Review Article

Sexual Development

Sex Dev 2018;12:46–90
DOI: 10.1159/000486840

Published online: February 14, 2018

Normative Basal Values of Hormones and Proteins of Gonadal and Adrenal Functions from Birth to Adulthood

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Keywords
Adrenals · Disorders of sex development · Gonads · Hormones · Immunoassays · Liquid chromatography-tandem mass spectrometry · Reference intervals

Abstract
In clinical practice, it is fundamental to compare the results of hormonal examinations obtained in the laboratory with reliable reference values. This is particularly difficult when faced with rare conditions, such as disorders of sex development, where not routinely assayed peptide hormones as well as intermediate steroid metabolites are often needed and local reliable reference values are not available. There are considerable differences among techniques and assays used in clinical and research laboratories. In fact, laboratory hormonology is undergoing a critical transition between techniques for quantitative determination: established immunoassays and mass spectrometry. Harmonizing results from different laboratories is a major challenge along the path leading to the establishment of consensus reference intervals for steroid hormones. Most of the efforts are being concentrated on testosterone, with very encouraging results being provided by the harmonization of liquid chromatography-tandem mass spectrometry results. However, this goal is still far from being achieved for the other steroid and small-molecule hormones, and a much more challenging perspective is foreseeable for protein hormones. In addition to technical issues, the importance of the definition and of the characterization of the reference population as well as sampling and processing methodology should not be underestimated, as these aspects may impact on hormonal axis and compound stability. The aim of the present review is to provide a comprehensive overview of the circulating reference values in basal condition of the hormones and proteins involved in sex development reported to date in the peer-reviewed literature. We present a series of tables where we have collected the reference intervals for each specific hormone and protein.

Laboratory hormonology is undergoing a critical period of transition between milestone techniques for quantitative determination: established immunoassays, mainly in their direct and automated versions, and mass spectrometry in its latest hyphenation with liquid chromatography (LC-MS/MS) [Taylor et al., 2015]. There are clear differences between the 2 techniques in terms of analytical principles, benefits, drawbacks, and potential, which

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have been extensively described elsewhere in the present issue.

LC-MS/MS is seen as the first real opportunity to achieve a global harmonization of results generated across laboratories worldwide. Considerable advancements have been achieved, as promoted by health agencies as well as scientific communities [Rosner et al., 2007, 2013; Vesper et al., 2009; Auchus, 2014; Wierman et al., 2014; Büttler et al., 2015, 2016]. The recent initiative of the Endocrine Society on the harmonization of results from large epidemiologic studies on male hypogonadism represents a milestone, as for the first time it established consensus reference intervals for testosterone [Travison et al., 2017]. Nonetheless, this goal is still far from being achieved for the other steroid and small-molecule hormones, and a much more challenging perspective is foreseeable for protein hormones [Sabbagh et al., 2016]. The techniques and assays used in clinical and research laboratories differ considerably. The choice of assay is too often dominated by convenience and financial reasons but rarely by an evaluation of the quality and reliability of the results. This situation is further exacerbated by the high workload faced by the laboratories. Thus, it is of key importance that each laboratory uses assay-specific reference values.

Nonetheless, the accuracy of reference intervals does not only rely on the assay used, since important aspects concerning the "reference" definition for the cohort and the sampling conditions need to be taken into account when generating normative limits, as well as when interpreting patients' results according to these normative levels. Reference values provided by ready-to-use kit vendors do not provide exhaustive information on such issues. On the other hand, it is very difficult for laboratories to have the resources to build up their own values [Fanelli et al., 2013a].

The aim of the present review is to provide a comprehensive overview of the circulating reference values in basal conditions of hormones involved in sex development and of sex hormone binding globulin reported to date in the peer-reviewed literature.

Database Search Parameters and Inclusion Criteria

Data included in Tables 2–38 were selected from the peer-reviewed literature available in PubMed. The search was performed using the name of each hormone plus the terms "reference interval," "reference value," or "normal value."

Criteria used to select relevant papers from all the resulting items are listed below. Due to the heterogeneity among the available studies as well as the paucity of available data for some hormones and/or for specific populations, we assumed the following specifications not as essential rules but rather as general desirable criteria for the generation, interpretation, and application of effective reference limits.

Type of Data Provided

Articles reporting lower and higher reference limits calculated from a large range of the distribution of the hormonal variable (90th central percentile or higher) were preferred over data referring to a narrow distribution range, i.e., mean ± standard deviation or median (25–75th percentiles). Studies reporting only graphical data were also considered, and rounded values for lower and upper limits were visually extrapolated.

Size and Stratification of the Reference Cohort

Studies reporting reference intervals tailored to gender, age, pubertal stage, menstrual and fertility status for females, and supported by an appropriate sample size for each subgroup were given greater preference. Studies reporting a case number above 120 were considered as equally satisfactory [Morselli Labate and Rusticali, 1986].

Source of the Reference Cohort

Studies in which volunteers were recruited from the general population were preferred over studies recruiting volunteers from a hospital referral population.

Definition and Assessment of the Health Status of the Reference Population

Data obtained from a reference population restricted to healthy individuals were given preference over data from an unselected, general population. Among the former, studies clearly stating specific inclusion and exclusion criteria were favored, along with those where volunteers underwent an anamnestic interview and examination by trained physicians as well as routine hormonal and biochemical assessments. In addition, studies restricted to normal weight or not obese individuals were favored. Data reported in the tables refer to not obese individuals, except where specified otherwise. For female populations, studies reporting normal menstrual cycles and excluding oral contraceptive drugs were favored. Data reported in the tables refer to eumenorrheic women not assuming estroprogestin drugs, except where specified otherwise. Whenever possible, we used a number to

indicate the geographical origin of the population studied in the publication (the legend for the numbers is listed in Table 1).

Sampling Conditions and Type of Specimen

Clearly defined and standardized sampling procedures were preferred. In particular, studies reporting blood withdrawal performed early in the morning and in fasting conditions were given preference. Data reported in the tables refer to samples collected in the morning and in fasting conditions, except where specified otherwise. In addition, the use of saline infusion to prevent stress response bias was favored. Although serum was the prevalent specimen, studies were considered equally relevant whether they measured hormones in plasma or serum. Data reported in the tables were obtained in serum specimens, except where specified otherwise. Studies where the type of specimen was not defined were avoided.

Assays

Data generated by in-house assays were selected if adequate information on method validation and performance were provided. Data on automated/commercial assays reported in the literature were avoided if obsolete.

Results were distinguished according to the type of technique used for hormone measurement: LC-MS/MS and immunoassays. We recorded whether the assay was developed in-house or was commercial and whether it was being used as a reference method or a routine assay. We also differentiated between direct immunoassays and those supposed to provide a superior performance, i.e., ultrasensitive and extraction-based assays. Assays were described as reported in the original papers. Moreover, for data obtained from large population studies, the name of the study was reported.

Estimation of Local Pediatric Reference Values

We used a local database containing a series of hormonal levels that had been assayed by commercial direct immunoassay kits. We stratified them in terms of sex, age, and pubertal stage. The samples had been collected after parents' consent from pediatric and adolescent subjects (115 males and 71 females) examined in the pediatric clinic of the S. Orsola-Malpighi University Hospital of Bologna due to idiopathic short stature and which had normal results in relation to all the specific diagnostic examinations. The results generated, the definition of the limits, and the specification of the assays are reported in the tables.

Table 1. Legend to geographical location

Africa	[1] Central
America	[2] North [3] Central [4] South
Asia	[5] East [6] Middle East
Europe	[7] North [8] Central [9] South
Oceania	[10] Australia
	[11] Multicenter

Results

Reference intervals selected for each adrenal and gonad hormone and for sex hormone binding globulin were collected in dedicated Tables 2–38. Values from different reports were listed according to increasing age or age range or developmental stage. All data generated by LC-MS/MS were obtained by in-house developed assays, except for Travison et al. [2017], in which a reference method was used, while no data were found to be generated by commercial LC-MS/MS assays.

Conclusion

The purpose of this article was to provide an updated review of the most relevant published studies reporting reference values of hormones and proteins involved in sexual development selected according to the criteria previously outlined. In addition, we have provided novel pediatric reference intervals estimated in the local population. Although it is possible that we unintentionally missed some significant studies, we believe our review can provide a useful practical reference for those interested in studying people with disorders of sex development (DSD).

The generated tables clearly show that reference values differ according to the assay, thus supporting the notion that the concept of normality in hormone determination is not universally acceptable but strictly bound to the specific method being used.

The proposed collection of data is particularly relevant for steroid hormones in such an age of transition from

established immunoassays toward new mass spectrometry technologies. Novel LC-MS/MS assays include in their profile steroid hormones not routinely assayed by immunoassays, such as dihydrotestosterone, precursors, such as 17OHpregnenolone and pregnenolone, as well as intermediates of mineralocorticoid and glucocorticoid pathways; however, only a few reports on normal values are presently available. Reference limits for these unconventional steroids are urgently needed in order to build a robust clinical interpretation of their circulating level.

Given the increasing presence of commercial LC-MS/MS assays in routine clinical laboratories, it is of note that no reference values generated by a commercial LC-MS/MS kit could be found in the literature. In our opinion, this represents an important issue that should be taken into account by researchers and stakeholders in order to provide clinicians and patients with a reliable laboratory tool.

Moreover, there is a general paucity of data in the literature on the response values of adrenal and gonad hormones after functional tests of axis stimulation or suppression. This lack represents a challenge for the endocrine community and should be addressed in the near future.

Acknowledgements

This work was supported by the Emilia-Romagna Region University Program, Alessandro Liberati Young Researcher Grants, PRUA 1-2012-004.

Disclosure Statement

The authors have no conflicts of interest to declare.

Table 2. Total testosterone (TT) reference intervals according to age and testicular volume in the male population

Age/ Testicular volume	LRL–URL, percentile	LC-MS/MS		Immunoassay					
				Direct or routine assay			Extractive or ultrasensitive assay		
		LRL–URL, nmol/L	Reference [geographic group[a]]; population study	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]; population study	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]; population study
<1 wk	0–100	0.2–2.7[b, c, e]	Kulle et al., 2010 [8]						
2 wk–2 m	0–100	0.5–12.6[b, c, e]	Kulle et al., 2010 [8]						
3–5 m	0–100	0.1–3.1[b, c]	Kulle et al., 2010 [8]						
<6 m/ 1–2 mL	0–100	0.1–15.0[b, c, e]	Kulle et al., 2010 [8]						
6 m-9 y/ 1–2 mL	0–100	0.1–1.50[b, c, e]	Kulle et al., 2010 [8]	0.3–1.0[f]	RIA, DPC	[h][9]			
7–9 y/ 1–2 mL	0–100						0.08–0.3[b, c]	RIA, Spectria, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>9 y/ 1–2 mL	0–100	0.1–1.0[b, c, e]	Kulle et al., 2010 [8]	0.3–1.4[f]	RIA, DPC	[h][9]	0.1–0.5[b, c]	RIA, Spectria, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>9 y/ 3–4 mL	0–100	0.1–10.0[b, c, e]	Kulle et al., 2010 [8]	0.3–1.5[f]	RIA, DPC	[h][9]	0.2–2.2[b, c]	RIA, Spectria, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>9 y/ 5–10 mL	0–100	1.2–15.0[b, c, e]	Kulle et al., 2010 [8]	0.5–14.6[f]	RIA, DPC	[h][9]	1.0–17.0[b, c]	RIA, Spectria, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>9 y/ 11–15 mL	0–100	1.7–16.4[b, c, e]	Kulle et al., 2010 [8]	4.5–18.0[f]	RIA, DPC	[h][9]	8.2–25.6[b, c]	RIA, Spectria, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>9 y/ >15 ml	0–100	5.0–24.0[b, c, e]	Kulle et al., 2010 [8]	8.7–25.0[f]	RIA, DPC	[h][9]	7.0–23.7[b, c]	RIA, Spectria, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
9–14 y	2.5–97.5			0.3–15.2[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study			
10–12 y	0–100	0.1–5.6[b, c, e]	Kulle et al., 2010 [8]						
13–15 y	0–100	0.1–17.6[b, c, e]	Kulle et al., 2010 [8]						
14–16 y	2.5–97.5			1.2–21.9[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study			
14–19 y	2.5–97.5			1.1–26.3[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study			
16–18 y	0–100	4.0–24.0[b, c, e]	Kulle et al., 2010 [8]						
16–19 y	2.5–97.5			5.1–27.6[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study			
18–30 y	2.5–97.5			9.8–33.3	CLIA, UniCell DXI 800, Beckman Coulter	Gonzalez-Sanchez et al., 2015 [9]			
18–81 y	2.5–97.5	7.6–37.1[b, c]	Eisenhofer et al., 2017 [8]						
18–89 y	2.5–97.5	9.8–28.4[f]	Fanelli et al., 2011 [9]						
19–39 y	2.5–97.5	9.2–31.8[g]	Travison et al., 2017 [11]; FHS, EMAS, MrOS and SIBLOS studies						
20–40 y	2.5–97.5	10.6–31.9[b, c, d]	Neale et al., 2013 [7]						
20–29 y	2.5–97.5						12.5–37.6	Extraction + HPLC + RIA	Nielsen et al., 2007 [7]; Odense Androgen Study
40–49 y	2.5–97.5			8.7–31.7[c, d]	RIA, DPC	Mohr et al., 2005 [2]; MMAS study			
50–59 y	2.5–97.5			7.5–30.4[c, d]	RIA, DPC	Mohr et al., 2005 [2]; MMAS study			
60–69 y	2.5–97.5			6.8–29.8[c, d]	RIA, DPC	Mohr et al., 2005 [2]; MMAS study			
60–74 y	2.5–97.5						12.6–38.3	Extraction + HPLC + RIA	Frost et al., 2013 [7]; Odense Androgen Study
70–79 y	2.5–97.5			5.4–28.4[c, d]	RIA, DPC	Mohr et al., 2005 [2]; MMAS study			

To convert TT from nmol/L to ng/mL, divide by 3.467. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; RIA, radioimmunoassay; CLIA, chemiluminescence immunoassay; HPLC, high pressure liquid chromatography.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [g] Data obtained upon harmonization vs. a reference method. [h] Novel data from the S. Orsola-Malpighi University-Hospital.

Table 3. Total testosterone (TT) reference intervals according to age, breast stage, menstrual phase, and fertility status in the female population

Age/ Breast stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay					
					Direct or routine assay			Extractive or ultrasensitive assay		
			LRL–URL, nmol/L	Reference [geographic group[a]]	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]; population study	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]
<1 wk	prepubertal	0–100	0.21–2.7[b, c, e]	Kulle et al., 2010 [8]						
2 wk–2 m	prepubertal	0–100	<0.1–0.7[b, c, e]	Kulle et al., 2010 [8]						
2–5 m	prepubertal	0–100	<0.1–0.4[b, c, e]	Kulle et al., 2010 [8]						
<8 y/ B1	prepubertal	0–100	<0.1–1.0[b, c, e]	Kulle et al., 2010 [8]	0.28–1.28[f]	RIA, DPC	[h][9]	<0.03–0.70[b, c]	RIA, Spectria®, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>8 y/ B1	prepubertal	0–100	0.1–1.5[b, c, e]	Kulle et al., 2010 [8]	0.35–1.39[f]	RIA, DPC	[h][9]	0.06–0.90[b, c]	RIA, Spectria®, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>8 y/ B2	no cycle	0–100	0.1–1.7[b, c, e]	Kulle et al., 2010 [8]	0.35–1.94[f]	RIA, DPC	[h][9]	0.40–1.10[b, c]	RIA, Spectria®, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>8 y/ B3	no cycle	0–100	0.3–1.3[b, c, e]	Kulle et al., 2010 [8]	0.42–5.13[f]	RIA, DPC	[h][9]	0.30–1.40[b, c]	RIA, Spectria®, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>8 y/ B4	n.s.	0–100	0.1–2.0[b, c, e, i]	Kulle et al., 2010 [8]	1.00–2.87[f]	RIA, DPC	[h][9]	0.40–1.60[b, c, i]	RIA, Spectria®, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
>8 y/ B5	all	0–100	0.2–2.5[b, c, e, i]	Kulle et al., 2010 [8]				0.70–1.40[b, c, i]	RIA, Spectria®, Orion Diagnostica	Ankarberg-Lindgren et al., 2015 [8]
9–14 y	n.s.	2.5–97.5			0.26–1.37[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study			
10–12 y	all	0–100	0.1–1.5[b, c, e, i]	Kulle et al., 2010 [8]						
13–15 y	all	0–100	0.1–2.0[b, c, e, i]	Kulle et al., 2010 [8]						
13–15 y	n.s.	2.5–97.5			0.36–1.54[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study			
14–19 y	n.s.	2.5–97.5			0.62–1.98[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study			
15–19 y	n.s.	2.5–97.5			0.49–1.70[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study			
16–18 y	n.s.	0–100	0.1–1.7[b, c, e, i]	Kulle et al., 2010 [8]						
16–19 y	all	2.5–97.5	0.45–1.75[f]	Fanelli et al., 2013b [9]						
16–19 y	follicular	2.5–97.5	0.43–1.52[f]	Fanelli et al., 2013b [9]						
16–19 y	luteal	2.5–97.5	0.40–1.93[f]	Fanelli et al., 2013b [9]						
16–45 y		2.5–97.5	<1.7[b, c, d]	Neale et al., 2013 [7]						
18–40 y		2.5–97.5			0.57–2.75[b, c, d, e]	CLIA, Immulite 2000, Siemens	Pesant et al., 2012 [2]			
18–49 y	luteal	0–100	0.27–2.18[b, e]	Eisenhofer et al., 2017 [8]						
18–54 y	premenopausal	2.5–97.5	0.36–1.57[f]	Fanelli et al., 2011 [9]						
18–54 y	follicular	2.5–97.5	0.40–1.49[f]	Fanelli et al., 2011 [9]						
19–49 y	follicular	0–100	0.42–1.92[b, e]	Eisenhofer et al., 2017 [8]						
45–77 y	postmenopausal	0–100	0.24–2.75[b, e]	Eisenhofer et al., 2017 [8]						
45–86 y	postmenopausal	2.5–97.5	0.27–1.36[f]	Fanelli et al., 2011 [9]						

To convert TT from nmol/L to ng/mL, divide by 3.467. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; B, breast stage; RIA, radioimmunoassay; CLIA, chemiluminescence immunoassay; n.s., not specified.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not-fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital. [i] Oral contraceptive not excluded or not specified.

Table 4. Calculated free testosterone (fT) reference intervals according to age in the male population

Age, years	Formula	LRL–URL, percentile	LC-MS/MS for assay TT		Immunoassay					
					Direct or routine assay for TT			Extractive or ultrasensitive assay for TT		
			LRL–URL, pmol/L	Reference [geographic group[a]]; population study	LRL–URL, pmol/L	Assay	Reference [geographic group[a]]; population study	LRL–URL, pmol/L	Assay	Reference [geographic group[a]]; population study
0–1	Vermeulen	2.5–97.5			0.09–198.4[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study			
1–9	Vermeulen	2.5–97.5			0.29–4.01[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study			
9–14	Vermeulen	2.5–97.5			1.45–250.6[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study			
14–19	Vermeulen	2.5–97.5			17.4–494.0[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study			
20–40	Vermeulen	2.5–97.5	230–630[b, c, d]	Neale et al., 2013 [7]						
19–40	Mazer	2.5–97.5	243–797	Bhasin et al., 2011 [2]; FHS study						
19–80	Sartorius	2.5–97.5			92–531	Siemens	Deutschbein et al., 2015 [8]			
20–29	Vermeulen	2.5–97.5						290–780	extraction + HPLC + RIA	Nielsen et al., 2007 [7]; Odense Androgen Study
40–49	Södegard	2.5–97.5			183–912[c, d]	RIA, DPC	Mohr et al., 2005 [2]; MMAS study			
50–59	Södegard	2.5–97.5			146–770[c, d]	RIA, DPC	Mohr et al., 2005 [2]; MMAS study			
60–69	Södegard	2.5–97.5			128–654[c, d]	RIA, DPC	Mohr et al., 2005 [2]; MMAS study			
60–74	Vermeulen	2.5–97.5						200–520	extraction + HPLC + RIA	Frost et al., 2013 [7]; Odense Androgen Study
70–79	Södegard	2.5–97.5			77–509[c, d]	RIA, DPC	Mohr et al., 2005 [2]; MMAS study			

To convert fT from pmol/L to pg/mL, divide by 3.467. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; TT, total testosterone; CLIA, chemiluminescence immunoassay; RIA, radioimmunoassay; HPLC, high pressure liquid chromatography.
[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified.

Table 5. Calculated free testosterone (fT) reference intervals according to age in the female population

Age, years	Formula	LRL–URL, percentile	Immunoassay		
			LRL–URL, pmol/L	Direct or routine assay for TT	Reference [geographic group[a]]; population study
0–1	Vermeulen	2.5–97.5	0.34–9.08[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
1–9	Vermeulen	2.5–97.5	0.34–9.08[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
9–14	Vermeulen	2.5–97.5	1.01–16.36[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
14–19	Vermeulen	2.5–97.5	4.93–34.31[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
18–40	Södegard	2.5–97.5	7–50[b, c, d, e]	CLIA, Immulite 2000, Siemens	Pesant et al., 2012 [2]
18–69	Vermeulen	2.5–97.5	3–55	Siemens	Deutschbein et al., 2015 [8]

To convert fT from pmol/L to pg/mL, divide by 3.467. LRL, low reference limit; URL, upper reference limit; TT, total testosterone; CLIA, chemiluminescence immunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified.

Table 6. Free androgen index (FAI) reference intervals according to age in the male population

Age, years	LRL–URL, percentile	Immunoassay		
		LRL–URL	Direct or routine assay for TT	Reference [geographic group[a]]; population study
0–1	2.5–97.5	0.02–32.72[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
1–9	2.5–97.5	0.03–0.60[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
9–14	2.5–97.5	0.15–34.7[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
14–19	2.5–97.5	3.58–83.3[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
18–30	2.5–97.5	25–193[b]	Siemens	Deutschbein et al., 2015 [8]
30–49	2.5–97.5	12–115[b]	Siemens	Deutschbein et al., 2015 [8]
>49	2.5–97.5	16–109[b]	Siemens	Deutschbein et al., 2015 [8]

Free androgen index (FAI) was calculated as the percentage molar ratio between total testosterone (TT) and sex hormone binding globulin (SHBG). LRL, low reference limit; URL, upper reference limit; CLIA, chemiluminescence immunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified.

Table 7. Free androgen index (FAI) reference intervals according to age and menstrual phase in the female population

Age, years	Menstrual phase/fertility status	LRL–URL, percentile	LC-MS/MS assay for TT		Immunoassay		
			LRL–URL	Reference [geographic group[a]]	LRL–URL	Direct or routine assay for TT	Reference [geographic group[a]]; population study
0–1		2.5–97.5			0.04–1.32[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
1–9		2.5–97.5			0.04–1.32[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
9–14		2.5–97.5			0.12–2.63[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
14–19		2.5–97.5			0.59–6.50[b, c, d]	IIgen CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
16–19	all	2.5–97.5	0.79–5.90	Fanelli et al., 2013b [9]			
16–19	follicular	2.5–97.5	0.79–4.71	Fanelli et al., 2013b [9]			
16–19	luteal	2.5–97.5	0.70–6.75	Fanelli et al., 2013b [9]			
18–69		2.5–97.5			<10.0	Siemens	Deutschbein et al., 2015 [8]
20–28	early follicular	5–95			0.8–6.7[e]	CLIA, ACS180·SE autoanalyzer, Bayer Diagnostic	Zhou et al., 2012 [5]
29–37	early follicular	5–95			0.7–6.3[e]	CLIA, ACS180·SE autoanalyzer, Bayer Diagnostic	Zhou et al., 2012 [5]
38–45	early follicular	5–95			0.5–4.5[e]	CLIA, ACS180·SE autoanalyzer, Bayer Diagnostic	Zhou et al., 2012 [5]

Free androgen index (FAI) was calculated as the percentage molar ratio between total testosterone (TT) and sex hormone binding globulin (SHBG). LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; CLIA, chemiluminescence immunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified.

Table 8. Sex hormone binding globulin (SHBG) reference intervals according to age in the male population

Age	LRL–URL, percentile	Immunoassay		
		LRL–URL, nmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
4 d–1 m	2.5–97.5	14–120[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
1 m–1 y	2.5–97.5	36–229[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
0–1 y	2.5–97.5	30–237[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
1–8 y	2.5–97.5	42–189[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
1–8 y	2.5–97.5	54–201[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
6–7 y	2.5–97.5	97–183[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
7–8 y	2.5–97.5	78–200[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
8–9 y	2.5–97.5	65–211[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
8–11 y	2.5–97.5	26–162[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
8–11 y	2.5–97.5	51–180[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
9–10 y	2.5–97.5	55–219[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
10–11 y	2.5–97.5	46–221[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
11–12 y	2.5–97.5	37–212[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
11–13 y	2.5- 97.5	15–108[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
11–13 y	2.5–97.5	13–146[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
12–13 y	2.5–97.5	29–191[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
13–14 y	2.5–97.5	23–162[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
13–15 y	2.5–97.5	11–98[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
13–15 y	2.5–97.5	17–146[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
14–15 y	2.5–97.5	19–131[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
15–16 y	2.5–97.5	16–105[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
15–19 y	2.5–97.5	10–50[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
15–19 y	2.5–97.5	12–69[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
16–17 y	2.5–97.5	14–85[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
17–18 y	2.5–97.5	13–71[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
18–19 y	2.5–97.5	12–62[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
19–20 y	2.5–97.5	11–55[b, c]	TR-IFMA, Delfia	Sørensen et al., 2007 [7]
60–74 y	2.5–97.5	30–105	CLIA, Immulite 2000, DPC	Frost et al., 2013 [7]; Odense Androgen Study

LRL, low reference limit; URL, upper reference limit; d, day; m, months; y, years; CLIA, chemiluminescence immunoassay; TR-IFMA, time-resolved immunofluorimetric assay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified.

Table 9. Sex hormone binding globulin (SHBG) reference intervals according to age and menstrual phase in the female population

Age	Menstrual phase/ fertility status	LRL–URL, percentile	Immunoassay		
			LRL–URL, nmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
4 d–1 m		2.5–97.5	14–120[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
1 m–1 y		2.5–97.5	36–229[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
0–1 y		2.5–97.5	30–237[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
1–8 y		2.5–97.5	42–189[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
1–8 y		2.5–97.5	54–201[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
6–7 y		2.5–97.5	53–240[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
7–8 y		2.5–97.5	47–242[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
8–9 y		2.5–97.5	42–239[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
8–11 y		2.5–97.5	26–162[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
8–11 y		2.5–97.5	51–180[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
9–10 y		2.5–97.5	39–230[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
10–11 y		2.5–97.5	36–215[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
11–12 y		2.5–97.5	33–196[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
11–13 y		2.5- 97.5	15–108[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
11–13 y		2.5–97.5	13–146[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
12–13 y		2.5–97.5	31–179[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
13–14 y		2.5–97.5	28–166[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
13–15 y		2.5–97.5	11–98[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
13–15 y		2.5–97.5	17–146	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
14–15 y		2.5–97.5	26–158[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
15–16 y		2.5–97.5	24–158[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
15–17 y		2.5–97.5	10–84[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
15–19 y		2.5–97.5	19–170[b, c, d]	CLIA, i2000SR, Abbott Architect	Raizman et al., 2015 [2]; CALIPER study
16–17 y		2.5–97.5	21–168[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
16–19 y	all	2.5–97.5	19–88	CLIA, Immulite 2000, Siemens	Fanelli et al., 2013 b [9]
16–19 y	follicular	2.5–97.5	19–89	CLIA, Immulite 2000, Siemens	Fanelli et al., 2013 b [9]
16–19 y	luteal	2.5–97.5	19–92	CLIA, Immulite 2000, Siemens	Fanelli et al., 2013 b [9]
17–18 y		2.5–97.5	18–188[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
17–19 y		2.5–97.5	11–155[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
18–19 y		2.5–97.5	16–212[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]
18–40 y		2.5–97.5	21–105[c,d,e]	CLIA, Immulite 2000, Siemens	Pesant et al., 2012 [2]
19–20 y		2.5- 97.5	14–236[b, c]	TR-IFMA, Delfia	Sorensen et al., 2007 [7]

LRL, low reference limit; URL, upper reference limit; d, day; m, months; y, years; CLIA, chemiluminescence immunoassay; TR-IFMA, time-resolved immunofluorescence.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified.

Table 10. Dihydrotestosterone (DHT) reference intervals according to age and testicular volume in the male population

Age/Testicular volume	LRL–URL, percentile	LC-MS/MS	
		LRL–URL, nmol/L	Reference [geographic group[a]]; population study
<1 wk	0–100	<0.1–0.7[b, c, e]	Kulle et al., 2010 [8]
2 wk–2 m	0–100	<0.1–2.6[b, c, e]	Kulle et al., 2010 [8]
3–5 m	0–100	<0.1–0.8[b, c, e]	Kulle et al., 2010 [8]
<6 m/1–2 mL	0–100	<0.1–3.4[b, c, e]	Kulle et al., 2010 [8]
6 m–9 y/1–2 mL	0–100	<0.1–1.3[b, c, e]	Kulle et al., 2010 [8]
>9 y/1–2 mL	0–100	0.1–0.7[b, c, e]	Kulle et al., 2010 [8]
>9 y/3–4 mL	0–100	0.1–1.7[b, c, e]	Kulle et al., 2010 [8]
>9 y/5–10 mL	0–100	0.1–1.7[b, c, e]	Kulle et al., 2010 [8]
>9 y/11–15 mL	0–100	0.3–1.9[b, c, e]	Kulle et al., 2010 [8]
>9 y/>15 mL	0–100	0.3–3.2[b, c, e]	Kulle et al., 2010 [8]
13–15 y	0–100	0.1–3.2[b, c, e]	Kulle et al., 2010 [8]
16–18 y	0–100	0.1–1.9[b, c, e]	Kulle et al., 2010 [8]
18–59 y	2.5–97.5	0.5–2.7[b, c]	Shiraishi et al., 2008 [2]
≥70 y	2.5–97.5	0.5–3.2[b, c, e]	Yeap et al., 2012 [11]; HIMS study

To convert DHT from nmol/L to ng/mL, divide by 3.443. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [e] Plasma specimen or not specified.

Table 11. Dihydrotestosterone (DHT) reference intervals according to age, breast stage, and menstrual phase in the female population

Age/ Breast stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS	
			LRL–URL, nmol/L	Reference [geographic group[a]]; population study
<1 wk		0–100	<0.1–0.1[b, c, e]	Kulle et al., 2010 [8]
2 wk–2 m		0–100	<0.1–1.0[b, c, e]	Kulle et al., 2010 [8]
3–5 m		0–100	<0.1–0.1[b, c, e]	Kulle et al., 2010 [8]
<8 y/B1		0–100	0.1–1.0[b, c, e]	Kulle et al., 2010 [8]
≥8 y/B1		0–100	0.1–0.5[b, c, e]	Kulle et al., 2010 [8]
>8 y/B2		0–100	0.1–0.5[b, c, e]	Kulle et al., 2010 [8]
>8 y/B3		0–100	0.1–0.8[b, c, e]	Kulle et al., 2010 [8]
>8 y/B4		0–100	0.1–1.0[b, c, e]	Kulle et al., 2010 [8]
>8 y/B5		0–100	0.1–0.7[b, c, e]	Kulle et al., 2010 [8]
13–15 y		0–100	0.1–1.0[b, c, e, i]	Kulle et al., 2010 [8]
16–18 y		0–100	0.1–1.0[b, c, e, i]	Kulle et al., 2010 [8]
18–59 y	follicular	2.5–97.5	0.1–0.9[b, c]	Shiraishi et al., 2008 [2]

To convert DHT from nmol/L to ng/mL, divide by 3.443. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; B, breast stage.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals [c] Blood withdrawn in not fasting condition or not specified. [e] Plasma matrix or not specified. [i] Oral contraceptive not excluded or not specified.

Table 12. Androstenedione (A) reference intervals according to age, Tanner stage, and testicular volume in the male population

Age/ Tanner stage/ Testicular volume	LRL–URL, percentile	LC-MS/MS		Immunoassay					
				Direct or routine assay			Extractive or ultrasensitive assay		
		LRL–URL, nmol/L	Reference [geographic group[a]]	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]; population study
<1 wk	0–100	<0.1 – 1.2[b, c, e]	Kulle et al., 2010 [8]						
2 wk–2 m	0–100	0.4 – 3.3[b, c, e]	Kulle et al., 2010 [8]						
3–5 m	0 -100	0.1 – 1.9[b, c, e]	Kulle et al., 2010 [8]						
<6 m/ 1–2 mL	0–100	0.1–3.2[b, c, e]	Kulle et al., 2010 [8]						
6 m–9 y	0–100	0.1–2.2[b, c, e]	Kulle et al., 2010 [8]						
<1 y	0–100						0.2–1.9[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
1–5 y	0–100						0.2–1.8[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
6–12 y	0–100						0.2–0.8[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
>9 y/ 1–2 mL	0–100	0.1–1.3[b, c, e]	Kulle et al., 2010 [8]	0.3–2.2[f]	RIA, DPC	[h][9]			
>9 y/ 3–4 mL	0–100	0.1–2.3[b, c, e]	Kulle et al., 2010 [8]	0.4–4.1[f]	RIA, DPC	[h][9]			
>9 y/ 5–10 mL	0–100	0.1–3.3[b, c, e]	Kulle et al., 2010 [8]	0.7–4.8[f]	RIA, DPC	[h][9]			
>9 y/ 11–15 mL	0–100	0.1–4.1[b, c, e]	Kulle et al., 2010 [8]	1.1–6.2[f]	RIA, DPC	[h][9]			
>9 y/ >15 mL	0–100	0.5–6.7[b, c, e]	Kulle et al., 2010 [8]	1.9–9.0[f]	RIA, DPC	[h][9]			
12–16 y/ T2–3	0–100						0.6–2.9[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
13–17 y/ T4–5	0–100						2.0–5.3[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
13–15 y	0–100	0.1–6.7[b, c, e]	Kulle et al., 2010 [8]						
16–18 y	0–100	0.8–5.7[b, c, e]	Kulle et al., 2010 [8]						
18–81 y	2.5–97.5	1.5–8.3[b, e]	Eisenhofer et al., 2017 [8]						
18–89 y	2.5–97.5	0.9–4.4[f]	Fanelli et al., 2011 [9]						
20–29 y	2.5–97.5						1.9–7.5	Extraction + HPLC + RIA	Nielsen et al., 2007 [7]; Odense Androgen Study
60–74 y	2.5–97.5						1.4–7.5	Extraction + HPLC + RIA	Frost et al., 2013 [7]; Odense Androgen Study

To convert A from nmol/L to ng/mL, divide by 3.491. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; T, Tanner stage; RIA, radioimmunoassay; HPLC, high pressure liquid chromatography.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi Hospital.

Table 13. Androstenedione (A) reference intervals according to age, Tanner stage, breast stage, menstrual phase, and fertility status in the female population

Age/ Tanner stage/ Breast stage	Menstrual phase/fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay					
					Direct or routine assay			Extractive or ultrasensitive assay		
			LRL–URL, nmol/L	Reference [geographic group[a]]	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]
<1 wk		0–100	<0.1 – 4.4[b, c, e]	Kulle et al., 2010 [8]						
2 wk–2 m		0–100	0.2 – 2.4[b, c, e]	Kulle et al., 2010 [8]						
3–5 m		0–100	0.1 – 1.7[b, c, e]	Kulle et al., 2010 [8]						
<1 yr/ T1		0–100						0.4–2.7[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
1-5 y/ T1		0–100						0.2–0.5[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
6–12 y/ T1		0–100						0.6–2.4[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
<8 y/ B1		0–100	0.1–2.2[b, c, e]	Kulle et al., 2010 [8]	0.3–2.0[g]	RIA, DPC	[h][9]			
≥8 y/ B1		0–100	0.1–2.7[b, c, e]	Kulle et al., 2010 [8]	0.4–2.9[g]	RIA, DPC	[h][9]			
>8 y/ B2		0–100	0.3–3.4[b, c, e]	Kulle et al., 2010 [8]	0.9–5.0[g]	RIA, DPC	[h][9]			
>8 y/ B3		0–100	0.5–3.4[b, c, e, i]	Kulle et al., 2010 [8]	2.1–6.5[g]	RIA, DPC	[h][9]			
>8 y/ B4		0–100	0.9–4.4[b, c, e, i]	Kulle et al., 2010 [8]	3.0–5.3[g]	RIA, DPC	[h][9]			
>8 y/ B5		0–100	0.1–5.2[b, c, e, i]	Kulle et al., 2010 [8]	0.3–2.0[g]	RIA, DPC	[h][9]			
11–14 y/ T2–3		0–100						1.5–6.2[b, c, f]	chromatography + RIA	Lashansky et al., 1991 [3]
13–15 y		0–100	0.1–5.0[b, c, e, i]	Kulle et al., 2010 [8]						
14 – 16 y/ T4–5		0–100						2.5–7.7[b, c, f]	chromatography + RIA	Lashansky et al., 1991 [3]
16–18 y		0–100	1.0–5.5[b, c, e, i]	Kulle et al., 2010 [8]						
16–19 y	all	2.5–97.5	1.4–5.8	Fanelli et al., 2013b [9]						
16–19 y	follicular	2.5–97.5	1.4–5.4	Fanelli et al., 2013b [9]						
16–19 y	luteal	2.5–97.5	1.1–6.1	Fanelli et al., 2013b [9]						
1–49 y	luteal	0–100	1.3–12.8[b, e]	Eisenhofer et al., 2017 [8]						
18–54 y	premenopausal	2.5–97.5	1.0–5.7[f]	Fanelli et al., 2011 [9]						
18–54 y	follicular	2.5–97.5	1.1–5.6[f]	Fanelli et al., 2011 [9]						
19–49 y	follicular	0–100	1.8–6.9[b, e]	Eisenhofer et al., 2017 [8]						
45–77 y	postmenopausal	0–100	1.1–9.5[b, e]	Eisenhofer et al., 2017 [8]						
45–86 y	postmenopausal	2.5–97.5	0.3–2.7[f]	Fanelli et al., 2011 [9]						

To convert A from nmol/L to ng/mL, divide by 3.491. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; T, Tanner stage; B, breast stage; RIA, radioimmunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi Hospital. [i] Oral contraceptive not excluded or not specified.

Table 14. Dehydroepiandrosterone (DHEA) reference intervals according to age and Tanner stage in the male population

Age/ Tanner stage	LRL–URL, percentile	LC-MS/MS		Immunoassay		
		LRL–URL, nmol/L	Reference [geographic group[a]]; population study	LRL–URL, nmol/L	Extractive or ultrasensitive assay	Reference [geographic group[a]]
<1 y	0–100			0.9–8.2[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
1–5 y	0–100			0.3–1.5[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
6–12 y	0–100			0.4–4.9[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
≤9 y/ T1	0–100	2.6–16.2[b]	Kim et al., 2016 [5]			
>9 y/ T2	0–100	4.6–19.8[b]	Kim et al., 2016 [5]			
>9 y/ T3	0–100	7.8–12.9[b]	Kim et al., 2016 [5]			
12–16 y/ T2–3	0–100			0.9–10.5[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
>9 y/ T4–5	0–100	5.1–21.7[b]	Kim et al., 2016 [5]			
13–17 y/ T4–5	0–100			3.5–13.9[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
18–81 y	2.5–97.5	2.5–46.7[b, e]	Eisenhofer et al., 2017 [8]			
18–89 y	2.5–97.5	4.9–49.5[f]	Fanelli et al., 2011 [9]			
30 y	2.5–97.5	5.7–43.5[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008			
40 y	2.5–97.5	3.8–36.0[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008			
50 y	2.5–97.5	1.9–28.3[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008			
60 y	2.5–97.5	1.5–22.7[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008			

To convert DHEA from nmol/L to ng/mL, divide by 3.467.LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; T, Tanner stage; RIA, radioimmunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to non-obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [f] Saline infusion 10 min before blood withdrawal. [l] Data derived from graph of the publication.

Table 15. Dehydroepiandrosterone (DHEA) reference intervals according to age, Tanner stage, and menstrual phase in the female population

Age/ Tanner stage	Menstrual phase/fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay		
			LRL–URL, nmol/L	Reference [geographic group[a]]; population study	LRL–URL, nmol/L	Extractive or ultrasensitive assay	Reference [geographic group[a]]
<1 y		0–100			1.1–20.3[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
1–5 y		0–100			0.4–1.0[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
6–12 y		0–100			1.3–5.3[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
≤8 y/ T1		0–100	2.6–29.2[b]	Kim et al., 2016 [5]			
>8 y/ T2		0–100	5.7–20.3[b]	Kim et al., 2016 [5]			
>8 y/ T3		0–100	6.8–20.1[b]	Kim et al., 2016 [5]			
11–14 y/ T2–3		0–100			2.4–21.0[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
>8 y/ T4–5		0–100	4.1–28.4[b]	Kim et al., 2016 [5]			
14–16 y/ T4–5		0–100			5.8–23.8[b, c]	chromatography + RIA	Lashansky et al., 1991 [3]
16–19 y	all	2.5–97.5	8.3–75.0	Fanelli et al., 2013b [9]			
16–19 y	follicular	2.5–97.5	8.5–84.2	Fanelli et al., 2013b [9]			
16–19 y	luteal	2.5–97.5	7.6–76.2	Fanelli et al., 2013b [9]			
18–49 y	luteal	0–100	4.0–58.6[b, e]	Eisenhofer et al., 2017 [8]			
18–54 y	premenopausal	2.5–97.5	4.1–65.6[f]	Fanelli et al., 2013b [9]			
18–54 y	follicular	2.5–97.5	7.0–93.8[f]	Fanelli et al., 2013b [9]			
19–49 y	follicular	0–100	3.5–41.3[b, e]	Eisenhofer et al., 2017 [8]			
45–77 y	postmenopausal	0–100	1.4–24.0[b, e]	Eisenhofer et al., 2017 [8]			
45–86 y	postmenopausal	2.5–97.5	2.8–22.9[f]	Fanelli et al., 2013b [9]			

To convert DHEA from nmol/L to ng/mL, divide by 3.467. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; T, Tanner stage; RIA, radioimmunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [f] Saline infusion 10 min before blood withdrawal.

Table 16. Dehydroepiandrosterone sulphate (DHEA-S) reference intervals according to age and Tanner stage in the male population

Age/ Tanner stage	LRL–URL, percentile	LC-MS/MS		Immunoassay		
		LRL–URL, µmol/L	Reference [geographic group[a]]; population study	LRL–URL µmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
<9 y/T1	5–95	0.02–2.53[c, e]	Kulle et al., 2017 [8]	0.10–2.11[f]	RIA, DPC	[h][9]
>9 y/T2	5–95	0.47–3.63[c, e]	Kulle et al., 2017 [8]	0.27–2.04[f]	RIA, DPC	[h][9]
>9 y/T3	5–95	1.65–5.92[c, e]	Kulle et al., 2017 [8]	0.41–2.16[f]	RIA, DPC	[h][9]
>9 y/T4	5–95	2.33–5.23[c, e]	Kulle et al., 2017 [8]	0.92–2.10[f]	RIA, DPC	[h][9]
>9 y/T5	5–95	2.54–7.73[c, e]	Kulle et al., 2017 [8]	0.80–6.96[f]	RIA, DPC	[h][9]
11 y	2.5–97.5			0.53–5.19[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
11–13 y	5–95	0.63–3.55[c, e]	Kulle et al., 2017 [8]			
12 y	2.5–97.5			0.32–10.13[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13 y	2.5–97.5			0.37–7.84[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13–16 y	2.5–97.5			1.50–12.5[b, c, d]	ci4100, Abbott Architect	Kelly et al., 2015 [2]; CALIPER study
13–16 y	5–95	0.41–4.46[c, e]	Kulle et al., 2017 [8]			
14 y	2.5–97.5			0.38–8.13[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y	2.5–97.5			1.41–11.95[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16 y	2.5–97.5			0.82–9.89[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16–19 y	2.5–97.5			3.36–18.2[b, c, d]	ci4100, Abbott Architect	Kelly et al., 2015 [2]; CALIPER study
16–40 y	5–95	1.36–7.51[c, e]	Kulle et al., 2017 [8]			
17 y	2.5–97.5			2.71–9.34[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17–19 y	2.5–97.5			2.74–11.83[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y	2.5–97.5			2.81–12.89[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–81 y	2.5–97.5	0.92–10.02[b, e]	Eisenhofer et al., 2017 [8]			
20 y	2.5–97.5			4.12–16.53[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
25 y	2.5–97.5			3.64–15.58[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
30 y	2.5–97.5			3.18–14.66[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
30 y	2.5–97.5	1.6–13.0[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008			
35 y	2.5–97.5			2.71–13.71[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
40 y	2.5–97.5			2.31–12.78[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
40 y	2.5–97.5	1.5–11.4[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008			
45 y	2.5–97.5			1.95–11.86[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
50 y	2.5–97.5			1.66–10.96[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
50 y	2.5–97.5	0.8–4.3[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008			
55 y	2.5–97.5			1.44–10.10[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
60 y	2.5–97.5			1.28–9.23[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
60 y	2.5–97.5	0.5–7.6[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008			
65 y	2.5–97.5			1.17–8.36[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
70 y	2.5–97.5			1.06–7.52[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study
75 y	2.5–97.5			0.98–6.68[c, d]	CLIA, Immulite 2500, Siemens	Friedrich et al., 2008 [8]; SHIP study

To convert DHEA-S from µmol/L to µg/mL, divide by 2.714. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; T, Tanner stage; RIA, radioimmunoassay; CLIA, chemiluminescence immunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital. [l] Data derived from graph of the publication.

Table 17. Dehydroepiandrosterone sulphate (DHEA-S) reference intervals according to age, Tanner stage, menstrual phase, and fertility status in the female population

Age/ Tanner stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay		
			LRL–URL, µmol/L	Reference [geographic group[a]]; population study	LRL–URL, µmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
<8 y/T1		5–95	0.01–1.98[c, e]	Kulle et al., 2017 [8]	0.10–1.34[f]	RIA, DPC	[h][9]
>8 y/T2		5–95	0.63–2.68[c, e]	Kulle et al., 2017 [8]	0.22–1.51[f]	RIA, DPC	[h][9]
>8 y/T3		5–95	1.21–3.47[c, e]	Kulle et al., 2017 [8]	0.19–1.37	RIA, DPC	[h][9]
>8 y/T4		5–95	1.76–4.49[c, e]	Kulle et al., 2017 [8]	0.52–1.45[f]	RIA, DPC	[h][9]
>8 y/T5		5–95	0.44–5.37[c, e]	Kulle et al., 2017 [8]	1.01–1.85[f]	RIA, DPC	[h][9]
11 y		2.5–97.5			0.23–2.71[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
11–13 y	follicular	5–95	0.61–3.20[c, e, i]	Kulle et al., 2017 [8]			
12 y		2.5–97.5			0.67–6.12[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13 y		2.5–97.5			0.58–4.59[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13–16 y		2.5–97.5			1.50–12.5[b, c, d]	ci4100, Abbott Architect	Kelly et al., 2015 [2]; CALIPER study
13–16 y	follicular	5–95	0.35–4.47[c, e, i]	Kulle et al., 2017 [8]			
14 y		2.5–97.5			0.60–8.86[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y		2.5–97.5			0.88–9.52[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16 y		2.5–97.5			1.52–10.45[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16–19 y		2.5–97.5			3.96 –15.5[b, c, d]	ci4100, Abbott Architect	Kelly et al., 2015 [2]; CALIPER study
16–40 y	follicular	5–95	0.36–5.75[c, e, i]	Kulle et al., 2017 [8]			
17 y		2.5–97.5			2.32–10.99[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17–19 y		2.5–97.5			3.87–11.85[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y		2.5–97.5			2.70–11.53[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–49 y	luteal	0–100	1.16–8.22[b, e]	Eisenhofer et al., 2017 [8]			
19–49 y	follicular	0–100	1.19–7.73[b, e]	Eisenhofer et al., 2017 [8]			
45–77 y	postmeno-pausal	0–100	0.37–12.4[b, e]	Eisenhofer et al., 2017 [8]			

To convert DHEA-S from µmol/L to µg/mL, divide by 2.714. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; T, Tanner stage; RIA, radioimmunoassay; CLIA, chemiluminescence immunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S.Orsola-Malpighi University-Hospital. [i] Oral contraceptive not excluded or not specified.

Table 18. Luteinizing hormone (LH) and follicular stimulating hormone (FSH) reference intervals according to age and Tanner stage in the male population

Age/ Tanner stage	LRL–URL, percentile	Immunoassay			
		LH LRL–URL, IU/L	FSH LRL–URL, IU/L	Direct or routine assay	Reference [geographic group[a]]; population study
0.6–2.5 y/T1.1	5–95	0.1–0.2[b, c]	0.1–0.9[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
2.7–12.0 y/T1.2	5–95	0.1–0.3[b, c]	0.1–0.9[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
10–13 y	2.5–97.5	<4.34[b, c, d]	0.3–3.9[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
10.1–14.8 y/T2	5–95	0.4–2.3[b, c]	0.1–2.8[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
11 y	2.5–97.5	0.3–1.8[b, c, d]	0.4–8.9[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
11.3–15.0 y/T3	5–95	0.5–1.8[b, c]	0.3–3.0[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
12 y	2.5–97.5	0.2–4.0[b, c, d]	0.5–10.5[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 20023 [8]
12.9–6.1 y/T4	5–95	0.3–1.6[b, c]	0.4–5.0[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
13 y	2.5–97.5	0.3–6.0[b, c, d]	0.7–10.8[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13–15 y	2.5–97.5	<4.11[b, c, d]		CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
13–19 y	2.5–97.5		0.8–5.1[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
14 y	2.5–97.5	0.5–7.9[b, c, d]	0.4–10.5[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y	2.5–97.5	0.50–10.73[b, c, d]	0.4–18.5[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15–17 y	2.5–97.5	0.79–4.76[b, c, d]		CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
16 y	2.5–97.5	0.48–10.83[b, c, d]	0.2–9.7[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17 y	2.5- 97.5	0.86–5.92[b, c, d]	2.2–12.9[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17–19 y	2.5–97.5	0.94–7.10[b, c, d]		CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
17–19 y	2.5–97.5	1.20–5.49[b, c, d]	2.1–14.2[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y	2.5–97.5	1.51–4.96[b, c, d]	1.9–15.4[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18.3–27.0 y/T5	5–95	1.5–6.3[b, c]	0.6–5.0[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
18–75 y	2.5–97.5	0.9–7.0[c]		DPC	Boyce et al., 2004 [7]
20 y	n.s.	1.9–9.4[b, c, d]	1.4–8.9[b, c, d]	ECLIA, Roche Modular E	Bjerner et al., 2009 [7]; NORIP study
30 y	n.s.	1.9–9.7[b, c, d]	1.5–10.3[b, c, d]	ECLIA, Roche Modular E	Bjerner et al., 2009 [7]; NORIP study
40 y	n.s.	1.9–10.0[b, c, d]	1.8–11.4[b, c, d]	ECLIA, Roche Modular E	Bjerner et al., 2009 [7]; NORIP study
50 y	n.s.	2.0–10.4[b, c, d]	2.0–12.4[b, c, d]	ECLIA, Roche Modular E	Bjerner et al., 2009 [7]; NORIP study
60 y	n.s.	2.1–10.8[b, c, d]	2.4–13.4[b, c, d]	ECLIA, Roche Modular E	Bjerner et al., 2009 [7]; NORIP study
70 y	n.s.	2.2–11.2[b, c, d]	2.7–14.2[b, c, d]	ECLIA, Roche Modular E	Bjerner et al., 2009 [7]; NORIP study
80 y	n.s.	2.4–11.7[b, c, d]	3.1–15.1[b, c, d]	ECLIA, Roche Modular E	Bjerner et al., 2009 [7]; NORIP study

LRL, low reference limit; URL, upper reference limit; y, years; T, Tanner stage; ICMA, immunochemiluminometric assay; CLIA, chemiluminescence immunoassay; ECLIA, electrochemiluminescence immunoassay; n.s., not specified.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified.

Table 19. Luteinizing hormone (LH) and follicular stimulating hormone (FSH) reference intervals according to age, Tanner stage, pubic hair stage, breast stage, menstrual phase, and fertility status in the female population

Age/Tanner/ Pubic hair/ Breast stage	Menstrual phase/ fertility status	LRL–URL, percentile	Immunoassay			
			LH LRL–URL, IU/L	FSH LRL–URL, IU/L	Direct or routine assay	Reference [geographic group[a]]; population study
0.1–2.3 y/T1.1		5–95	0.1–0.1[b, c]	0.2–8.0[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
3.0–10.6 y/T1.2		5–95	0.1–0.2[b, c]	0.1–2.1[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
PH1		10–90	<0.05–0.67[b, c, d]		ELISA, BQ049F, Bio-Quant	Sims et al., 2012 [2]; NHANES III study
B1		10–90	<0.05–1.02[b, c, d]		ELISA, BQ049F, Bio-Quant	Sims et al., 2012 [2]; NHANES III study
9–11 y		2.5–97.5		0.4–4.2[b, c]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
9.1–12.9 y/T2		5–95	0.1–4.1[b, c]	0.4–2.8[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
9.9–13.5 y/T3		5–95	0.5–4.3[b, c]	0.8–4.6[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
9.9–15.0 y/T4		5–95	1.0–4.0[b, c]	1.0–8.8[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
PH2		10–90	<0.05–4.35[b, c, d]		ELISA, BQ049F, Bio-Quant	Sims et al., 2012 [2]; NHANES III study
B2		10–90	<0.05–4.09[b, c, d]		ELISA, BQ049F, Bio-Quant	Sims et al., 2012 [2]; NHANES III study
10–13 y		2.5–97.5	<4.3[b, c, d]		CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
PH3		10–90	<0.05–4.23[b, c, d]		ELISA, BQ049F, Bio-Quant	Sims et al., 2012 [2]; NHANES III study
B3		10–90	0.18–3.81[b, c, d]		ELISA, BQ049F, Bio-Quant	Sims et al., 2012 [2]; NHANES III study
11 y		2.5–97.5	<0.2–6.5[b, c, d]	0.4–9.0[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2003 [8]
11–19 y		2.5–97.5		0.3–7.8[b, c]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
PH>4/B>4		10–90	0.19–11.65[b, c, d]		ELISA, BQ049F, Bio-Quant	Sims et al., 2012 [2]; NHANES III study
12 y		2.5–97.5	0.4–9.9[b, c, d]	0.9–17.2[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13 y		2.5–97.5	0.3–5.4[b, c, d]	1.8–9.9[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13–15 y		2.5–97.5	0.4–6.5[b, c, d]		CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
14 y		2.5–97.5	0.5–31.2[b, c, d]	0.9–11.8[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y		2.5–97.5	0.5–20.7[b, c, d]	1.2–12.4[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15–17y		2.5–97.5	<13.1[b, c, d]		CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
16 y		2.5–97.5	0.4–29.4[b, c, d]	1.1–12.4[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16–19 y	all	25–75	3.5–9.0	3.8–6.5	Modular Analytics E170, Roche	Fanelli et al., 2013b [9]
16–19 y	follicular	25–75	3.5–6.1	4.9–6.7	Modular Analytics E170, Roche	Fanelli et al., 2013b [9]
16–19 y	luteal	25–75	2.8–8.4	2.4–4.7	Modular Analytics E170, Roche	Fanelli et al., 2013b [9]
16.9–27.2 y/T5		5–95	0.8–12.1[b, c]	0.1–6.7[b, c]	ICMA, Immulite 1000, DPC	Resende et al., 2007 [4]
17 y		2.5–97.5	1.6–12.4[b, c, d]	1.2–9.6[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17–19 y		2.5–97.5	<8.4[b, c, d]		CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
17–19 y		2.5–97.5	1.6–12.1[b, c, d]	0.9–9.6[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y		2.5–97.5	1.8–11.2[b, c, d]	<0.10–9.50[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–48 y	early follicular (d2–7)	2.5–97.5	0.5–7.7[b, c, d]	2.3–9.8[b, c, d]	IFMA, AutoDELFIA, PerkinElmer	Woloszynek et al., 2015 [4]
20 y	early follicular (d3)	10–90		2.0–8.5[b, c, d, l]	ELISA, Monobind	Okunola et al., 2016 [1]
20 y	early follicular (d3)	5–95		3.0–7[b, c, d, l]	CLIA, ADVIA Centaur, Siemens	Grisendi et al., 2014 [9]
25 y	early follicular (d3)	10–90		3.0–9.5[b, c, d, l]	ELISA, Monobind	Okunola et al., 2016 [1]
30 y	early follicular (d3)	10–90		4.5–11.0[b, c, d, l]	ELISA, Monobind	Okunola et al., 2016 [1]
30 y	early follicular (d3)	5–95		3.0–10.5[b, c, d, l]	CLIA, ADVIA Centaur, Siemens	Grisendi et al., 2014 [9]
35 y	early follicular (d3)	10–90		6.5–12.5[b, c, d, l]	ELISA, Monobind	Okunola et al., 2016 [1]
40 y	early follicular (d3)	10–90		8.0–14.5[b, c, d, l]	ELISA, Monobind	Okunola et al., 2016 [1]
40 y	early follicular (d3)	5–95		3.0–15.0[b, c, d, l]	CLIA, ADVIA Centaur, Siemens	Grisendi et al., 2014 [9]
45 y	early follicular (d3)	10–90		8.5–17.0[b, c, d, l]	ELISA, Monobind	Okunola et al., 2016 [1]

LRL, low reference limit; URL, upper reference limit; y, years; T, Tanner stage; PH, pubic hair stage; B, breast stage; ICMA, immunochemiluminometric assay; ELISA, enzyme-linked immunosorbent assay; CLIA, chemiluminescence immunoassay; IFMA, immunofluorimetric assay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [l] Data derived from graph of the publication.

Table 20. Human Chorionic Gonadotropin (hCG) and βhCG reference intervals according to age in the male population

Age	LRL–URL, percentile	Immunoassay				
		hCG LRL–URL, IU/L	βhCG LRL–URL, IU/L	hCG + βhCG LRL–URL, IU/L	Assay	Reference [geographic group[a]]
birth–3 m	n.s.			<50[b, c, d]	Roche Cobas	Mayo Medical Laboratories, 2017
3 m–18 y	n.s.			<1.4[b, c, d]	Roche Cobas	Mayo Medical Laboratories, 2017
Adult	2.5–97.5			<1.4[b, c, d]	Roche Cobas	Mayo Medical Laboratories, 2017
<50 y	2.5–97.5	<2.1[b, c, d]	<1.9[b, c, d]	<3.2[b, c, d]	TR-IFMA	Alfthan et al., 1992 [7]
>50 y	2.5–97.5	<6.1[b, c, d]	<2.1[b, c, d]	<7.1[b, c, d]	TR-IFMA	Alfthan et al., 1992 [7]

LRL, low reference limit; URL, upper reference limit; m, months; y, years; TR-IFMA, time-resolved immunofluorimetric assay.
[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified.

Table 21. Human Chorionic Gonadotropin (hCG) and βhCG reference intervals according to age and fertility status in the female population

Age	Menstrual phase/ fertility status	LRL–URL, percentile	Immunoassay				
			hCG LRL–URL, IU/L	βhCG LRL–URL, IU/L	hCG + βhCG LRL–URL, IU/L	Assay	Reference [geographic group[a]]
Birth–3 m		n.s.			<50[b, c, d]	Roche Cobas	Mayo Medical Laboratories, 2017
3 m–18 y		n.s.			<1.0[b, c, d]	Roche Cobas	Mayo Medical Laboratories, 2017
Adult	premenopausal, non-pregnant	2.5–97.5			<1.0[b, c, d]	Roche Cobas	Mayo Medical Laboratories, 2017
Adult	postmenopausal	2.5–97.5	1.4–7.3		<7.0[b, c, d]	Roche Cobas	Mayo Medical Laboratories, 2017
<50 y	non-pregnant	2.5–97.5	<8.6[b, c, d]	<1.6[b, c, d]	<9.0[b, c, d]	TR-IFMA	Alfthan et al., 1992 [7]
>50 y	non-pregnant	2.5–97.5	<15.5[b, c, d]	<2.0[b, c, d]	<17.0[b, c, d]	TR-IFMA	Alfthan et al., 1992 [7]

LRL, low reference limit; URL, upper reference limit; m, months; y, years; TR-IFMA, time-resolved immunofluorimetric assay.
[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified.

Table 22. Anti-müllerian hormone (AMH) reference intervals according to age and genital stage in the male population

Age/ Genital stage	LRL–URL, percentile	Immunoassay		
		LRL–URL, pmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
Cord blood	5–95	53–340[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; "healthy pregnant women and their offspring" study
0.2–0.5 y/ minipuberty	5–95	749–1,930[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; "healthy pregnant women and their offspring" study
0.9–1.3 y	5–95	395–1,397[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; "healthy pregnant women and their offspring" study
4.5–5.8 y	5–95	395–1,335[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; "healthy pregnant women and their offspring" study
6.1–8.9 y/ G1a	5–95	321–1,218[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; COPENHAGEN Puberty Study
9.0–13.2 y/ G1b	5–95	297–1,113[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; COPENHAGEN Puberty Study
10.5–4.8 y/ G2	5–95	46–1,120[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; COPENHAGEN Puberty Study
11.1–14.4 y/ G3	5–95	22–734[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; COPENHAGEN Puberty Study
11.7–15.8 y/ G4	5–95	15–112[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; COPENHAGEN Puberty Study
12.1–19.8 y/ G5	5–95	23–128[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; COPENHAGEN Puberty Study
18–30 y	2.5–97.5	13.6-146.4[b, c, d]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
18–50 y	2.5–97.5	15.0-145.7[m, c, d]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
18–50 y	2.5–97.5	14.3-111.4[n, c, d]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
18–50 y	2.5–97.5	17.1–38.6[o, c, d]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
20 y	2.5–97.5	15–128[b, c, l]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; Health2006 study
21.6–64.4 y	5–95	13–98[b, c]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; Health2006 study
30 y	2.5–97.5	30–120[b, c, l]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; Health2006 study
31–40 y	2.5–97.5	19.3-105.7[b, c, g]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
40 y	2.5–97.5	15–100[b, c, l]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; Health2006 study
41–50 y	2.5–97.5	14.3-115.7[b, c, d]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
50 y	2.5–97.5	10–90[b, c, l]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; Health2006 study
60 y	2.5–97.5	6–92[b, c, l]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; Health2006 study
70 y	2.5–97.5	5–92[b, c, l]	Immunotech, Beckman Coulter	Aksglaede et al., 2010 [7]; Health2006 study

To convert AMH from pmol/L to ng/mL, divide by 7.14. Note that Immunotech by Beckman Coulter is no longer available. LRL, low reference limit; URL, upper reference limit; y, years; G, genital stage.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [l] Data derived from graph of the publication. [m] Population restricted to normal weight individuals. [n] Population restricted to overweight individuals. [o] Population restricted to obese individuals.

Table 23. Anti-müllerian hormone (AMH) reference intervals according to age, menstrual phase, and fertility status in the female population

Age	Menstrual phase/ fertility status	LRL–URL, percentile	Immunoassay		
			LRL–URL, pmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
Cord blood		2.5–97.5	<2–15.5[b, c, d]	Immunotech, Beckman Coulter	Hagen et al., 2010 [7]; "healthy pregnant women and their offspring" study
3 m		2.5–97.5	4.5–29.5[b, c, d]	Immunotech, Beckman Coulter	Hagen et al., 2010 [7]; "healthy pregnant women and their offspring" study
1 y		2.5–97.5	3.0–18.9[b, c, d]	Immunotech, Beckman Coulter	Hagen et al., 2010 [7]; "healthy pregnant women and their offspring" study
4 y		2.5–97.5	1.9–39.2[b, c, d]	Immunotech, Beckman Coulter	Hagen et al., 2010 [7]; "healthy pregnant women and their offspring" study
4 y		2.5–97.5	<46.4[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
8 y		2.5–97.5	5.5–57.1[b, c, d]	Immunotech, Beckman Coulter	Hagen et al., 2010 [7]; COPENHAGEN Puberty Study
8 y		2.5–97.5	2.0–82.1[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
8–25 y		2.5–97.5	4.7–60.1[b, c, d]	Immunotech, Beckman Coulter	Hagen et al., 2010 [7]; COPENHAGEN Puberty Study
10 y		2.5–97.5	1.6–80.1[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
14 y		2.5–97.5	1.6–78.5[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
14 y	premenopausal	10–90	7.1-121.44[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]
18 y		2.5–97.5	4.3–110.7[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
18 y	premenopausal	5–95	19.0–65.2[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
18 y	premenopausal	5–95	12.4–92.1[b, c, d]	ELISA, Immunotech, Beckman Coulter	La Marca et al., 2012 [9]
18 y	premenopausal	10–90	7.8–97.8[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]
18–30 y	early follicular (d 2–7)	2.5–97.5	4.3–89.3[b, c, d, i]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
18–50 y	early follicular (d 2–7)	2.5–97.5	<1.4–76.4[b, c, d]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
20 y		2.5–97.5	5.7–121.4[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
20 y	premenopausal	5–95	14.4–63.7[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
20 y	early follicular (d 3)	10–90	16.8–17.9[b, c, d, l]	ELISA, Span Biotech	Okunola et al., 2016 [1]
20 y	premenopausal	5–95	11.4–89.8[b, c, d]	ELISA, Immunotech, Beckman Coulter	La Marca et al., 2012 [9]
20 y	premenopausal	10–90	7.9–89.3[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]
20–24 y		2.5–97.5	8.7–83.6[c, d]	ECLIA, Elecsys, Roche	Anckaert et al., 2016 [11]
20–31 y	early follicular	5–95	8.5–81.5[c, d]	EIA, Immunotech, Beckman Coulter	Yoo et al., 2011 [5]
25 y		2.5–97.5	6.4–125.7[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
25 y	premenopausal	5–95	6.6–57.9[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
25 y	early follicular (d 3)	10–90	18.2–27.1[b, c, d, l]	ELISA, Span Biotech	Okunola et al., 2016 [1]
25 y	premenopausal	5–95	9.0–83.2[b, c, d]	ELISA, Immunotech, Beckman Coulter	La Marca et al., 2012 [9]
25 y	premenopausal	10–90	7.1–78.5[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]
25–29 y		2.5–97.5	6.4–70.3[c, d]	ECLIA, Elecsys, Roche	Anckaert et al., 2016 [11]
30 y		2.5–97.5	3.6–96.4[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature

Table 23 (continued)

Age	Menstrual phase/ fertility status	LRL–URL, percentile	Immunoassay		
			LRL–URL, pmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
30 y	premenopausal	5–95	2.8–48.5[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
30 y	early follicular (d 3)	10–90	10.4–20.7[b, c, d, l]	ELISA, Span Biotech	Okunola et al., 2016 [1]
30 y	premenopausal	5–95	7.1–75.3[b, c, d]	ELISA, Immunotech, Beckman Coulter	La Marca et al., 2012 [9]
30 y	premenopausal	10–90	4.3–75.0[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]
30–34 y		2.5–97.5	4.1–58.0[c, d]	ECLIA, Elecsys, Roche	Anckaert et al., 2016 [11]
31–40 y	early follicular (d 2–7)	2.5–97.5	3.6–68.5[b, c, d, i]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
32–34 y	early follicular	5–95	4.3–76.4[c, d]	EIA, Immunotech, Beckman Coulter	Yoo et al., 2011 [5]
35 y		2.5–97.5	1.4–75.0[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
35 y	premenopausal	5–95	1.1–35.5[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
35 y	early follicular (d 3)	10–90	5.7–14.3[b, c, d, l]	ELISA, Span Biotech	Okunola et al., 2016 [1]
35 y	premenopausal	5–95	5.4–65.8[b, c, d]	ELISA, Immunotech, Beckman Coulter	La Marca et al., 2012 [9]
35 y	premenopausal	10–90	4.3–54.3[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]
35–37 y	early follicular	5–95	3.0–58.4[c, d]	EIA, Immunotech, Beckman Coulter	Yoo et al., 2011 [5]
35–39 y		2.5–97.5	1.1–53.5[c, d]	ECLIA, Elecsys, Roche	Anckaert et al., 2016 [11]
38–40 y	early follicular	5–95	1.9–48.7[c, d]	EIA, Immunotech, Beckman Coulter	Yoo et al., 2011 [5]
40 y		2.5–97.5	<60.7[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
40 y	premenopausal	5–95	0.5–21.5[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
40 y	early follicular (d 3)	10–90	3.6–7.1[b, c, d, l]	ELISA, Span Biotech	Okunola et al., 2016 [1]
40 y	all	5–95	0.5–20.4[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
40 y	premenopausal	5–95	3.8–54.0[b, c, d]	ELISA, Immunotech, Beckman Coulter	La Marca et al., 2012 [9]
40 y	premenopausal	10–90	<26.8[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]
40–44 y		2.5–97.5	0.2–39.1[c, d]	ECLIA, Elecsys, Roche	Anckaert et al., 2016 [11]
41–43 y	early follicular	5–95	1.0–27.3[c, d]	EIA, Immunotech, Beckman Coulter	Yoo et al., 2011 [5]
41–50 y	early follicular (d 2–7)	2.5–97.5	1.4–10.0[b, c, d, i]	GenII Immunotech, Beckman Coulter	Woloszynek et al., 2015 [4]
≥44 y	early follicular	5–95	0.7–23.3[c, d]	EIA, Immunotech, Beckman Coulter	Yoo et al., 2011 [5]
45 y		2.5–97.5	<32.1[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
45 y	premenopausal	5–95	0.3–10.1[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
45 y	all	5–95	0.3–8.4[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
45 y	early follicular (d 3)	10–90	1.4–3.6[b, c, d, l]	ELISA, Span Biotech	Okunola et al., 2016 [1]
45 y	premenopausal	5–95	2.4–39.5[b, c, d]	ELISA, Immunotech, Beckman Coulter	La Marca et al., 2012 [9]
45 y	premenopausal	10–90	<12.2[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]

Table 23 (continued)

Age	Menstrual phase/ fertility status	LRL–URL, percentile	Immunoassay		
			LRL–URL, pmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
45–50 y		2.5–97.5	0.1–19.3[c, d]	ECLIA, Elecsys, Roche	Anckaert et al., 2016 [11]
50 y		2.5–97.5	<17.9[b, c, d, l]	Immunotech, Beckman Coulter[p]	Kelsey et al., 2011 [11]; model from all data in literature
50 y	premenopausal	5–95	0.2–3.4[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
50 y	all	5–95	0.2–2.4[b]	GenII Immunotech, Beckman Coulter	Tehrani et al., 2014 [6]; TLGS study
50 y	premenopausal	5–95	1.1–20.8[b, c, d]	ELISA, Immunotech, Beckman Coulter	La Marca et al., 2012 [9]
50 y	premenopausal	10–90	<5.0[b, c, d, l]	GenII Immunotech, Beckman Coulter[q]	Lie Fong et al., 2012 [7]

To convert AMH from pmol/L to ng/mL, divide by 7.14. Note that Immunotech by Beckman Coulter is no longer available. LRL, low reference limit; URL, upper reference limit; m, months; y, years; d, menstrual cycle day; ELISA, enzyme-linked immunosorbent assay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [i] Oral contraceptive not excluded or not specified. [l] Data derived from graph of the publication. [p] Valid also for GenII Immunotech, Beckman Coulter. [q] Valid also for Immunotech Beckman Coulter.

Table 24. Inhibin B (InB) reference intervals according to age in the male population

Age, years	LRL–URL, percentile	Immunoassay,		
		LRL–URL, pg/L	Assay	Reference [geographic group[a]]
0	2.5–97.5	99–439[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
1	2.5–97.5	89–418[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
2	2.5–97.5	43–310[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
3	2.5–97.5	23–251[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
4	2.5–97.5	16–224[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
5	2.5–97.5	13–214[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
6	2.5–97.5	14–216[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
7	2.5–97.5	17–227[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
8	2.5–97.5	22–245[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
9	2.5–97.5	29–269[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
10	2.5–97.5	40–299[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
11	2.5–97.5	53–333[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
12	2.5–97.5	68–370[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
13	2.5–97.5	85–408[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
14	2.5–97.5	102–444[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
15	2.5–97.5	118–478[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
16	2.5–97.5	132–506[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
17	2.5–97.5	141–528[b, c, d, e]	ELISA by Groome et al., 1996	Kelsey et al., 2016 [11]; model from all published data
<20	10–90	34–195[b, c]	IRMA, Beckman Coulter	Grunewald et al., 2013 [8]
20–30	10–90	54–248[b, c]	IRMA, Beckman Coulter	Grunewald et al., 2013 [8]
25–48	2.5–97.5	92–316[b, c]	Gen II ELISA, Beckman Coulter	Barbotin et al., 2015 [8]
30–40	10–90	57–247[b, c]	IRMA, Beckman Coulter	Grunewald et al., 2013 [8]
40–70	10–90	52–232[b, c]	IRMA, Beckman Coulter	Grunewald et al., 2013 [8]

LRL, low reference limit; URL, upper reference limit; ELISA, enzyme-linked immunosorbent assay; IRMA, immunoradiometric assay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified.

Table 25. Inhibin B (InB) reference intervals according to age, Tanner stage, pubic hair stage, breast stage, menstrual phase, and fertility status in the female population

Age/ Tanner stage/ Pubic hair/ Breast stage	Menstrual phase/fertility status	LRL–URL, percentile	Immunoassay		
			LRL–URL, pg/L	Assay	Reference [geographic group[a]]; population study
5.9–11.8 y/ T1		2.5–97.5	<20–100[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
PH1		10–90	<7–33.2[b, c, d]	ELISA, 10-84100 ACTIVE, DSL	Sims et al., 2012 [2]; NHANES III study
B1		10–90	<7–33.2[b, c, d]	ELISA, 10-84100 ACTIVE, DSL	Sims et al., 2012 [2]; NHANES III study
9.2–13.6 y/ T2		2.5–97.5	<20–240[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
PH2		10–90	<7–75.5[b, c, d]	ELISA, 10-84100 ACTIVE, DSL	Sims et al., 2012 [2]; NHANES III study
B2		10–90	<7–68.0[b, c, d]	ELISA, 10-84100 ACTIVE, DSL	Sims et al., 2012 [2]; NHANES III study
10.5–15.9 y/ T3		2.5–97.5	28–227[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
PH3		10–90	<7–71.4[b, c, d]	ELISA, 10-84100 ACTIVE, DSL	Sims et al., 2012 [2]; NHANES III study
B3		10–90	<7–71.4[b, c, d]	ELISA, 10-84100 ACTIVE, DSL	Sims et al., 2012 [2]; NHANES III study
11.5–17.4 y/ T4		2.5–97.5	<20–205[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
PH>4		10–90	<7–62.6[b, c, d]	ELISA, 10-84100 ACTIVE, DSL	Sims et al., 2012 [2]; NHANES III study
B>4		10–90	<7–83.8[b, c, d]	ELISA, 10-84100 ACTIVE, DSL	Sims et al., 2012 [2]; NHANES III study
12.8–19.5 y/ T5		2.5–97.5	<20–177[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
20–32 y	all	2.5–97.5	<20–185[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
20–32 y	early follicular	2.5–97.5	<20–261[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
20–32 y	late follicular	2.5–97.5	<20–286[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
20–32 y	periovulatory	2.5–97.5	<20–189[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
20–32 y	midluteal	2.5–97.5	<20–164[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]
20–32 y	end luteal	2.5–97.5	<20–107[b, c]	ELISA by Groome et al., 1996	Sehested et al., 2000 [7]

LRL, low reference limit; URL, upper reference limit; y, years; T, Tanner stage; ELISA, enzyme-linked immunosorbent assay; PH, pubic hair stage; B, breast stage.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified.

Table 26. Cortisol (F) reference intervals according to age and Tanner stage in the male population

Age/Tanner stage	LRL–URL, percentile	LC-MS/MS		Immunoassay		
		LRL–URL, nmol/L	Reference [geographic group[a]]	LRL–URL, nmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
<1 wk	2.5–97.5	9–325[b, c, e]	Kulle et al., 2013 [8]			
2 wk–2 m	2.5–97.5	6–268[b, c, e]	Kulle et al., 2013 [8]			
3–11 m	2.5–97.5	51–341[b, c, e]	Kulle et al., 2013 [8]			
<1 y	0–100			83–579[b, c]	RIA	Lashansky et al., 1991 [3]
1–5 y	0–100			157–690[b, c]	RIA	Lashansky et al., 1991 [3]
1–5 y	0–100			110—309[f]	ICMA, Bayer	[h][9]
1–6 y	2.5–97.5	50–611[b, c, e]	Kulle et al., 2013 [8]	110–408[f]	ICMA, Bayer	[h][9]
6–12 y	0–100			157–414[b, c]	RIA	Lashansky et al., 1991 [3]
6–12 y	0–100			117–621[f]	ICMA, Bayer	[h][9]
7–12 y	2.5- 97.5	64–409[b, c, e]	Kulle et al., 2013 [8]	116–547[f]	ICMA, Bayer	[h][9]
11 y	2.5–97.5			133–578[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
12 y	2.5–97.5			233–681[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
12–16 y/T2–3	0–100			110–359[b, c]	RIA	Lashansky et al., 1991 [3]
13 y	2.5–97.5			97–654	FPEA, AxSYM, Abbott Diagnostics	Koester-Weber et al., 2014 [11]; HELENA study
13 y	2.5–97.5			232–746[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2003 [8]
13–15 y	2.5–97.5	71–402[b, c, e]	Kulle et al., 2013 [8]	99–560[f]	ICMA, Bayer	[h][9]
13–17 y/T4–5	0–100			138–414[b, c]	RIA	Lashansky et al., 1991 [3]
14 y	2.5–97.5			113–557	FPEA, AxSYM, Abbott Diagnostics	Koester-Weber et al., 2014 [11]; HELENA study
14 y	2.5–97.5			216–644[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y	2.5–97.5			231–685[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y	2.5–97.5			135–629	FPEA, AxSYM, Abbott Diagnostics	Koester-Weber et al., 2014 [11]; HELENA study
16 y	2.5–97.5			179–618[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16 y	2.5–97.5			157–828	FPEA, AxSYM, Abbott Diagnostics	Koester-Weber et al., 2014 [11]; HELENA study
>16 y	2.5–97.5			373–613[f]	ICMA, Bayer	[h][9]
16–40 y	2.5–97.5	101–713[b, c, e]	Kulle et al., 2013 [8]			
17 y	2.5–97.5			218–656[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17–19 y	2.5–97.5			218–707[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y	2.5–97.5			218–731[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–81 y	2.5–97.5	134–644[b, e]	Eisenhofer et al., 2017 [8]			
18–89 y	2.5–97.5	126—550[f]	Fanelli et al., 2011 [9]			

To convert F from nmol/L to ng/mL, divide by 2.759. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; T, Tanner stage; RIA, radioimmunoassay; ICMA, immunochemiluminometric assay; CLIA, chemiluminescence immunoassay; FPEA, fluorescence polarisation enzymoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital.

Table 27. Cortisol (F) reference intervals according to age, menstrual phase, and fertility status in the female population

Age/ Tanner stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay		
			LRL–URL, nmol/L	Reference [geographic group[a]]	LRL–URL, nmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
<1 wk		2.5–97.5	15–311[b, c, e]	Kulle et al., 2013 [8]			
2 wk–2 m		2.5–97.5	63–380[b, c, e]	Kulle et al., 2013 [8]			
3–11 m		2.5–97.5	43–348[b, c, e]	Kulle et al., 2013 [8]			
< 1 y		0–100			116–634[b, c]	RIA	Lashansky et al., 1991 [3]
1–5 y		0–100			201–524[b, c]	RIA	Lashansky et al., 1991 [3]
1–6 y		2.5–97.5	22–439[b, c, e]	Kulle et al., 2013 [8]	110–359[f]	ICMA, Bayer	[h][9]
6–12 y		0–100			83–331[b, c]	RIA	Lashansky et al., 1991 [3]
7–12 y		2.5–97.5	51–437[b, c, e]	Kulle et al., 2013 [8]	106–667[f]	ICMA, Bayer	[h][9]
11 y		2.5–97.5			156–616[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
11–14 y/ T2–3		0–100			119–441[b, c]	RIA	Lashansky et al., 1991 [3]
12 y		2.5–97.5			153–707[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13 y		2.5–97.5			116–684	FPEA, AxSYM, Abbott Diagnostics	Koester-Weber et al., 2014 [11]; HELENA study
13 y		2.5–97.5			216–621[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13–15 y		2.5–97.5	50–546[b, c, e, i]	Kulle et al., 2013 [8]	102–527[f]	ICMA, Bayer	[h][9]
14 y		2.5–97.5			124–635	FPEA, AxSYM, Abbott Diagnostics	Koester-Weber et al., 2014 [11]; HELENA study
14 y		2.5–97.5			224–740[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
14–16 y/ T4–5		0–100			166–414[b, c, e]	RIA	Lashansky et al., 1991 [3]
15 y		2.5–97.5			182–749[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y		2.5–97.5			121–916	FPEA, AxSYM, Abbott Diagnostics	Koester-Weber et al., 2014 [11]; HELENA study
16 y		2.5–97.5			240–697[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16 y		2.5–97.5			152–1112	FPEA, AxSYM, Abbott Diagnostics	Koester-Weber et al., 2014 [11]; HELENA study
17 y		2.5–97.5			240–665[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16–40 y		2.5–97.5	138–810[b, c, e, i]	Kulle et al., 2013 [8]			
17–19 y		2.5–97.5			242–648[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y		2.5–97.5			245–617[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–49 y	luteal	0–100	150–822[b, e]	Eisenhofer et al., 2017 [8]			

Table 27 (continued)

Age/ Tanner stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay		
			LRL–URL, nmol/L	Reference [geographic group[a]]	LRL–URL, nmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
18–54 y	premeno-pausal	2.5–97.5	131–551[f]	Fanelli et al., 2011 [9]			
18–54 y	follicular	2.5–97.5	112–551[f]	Fanelli et al., 2011 [9]			
19–49 y	follicular	0–100	97–979[b, e]	Eisenhofer et al., 2017 [8]			
45–77 y	postmeno-pausal	0–100	124–698[b, e]	Eisenhofer et al., 2017 [8]			
45–86 y	postmeno-pausal	2.5–97.5	157–498[f]	Fanelli et al., 2011 [9]			

To convert F from nmol/L to ng/mL, divide by 2.759. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; T, Tanner stage; RIA, radioimmunoassay; ICMA, immunochemiluminometric assay; CLIA, chemiluminescence immunoassay; FPEA, fluorescence polarisation enzymoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital. [i] Oral contraceptive not excluded or not specified.

Table 28. Cortisone (E), corticosterone (B), 11deoxycortisol (11S), and 21deoxycortisol (21S) reference intervals by LC-MS/MS according to age in the male population

Age/ Tanner stage	LRL–URL, percentile	LRL–URL, nmol/L				Reference [geographic group[a]]
		Cortisone	Corticosterone	11Deoxycortisol	21Deoxycortisol	
<1wk	2.5–97.5	29.0–110.5[b, c, e]	0.26–21.39[b, c, e]	0.58–10.71[b, c, e]	0.12–1.47[b, c, e]	Kulle et al., 2013 [8]
2 wk–2m	2.5–97.5	24.6–122.7[b, c, e]	0.26–7.74[b, c, e]	0.26–3.32[b, c, e]	0.14–1.82[b, c, e]	Kulle et al., 2013 [8]
3–11 m	2.5–97.5	31.9–93.7[b, c, e]	0.26- 13.13[b, c, e]	0.26–3.12[b, c, e]	0.12–1.24[b, c, e]	Kulle et al., 2013 [8]
1–6 y	2.5–97.5	9.8–81.8[b, c, e]	0.26–12.27[b, c, e]	0.26–3.87[b, c, e]	0.12–1.44[b, c, e]	Kulle et al., 2013 [8]
<9 y/ T1	2.5–97.5			<3.03[b, c, d, e]		Kushnir et al., 2006 [2]
7–9 y	2.5–97.5			<3.41[b, c, d, e]		Kushnir et al., 2006 [2]
7–12 y	2.5–97.5	18.2–85.8[b, c, e]	0.26–9.90[b, c, e]	0.26–2.51[b, c, e]	0.12–1.85[b, c, e]	Kulle et al., 2013 [8]
>9 y/ T2	2.5–97.5			<3.06[b, c, d, e]		Kushnir et al., 2006 [2]
>9 y/ T3	2.5–97.5			<3.20[b, c, d, e]		Kushnir et al., 2006 [2]
>9 y/ T4–5	2.5–97.5			<2.34[b, c, d, e]		Kushnir et al., 2006 [2]
10–11 y	2.5–97.5			<3.06[b, c, d, e]		Kushnir et al., 2006 [2]
12–13 y	2.5–97.5			<2.68[b, c, d, e]		Kushnir et al., 2006 [2]
13–15 y	2.5–97.5	21.9–93.7[b, c, e]	0.35–9.15[b, c, e]	0.26–2.83[b, c, e]	0.12–1.41[b, c, e]	Kulle et al., 2013 [8]
14–15 y	2.5–97.5			<2.66[b, c, d, e]		Kushnir et al., 2006 [2]
16–17 y	2.5–97.5			<3.03[b, c, d, e]		Kushnir et al., 2006 [2]
16–40 y	2.5–97.5	27.1–100.9[b, c, e]	0.26–46.81[b, c, e]	0.26–3.13[b, c, e]	0.12–1.50[b, c, e]	Kulle et al., 2013 [8]
18–52 y	2.5–97.5			<1.44[b, c, d, e]		Kushnir et al., 2006 [2]
18–81 y	2.5–97.5	28.9–90.9[b, e]	1.65–40.51[b, e]	0.13–2.58[b, e]	<0.45[b, e]	Eisenhofer et al., 2017 [8]
18–89 y	2.5–97.5		1.33–36.36[f]	0.25–3.16[f]		Fanelli et al., 2011 [9]

To convert from nmol/L to ng/mL, divide by 2.774 for E and by 2.886 for B, 11S, and 21S. LC-MS/MS, liquid chromatography-tandem mass spectrometry; LRL, low reference limit; URL, upper reference limit; wk, weeks; m, months; y, years; T, Tanner stage.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal.

Table 29. Cortisone (E), corticosterone (B), 11deoxycortisol (11S), and 21deoxycortisol (21S) reference intervals by LC-MS/MS according to age, menstrual phase, and fertility status in the female population

Age/ Tanner stage	Menstrual phase/ fertility status	LRL–URL, percentile	LRL–URL, nmol/L				Reference [geographic group[a]]
			Cortisone	Corticosterone	11Deoxycortisol	21Deoxycortisol	
<1 wk		2.5–97.5	17.2–138.0[b, c, e]	1.07–23.67[b, c, e]	0.90–6.90[b, c, e]	0.12–3.06[b, c, e]	Kulle et al., 2013 [8]
2 wk–2 m		2.5–97.5	36.3–163.7[b, c, e]	0.26–21.18[b, c, e]	0.32–5.14[b, c, e]	0.14–2.40[b, c, e]	Kulle et al., 2013 [8]
3–11 m		2.5–97.5	17.0–88.7[b, c, e]	0.38–15.47[b, c, e]	0.23–5.92[b, c, e]	0.12–2.68[b, c, e]	Kulle et al., 2013 [8]
1–6 y		2.5–97.5	5.4–94.0[b, c, e]	0.26–8.51[b, c, e]	0.26–2.74[b, c, e]	0.12–1.82[b, c, e]	Kulle et al., 2013 [8]
<8 y>/ T1		2.5–97.5			<2.68[b, c, d, e]		Kushnir et al., 2006 [2]
>8 y/ T2		2.5–97.5			<3.92[b, c, d, e]		Kushnir et al., 2006 [2]
7–9 y		2.5–97.5			<2.68[b, c, d, e]		Kushnir et al., 2006 [2]
7–12 y		2.5–97.5	11.4–89.6[b, c, e]	0.26–12.09[b, c, e]	0.20–3.64[b, c, e]	0.12–1.53[b, c, e]	Kulle et al., 2013 [8]
>8 y/ T3		2.5–97.5			<2.80[b, c, d, e]		Kushnir et al., 2006 [2]
>8 y/ T4–5		2.5–97.5			<1.41[b, c, d, e]		Kushnir et al., 2006 [2]
10–11 y		2.5–97.5			<3.06[b, c, d, e]		Kushnir et al., 2006 [2]
12–13 y		2.5–97.5			<3.87[b, c, d, e]		Kushnir et al., 2006 [2]
13–15 y		2.5–97.5	12.0–92.0[b, c, e, i]	0.26–10.33[b, c, e, i]	0.26–2.57[b, c, e, i]	0.12–1.44[b, c, e, i]	Kulle et al., 2013 [8]
14–15 y		2.5–97.5			<3.03[b, c, d, e]		Kushnir et al., 2006 [2]
16–17 y		2.5–97.5			<1.36[b, c, d, e]		Kushnir et al., 2006 [2]
16–40 y		2.5–97.5	8.2–9.9[b, c, e, i]	0.26–20.26[b, c, e, i]	0.26–3.06[b, c, e, i]	0.12–1.01[b, c, e, i]	Kulle et al., 2013 [8]
18–49 y	luteal	0–100	34.4–92.1[b, e]	1.9–36.1[b, e]	0.15–3.81[b, e]	<0.54[b, e]	Eisenhofer et al., 2017 [8]
18–51 y	premenopausal	2.5–97.5			<1.18[b, c, d, e]		Kushnir et al., 2006 [2]
18–54 y	premenopausal	2.5–97.5		1.79–34.20[f]	<3.12[f]		Fanelli et al., 2011 [9]
18–54 y	follicular	2.5–97.5		1.30–34.46[f]	<3.88[f]		Fanelli et al., 2011 [9]
19–49 y	follicular	0–100	28.9–87.9[b, e]	2.0–87.2[b, e]	0.12–1.52[b, e]	<0.22[b, e]	Eisenhofer et al., 2017 [8]
45–77 y	postmenopausal	0–100	24.7–75.2[b, e]	1.5–35.8[b, e]	0.11–5.25[b, e]	<0.35[b, e]	Eisenhofer et al., 2017 [8]
45–86 y	postmenopausal	2.5–97.5		1.96–24.65[f]	0.24–2.42[f]		Fanelli et al., 2011 [9]

To convert from nmol/L to ng/mL, divide by 2.774 for E and by 2.886 for B, 11S, and 21S. LC-MS/MS, liquid chromatography-tandem mass spectrometry; LRL, low reference limit; URL, upper reference limit; wk, weeks; m, months; y, years; T, Tanner stage.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [i] Oral contraceptive not excluded or not specified.

Table 30. Progesterone (P) reference intervals according to age in the male population

Age	LRL–URL, percentile	LC-MS/MS		Immunoassay		
		LRL–URL, nmol/L	Reference [geographic group[a]]	LRL–URL, nmol/L	Direct or routine assay	Reference [geographic group[a]]
<1 wk	2.5–97.5	0.16–3.62[b, c, e]	Kulle et al., 2013 [8]			
2 wk–2 m	2.5–97.5	0.10–0.57[b, c, e]	Kulle et al., 2013 [8]			
3–11 m	2.5–97.5	0.10–0.48[b, c, e]	Kulle et al., 2013 [8]			
1–6 y	2.5–97.5	0.13–0.45[b, c, e]	Kulle et al., 2013 [8]	0.10–0.57[f]	ICMA, Bayer	[h][9]
7–12 y	2.5–97.5	0.10–1.91[b, c, e]	Kulle et al., 2013 [8]	0.10–0.61[f]	ICMA, Bayer	[h][9]
10–15 y	2.5–97.5			0.41–2.70[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
11 y	2.5–97.5			0.7–3.6[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
12 y	2.5–97.5			1.0–5.1[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13 y	2.5–97.5			1.2–4.8[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13–15 y	2.5–97.5	0.10–0.70[b, c, e]	Kulle et al., 2013 [8]	0.10–0.90[f]	ICMA, Bayer	[h][9]
14 y	2.5–97.5			1.1–4.1[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y	2.5–97.5			2.0–9.6[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15–19 y	2.5–97.5			0.51–1.81[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
16 y	2.5–97.5			2.2–14.5[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
>16 y	2.5–97.5	0.13–0.73[b, c, e]	Kulle et al., 2013 [8]	0.18–0.23[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17 y	2.5–97.5			2.2–6.9[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17–19 y	2.5–97.5			2.7–8.9[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y	2.5–97.5			3.7–9.6[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–81 y	2.5–97.5	0.04–0.70[b, e]	Eisenhofer et al., 2017 [8]			
18–89 y	2.5–97.5	<0.60[f]	Fanelli et al., 2011 [9]			
20–69 y	2.5–97.5			<2.73[b, c]	AdviaCentaur, Siemens	Schüring et al., 2016 [8]
20–69 y	2.5–97.5			<2.61[b, c]	Immulite2000, Siemens	Schüring et al., 2016 [8]

To convert P from nmol/L to ng/mL, divide by 3.180. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; ICMA, immunochemiluminometric assay; CLIA, chemiluminescence immunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital.

Table 31. Progesterone (P) reference intervals according to age, menstrual phase and fertility status in the female population

Age	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay		
			LRL–URL, nmol/L	Reference [geographic group[a]]	LRL–URL, nmol/L	Direct or routine assay	Reference [geographic group[a]]; population study
< 1 wk		2.5–97.5	0.32–107.61[b, c, e]				
2 wk–2 m		2.5–97.5	0.13–1.24[b, c, e]				
3–11 m		2.5–97.5	0.10–0.80[b, c, e]	Kulle et al., 2013 [8]			
1–6 y		2.5–97.5	0.13–1.37[b, c, e]	Kulle et al., 2013 [8]	0.32–1.20[f]	ICMA, Bayer	[h][9]
7–12 y		2.5–97.5	0.10–3.05[b, c, e]	Kulle et al., 2013 [8]	0.32–2.00[f]	ICMA, Bayer	[h][9]
10–15 y		2.5–97.5			0.41–2.70[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
11 y		2.5–97.5			1.1–3.0[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
12 y		2.5–97.5			1.5–5.9[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2003 [8]
13–15 y		2.5 -97.5	0.13–14.50[b, c, e, i]	Kulle et al., 2013 [8]	0.32–2.38[f]	ICMA, Bayer	[h][9]
13 y		2.5–97.5			1.2–4.8[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
14 y		2.5–97.5			1.5–41.7[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y		2.5–97.5			1.5–45.7[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15–19 y		2.5–97.5			0.64–32.63[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
16 y		2.5–97.5			1.8–46.9[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
16–40 y		2.5–97.5	0.13–15.61[b, c, e, i]	Kulle et al., 2013 [8]			
17 y		2.5–97.5			2.3–41.2[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17–19 y		2.5–97.5			2.9–42.5[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y		2.5–97.5			3.8–43.2[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–49 y	luteal	0–100	0.07–83.00[b, e]	Eisenhofer et al., 2017 [8]			
18–54 y	premenopausal	2.5–97.5	<56.65[f]	Fanelli et al., 2011 [9]			
18–54 y	follicular	2.5–97.5	<5.32[f]	Fanelli et al., 2011 [9]			
19–49 y	follicular	0–100	0.06–18.64[b, e]	Eisenhofer et al., 2017 [8]			
25–44 y	early follicular	2.5–97.5			<3.28[b, c]	AdviaCentaur, Siemens	Schüring et al., 2016 [8]
25–44 y	early follicular	2.5–97.5			<3.08[b, c]	Immulite2000, Siemens	Schüring et al., 2016 [8]
25–44 y	luteal	2.5–97.5			3.62–65.51[b, c]	AdviaCentaur, Siemens	Schüring et al., 2016 [8]
25–44 y	luteal	2.5–97.5			1.75–55.65[b, c]	Immulite2000, Siemens	Schüring et al. 2016 [8]
45–77 y	postmenopausal	0–100	0.03–11.42[b, e]	Eisenhofer et al., 2017 [8]			
45–86 y	postmenopausal	2.5–97.5	<0.25[f]	Fanelli et al., 2011 [9]			
49–66 y	postmenopausal	2.5–97.5			<1.91[b, c]	AdviaCentaur, Siemens	Schüring et al., 2016 [8]
49–66 y	postmenopausal	2.5–97.5			<1.30[b, c]	Immulite2000, Siemens	Schüring et al., 2016 [8]
55–89 y	postmenopausal	2.5–97.5	<2.88[b, c, d]	Ray et al., 2015 [2]			

To convert P from nmol/L to ng/mL, divide by 3.180. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; ICMA, immunochemiluminometric assay; CLIA, chemiluminescence immunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital. [i] Oral contraceptive not excluded or not specified.

Table 32. 17OH-Progesterone (17OHP) reference intervals according to age and Tanner stage in the male population

Age/ Tanner stage	LRL–URL, percentile	LC-MS/MS		Immunoassay					
		LRL–URL, nmol/L	Reference [geographic group[a]]; population study	Direct or routine assays			Extractive or ultrasensitive assays		
				LRL–URL, nmol/L	Assay	Reference [geographic group[a]]	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]
<1 wk	2.5–97.5	0.24–3.63[b, c, e]	Kulle et al., 2013 [8]						
2 wk–2 m	2.5–97.5	0.30–5.87[b, c, e]	Kulle et al., 2013 [8]						
<2 m	2.5–97.5			5.5–53.9[b, c, d]	RIA, Diasource	Ballerini et al., 2014 [4]	0.36–11.5[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]
2–6 m	2.5–97.5			0.3–23.9[b, c, d]	RIA, Diasource	Ballerini et al., 2014 [4]	0.31–8.5[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]
3–11 m	2.5–97.5	0.18–6.51[b, c, e]	Kulle et al., 2013 [8]						
6–12 m	2.5–97.5			0.3–6.1[b, c, d]	RIA, Diasource	Ballerini et al., 2014 [4]	0.30–2.2[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]
1–5 y/T1	2.5–97.5			0.8–1.9[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]			
<9 y/T1	2.5–97.5	<1.88[b, c, d, e]	Kushnir et al., 2006 [2]						
1–6 y	2.5–97.5	0.18–1.72[b, c, e]	Kulle et al., 2013 [8]	0.3–2.2[f]	RIA, Adaltis	[h][9]			
5–8 y/T1	2.5–97.5			1.0–3.5[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]			
7–9 y	2.5–97.5	<1.91[b, c, d, e]	Kushnir et al., 2006 [2]						
7–12 y	2.5–97.5	0.18–2.51[b, c, e]	Kulle et al., 2013 [8]	0.3–4.1[f]	RIA, Adaltis	[h][9]			
≥ 9 y/T1	2.5–97.5			1.7–5.0[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]			
>9 y/T2	2.5–97.5	<3.15[b, c, d, e]	Kushnir et al., 2006 [2]						
>9 y/T3	2.5–97.5	<4.57[b, c, d, e]	Kushnir et al., 2006 [2]						
>9 y/T2–3	2.5–97.5			1.9–5.2[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]			
>9 y/T4–5	2.5–97.5	0.61–4.21[b, c, d, e]	Kushnir et al., 2006 [2]	3.6–10.3[b, c, d]	RIA, Diasource	Ballerini et al., 2014 [4]			
10–11 y	2.5–97.5	<2.12[b, c, d, e]	Kushnir et al., 2006 [2]						
12–13 y	2.5–97.5	<3.18[b, c, d, e]	Kushnir et al., 2006 [2]						
13–15 y	2.5–97.5	0.18–3.51[b, c, e]	Kulle et al., 2013 [8]	0.4–4.4[f]	RIA, Adaltis	[h][9]			
14–15 y	2.5–97.5	<4.60[b, c, d, e]	Kushnir et al., 2006 [2]						
16–17 y	2.5–97.5	<5.84[b, c, d, e]	Kushnir et al., 2006 [2]						
16–40 y	2.5–97.5	0.24–5.63[b, c, e]	Kulle et al., 2013 [8]	0.5–5.5[f]	RIA, Adaltis	[h][9]			
18–52 y	2.5–97.5	0.76–4.21[b, c, d, e]	Kushnir et al., 2006 [2]						
18–81 y	2.5–97.5	0.87–6.24[b, e]	Eisenhofer et al., 2017 [8]						
18–89 y	2.5–97.5	1.26–7.69[f]	Fanelli et al., 2011 [9]						
30 y	2.5–97.5	1.6–8.1[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008						
40 y	2.5–97.5	1.5–7.7[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008						
50 y	2.5–97.5	1.5–7.4[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008						
60 y	2.5–97.5	1.3–7.0[b, l]	Damgaard-Olesen et al., 2016 [7]; Health2008						

To convert 17OHP from nmol/L to ng/mL, divide by 3.026. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography- tandem mass spectrometry; wk, weeks; m, months; y, years; T, Tanner stage; RIA, radioimmunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital. [l] Data derived from graph of the publication. [r] Data referred to mixed male and female population.

Table 33. 17OH-Progesterone (17OHP) reference intervals according to age, Tanner stage, menstrual phase, and fertility status in the female population

Age/ Tanner stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay					
			LRL–URL, nmol/L	Reference [geographic group[a]]	Direct or routine assays			Extractive or ultrasensitive assays		
					LRL–URL, nmol/L	Assay	Reference [geographic group[a]]	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]
<1 wk		2.5–97.5	1.33–8.47[b, c, e]	Kulle et al., 2013 [8]						
2 wk–2 m		2.5–97.5	0.97–3.90[b, c, e]	Kulle et al., 2013 [8]						
<2 m		2.5–97.5			4.8–41.8[b, c, d]	RIA, Diasource	Ballerini et al., 2014 [4]	0.36–11.5[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]
2–6 m		2.5–97.5			0.3–15.8[b, c, d]	RIA, Diasource	Ballerini et al., 2014 [4]	0.31–8.5[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]
3–11 m		2.5–97.5	0.18–2.42[b, c, e]	Kulle et al., 2013 [8]						
6–12 m		2.5–97.5			0.3–2.9[b, c, d]	RIA, Diasource	Ballerini et al., 2014 [4]	0.30–2.2[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]
1–5 y/T1		2.5–97.5			0.8–1.9[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]			
<8 y/T1		2.5–97.5	<2.24[b, c, d, e]	Kushnir et al., 2006 [2]						
1–6 y		2.5–97.5	0.18–1.72[b, c, e]	Kulle et al., 2013 [8]	0.42–4.08[f]	RIA, Adaltis	[h][9]			
5–8 y/T1		2.5–97.5			1.0–3.5[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]			
7–9 y		2.5–97.5	<2.15[b, c, d, e]	Kushnir et al., 2006 [2]						
7–12 y		2.5–97.5	0.18–2.57[b, c, e]	Kulle et al., 2013 [8]	0.73–4.84[f]	RIA, Adaltis	[h][9]			
≥8 y/T1		2.5–97.5			1.7–5.0[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]			
>8 y/T2		2.5–97.5	<4.96[b, c, d, e]	Kushnir et al., 2006 [2]						
>8 y/T3		2.5–97.5	0.36–6.32[b, c, d, e]	Kushnir et al., 2006 [2]						
>8 y/T2–3		2.5–97.5			1.9–5.2[b, c, d, r]	RIA, Diasource	Ballerini et al., 2014 [4]			
>8 y/T4–5		2.5–97.5	0.21–5.14[b, c, d, e]	Kushnir et al., 2006 [2]	2.0–6.0[b, c, d]	RIA, Diasource	Ballerini et al., 2014 [4]			
10–11 y		2.5–97.5	<2.69[b, c, d, e]	Kushnir et al., 2006 [2]						
12–13 y		2.5–97.5	<4.99[b, c, d, e]	Kushnir et al., 2006 [2]						
13–15 y		2.5–97.5	0.18–2.69[b, c, e, i]	Kulle et al., 2013 [8]	1.08–6.17[f]	RIA, Adaltis	[h][9]			
14–15 y		2.5–97.5	0.36–6.29[b, c, d, e]	Kushnir et al., 2006 [2]						
16–40 y		2.5–97.5	0.24–2.57[b, c, e, i]	Kulle et al., 2013 [8]	1.88–8.96[f]	RIA, Adaltis	[h][9]			
16–17 y		2.5–97.5	<5.42[b, c, d, e]	Kushnir et al., 2006 [2]						
16–19 y	all	2.5–97.5	0.52–9.27[f]	Fanelli et al., 2013b [9]						
16–19 y	follicular	2.5–97.5	0.47–3.01[f]	Fanelli et al., 2013b [9]						
16–19 y	luteal	2.5–97.5	0.26–8.63[f]	Fanelli et al., 2013b [9]						

Table 33 (continued)

Age/ Tanner stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS		Immunoassay				
			LRL–URL, nmol/L	Reference [geographic group[a]]	Direct or routine assays			Extractive or ultrasensitive assays		
					LRL–URL, nmol/L	Assay	Reference [geographic group[a]]	LRL–URL, nmol/L	Assay	Reference [geographic group[a]]
18–49 y	luteal	0–100	0.37–8.28[b, e]	Eisenhofer et al., 2017 [8]						
18–51 y	premenopausal	2.5–97.5	0.30–5.99[b, c, d, e]	Kushnir et al., 2006 [2]						
18–54 y	premenopausal	2.5–97.5	0.46–6.86[f]	Fanelli et al., 2011 [9]						
18–54 y	follicular	2.5–97.5	0.49–2.87[f]	Fanelli et al., 2011 [9]						
19–49 y	follicular	0–100	0.36–4.99[b, e]	Eisenhofer et al., 2017 [8]						
45–77 y	postmenopausal	0–100	0.19–3.12[b, e]	Eisenhofer et al., 2017 [8]						
45–86 y	postmenopausal	2.5–97.5	<1.59[f]	Fanelli et al., 2011 [9]						

To convert 17OHP from nmol/L to ng/mL, divide by 3.026. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; wk, weeks; m, months; y, years; T, Tanner stage; RIA, radioimmunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital. [i] Oral contraceptive not excluded or not specified. [r] Data referred to mixed male and female population.

Table 34. 17OH-Pregnenolone (17OHPre) and pregnenolone (Pre) reference intervals according to age and Tanner stage in the male population

Age/ Tanner stage	LRL–URL, percentile	LC-MS/MS			Immunoassay		
		17OH-Pregnenolone LRL–URL, nmol/L	Pregnenolone LRL–URL, nmol/L	Reference [geographic group[a]]	17OH-Pregnenolone LRL–URL, nmol/L	Extractive or ultrasensitive assays	Reference [geographic group[a]]
<1 y	0–100				0.42–23.04[b, c]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
1–5 y	0–100				0.36–3.10[b, c]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
6–12 y	0–100				0.93–5.59[b, c]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
7–9 y	2.5–97.5	<5.62[b, c, d, e]	0.41–6.48[b, c, d, e]	Kushnir et al., 2006 [2]			
<9 y/ T1	2.5–97.5	<6.26[b, c, d, e]	0.41–4.90[b, c, d, e]	Kushnir et al., 2006 [2]			
>9 y/ T1	5–95	0.09–15.22[c, e]		Kulle et al., 2017 [8]			
>9 y/ T2	2.5–97.5	<10.68[b, c, d, e]	0.38–4.52[b, c, d, e]	Kushnir et al., 2006 [2]			
>9 y/ T2	5–95	0.84–6.74[c, e]		Kulle et al., 2017 [8]			
> 9 y/ T3	2.5–97.5	<13.54[b, c, d, e]	0.51–6.76[b, c, d, e]	Kushnir et al., 2006 [2]			
>9 y/ T3	5–95	0.51–3.07[c, e]		Kulle et al., 2017 [8]			
10–11 y	2.5–97.5	<11.64[b, c, d, e]	0.40–4.77[b, c, d, e]	Kushnir et al., 2006 [2]			
11–13 y	5–95	0.21–3.37[c, e]		Kulle et al., 2017 [8]			
12–13 y	2.5–97.5	<10.89[b, c, d, e]	0.57–5.37[b, c, d, e]	Kushnir et al., 2006 [2]			
12–16 y/ T2–3	0–100				0.60–10.92[b, c]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
13–16 y	5–95	0.27–8.21[c, e]		Kulle et al., 2017 [8]			
13–17 y/ T4–5	0–100				0.96–8.93[b, c]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
14–15 y	2.5–97.5	0.96–12.87 [b, c, d, e]	0.54–6.26[b, c, d, e]	Kushnir et al., 2006 [2]			
T4	5–95	0.51–4.84[c, e]		Kulle et al., 2017 [8]			
T4–5	2.5–97.5	1.05–14.38[b, c, d, e]		Kushnir et al., 2006 [2]			
T5	5–95	1.53–10.10[c, e]		Kulle et al., 2017 [8]			
16–17 y	2.5–97.5	0.93–14.38[b, c, d, e]	0.51–7.24[b, c, d, e]	Kushnir et al., 2006 [2]			
16–40 y	5–95	0.57–9.78[c, e]		Kulle et al., 2017 [8]			
18–51 y	2.5–97.5	1.08–12.30[b, c, d, e]	0.88–5.21[b, c, d, e]	Kushnir et al., 2006 [2]			
18–81 y	2.5–97.5		1.45–22.88[b, e]	Eisenhofer et al., 2017 [8]			

To convert 17OHPre and Pre from nmol/L to ng/mL, divide by 3.008 and by 3.160, respectively. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; T, Tanner stage; HPLC, high pressure liquid chromatography; RIA, radioimmunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified.

Table 35. 17OH-Pregnenolone (17OHPre) and pregnenolone (Pre) reference intervals according to age, Tanner stage, menstrual phase, and fertility status in the female population

Age/ Tanner stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS			Immunoassay		
			17OH-Pregnenolone LRL–URL, nmol/L	Pregnenolone LRL–URL, nmol/L	Reference [geographic group[a]]	17OH-Pregnenolone LRL–URL, nmol/L	Extractive or ultrasensitive assay	Reference [geographic group[a]]
<1 y		0–100				1.86–24.90[b, c]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
1–5 y		0–100				0.30–1.41[b, c]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
6–12 y		0–100				0.33–4.24[b, c]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
7–9 y		2.5–97.5	<6.38[b, c, d, e]	0.44–4.74[b, c, d, e]	Kushnir et al., 2006 [2]			
<8 y/ T1		2.5–97.5	<7.07[b, c, d, e]	0.47–4.83[b, c, d, e]	Kushnir et al., 2006 [2]			
<8 y/ T1		5–95	0.21–25.06[c, e]		Kulle et al., 2017 [8]			
>8 y/ T2		2.5–97.5	<11.04[b, c, d, e]	0.70–7.24[b, c, d, e]	Kushnir et al., 2006 [2]			
>8 y/ T2		5–95	0.18–5.08[c, e]		Kulle et al., 2017 [8]			
>8 y/ T3		2.5–97.5	<12.93[b, c, d, e]	1.07–6.79[b, c, d, e]	Kushnir et al., 2006 [2]			
>8 y/ T3		5–95	0.03–9.63[c, e]		Kulle et al., 2017 [8]			
>8 y/ T4		5–95	1.08–10.80[c, e]		Kulle et al., 2017 [8]			
>8 y/ T4–5		2.5–97.5	0.78–12.39[b, c, d, e]	0.82–7.43[b, c, d, e]	Kushnir et al., 2006 [2]			
>8 y/ T5		5–95	0.21–7.79[c, e]		Kulle et al., 2017 [8]			
10–11 y		2.5–97.5	<9.63[b, c, d, e]	0.47–6.23[b, c, d, e]	Kushnir et al., 2006 [2]			
11–13 y	follicular	5–95	0.30–8.15[c, e, i]		Kulle et al., 2017 [8]			
11–14 y/ T2–3		0–100				1.74 –13.56[b, c, i]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
12–13 y		2.5–97.5	<10.89[b, c, d, e]	0.70–6.95[b, c, d, e]	Kushnir et al., 2006 [2]			
13–16 y	follicular	5–95	0.33–11.67[c, e, i]		Kulle et al., 2017 [8]			
14–15 y		2.5–97.5	0.84–12.69[b, c, d, e]	0.73–6.76[b, c, d, e]	Kushnir et al., 2006 [2]			
16–17 y		2.5–97.5	0.75–12.60[b, c, d, e]	0.70–7.24[b, c, d, e]	Kushnir et al., 2006 [2]			
14–16 y/ T4–5		0–100				1.59–16.30[b, c, i]	extraction + HPLC + RIA	Lashansky et al., 1991 [3]
16–40 y	follicular	5–95	0.48–10.92[c, e, i]		Kulle et al., 2017 [8]			
18–49 y	luteal	0–100		2.46–29.67[b, e]	Eisenhofer et al., 2017 [8]			
18–51 y	premenopausal	2.5–97.5	<6.26[b, c, d, e]	0.54–4.11[b, c, d, e]	Kushnir et al., 2006 [2]			
19–49 y	follicular	0–100		1.54–24.77[b, e]	Eisenhofer et al., 2017 [8]			
45–77 y	postmenopausal	0–100		0.32–9.23[b, e]	Eisenhofer et al., 2017 [8]			

To convert 17OHPre and Pre from nmol/L to ng/mL, divide by 3.008 and by 3.160, respectively. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; T, Tanner stage; HPLC, high pressure liquid chromatography; RIA, radioimmunoassay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [i] Oral contraceptive not excluded or not specified.

Table 36. Estradiol (E2) and estrone (E1) reference intervals according to age and Tanner stage in the male population

Age/ Tanner stage	LRL–URL, percentile	LC-MS/MS			Immunoassay					
					Direct or routine assays			Extractive or ultrasensitive assays		
		Estradiol LRL–URL, pmol/L	Estrone LRL–URL, pmol/L	Reference [geographic group[a]]; population study	Estradiol LRL–URL, pmol/L	Assay	Reference [geographic group[a]]; population study	Estradiol LRL–URL, pmol/L	Assay	Reference [geographic group[a]]; population study
7–9 y	2.5–97.5	<22[b, c, d]	<22[b, c, d]	Kushnir et al., 2008 [2]						
<9 y/T1	2.5–97.5	<29[b, c, d]	<26[b, c, d]	Kushnir et al., 2008 [2]	<11[f]	RIA, DPC	[h][9]			
>9 y/T2	2.5–97.5	<33[b, c, d]	<37[b, c, d]	Kushnir et al., 2008 [2]	<18[f]	RIA, DPC	[h][9]			
>9 y/T3	2.5–97.5	4–129[b, c, d]	4–115[b, c, d]	Kushnir et al., 2008 [2]	11–18[f]	RIA, DPC	[h][9]			
>9 y/T4–5	2.5–97.5	11–129[b, c, d]	7–111[b, c, d]	Kushnir et al., 2008 [2]	11–142[f]	RIA, DPC	[h][9]			
10–12 y	2.5–97.5	<37[b, c, d]	<37[b, c, d]	Kushnir et al., 2008 [2]						
11 y	2.5–97.5				28–110[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
11–13 y	2.5–97.5				<95[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study			
12 y	2.5–97.5				26–131[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
13 y	2.5–97.5				<20–232[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
13–15 y	2.5–97.5				<103[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study			
13–15 y	2.5–97.5	4–132[b, c, d]	4–111[b, c, d]	Kushnir et al., 2008 [2]						
14 y	2.5–97.5				22–273[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
15 y	2.5–97.5				<20–302[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
15–19 y	2.5–97.5				<140[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study			
16 y	2.5–97.5				40–137[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
16–17 y	2.5–97.5	11–125[b, c, d]	4–118[b, c, d]	Kushnir et al., 2008 [2]						
17 y	2.5–97.5				40–103[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
17–19 y	2.5–97.5				35–109[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
18–19 y	2.5–97.5				28–129[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]			
18–61 y	2.5–97.5	29–154[b, c, d]	33–133[b, c, d]	Kushnir et al., 2008 [2]						
20–29 y	2.5–97.5							36.5–168	extraction + HPLC + RIA	Nielsen et al., 2007 [7]; Odense Androgen Study

Table 36 (continued)

Age/ Tanner stage	LRL–URL, percentile	LC-MS/MS			Immunoassay					
					Direct or routine assays			Extractive or ultrasensitive assays		
		Estradiol LRL–URL, pmol/L	Estrone LRL–URL, pmol/L	Reference [geographic group[a]]; population study	Estradiol LRL–URL, pmol/L	Assay	Reference [geographic group[a]]; population study	Estradiol LRL–URL, pmol/L	Assay	Reference [geographic group[a]]; population study
20–69 y	2.5–97.5				<152[b,c]	AdviaCentaur, Siemens	Schüring et al. 2016 [8]			
20–69 y	2.5–97.5				<173[b, c]	Immulite2000, Siemens	Schüring et al. 2016 [8]			
60–74 y	2.5–97.5							33.0 –123	extraction + HPLC + RIA	Frost et al., 2013 [7]; Odense Androgen Study
≥70	2.5–97.5	28–139[b, c, e]		Yeap et al., 2012 [11]; HIMS study						

To convert E2 and E1 from pmol/L to pg/mL, divide by 3.671 and by 3.699, respectively. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; T, Tanner stage; RIA, radioimmunoassay; CLIA, chemiluminescence immunoassay; HPLC, high pressure liquid chromatography.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital.

Table 37. Estradiol (E2) and estrone (E1) reference intervals according to age, Tanner stage, menstrual phase, and fertility status in the female population

Age/ Tanner stage	Menstrual phase/ fertility status	LRL–URL, percentile	LC-MS/MS			Immunoassay		
			Estradiol LRL–URL, pmol/L	Estrone LRL–URL, pmol/L	Reference [geographic group[a]]; population study	Estradiol LRL–URL, pmol/L	Direct or routine assays	Reference [geographic group[a]]; population study
7–9 y		2.5–97.5	<129[b, c, d]	<93[b, c, d]	Kushnir et al., 2008 [2]			
<8y/ T1		2.5–97.5	<202[b, c, d]	<96[b, c, d]	Kushnir et al., 2008 [2]	11.0–37.4[f]	RIA, DPC	[h][9]
>8 y/ T2		2.5–97.5	7–488[b, c, d]	4–144[b, c, d]	Kushnir et al., 2008 [2]	11.0–63.5[f]	RIA, DPC	[h][9]
>8 y/ T3		2.5–97.5	44–1017[b, c, d]	30–433[b, c, d]	Kushnir et al., 2008 [2]	36.7–83.33[f]	RIA, DPC	[h][9]
>8 y/ T4–5		2.5–97.5	7–951[b, c, d]	15–403[b, c, d]	Kushnir et al., 2008 [2]			
n.s.	before menarche	2.5–97.5	4–308[b, c, d]	<152[b, c, d]	Kushnir et al., 2008 [2]			
n.s.	after menarche	2.5–97.5	11–969[b, c, d]	15–418[b, c, d]	Kushnir et al., 2008 [2]			
10–12 y		2.5–97.5	<319[b, c, d]	<155[b, c, d]	Kushnir et al., 2008 [2]			
11 y		2.5–97.5				33–188[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
11–12 y		2.5–97.5				<354[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
12 y		2.5–97.5				<20–221[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
12–14 y		2.5–97.5				<631[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
13 y		2.5–97.5				<20–157[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
13–15 y		2.5–97.5	33–910[b, c, d]	30–388[b, c, d]	Kushnir et al., 2008 [2]			
14 y		2.5–97.5				42–541[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
15 y		2.5–97.5				25–909[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
14–19 y		2.5–97.5				<936[b, c, d]	CLIA, i2000SR, Abbott Architect	Konforte et al., 2013 [2]; CALIPER study
16 y		2.5–97.5				76–849[b, c, d]	Immulite	Elmlinger et al., 2002 [8]
16–17 y		2.5–97.5	7–977[b, c, d]	15–492[b, c, d]	Kushnir et al., 2008 [2]			
17 y		2.5–97.5				49–507[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
17–19 y		2.5–97.5				51–586[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2002 [8]
18–19 y		2.5–97.5				53–688[b, c, d]	CLIA, Immulite, DPC	Elmlinger et al., 2003 [8]
25–44 y	early follicular (d 3–5)	2.5–97.5				<304[b, c]	AdviaCentaur, Siemens	Schüring et al. 2016 [8]
25–44 y	early follicular (d 3–5)	2.5–97.5				<356[b, c]	Immulite2000, Siemens	Schüring et al. 2016 [8]
25–44 y	luteal (d 21–23)	2.5–97.5				143–1087[b, c]	AdviaCentaur, Siemens	Schüring et al. 2016 [8]
25–44 y	luteal (d 21–23)	2.5–97.5				117–1127[b, c]	Immulite2000, Siemens	Schüring et al. 2016 [8]
41–63 y	postmenopausal	2.5–97.5	7–77[b, c, d]	11–118[b, c, d]	Kushnir et al., 2008 [2]			
49–66 y	postmenopausal	2.5–97.5				<79[b, c]	AdviaCentaur, Siemens	Schüring et al. 2016 [8]
49–66 y	postmenopausal	2.5–97.5				<114[b, c]	Immulite2000, Siemens	Schüring et al. 2016 [8]

To convert E2 and E1 from pmol/L to pg/mL, divide by 3.671 and by 3.699, respectively. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; d, menstrual cycle day; T, Tanner stage; RIA, radioimmunoassay; CLIA, chemiluminescence immunoassay; n.s., not specified.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [f] Saline infusion 10 min before blood withdrawal. [h] Novel data from the S. Orsola-Malpighi University-Hospital.

Table 38. Plasma aldosterone (Al), plasma renin concentration (PRC), and plasma renin activity (PRA) reference intervals according to age in the male and female population

Age	LRL–URL, percentile	LC-MS/MS		Immunoassay						
		Aldosterone LRL–URL, nmol/L	Reference [geographic group[a]]	Aldosterone LRL–URL, nmol/L	Aldosterone assay	PRC LRL–URL, pmol/L	PRC assay (direct, routine)	PRA LRL–URL, nmol/L/h	PRA assay (direct, routine)	Reference [geographic group[a]]; population study
0–8 y	2.5–97.5		Soldin et al., 2009 [2]							
2 h	0–100			3.33–23.6[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
7 d	0–100			0.97–5.85[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
1wk–3 m	0–100			0.69–5.91[b, c, t]	direct RIA			3.08–18.35[b, c, t]	Angiotensin I RIA, Clinical Assays	Fiselier et al., 1984 [7]
2wk–3 m	0–100			0.39–2.91[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
3 m–1 y	0–100			0.17–2.55[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
3 m–1 y	0–100			0.19–3.00[b, c, t]	direct RIA			1.16–7.86[b, c, t]	Angiotensin I RIA, Clinical Assays	Fiselier et al., 1984 [7]
1–3 y	0–100			0.28–2.19[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
1–4 y	0–100			0.08–2.14[b, c, t]	direct RIA			1.31–9.10[b, c, t]	Angiotensin I RIA, Clinical Assays	Fiselier et al., 1984 [7]
3–5 y	0–100			0.31–1.86[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
4–8 y	0–100			0.14–.22[b, c, t]	direct RIA			0.69–7.09[b, c, t]	Angiotensin I RIA, Clinical Assays	Fiselier et al., 1984 [7]
5–7 y	0–100			0.50–1.91[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
<8y	2.5–97.5	0.003–0.547[b, c, d, e]	Soldin et al., 2009 [2]							
7–11 y	0–100			0.28 –1.72[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
11–15 y	0–100			0.39–2.44[b, c, s]	chromatography + RIA					Sippell et al., 1980 [7]
8–16 y	0–100			0.11–0.61[b, c, t]	direct RIA			0.69–5.86[b, c, t]	Angiotensin I RIA, Clinical Assays	Fiselier et al., 1984 [7]
8–18 y	2.5–97.5	0.006–0.555[b, c, d, e]	Soldin et al., 2009 [2]							
18–65 y	2.5–97.5			<0.138–0. 670[c, u] males	ICMA, IDS-iSYS	0.13–1.47[c, u] males	ICMA, IDS-iSYS			O'Shea et al., 2016 [7]
18–65 y	2.5–97.5			<0.138–1.179[c, u] females	ICMA, IDS-iSYS	<0.12–0.89[c, u] females	ICMA, IDS-iSYS			O'Shea et al., 2016 [7]
18–77 y	2.5–97.5	0.02–0.67[b, e, i, s] female	Eisenhofer et al., 2017 [8]							
18–81 y	2.5–97.5	0.01–0.45[b, e, s] males	Eisenhofer et al., 2017 [8]							
20–70 y	2.5–97.5			0.035–0.827[b, c, e, u]	RIA Coat-a-Count®; Siemens	0.08–0.66[b, c, e, u]	Renin III Generation®; Cisbio	0.10–2.35[b, c, e, u]	REN-CT2®; Cisbio	Kerstens et al., 2011 [7]
20–70 y	2.5–97.5			0.030–0.640[u]	RIA Coat-a-Count, DPC			<0.23–5.77[u]	RIA by Hollemans et al., 1969	Baas et al., 2003 [7]

To convert Al from nmol/L to ng/mL and PRA from nmol/L/h to ng/mL/h, divide by 2.774 and by 0.77, respectively. To convert PRC from pmol/L to pg/mL divide by 0.0237. LRL, low reference limit; URL, upper reference limit; LC-MS/MS, liquid chromatography-tandem mass spectrometry; y, years; h, hours; d, days; wk, weeks; m, months; RIA, radioimmunoassay; ICMA, immunochemiluminometric assay.

[a] Geographic location according to Table 1. [b] Population not restricted to not obese individuals. [c] Blood withdrawn in not fasting condition or not specified. [d] Blood withdrawal not restricted to the morning or not specified. [e] Plasma specimen or not specified. [i] Oral contraceptive not excluded or not specified. [s] Blood withdrawn in supine position unrestrained activity. [t] Blood withdrawn in supine position after 3 h rest. [u] Blood withdrawn in sitting position after 10–15 min rest.

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