	8.91176	10.5248	12.16798	14.3704
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	20.4	13.5	38.5	41.5	19.9	24.7	32.7	15.6	19	8.2	2.6	5.8	7	2.2	5	10.6072174	5.0399856	14.48293145	6.8815188
male	39	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13.5	2.56	60.2	32.1	18.5	22.2	36.5	18.4	23.4	8.6	2.1	5.1	6.8	2.5	5.3	6.8554044	8.1720288	9.3602637	11.1579624
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	50	66.12	32.1	37.6	20.7	23	41.9	21.5	20.3	6.9	2.4	6.2	8.5	2	5.3	9.3087072	9.5093726	12.7099656	12.98395105

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	30.2	23.76	43.9	40	19	22	43	19	22	8.7	2.6	4.7	8.6	2.3	4.2	8.6944	9.34648	11.8712	12.76154	
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	16.8	15.18	52.4	40	21	23	39	19	24	7.4	2.8	6.2	6.4	2.5	4.8	10.0464	9.24768	13.7172	12.62664	
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	25.5	49.68	40.1	38.6	20.5	25.1	41.8	19.6	25.5	6.8	2.9	5.4	6.9	2.1	5.4	10.3280476	10.8636528	14.1017573	14.8330644	
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	35.4	17.42	35.9	39	19	22	42	19	22	7.9	1.7	4.8	8.5	2.4	5.2	8.47704	9.12912	11.57442	12.46476	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	52	68.08	34	42.2	20.5	21.6	42.6	21.3	21.2	8.4	2.1	4.7	9.3	2.4	6.3	9.7168032	10.00295712	13.2671736	13.65788376	

male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	21.9	22	45.1	38.7	18.8	23.5	40	18.5	21.8	9.4	2.2	4	7.7	2.8	3.9	8.8907832	8.38864	12.1393386	11.45372
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	49	14.85	54.5	35.7	17.6	21.1	36.3	17.5	19.4	8.3	2.8	4.7	7.7	2.6	6	6.89392704	6.408402	9.41286192	8.7499335
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	26.2	17.34	63	39	19	23	37	20	25	9.2	2.2	5.8	8	2.6	5.8	8.86236	9.62	12.10053	13.135
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	33.9	19.2	36.9	39	22	23	42	22	23	8.2	2.3	6.1	8	2.5	5.5	10.26168	11.05104	14.01114	15.08892
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	36.1	24.8	40.9	32	18	20	34	19	22	7.1	2.1	7.6	6.9	1.9	3.3	5.9904	7.39024	8.1792	10.09052

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	67.8	50.74	55.4	34	19	20	33	19	17	9.3	3.1	5.6	8.7	3.7	6.1	6.7184	5.54268	9.1732	7.56789	
male	22	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	35.9	23.1	39.8	37	19	22	39	20	22	8.6	2.3	4.4	7	2.3	4.1	8.04232	8.9232	10.98086	12.1836	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	112.3	84.28	43.1	38	21	23	42	23	26	8	2.5	6.3	8.1	2.4	4.2	9.54408	13.06032	13.03134	17.83236	
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.4	3.4	47.8	33	17	19	33	17	18	7.6	2.4	6.4	7.8	2.1	6.3	5.54268	5.25096	7.56789	7.16958	
male	24	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	21.8	18	34.7	36	17	20	38	17	21	8.1	2.1	5.2	7.8	2.3	3.7	6.3648	7.05432	8.6904	9.63186	

male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	2.2	1.16	32	35	19	22	37	20	21	8	2.4	5.6	7.9	2.2	4.9	7.6076	8.0808	10.3873	11.0334
male	38	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	32.8	31.32	53.6	38	19	24	42	24	27	7.5	2.2	5.9	6.7	3	3.2	9.01056	14.15232	12.30288	19.32336
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	33	16.56	45.3	36	18	20	37	19	21	8.8	2.4	4.4	7.9	2.5	4.5	6.7392	7.67676	9.2016	10.48173
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	5	0.56	54.4	31	16	17	36	19	19	6.8	2	4.6	6.8	2.6	4.9	4.38464	6.75792	5.98672	9.22716
male	40	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	22.5	16.38	39	38	19	25	36	20	23	7.9	2.3	4.2	7.6	2.4	5.2	9.386	8.6112	12.8155	11.7576

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19.5	10.92	47.9	35	18	20	36	19	22	6.7	2.3	6.4	6.6	2.5	6.1	6.552	7.82496	8.946	10.68408	
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	62	42.47	34.8	39	21.4	19.7	35.5	19.5	22.4	8.2	3.3	6.2	8	3.6	6.5	8.5496424	8.063328	11.6735502	11.009544	
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	52.6	40.85	39.6	38.4	22	23.9	38.3	20.7	21.3	10.3	2.6	6.4	7.6	2.1	4.7	10.4991744	8.78116356	14.3354112	11.98966563	
male	22	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	23.3	11.2	50	48	21	24	44	21	25	9.6	2.6	4.7	6.8	2.3	5	12.57984	12.012	17.17632	16.401	
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	29.7	24.99	55.8	33	20.3	21	38	20	21.7	9	2.8	7.9	8.3	2.5	4.7	7.315308	8.57584	9.988209	11.70932	

male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	24.5	21.62	45.1	39.4	22.3	25.5	43.8	22.2	25.6	7.8	2	4.9	9.2	2.3	5.6	11.6505012	12.94405632	15.9074151	17.67361536
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	3.7	3.3	59.2	35	18.8	20.8	36.8	19.2	21.4	8.3	2.4	4.6	9	4.2	8.3	7.116928	7.86259968	9.717344	10.73547264
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.2	4.32	43.9	39.7	19.1	20.1	37.8	19.9	21.4	8.5	2.6	6.5	22.2	2.6	6.5	7.92543804	8.37070416	10.82127117	11.42923068
male	39	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	57.5	18.36	39.4	37.2	20.4	21.5	39.6	19	20.7	8.5	2.7	6.6	7.8	2.6	6.6	8.4842784	8.0988336	11.5843032	11.0580228
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	37.3	11.2	73	36.6	20	23.1	36.4	20.3	23.4	9.1	2.5	5.1	8.3	3	5.5	8.792784	8.99117856	12.005532	12.27641688

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Hansen" formula)	Testicular volume Right ("Lambert" formula)
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	12.5	14.25	64.3	35	19	21	39	20	22	8.8	2.3	4.4	7.6	2.1	4.9	7.2618	8.9232	9.91515	12.1836
male	40	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	28	6	39.2	30.5	14.5	16.1	34.9	14.7	20	9.8	2.7	5.5	8.2	2.6	7.9	3.702517	5.335512	5.05535975	7.285026
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	11.3	6.48	34.8	39	18	21	36	18	23	8.2	2.7	7.6	7.6	4.5	5.5	7.66584	7.75008	10.46682	10.58184
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	17.4	16.53	57.1	35.9	16.3	19.9	34.5	17.6	18	8	2.6	5.3	8.6	2.3	5.2	6.05533916	5.683392	8.26786693	7.760016
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.6	5.04	38.2	33.8	18.4	18.4	36.9	18.5	20.3	7.9	1.8	5.1	6.9	2.4	6.8	5.95053056	7.2060534	8.12476288	9.83903445

male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	16.4	4.6	36.4	35.7	18	18.6	33.5	17.4	19.6	6.6	2.7	5.7	6.4	2.6	5.4	6.2152272	5.9409168	8.4861756	8.1116364
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	54.8	30.8	54.9	33	18	21	40	19	22	7.1	2.4	4.7	7.5	2	5.7	6.48648	8.6944	8.85654	11.8712
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	29	20.48	45.2	40	21.4	24.3	39.3	21.8	24	9.4	2.5	4.4	8.2	2.1	4.7	10.816416	10.6921152	14.768568	14.5988496
male	25	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	18.9	31.92	37.8	36.1	19.8	20.9	35.7	21.9	23	9.6	2.8	6.5	9.4	2.7	4.9	7.76822904	9.3506868	10.60662042	12.7672839
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	5.6	9.69	39.6	36	18	19	33	19	22	8.6	2.3	4.8	6.4	2	4.4	6.40224	7.17288	8.74152	9.79374

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	42	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	16	6.8	56.5	36.1	19.9	18.7	38.4	22.1	22.4	7.2	2.6	5	6.6	2.2	5.8	6.98562436	9.88495872	9.53806403	13.49677056	
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	23.6	15.77	36.8	40	20	25	41	20	27	7.5	2.3	4.6	7.7	2.1	5	10.4	11.5128	14.2	15.7194	
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19.9	7.68	51.2	39.9	19.8	21.8	38.6	19.6	23.7	9.1	2.1	4.9	8.8	2.5	4.7	8.95566672	9.32384544	12.22792956	12.73063512	
male	23	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19.6	34.02	42.3	34.8	20.8	22	41.2	22.1	21.2	9.3	2.6	5.3	7.4	2.3	5	8.2807296	10.03757248	11.3063808	13.70514704	
male	41	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	76.9	55.26	40.9	39.9	22.7	26.2	39.2	29.9	23.3	7.4	2.5	4.8	8	2.8	4.6	12.33966552	14.20092128	16.84838946	19.38971944	

male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	31.4	13.68	48.5	35.8	19.5	22.1	37.3	19.2	21.7	6.2	2.7	5.2	7.4	2.5	5	8.0225652	8.08114944	10.9538871	11.03387712
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	25.7	16.12	68.6	38.8	20.5	21	35.1	18.3	23	9.6	2.3	5.5	8	2.3	4.6	8.685768	7.6822668	11.859414	10.4892489
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	10.9	14.4	32	38.2	22	23	37.9	17.9	22	8	2.7	5	6.1	2.6	7.7	10.051184	7.7610104	13.723732	10.5967642
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	4.7	2.16	37.4	33.1	15.7	19.1	33.6	16.5	19.4	5.9	2.7	5.1	8.4	5.2	7.6	5.16136244	5.5927872	7.04724487	7.6363056
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	26.2	23.45	43.6	41.2	19.5	23.1	41.7	21.7	23.9	7.6	2.5	4.8	7.5	2.2	5.2	9.6504408	11.24597292	13.1765634	15.35507841

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	17.5	18.7	46	38.3	20.4	20.6	35.7	18.7	20.7	7.4	2	6.4	7.1	2.3	5.2	8.36949984	7.18593876	11.42758632	9.81157023	
male	24	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	17.1	12.25	44.8	35.9	18.4	21.4	38.3	18	22.5	8.6	2.2	4.5	7.6	2.4	7	7.35071168	8.06598	10.03654864	11.013165	
male	24	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	18.9	14.64	49.3	36.7	18.5	18.2	36.5	17.5	20.2	7	2.1	4.3	5.6	2	5.5	6.4255828	6.70943	8.7733919	9.1609525	
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	6.7	5.25	39.2	40.9	19.9	22.7	37.1	19.1	21.9	8.3	2.3	6.5	8	2.6	5	9.60739364	8.06965068	13.11778747	11.01817689	
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	23	36.04	35.1	35.6	22.1	24.1	35.9	20	21.1	8.2	2.5	5.8	7.3	2.7	5.5	9.85967632	7.877896	13.4625036	10.756358	

male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13.3	13.6	34.9	37	19.5	21.5	38.2	19.8	21	8.5	3.5	5.6	7.8	3.6	6	8.06637	8.2594512	11.0136975	11.2773276
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	4.8	12.42	36.9	32	15.3	18	34	15.5	20.3	7.8	2.6	5.6	8.2	2.2	6.1	4.582656	5.563012	6.257088	7.595651
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	2.3	1.68	35.8	34.6	17.8	19.6	34.4	18.9	19.8	6.5	2.5	4.5	8.4	2.6	4.3	6.27704896	6.69404736	8.57058608	9.13994928
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	39.8	36.12	49.9	41	21.1	23.4	40.3	21.8	24.2	7.9	1.6	5.5	8.8	2.1	6.2	10.5265368	11.05554736	14.3727714	15.09507428
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	32.8	17.17	38.4	37.8	19	21.5	40.2	20.5	20.6	7.5	2.5	6.1	8.1	2	4.1	8.029476	8.8277592	10.963323	12.0532866
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	39	6.72	59.4	35.6	19.6	20.9	39.2	22.1	20.6	8.4	2.1	5.7	8.2	2.6	6.1	7.58325568	9.28001984	10.35406064	12.67079632

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	32.5	22.05	64.5	36.8	18.8	20.8	39.1	19.3	20.9	5.8	2.5	4.8	7.9	2.4	6.1	7.48294144	8.20131884	10.21709312	11.19795457	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	6.5	9.8	36.7	33.1	21.4	22.6	36.2	18.5	20.2	6.2	2.4	6.3	6.2	2.8	6.1	8.32441168	7.0345288	11.36602364	9.6048374	
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	34.4	9.18	48.2	34.1	16.8	20.5	35.8	17.5	18.7	7.7	2.1	4.4	6.2	2.3	4.7	6.1069008	6.092086	8.3382684	8.3180405	
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19	42.48	36.8	37.8	16	20	34.4	16.1	20.5	8.2	2.6	7.1	8.9	2.5	6.4	6.28992	5.9039344	8.58816	8.0611412	
male	42	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	17.2	8.32	32.5	39.5	20.4	24.1	40.5	21.6	24.2	9.8	2.9	7.1	7.8	2.6	6.1	10.0982856	11.0084832	13.7880438	15.0308136	

male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	12.4	19.89	50	34.6	20.1	22.1	31.7	20.8	23.2	5.7	2.6	2.6	4.6	6.3	2.6	4.2	7.99222632	7.95451904	10.91246286	10.86097792
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	16	7.92	46	43	22	22	44	23	25	8.3	2.7	5.4	7.7	2.9	5.9	10.82224	13.156	14.77652	17.963	
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	18.7	5.1	50.4	37	19.4	19	36.7	17.5	20.8	7.2	2.6	4.7	7.9	2.7	4.1	7.091864	6.946576	9.683122	9.484748	
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	48.4	18	51.8	39.7	24.8	25.2	41.7	25.2	27.2	5	2.6	5.3	7.9	2.5	5.4	12.90167424	14.86308096	17.61574752	20.29382208	
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	46.3	45	56.5	34.4	17.9	21.3	37.7	20	22.3	7.1	2.7	4.9	7.8	2.5	5.8	6.82015776	8.743384	9.31213848	11.938082	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	15.5	15.98	44.5	36.2	19.3	21.1	35.8	17.7	18.8	7.9	2.3	5.6	7.3	2.2	6.8	7.66569752	6.19466016	10.46662546	8.45809368	

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	20.6	49.64	51.1	36	17	18.7	34.5	16.7	21.1	6.5	2.9	6.6	18.4	2.3	4.2	5.951088	6.3215178	8.125524	8.63130315	
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	39.3	9.1	45	34.5	17	18.3	38.5	19.1	20.8	8.1	2.6	5.3	7.7	2.7	4.4	5.581134	7.9535456	7.6203945	10.8596488	
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	23.7	30.6	45.2	40	19	23	42	20	26	6.9	2.5	5.6	5.9	2.1	6.2	9.0896	11.3568	12.4108	15.5064	
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14.2	24.96	34.7	41.3	24.2	27.8	42.7	21.7	23.2	9.3	2.3	5.5	11.4	2.7	6.8	14.44819376	11.17838176	19.72734148	15.26279048	
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	11.6	5.6	55.1	34.7	20.7	20.7	32.9	18.5	21.7	9.7	2.6	6.2	8.7	2.6	4.3	7.73167356	6.8680066	10.55670813	9.37747055	

male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	20.3	14.7	39.5	31.8	16.1	18.5	36.2	17.5	19.9	8.8	2.2	4.2	7	2.5	7.1	4.9252476	6.555458	6.7248573	8.9507215
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	2.7	1.35	32.3	33.1	16.4	20.3	35	18.9	17.2	6.6	2.2	4.8	5.5	2.6	3	5.73021904	5.916456	7.82395292	8.078238
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	18.9	12.15	38.5	45	21	25	42	20	24	7.6	2.1	4.4	7.7	2.6	5	12.285	10.4832	16.77375	14.3136
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	10.3	2.2	62.6	31.8	16.1	16.4	32.9	16.3	16.8	9.4	2.4	4.3	8.2	2.5	7.2	4.36616544	4.68485472	5.96149512	6.39662856
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	39.3	58.08	36.6	34.2	18.1	19.3	37	19.3	23.1	9.7	2.5	5.7	7.9	2.3	5	6.21248472	8.5777692	8.48243106	11.7119541

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	44	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19	18.4	35.6	32	19.3	20.6	37.1	16.8	21.6	8.2	2.3	6.2	8.2	2.3	4.9	6.6157312	7.00068096	9.0330176	9.55862208	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	79.2	51.15	43.8	32.8	22.6	22.7	34.8	22	23	7.5	2.7	7	7.1	2.6	3.6	8.75006912	9.156576	11.94720976	12.502248	
male	24	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	6	4.7	32.8	37	19	21	42	18	21	8.1	2.8	4.7	8.5	2.2	4.6	7.67676	8.25552	10.48173	11.27196	
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	21	14.28	58.6	41.8	21.6	24.3	42.1	20.9	26	9.7	2.8	6.6	7.7	2.1	4.6	11.40879168	11.8961128	15.57738864	16.2427694	
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13.7	23.1	40	35.6	19.3	21	38.1	18.7	18.8	9.8	2.4	6	9	2.5	5.6	7.5029136	6.96510672	10.2443628	9.51004956	

male	38	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	52.8	23.94	48.4	39.4	18.2	23.4	39.1	17.8	25.7	8.1	1.9	4.1	8.3	2	3.6	8.72542944	9.30107672	11.91356712	12.69954706
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	18.9	18.91	43.9	32	15	22	39	21	22	8.9	3.1	6	8.8	2.3	4.1	5.4912	9.36936	7.4976	12.79278
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	72.9	75.25	41.3	40.7	22.7	27.9	38.8	21.5	27.7	8.5	2.7	6.2	9.8	2.3	6.5	13.40879612	12.0158168	18.30133701	16.4062114
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13.3	35.2	33.5	36.8	18.9	21.7	38.8	20.4	24.5	9.3	2.4	4.8	8.4	2.3	5.9	7.84824768	10.0839648	10.71587664	13.7684904
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	37.5	68.46	33.2	36	19	22	43	23	19	8.2	2.6	6.4	7.1	2.3	3.4	7.82496	9.77132	10.68408	13.34161

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	34.6	36.63	46.6	37.2	20.4	21.7	34.5	17.8	24.4	9.6	2.5	5.1	9.7	2.8	7.4	8.56320192	7.7917008	11.69206416	10.6386684	
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	20	21.12	53.6	34.9	19.9	22.9	37.4	19.9	24.7	8.5	2.7	5	8.8	2.2	4.6	8.27022508	9.55927544	11.29203809	13.05208762	
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	23.8	39.95	37	36.1	20.8	24.2	37.8	19	25.4	10.9	2.6	6.9	10.8	2.7	6.6	9.44907392	9.4859856	12.90162016	12.9520188	
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19.2	24.18	41.2	28.7	17.1	19.2	34.1	16.1	24.4	8.2	2.4	6.5	8.1	2.2	5.5	4.89984768	6.96583888	6.69017664	9.51104924	
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	3.1	1.4	45.6	34.8	18.6	23.2	34.8	21.5	20.2	7.2	2.3	5.2	7.3	2.3	4.4	7.80878592	7.8590928	10.66199616	10.7306844	

male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	3.7	2.55	42.9	38.4	19.8	26.7	37.7	19.6	25.8	8.3	2.3	5.3	7.7	2.4	5.2	10.55628288	9.91335072	14.41338624	13.53553656
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.8	12.6	32.9	35.8	18.4	22.3	38.2	19.7	23.6	7.3	2.3	5.4	6.8	2.3	4.6	7.63851712	9.23517088	10.42951376	12.60956024
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	47.9	16.5	58.6	33.4	18.4	20.6	35.7	19	21.9	6.2	2	4	6.6	2.3	4.6	6.58316672	7.7244804	8.98855456	10.5468867
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.1	8.4	40.1	33	16.7	21.5	35.6	17.4	18.1	6.9	2	6.4	5.3	2.1	4.6	6.161298	5.83016928	8.4125415	7.96042344
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	17.5	16.32	51.3	35.8	19.2	22.2	37.5	20	24.9	10.3	2.4	5.6	8.4	2.4	4.3	7.93488384	9.711	10.83416832	13.25925

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	16.5	23.12	44.5	34.9	19.2	20.1	35.6	18.4	21	7.7	2.5	4.8	8	2.6	5.6	7.00367616	7.1530368	9.56271168	9.7666464	
male	38	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	5.4	5.8	38.7	35.7	16.2	20.8	35.1	15.9	19.3	6.9	2.4	6	6.5	1.8	5.7	6.25532544	5.60099124	8.54092512	7.64750727	
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	6.6	3.04	45.4	33.4	15.6	21.2	35.5	15.7	20.9	7.5	2.1	4.6	10	1.8	3.5	5.74394496	6.0572798	7.84269408	8.27051665	
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	28.3	21.63	34.8	35.2	16.4	21.1	38.4	17.2	21.4	6	2.9	3	6.9	2.3	5.5	6.33391616	7.34982144	8.64823168	10.08533312	
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	83.2	36.89	65.6	37.3	19.4	22.5	36.9	19.3	21.5	8.3	2.9	5.4	7.7	2.4	4.3	8.466354	7.9620606	11.5598295	10.87127505	

male	39	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	25.2	20.68	50.3	34.9	18.9	21.5	39.6	19	21.8	9.8	2.5	6	7.9	2.6	5.9	7.3744398	8.5292064	10.06894665	11.6456472
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	11.5	10.25	40.3	32.9	16.2	21.8	36.6	17.9	23	10.8	2.4	4.8	9.1	2.5	5.5	6.04186128	7.8354744	8.24946444	10.6984362
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	34.5	17.36	53.3	43.5	19.9	23.9	40.8	17.1	26.5	6.8	2.3	6.2	5.7	2.9	6.9	10.7582982	9.6140304	14.68921485	13.1268492
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	23.3	22.2	33.3	35.6	17.6	18	35.7	18.3	22.4	7.7	2.9	5.2	8.3	2.4	6	5.8646016	7.60975488	8.0074368	10.39024224
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	37.4	16.82	52.1	36.1	17.9	24.7	37.5	19.5	22	10.4	2.5	4.8	7.4	2.8	4.7	8.29966436	8.3655	11.33223403	11.422125

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14.2	17.63	41.8	33.2	18.2	17.7	32.4	16.6	17.5	7.3	2.8	2.4	7	2.3	4.1	5.56142496	4.894344	7.59348408	6.682662	
male	44	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	47.2	26.1	59.1	35.9	17.8	20	37.5	17.9	19.9	8.2	2.9	4.5	8.5	2.4	4.8	6.645808	6.946095	9.074084	9.48409125	
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	24.1	9.92	70.3	32.7	18.3	21.7	34	17.5	22.6	7.8	3	6	8.8	2.4	5.2	6.75245844	6.99244	9.21970287	9.54737	
male	38	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	92.6	100.5	49.8	36	18.2	21.7	35.2	17.8	24.4	8.1	2.3	4.8	6.4	2.6	4.8	7.3932768	7.94979328	10.0946664	10.85452544	
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	2.5	2.04	35.6	33.1	17	20.3	32.4	14.5	18.4	8.5	2.3	5.8	8.3	2.3	4.9	5.9398612	4.4950464	8.1101951	6.1374672	

male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	13.6	10.8	37.3	37.3	35.6	19	20.1	38.1	22.9	24.6	8.9	7.9	2.3	4.5	8.4	2.1	5.9	8.893066	10.71979584	12.1424555	14.63664432
male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19.3	19.14	52.4	52.4	35.6	19	20.1	38.1	22.9	24.6	8.9	7.9	2.3	6	8.7	2.6	5.4	7.0697328	11.16089208	9.6529044	15.23891034
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	8.6	10.78	39.6	39.6	42	19	22	44	20	23	7.9	7.9	2.7	4.1	9.4	2.5	5.1	9.12912	10.5248	12.46476	14.3704
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14	6.67	57.5	57.5	39	18	24	40	18	28	8.7	8.7	1.4	5.4	8	4.2	7	8.76096	10.4832	11.96208	14.3136
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	27.8	10.79	35.4	35.4	27.2	14.8	19.5	29.6	13.4	14.5	7.7	7.7	2.8	5	7	2.3	4.5	4.0819584	2.9906656	5.5734432	4.0834088

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	29	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	11.1	9.69	40.5	38.7	17.4	21.5	36.4	18.2	19.6	9.1	2.4	5.8	7.7	1.9	5	7.5283884	6.75199616	10.2791457	9.21907168	
male	31	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	7.4	5.88	41.6	36	17	20	34	16	21	8.2	2.3	5.2	7.8	2.2	4.6	6.3648	5.94048	8.6904	8.11104	
male	36	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	3.8	7.02	32.7	37	21	20	37	18	23	9.1	2.3	4.4	8.7	2.4	5.7	8.0808	7.96536	11.0334	10.87578	
male	28	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	15.1	7.59	45.6	40	21	23	42	22	21	6.6	1.8	5.9	7.4	2.2	5.9	10.0464	10.09008	13.7172	13.77684	
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	21.2	19.36	46.5	38.4	17.4	22.7	36.4	18.1	20.6	21.9	2	5.6	1.4	2.4	4.6	7.88696064	7.05749408	10.76873472	9.63619384	

male	32	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	19.6	34.5	32.1	37.3	19.4	24.1	38.6	19	25	8.4	2.3	5.6	7.8	2.1	4.4	9.06840584	9.5342	12.38186182	13.01785
male	24	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	27.5	32.4	42.6	39.8	20.8	23.8	38.4	22.4	25.2	8.9	2.8	6.5	8.8	2.4	5.6	10.24534784	11.27153664	13.98884032	15.38998272
male	30	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	66.5	32.63	48	34.2	18.2	20.1	33.7	17.2	18.6	9	2.2	4.6	8.4	2.4	4.7	6.50574288	5.60627808	8.88284124	7.65472584
male	38	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	22.3	13.26	55.4	36.6	17.4	20	38.4	18.3	22.4	8.1	2.1	5.1	7.7	2.4	5.2	6.623136	8.18528256	9.043128	11.17605888
male	27	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	9.1	6.05	50.1	35	16	25	39	17	22	7.5	2.1	4.9	7.1	2.1	5	7.28	7.58472	9.94	10.35606

Table S1 (Continued)

Gender	Age	Check item	Forward motile sperm PR semen density	Non-forward moving sperm NP total sperm count	sperm motility	L1	L2	L3	R1	R2	R3	La1	La2	La3	Ra1	Ra2	Ra3	Testicular volume Left ("Ellipsoid" formula)	Testicular volume Right ("Ellipsoid" formula)	Testicular volume Left ("Lambert" formula)	Testicular volume Right ("Lambert" formula)	Testicular volume Left ("Hansen" formula)
male	26	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	5	2.6	33.8	39.3	19.6	24.4	37.9	19.1	25	9.3	2.7	6.3	7.7	2.4	5	9.77331264	9.41057	13.34433072	12.8490475	
male	41	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	49.7	67.68	35.4	37.1	18.9	23.7	41.3	20.2	22.2	7.8	2.5	5.1	8.8	2.7	5.4	8.64146556	9.63069744	11.79892413	13.14960612	
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14.5	22.4	32.4	35	16	20	18	6	8	6.9	2.8	4.6	3.5	2	2.5	5.824	0.44928	7.952	0.61344	
male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	14.1	10.75	40.5	36	18	22	35	16	19	6.7	2	5.1	9.9	2.3	4.5	7.41312	5.5328	10.12176	7.5544	
male	34	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	23	23.18	60	39	21	22	41	20	22	6.7	2.5	6.1	9.1	2.7	4.8	9.36936	9.3808	12.79278	12.8084	

male	35	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	26.1	8.1	65	33.6	17.4	20.2	34	17.1	22.8	5.9	2.7	6.9	7	2.3	4.6	6.14105856	6.8930784	8.38490688	9.4117032
male	37	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	37.9	13.3	37.6	39.6	19.9	24.2	40.2	20.5	23.7	7.4	2.8	4.9	8.3	2.1	3.6	9.91669536	10.1562084	13.54010328	13.8671307
male	33	Color Doppler ultrasound examination of superficial organs (scrotum, bilateral testicles, epididymis)	12.4	11.02	44.3	33.4	15.7	18	33.4	16.9	20.3	8.1	2.1	3.1	12	2.8	5.6	4.9081968	5.95843976	6.7015764	8.13556198