Saliva Reference Range Determination

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Introduction

This document describes the methodology used by ZRT in determining reference ranges for saliva tests. See ZRT's Saliva Observed Reference Ranges on Page 25.

For physicians and patients to obtain maximum clinical relevance from their ZRT Laboratory results, accurate and appropriate reference ranges must be provided. In classical laboratory work, reference ranges are determined by looking at a relatively large number of normal subjects with respect to the analyte of interest. A reference range is usually determined statistically by using the average value plus and minus two standard deviations. Theoretically, this range represents 90 percent of the population (5^{th} to 95^{th} percentile) as shown in Figure 1.

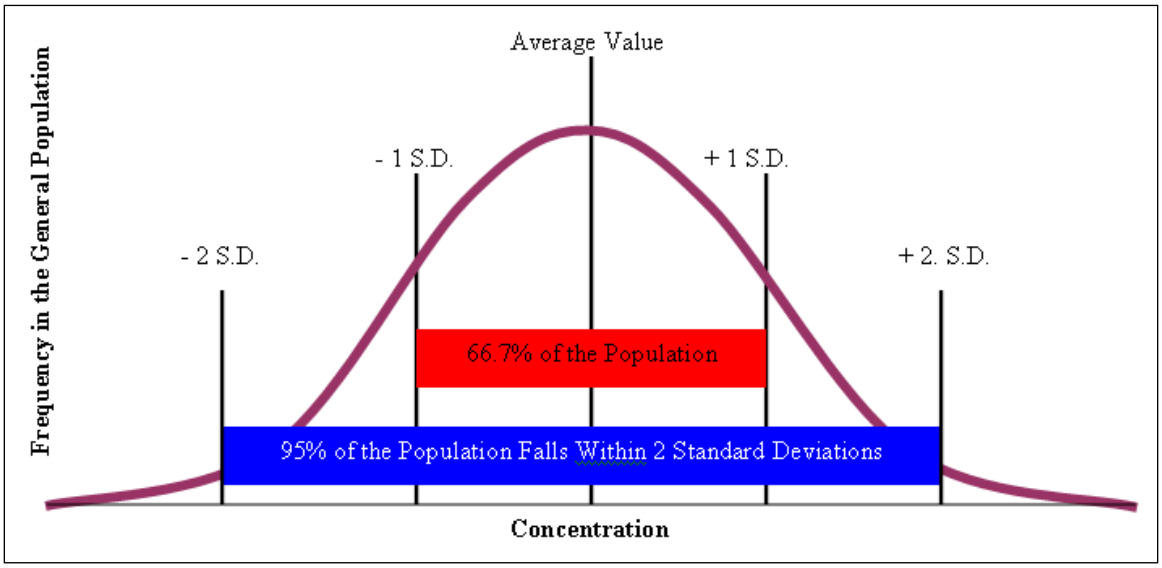

Figure 1. Reference Range Determined Using Average Value Plus and Minus Two Standard Deviations

The above approach to determining "normal" ranges is effective when testing patients for conditions that are present in less than five percent of the population; however, this method is insufficient for conditions found in a larger percentage of the population.

Cortisol testing, in cases of suspected Cushing's Disease or Addison's Disease, is an example in which results would be expected to fall outside two standard deviations of the average in the general population. This is true whether cortisol is measured in urine, blood serum, or saliva.

Conversely, stress-related adrenal dysfunction is more difficult to screen for with standard reference ranges. Low cortisol levels associated with severe fatigue and other stress-related symptoms, as seen in a significant percentage of patients testing with ZRT, suggest that inadequate stress hormone production affects many more patients than those who fit the criteria for Addison's Disease. This makes determining the normal cortisol reference range difficult. Classical methods for determining reference ranges may lead to many individuals labeled as "normal" when in fact they may have cortisol-related symptoms that could be addressed with tighter reference ranges. An example of this concept is measurement of methylmalonic acid in determining Vitamin B12 deficiency.

Methylmalonic Acid: An Example of the Ineffectiveness of Classical Reference Ranges

Urinary methylmalonic acid (MMA) is a marker for Vitamin B12 deficiency. It is an example of how a reference range determined by the mean plus and minus two standard deviations can be inadequate to screen for pathology. MMA is not related to any of the hormones measured by ZRT Laboratory, but directs us away from a one-size-fits-all style with respect to reference ranges in clinical laboratory work. Consider the following:

- When the body has insufficient levels of Vitamin B12, methylmalonic acid (MMA) in serum and urine increases.
- Many people in the general population, and nearly 20 percent of the elderly, have decreased levels of Vitamin B12.
- 20 percent of the population has a genetic defect that negatively affects the body's ability to deliver B12 to cells even if a "normal" level is present. (This fact makes MMA a better marker than B12.)
- Urinary levels of MMA are reported in micrograms per milligram of creatinine (to normalize for hydration); simply put, creatinine is involved in the reporting of MMA.
- Creatinine levels decrease with age making age-dependent reference ranges a necessity.

Goal

- Determine an appropriate reference range for urinary MMA in the elderly.
  Note: This is not a ZRT goal, but simply an analogy for our reference range philosophy.

Problem

- At least 20 percent of the population may be B12 deficient due to genetic defect. Of the remaining 80 percent, up to 20 percent of those may be B12 deficient due to an actual B12 deficiency. Therefore, it is possible that 36 percent of the total population has a B12 deficiency.
- Without genetic and serum B12 screening, the 36 percent of the population that may be B12 deficient could be included in the reference range study.
- Using a classical interpretation of a reference range, only 5 percent of the population would be classified as having an elevated urinary MMA (and, therefore, low B12 status).

Possible Solutions

- Use classic reference ranges and deliver a possible 86 percent false-negative rate.
- Abandon MMA measurements in exchange for genetic screening AND Vitamin B12 measurements – very expensive and completely impractical for patient and physician.
- Adjust the "normal" range for more clinically useful results.

Laboratories measuring urinary MMA have adjusted their reference range philosophy using a cut-off of the 80th percentile instead of two standard deviations. Ultimately, reference ranges include a degree of arbitrariness, and can never include 100 percent of those with a particular condition or exclude 100 percent of those without.

ZRT Reference Range Philosophy

A classical reference range is often of limited clinical utility. If using this approach (average, +/- two standard deviations), premenopausal estradiol reference ranges would be 0.0 – 5.0 pg/ml. If instead of this approach, we use a more aggressive reference range such as that used for urinary methylmalonic acid in the previous example, a range of 1.3 – 3.3 pg/ml is derived. By examining clinical symptoms that accompany the patient results, we can show that using the 20th and 80th percentiles gives a more clinically useful range. With respect to women's hot flash severity, as well as other estrogen-related conditions, symptoms are at their peak at estradiol levels of <1.0 pg/ml. Symptoms subside considerably as the estradiol rises to around 1.3 pg/ml. Similarly, breast tenderness is a symptom related to excessive estradiol (see Figure 4) and peaks at an estradiol of approximately 3.3 pg/ml. The idea of balancing a woman's hormone level to optimize both estrogen deficiency and estrogen excess-related symptoms is not possible when utilizing a classical reference range. A range of 1.3 – 3.3 pg/ml can be more clinically useful than the classic two standard deviation range, within which the entire rise and fall of the related symptoms occur.

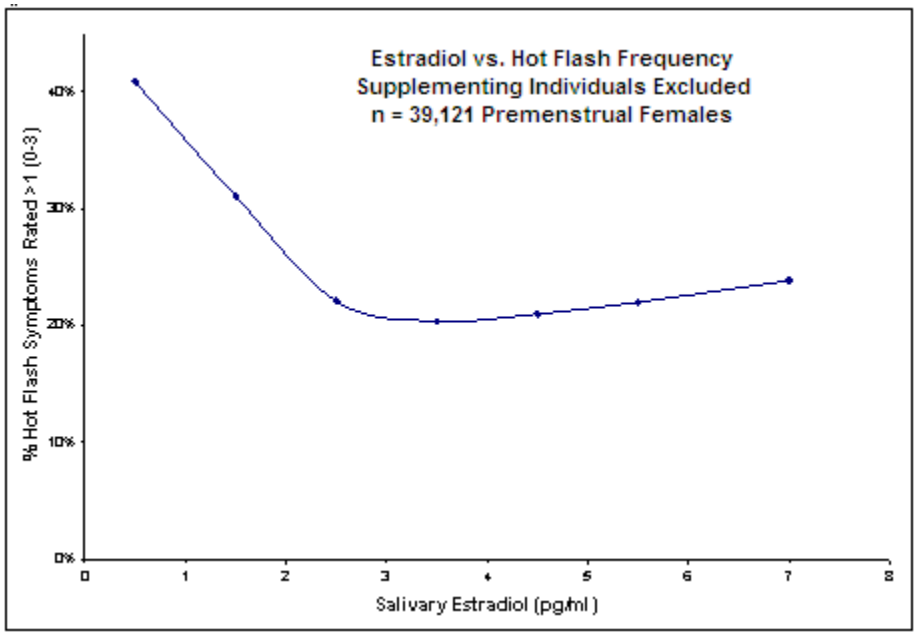

Figure 2. Hot Flash Frequency vs. Salivary Estradiol Levels

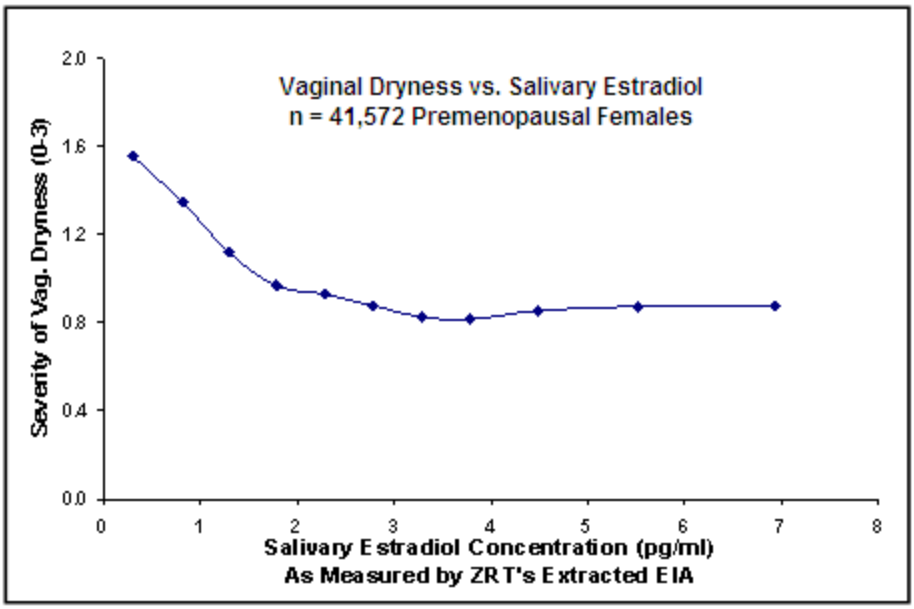

Figure 3. Vaginal Dryness vs. Salivary Estradiol Levels

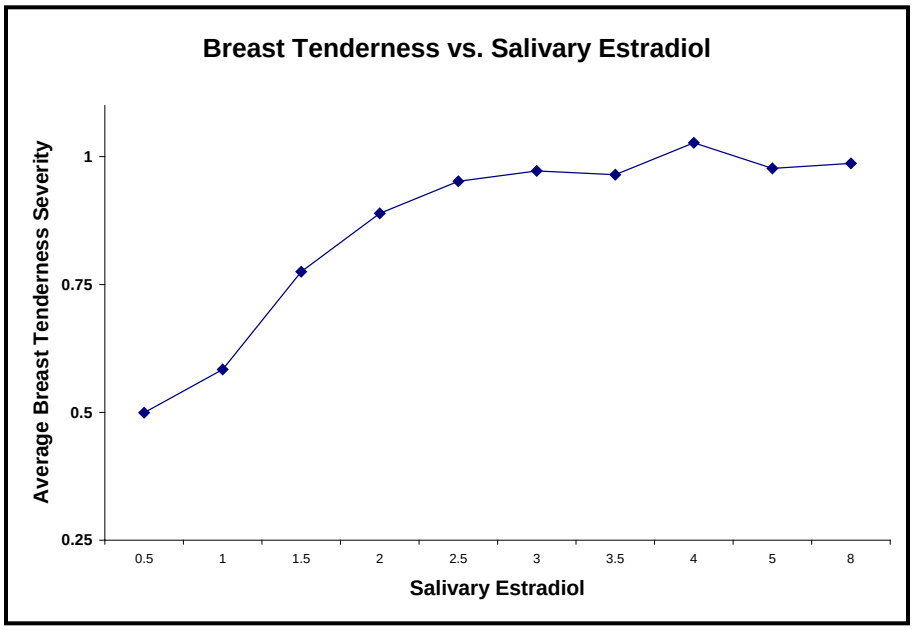

Figure 4. Breast Tenderness vs. Salivary Estradiol Levels

Importance of Considering Symptoms When Determining Ranges

When normal hormone ranges are determined, individuals with hormone-related symptoms and conditions must be excluded. Reference ranges for testosterone, for example, would be inappropriately determined for premenopausal females if individuals with Polycystic Ovarian Syndrome (PCOS) or androgen-excess symptoms are not excluded.

All samples submitted to ZRT include a comprehensive, hormone-related symptom list. Patients fill out the symptom section, scoring the severity of symptoms (0-3 scale). Individuals with androgen-excess symptoms (e.g., increased facial/body hair or acne) were excluded when the female testosterone range was determined. See Figure 5.

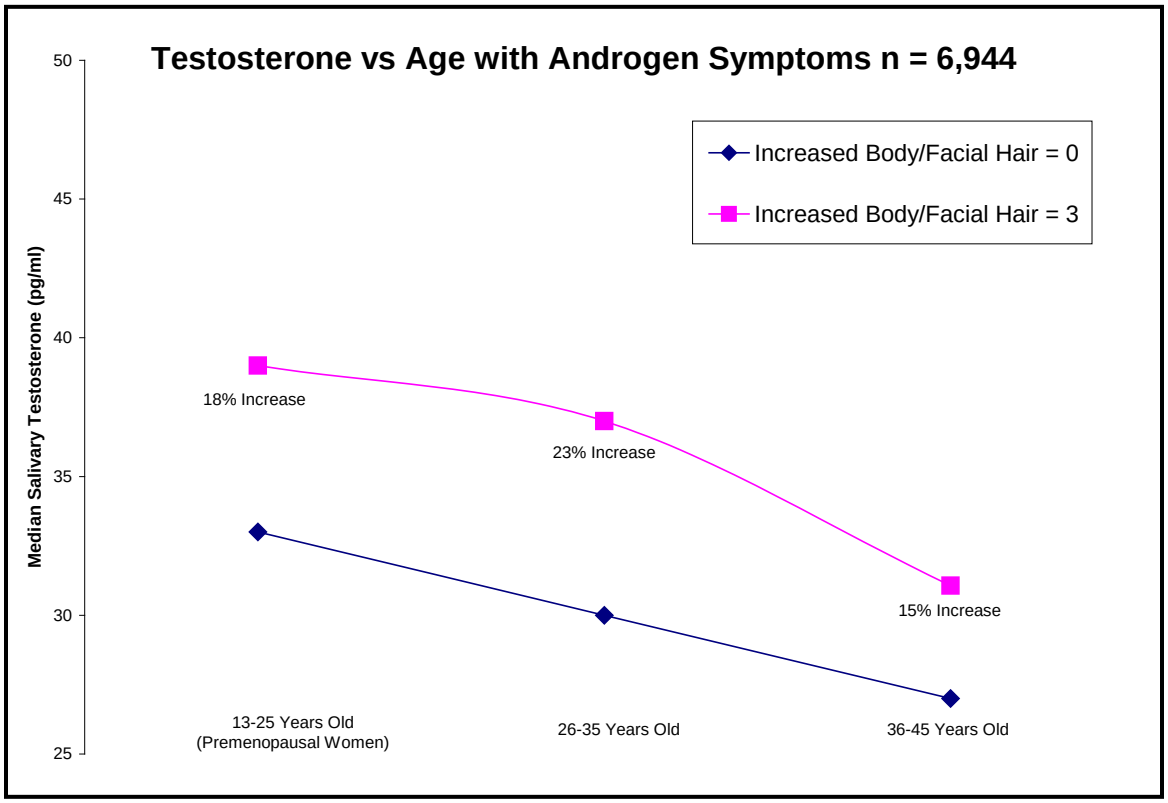

Figure 5. Testosterone Values for Premenopausal Women with and Without Androgen-Excess Symptoms

The following exclusions were made for reference and optimal range determinations:

Table 1. Exclusions Made for Reference and Optimal Hormone Range Determinations

Hormone	Exclusions
Cortisol	• Stress >1 • Morning Fatigue >1 • Evening Fatigue >1
Estradiol	• Hot Flashes >1 • Vaginal Dryness >1 • Urinary Incontinence >1
Progesterone	• Tender Breasts >1 • Fibrocystic Breasts >1 • Uterine Fibroids >1
Testosterone	• Increased Body and Facial Hair >1 (women only)
All Hormones	Individuals with symptoms of hormone deficiency or excess for the hormone ranges in question

Consideration of all relevant variables was made when establishing optimal and reference ranges. The actual approach to assessing each range is complicated, involving many variables. Each hormone has been considered independently to achieve clinical usefulness. Following is a description of the philosophy and statistical methods used for the determination of reference range determination for each salivary hormone measured by ZRT.

Even with the exclusion of individuals taking supplementation and those who were excluded due to hormone-related symptoms, the following population sizes were available for the determination of ZRT reference ranges:

Reference Range Sample Sizes

Estradiol – 7,436 women, 11,681 men
Estrone – 1,107 women
Estriol – 1,107 women
Progesterone – 12,157 women, 9,257 men
Testosterone – 1,248 women, 3,021 men
DHEA-S – 10,125 women, 2,910 men
Cortisol – 2,597 (morning sample), 2,265 (noon), 2,261 (evening), and 3,405 (night)

Estradiol

Estradiol production in women is stable throughout most of their reproductive years. During perimenopause, estradiol synthesis begins to decrease, but can also fluctuate significantly. After menopause, estradiol levels remain stable at lower levels. In men, estradiol levels are not age-dependent, and low levels have little clinical significance so the range is broader on the bottom end of the range. The 20th percentile is used for females and the 10th percentile for men.

To eliminate individuals with obvious estrogen-related conditions, women who indicated they had hot flashes, vaginal dryness, or urinary incontinence were excluded.

The tables and figures that follow indicate how estradiol reference ranges were determined.

Table 2. Numerical Data Used for Determining Estradiol Reference Ranges for Women and Men

Group	Mean	Median	– 2 S.D.	+ 2 S.D.	20^{th} Percentile	80^{th} Percentile
Premenopausal	2.3 pg/ml	1.9 pg/ml	0.0	5.0	1.3	3.3
Postmenopausal	1.3 pg/ml	1.0 pg/ml	0.0	3.6	0.5	1.7
Male	1.6 pg/ml	1.3 pg/ml	0.0	3.6	0.5*	2.2

* 10^{th} percentile is used for men

Table 3. Classical vs. Observed Ranges for Estradiol

Group	Classic Reference Range	Observed Range
Male	0 – 3.6 pg/ml	0.5 – 2.2 pg/ml
Premenopausal	0 – 5.0 pg/ml	1.3 – 3.3 pg/ml
Postmenopausal	0 – 3.6 pg/ml	0.5 – 1.7 pg/ml

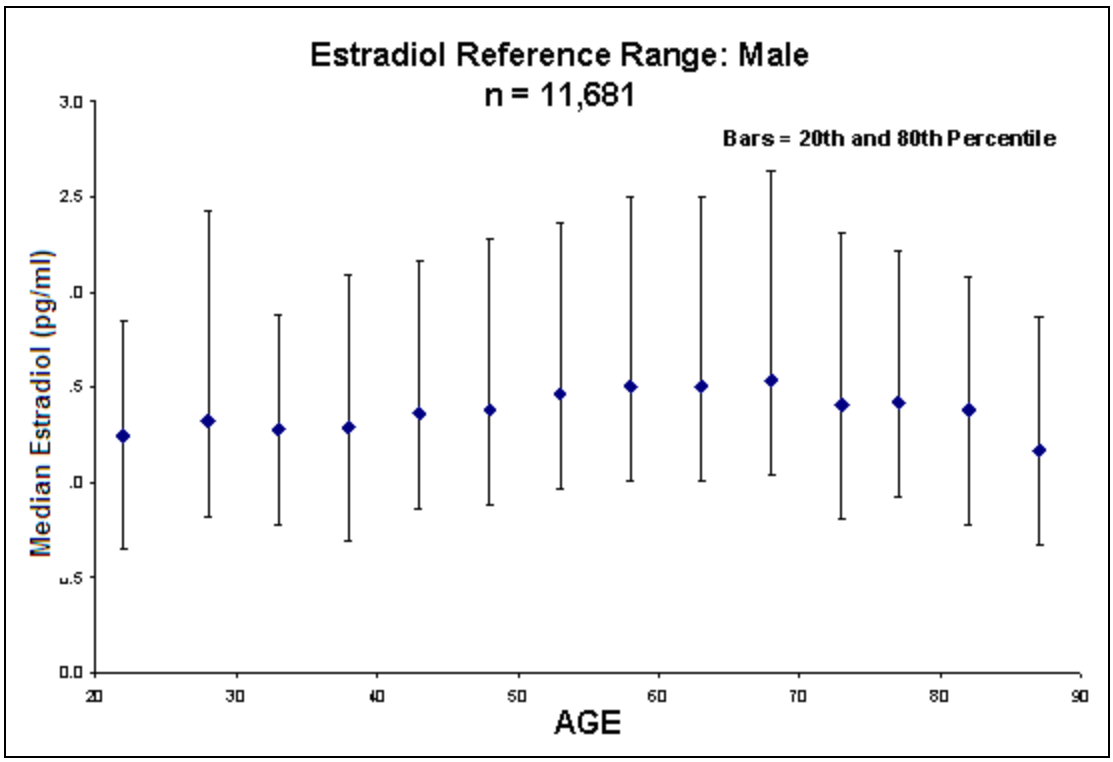

Figure 6. Estradiol Age-Dependent Reference Ranges for Males

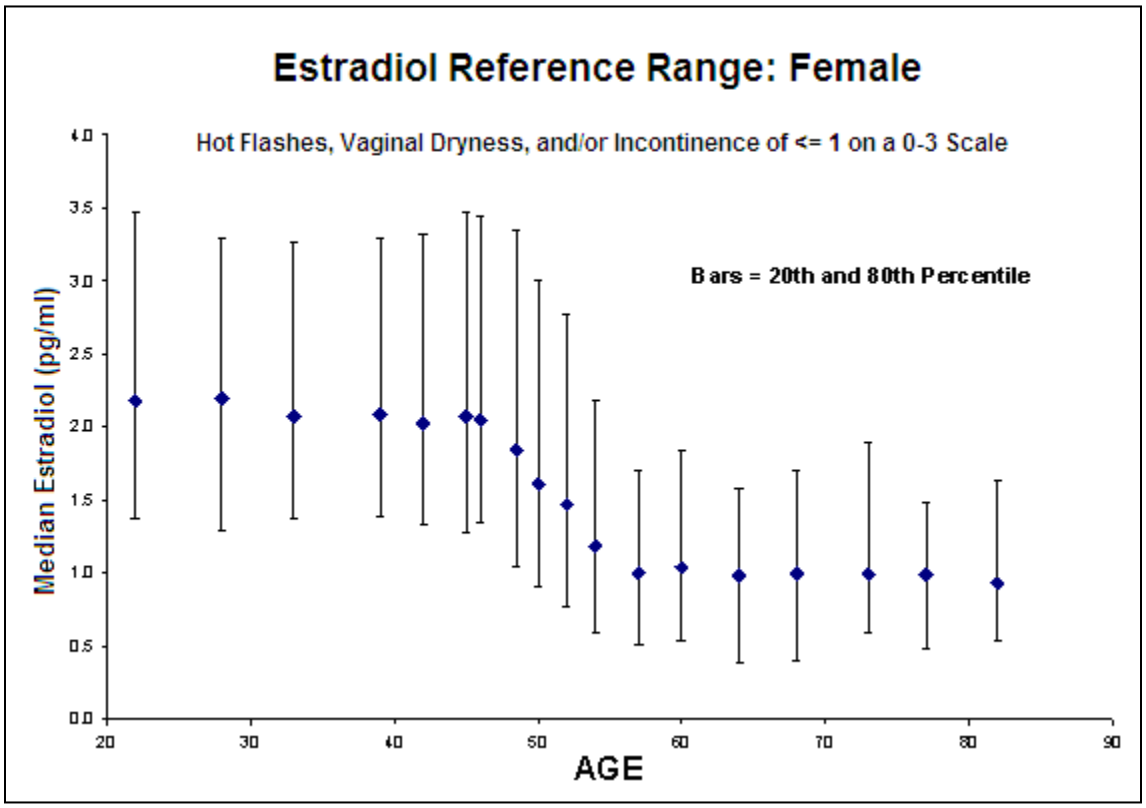

Figure 7. Estradiol Age-Dependent Reference Ranges for Females

Estrone

The philosophy for optimal ranges for estrone parallels that used for estradiol (see Estradiol on Page 11.)

The tables and figure that follow indicate how the estrone reference range was determined.

Table 4. Numerical Data Used for Determining Estrone Reference Range for Premenopausal Women

Group	Mean	Median	- 2 S.D.	+ 2 S.D.	20th Percentile	80th Percentile
Premenopausal	3.4 pg/ml	2.5 pg/ml	0.0	9.0	1.6	5.0

Table 5. Classical vs. Observed Ranges for Estrone

Group	Classic Reference Range	Observed Range
Premenopausal	0 – 9.0 pg/ml	1.6 – 5.0pg/ml

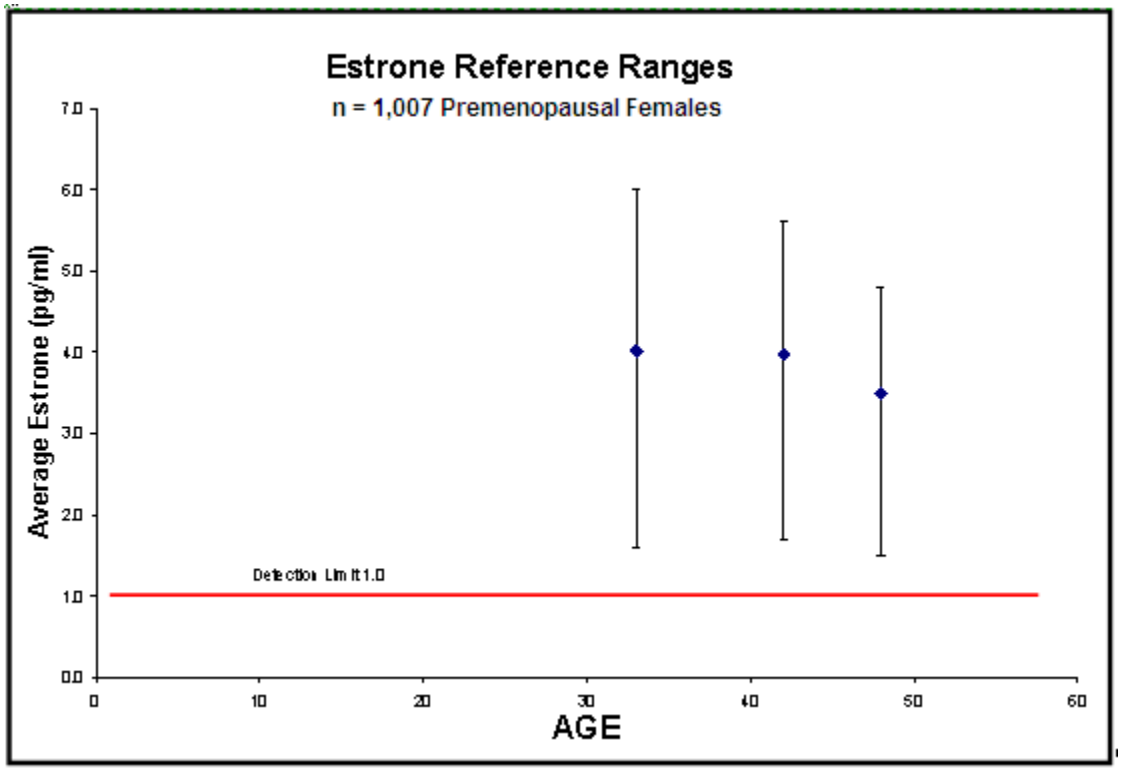

Figure 8. Estrone Age-Dependent Reference Ranges for Females

Estriol

The analytical performance for estriol is less precise at low concentrations than for the other estrogens. Therefore, estriol testing may be more useful for monitoring supplementation rather than for determining endogenous production. Estriol testing may also be desired during pregnancy when endogenous production increases.

The tables and figure that follow indicate how the estriol reference range was determined.

Table 6. Numerical Data Used for Determining Estriol Reference Ranges for Non-pregnant, Pre-menopausal Women

Group	Mean	Median	– 2 S.D.	+ 2 S.D.	20th Percentile	80th Percentile
Non-pregnant, Premenopausal	3.0 pg/ml	2.7 pg/ml	0.0	7.0	1.3	3.9

Table 7. Classical vs. Observed Ranges for Estriol

Group	Classic Reference Range	Observed Range
Non-pregnant, Premenopausal	0 – 7.0 pg/ml	0 – 7pg/ml

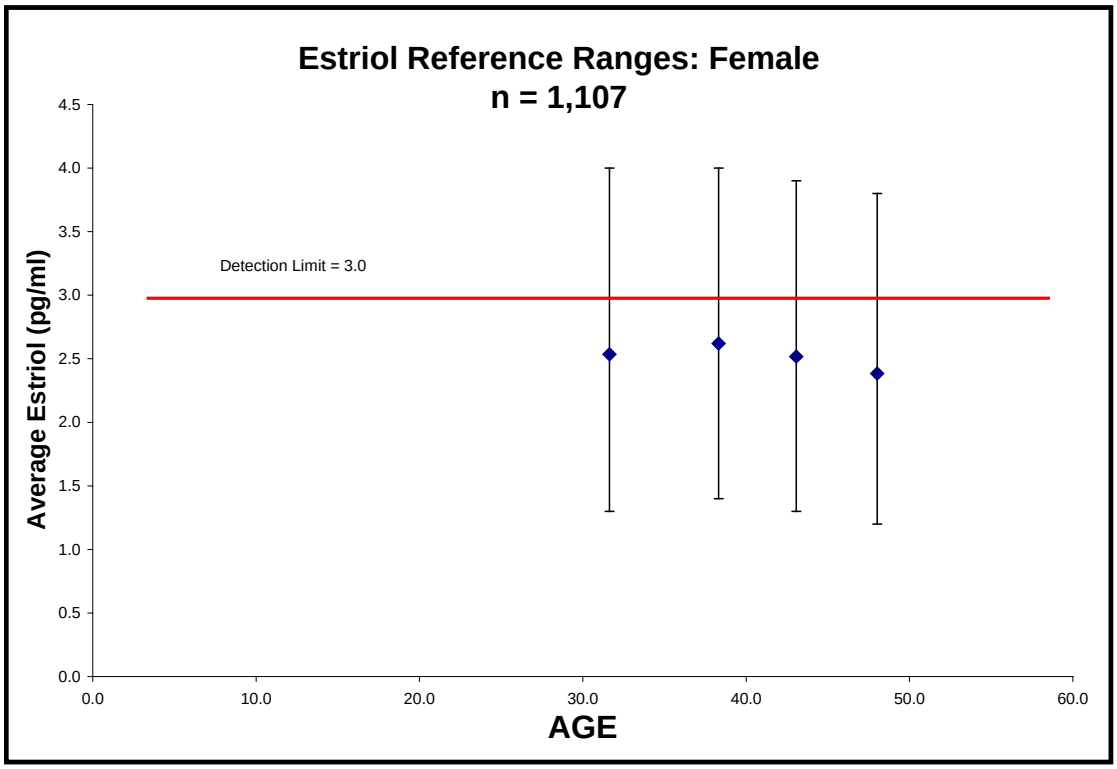

Figure 9. Estriol Age-Dependent Reference Ranges for Females

Progesterone

The consensus from the literature is that mid-luteal salivary progesterone levels are approximately 150 pg/ml +/- 100 (see Figure 10 below). ZRT has noted similar results, but the issue of sample exclusion is uniquely difficult for progesterone.

In women, progesterone is made mainly by the corpus luteum following ovulation. Levels rise to their maximum value (in non-pregnant women) around days 19-21 of the menstrual cycle, which is when ZRT recommends sample collection in premenopausal women. It is difficult to determine whether or not ovulation has occurred in any given cycle. Literature review suggests that the rate of anovulation for any given cycle is as high as 50 percent. If the results of women who do not ovulate in the month of collection are included in a reference range study, the range will be skewed toward the low end, and will not accurately reflect mid-luteal, expected progesterone levels. Based on the combined information in the literature, and the ZRT database, women with a progesterone of <60 pg/ml were considered to be either anovulatory or not collecting during the luteal phase peak.

Women who had undergone hysterectomy or who suffered from classical progesterone deficiency symptoms (e.g., fibrocystic breast changes, breast tenderness, or uterine fibroids) were excluded from the reference range determination. Due to lack of related conditions with respect to moderately elevated progesterone, a less aggressive cutoff was used for the upper end of normal. Likewise, a slightly higher cutoff was utilized for the low end of the observed range for postmenopausal women.

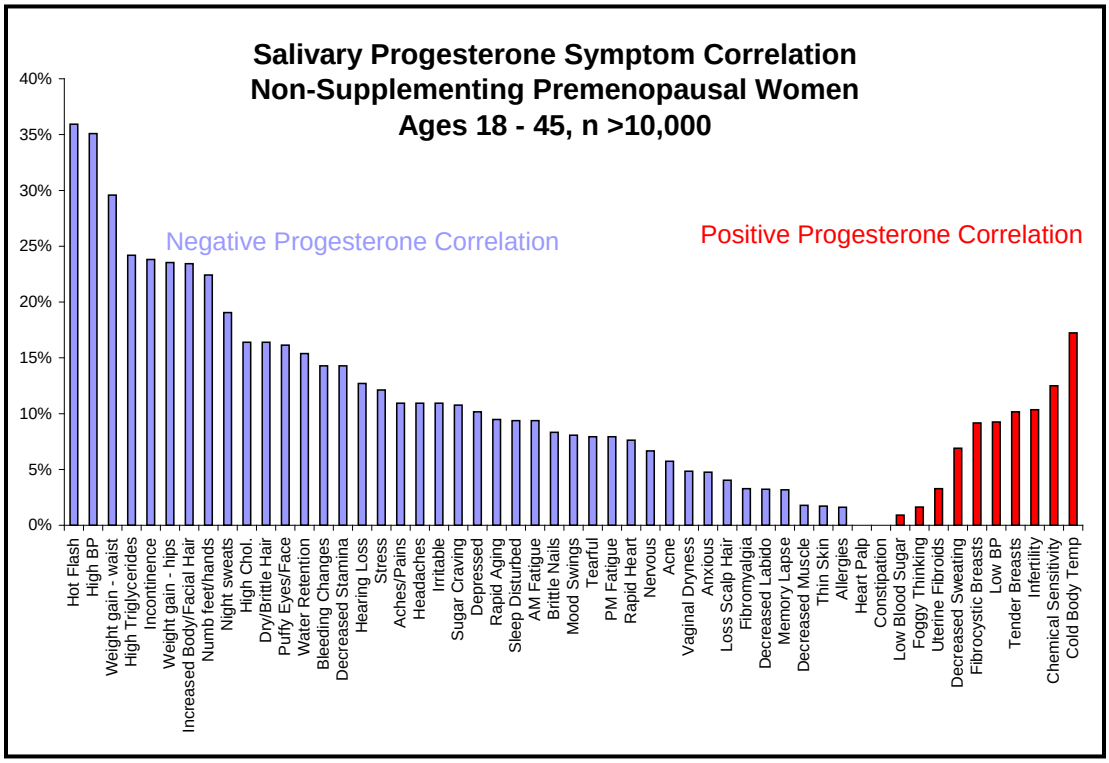

Figure 10. Progesterone Correlation with Symptoms Weighted More Toward Progesterone Deficiency

The tables and figures that follow indicate how the progesterone reference ranges were determined.

Table 8. Numerical Data Used for Determining Progesterone Reference Ranges for Women and Men

Group	Mean	Median	– 2 S.D.	+ 2 S.D.	20th Percentile	80th Percentile	90th Percentile
Luteal Premenopausal	87 pg/ml	61 pg/ml	0	275	75	180	270
Postmenopausal	36 pg/ml	18 pg/ml	0	133	12*	50	100*
Men	44 pg/ml	24 pg/ml	0.0	146	15**	52	100**

Table 9. Classical vs. Optimal Ranges for Progesterone by Gender

Group	Classic Reference Range	Observed Range
Premenopausal	0 – 275 pg/ml	75 – 270 pg/ml
Postmenopausal	0 – 133 pg/ml	12 – 100 pg/ml*
Male	0 – 146 pg/ml	15 – 100 pg/ml**

* Actual population percentiles were 30th and 93th percentile
** Actual population percentiles were 30th and 87th percentile

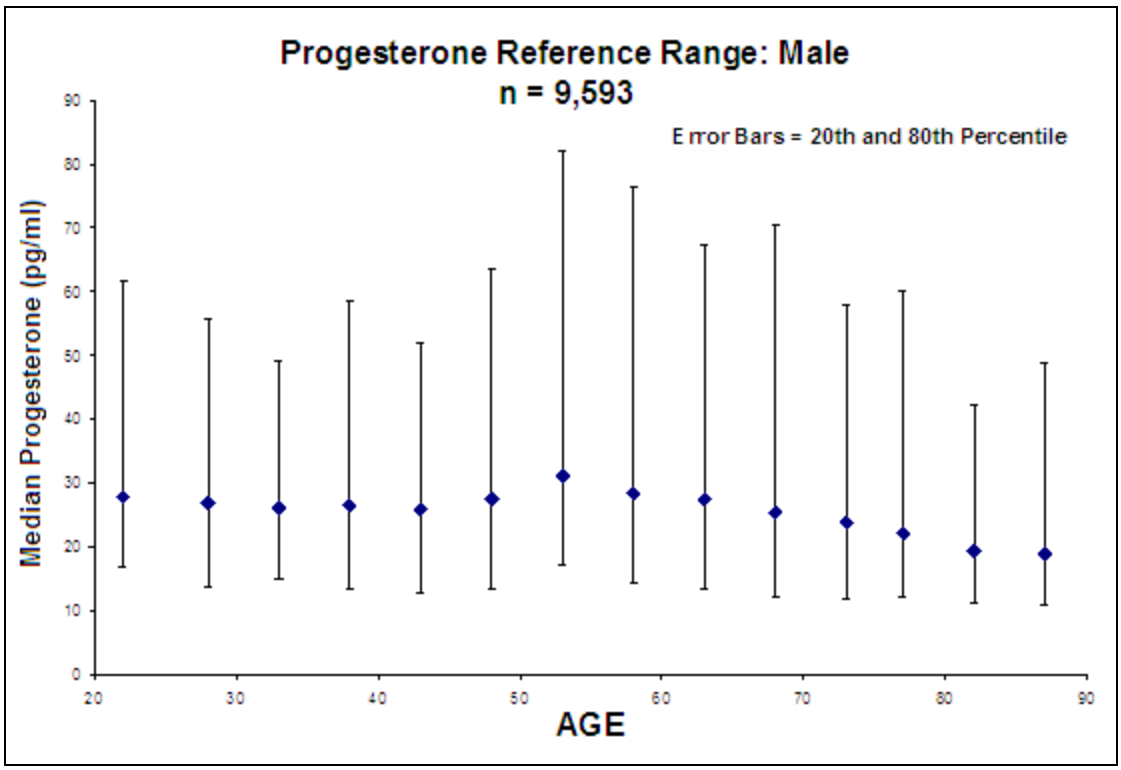

Figure 11. Progesterone Age-Dependent Reference Ranges for Males

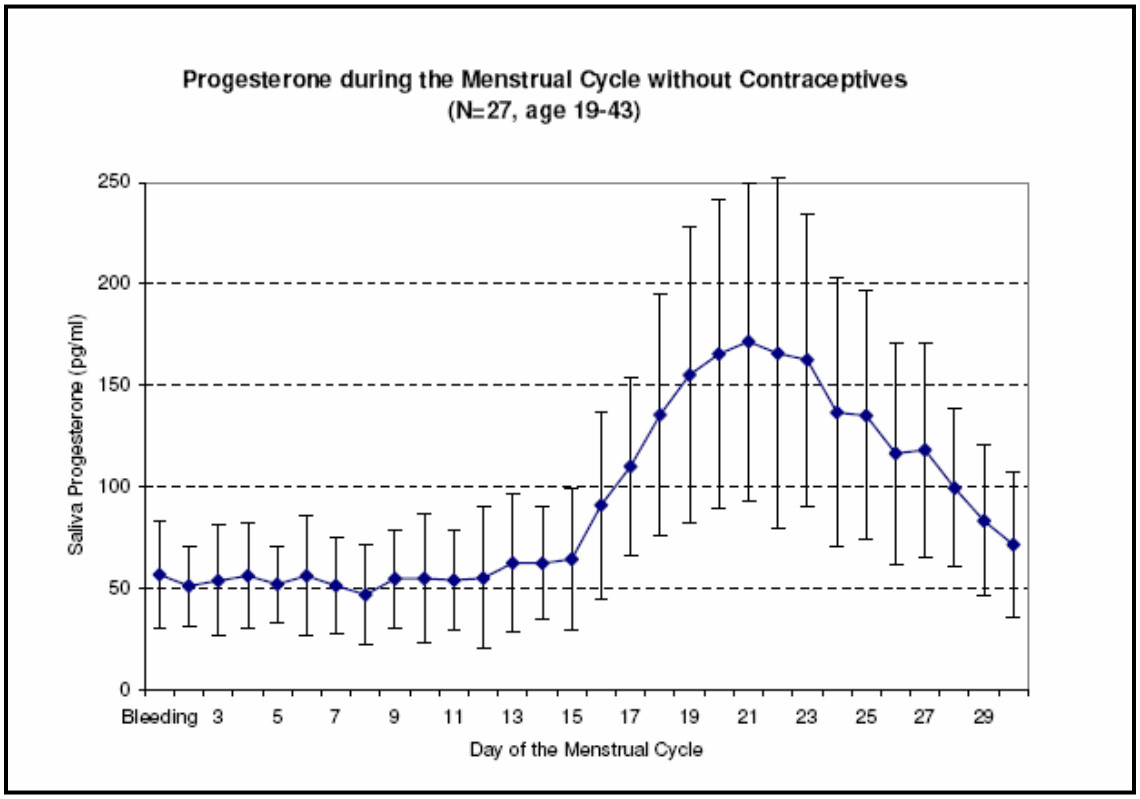

Figure 12. Progesterone During the Menstrual Cycle Without Contraceptives (IBL 2006)

Testosterone

Testosterone levels decrease with age in both men and women. For women, many samples may be submitted from those with androgen-excess symptoms such as increased facial/body hair or acne. To exclude these individuals, only women with a score of ≤1 (for a 0–3 scale) was allowed for those symptoms for premenopausal women ages 16-45.

The tables and figures that follow indicate how the testosterone reference ranges were determined.

Table 10. Numerical Data Used for Determining Testosterone Reference Ranges by Gender

Group	Mean	Median	– 2 S.D.	+ 2 S.D.
Male	73 pg /ml	69 pg /ml	0.0	140

Table 11. Female and Male Testosterone Ranges

FEMALE	2 S.D. Ranges		Observed Ranges	
	-2 S.D.	+2 S.D.	20th %	80th %
16-30	0.0	88.0	18.0	55.0
>31	0.0	60.2	16.0	40.0
All	0.0	74.1	16.0	55.0
All results in pg/ml				

MALE	2 S.D. Ranges		Observed Ranges	
	-2 S.D.	+2 S.D.	20th %	80th %
18-30	18	205	72	148
31-50	11	159	58	120
51-70	1	128	44	94
>70	0	112	30	77
All	0	140	44	148
All results in pg/ml				

Table 12. Classical vs. Optimal Ranges for Testosterone by Gender

Group	Classic Reference Range	Optimal Range
Male	0 – 140 pg/ml	44 – 148 pg/ml
Female	0 – 74 pg/ml	16 – 55 pg/ml

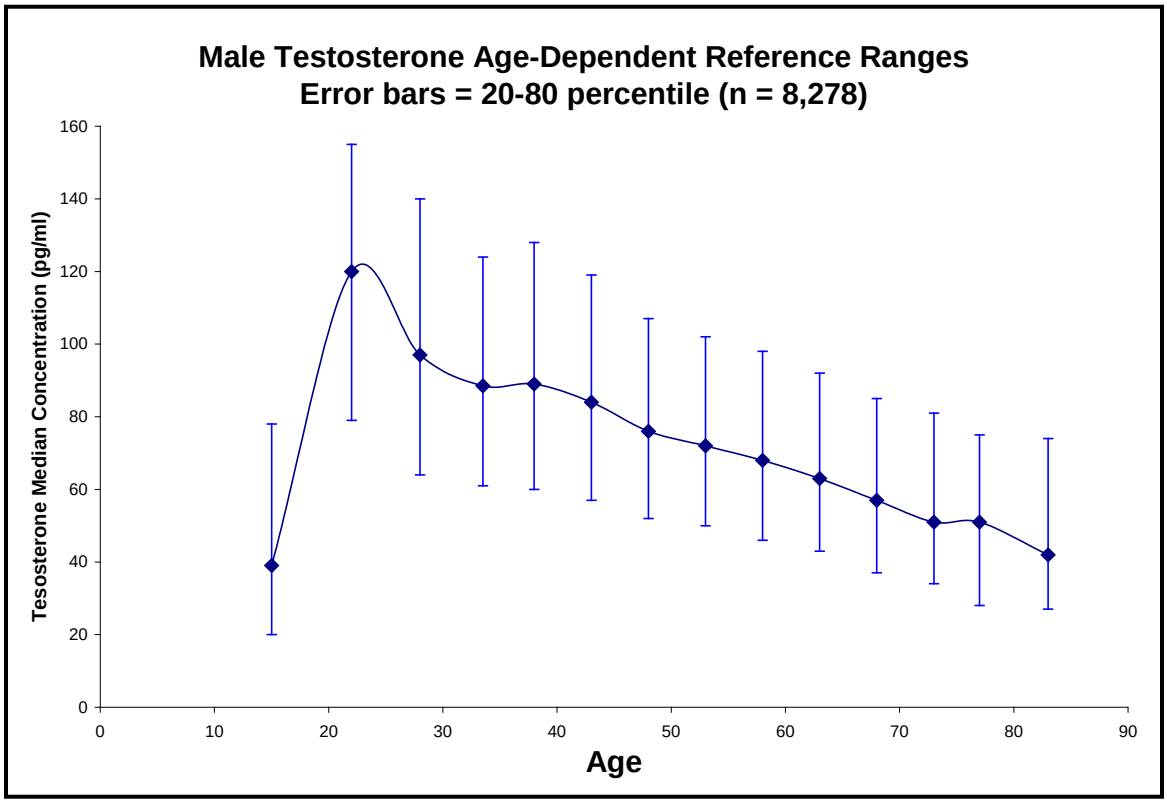

Figure 13. Testosterone Age-Dependent Reference Ranges for Males

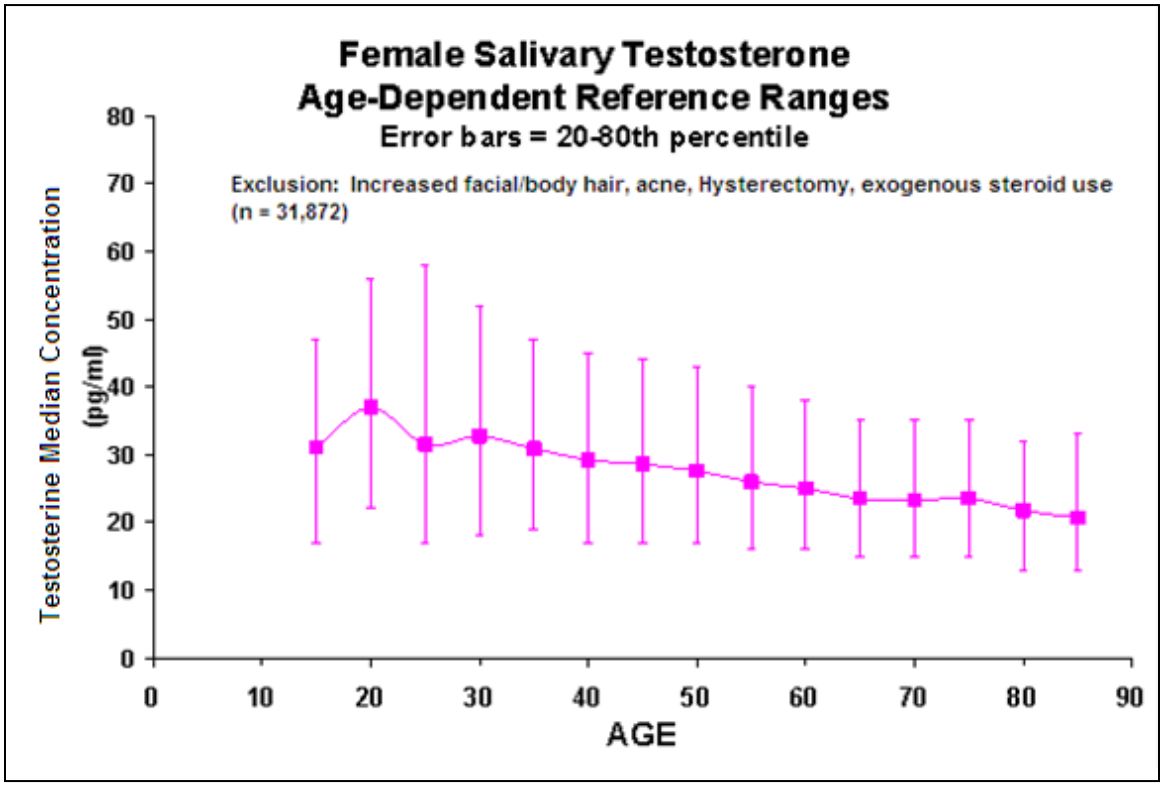

Figure 14. Testosterone Age-Dependent Reference Ranges for Females

DHEA-S

DHEA levels are known to decline rapidly throughout the day. Since DHEA-S is much more slowly metabolized, it serves as a better marker for overall DHEA production, and is, therefore, the analyte tested by ZRT.

DHEA-S is known to decrease with age.[1] This decline makes the process of developing reference ranges challenging. An endogenous DHEA-S level of 13.3 is "normal" for a 20-year-old yet is found in only 5-10 percent of elderly males and less than 2 percent of elderly females.

Although it may seem obvious that DHEA-S levels should be reported in gender and age-specific reference ranges, the purpose of testing should also be addressed. The decline in DHEA-S with age is accompanied by an increase in related symptoms commonly seen in the aging population. These symptoms may indeed be the reason that patients or their health care providers want to test DHEA-S. In addition, physicians differ in terms of whether they believe a result within an expected age range is normal, or whether a patient's level should be interpreted in the context of younger subjects.

Because the gradual drop in DHEA-S is often associated with symptoms of aging, a classic reference range using the mean +/- 2 standard deviations has little clinical utility. A tighter range with age and gender breakdowns was used (20^{th} to 80^{th} percentile).

The tables that follow indicate how the DHEA-S reference ranges were determined.

Table 13. Numerical Data Used for Determining DHEA-S Reference Ranges for Women and Men

Group	Mean	Median	– 2 S.D	+ 2 S.D.
Female	7.6 ng/ml	5.9 ng /ml	0.0	15.7
Male	10.3 ng/ml	8.3 ng /ml	0.0	22.6

Table 14. Female and Male DHEA-S Ranges

FEMALE	2 S.D. Ranges		Observed Ranges	
	-2 S.D.	+2 S.D.	20th %	80th %
18-30	0.0	25.3	6.4	18.6
31-45	0.0	16.1	3.9	11.4
46-60	0.0	11.3	2.7	8.0
61-75	0.0	7.8	1.9	5.6
All	0.0	15.7	2.0	19.0
All results in ng/ml				

MALE	2 S.D. Ranges		Observed Ranges	
	-2 S.D.	+2 S.D.	20th %	80th %
18-30	0.0	31.5	8.4	23.0
31-45	0.0	24.7	6.1	17.8
46-60	0.0	17.0	3.9	11.5
61-75	0.0	14.0	2.4	7.5
All	0.0	22.6	2.0	23.0
All results in ng/ml				

[1] Williams' Textbook of Endocrinology, 2003

Figure 15 and Figure 16 show how DHEA-S decreases with advancing age in women and men.

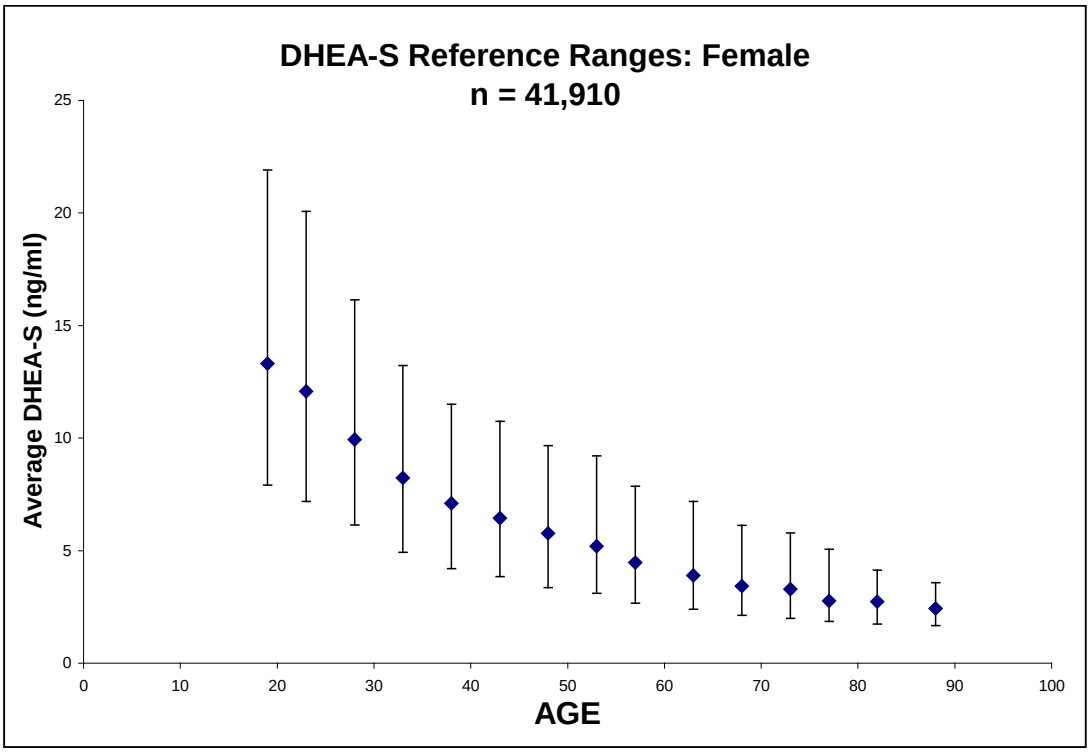

Figure 15. DHEA-S Age-Dependent Reference Ranges for Females

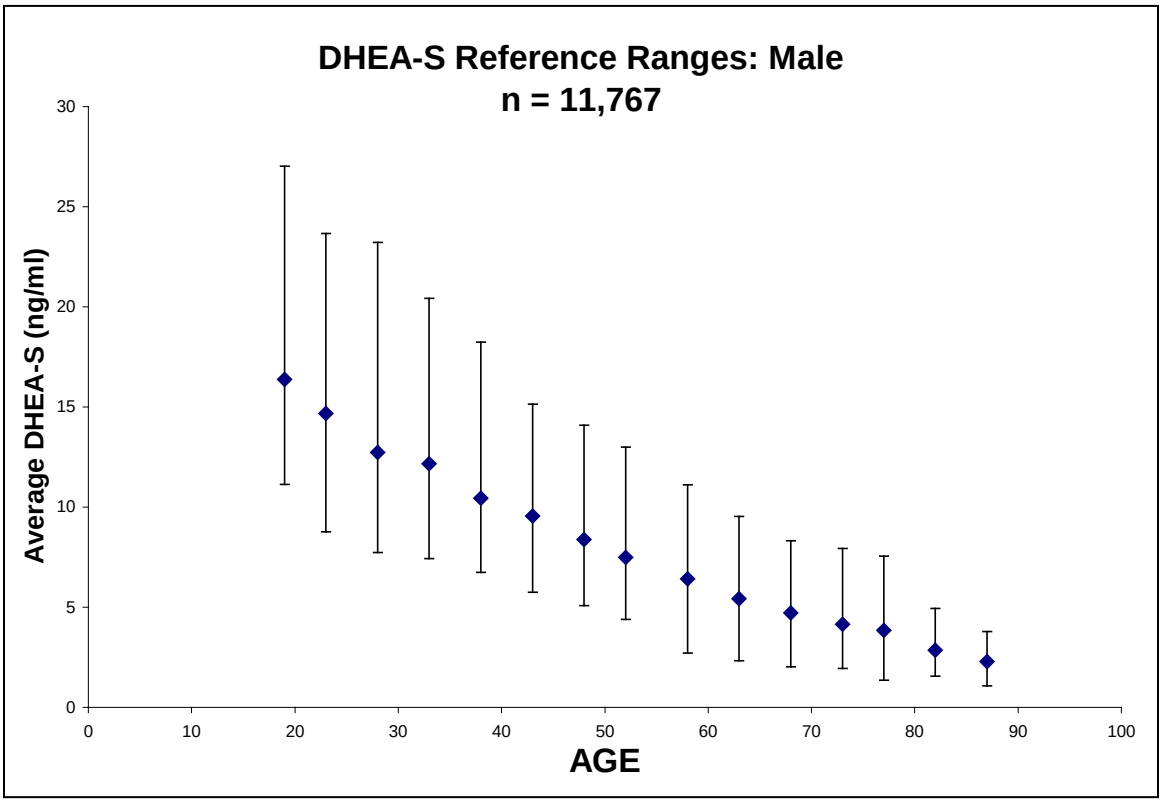

Figure 16. DHEA-S Age-Dependent Reference Ranges for Males

Cortisol

Because of the number of factors affecting adrenal production of cortisol and the high number of people suffering from adrenal dysfunction, tighter reference ranges must be used compared to the classical model. Using the 80th percentile makes the most sense for establishing the high end of the range. With many cortisol-related symptoms able to increase production in some scenarios, and decrease them in others, a symmetrical reference range seems the best choice. Therefore, the 20th percentile mark is used for the low end of the reference ranges for all four cortisol levels measured.

To eliminate those with abnormal cortisol levels, individuals with very high levels of stress and fatigue were eliminated from consideration for C1. Overall, these symptoms were associated with slightly lower (about 4 percent) levels. Symptoms of stress and fatigue were not shown to affect B, C, and D results and were not used for exclusion in B, C, and D range determination. Individuals known to have Cushing's Disease or Addison's Disease were excluded. It is important to include the classically determined ranges for cortisol for the determination of conditions such as Cushing's Disease.

The tables and figures that follow indicate how the cortisol reference ranges were determined.

Table 15. Numerical Data Used for Determining Cortisol Reference Ranges

Test	Mean	– 2 S.D.	+ 2 S.D.	20th Percentile	80th Percentile
C1	6.3 ng/ml	0.0	14.4	3.7	9.5
C2	1.9 ng/ml	0.0	4.6	1.2	3.0
C3	1.1 ng/ml	0.0	3.2	0.6	1.9
C4	0.6 ng/ml	0.0	2.1	0.35	1.0

Table 16. Classical vs. Observed Reference Ranges for Morning, Noon, Evening, and Nighttime Cortisol

Test	Classical Reference Range	Optimal Range
C1	0 – 14.4 ng/ml	3.7 – 9.5 ng/ml
C2	0 – 4.6 ng/ml	1.2 – 3.0 ng/ml
C3	0 – 3.2 ng/ml	0.6 – 1.9 ng/ml
C4	0 – 2.1 ng/ml	0.35 – 1.0 ng/ml

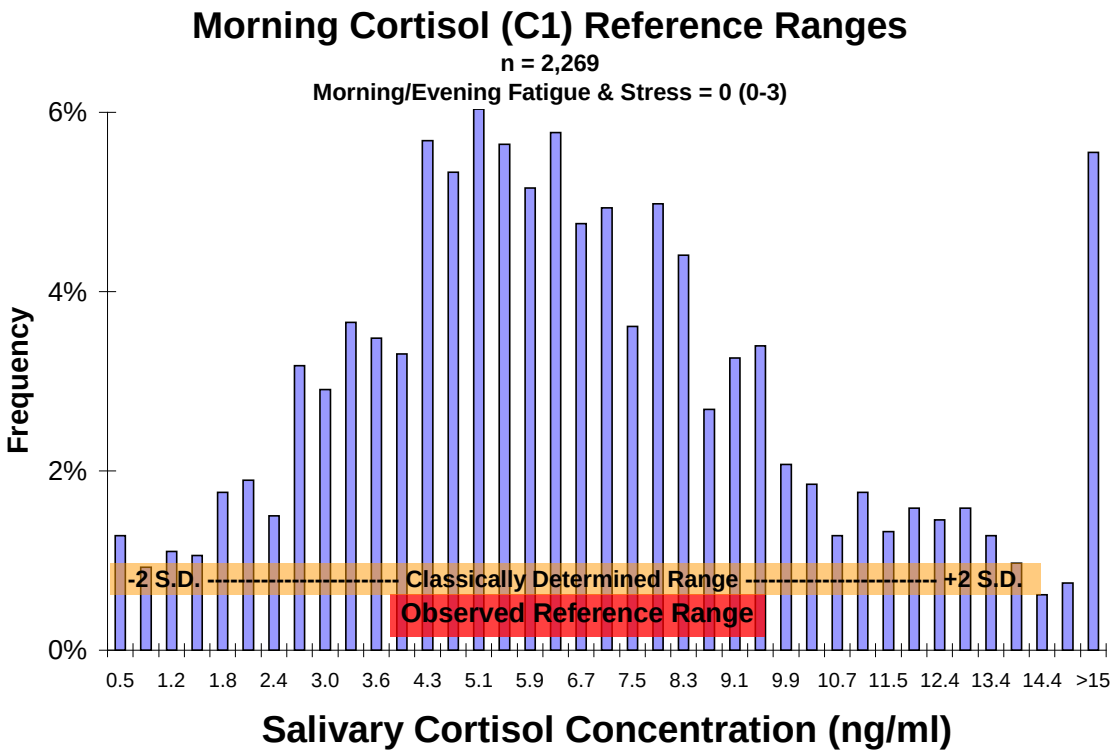

Figure 17. Reference Ranges for C1, Showing Classically Determined Range vs. Observed Range

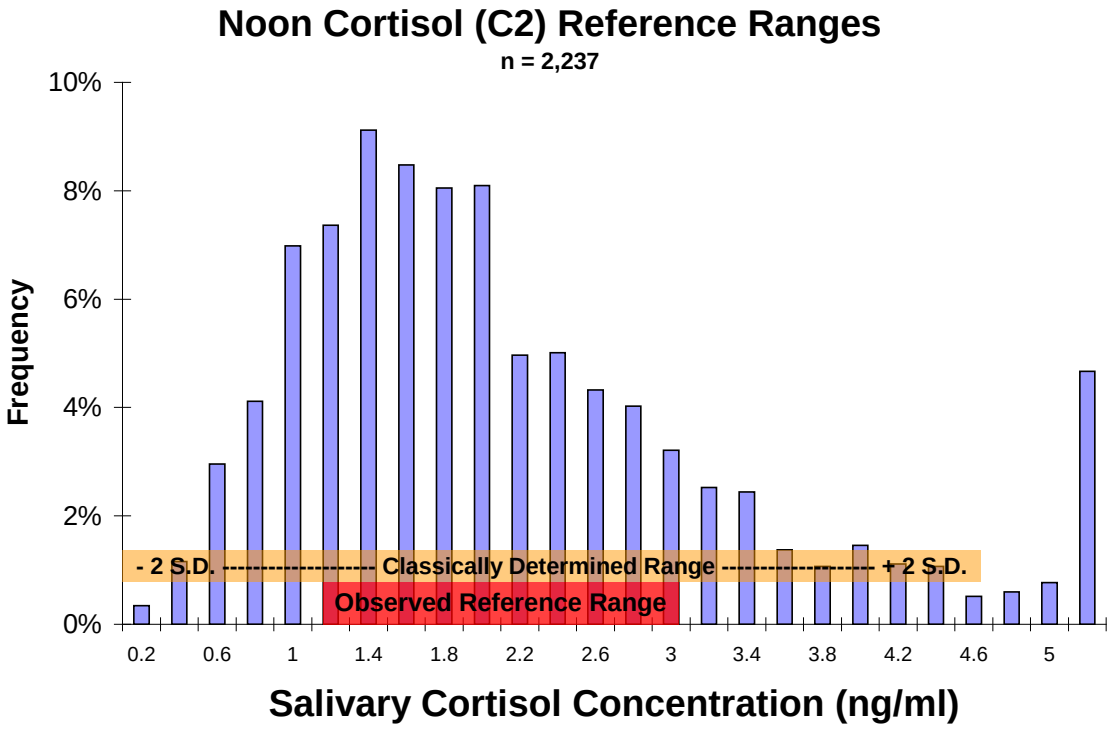

Figure 18. Reference Ranges for C2, Showing Classically Determined Range vs. Observed Range

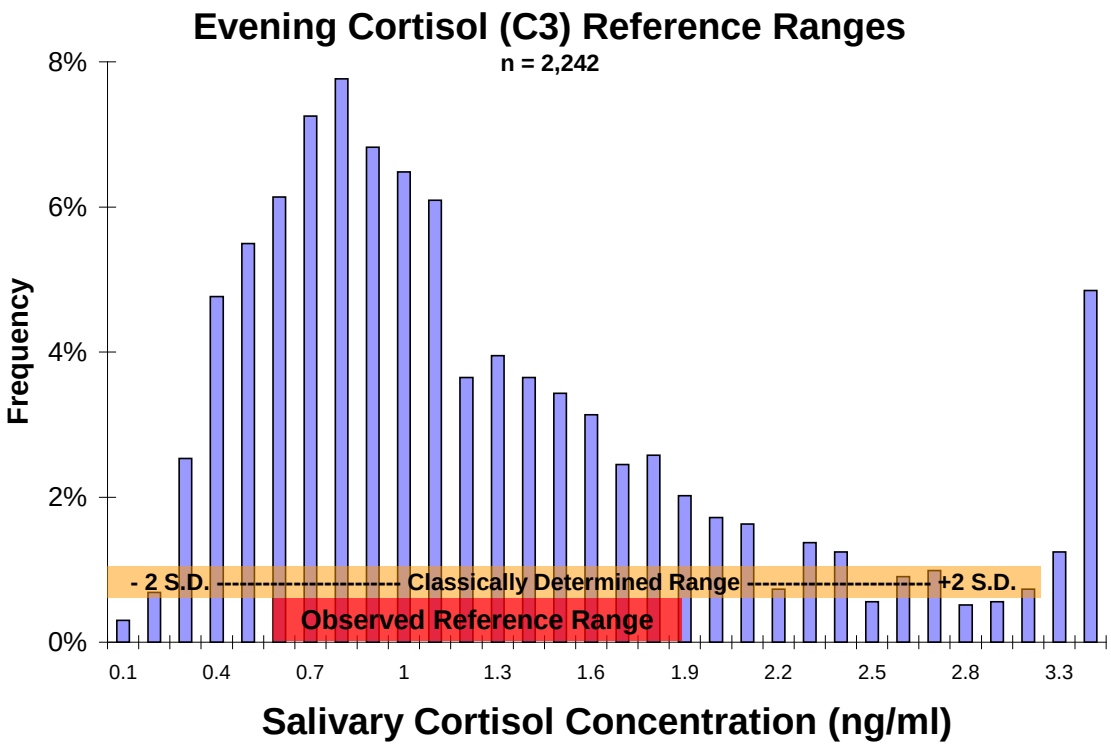

Figure 19. Reference Ranges for C3, Showing Classically Determined Range vs. Observed Range

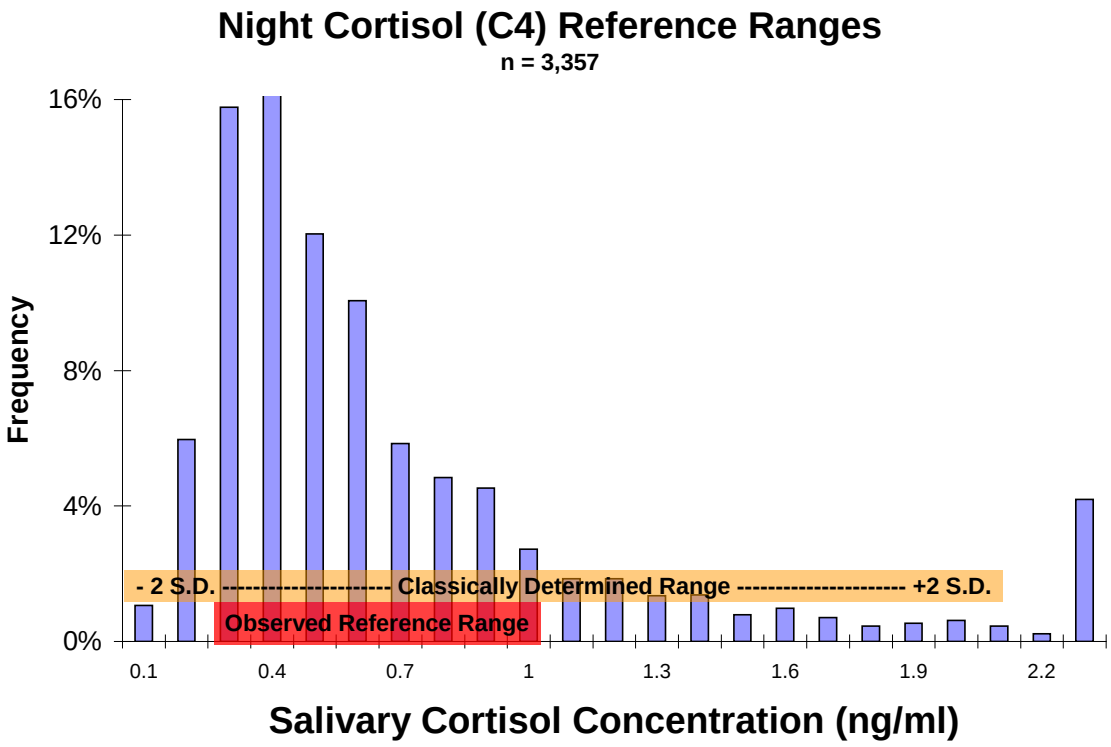

Figure 20. Reference Ranges for C4, Showing Classically Determined Range vs. Observed Range

Saliva Reference Ranges

Disclaimer: Supplement type and dosage are for provider information and are not recommendations for treatment. Reference ranges are observed ranges based on collected laboratory data. For more information, please contact ZRT Laboratory.

Saliva Test	Reference Ranges for WOMEN		Reference Ranges for MEN	
Estradiol (E2) pg/mL	Premenopausal - Luteal	1.3-3.3		0.5-2.2
	Premenopausal - Follicular	0.5-1.7		
	Postmenopausal	0.5-1.7		
	Estrogen Replacement	0.8-12		
	Synthetic HRT, Contraceptive	0.5-2.2		
Estrone (E1) pg/mL	Pre- and Postmenopausal	1.6-5.0		0-3
Estriol (E3) pg/mL	Pre- and Postmenopausal	<7		0-3
	Topical Estriol/Biest/Triest	5-100		
	Oral Estriol/Biest/Triest	5-20		
Progesterone (Pg) pg/mL	Premenopausal - Luteal	75-250		12-100
	Premenopausal - Follicular	12-100	Topical Progesterone (5-10 mg)	100-500
	Postmenopausal	12-100		
	Oral Progesterone (100-300 mg)	30-300		
	Topical, Troche, Vaginal Pg (10-30 mg)	200-3000		
	Synthetic Progestins (HRT, Contraceptive)	10-53		
Testosterone (T) pg/mL	Age Dependent	16-55	Age Dependent	44-148
			(5-50 mg topical 12-24 hr)	115-3700
DHEA-S (DS) ng/mL	Age Dependent	2-23	Age Dependent	2-23
Cortisol (C) ng/mL	Morning	3.7-9.5	Morning	3.7-9.5
	Noon	1.2-3.0	Noon	1.2-3.0
	Evening	0.6-1.9	Evening	0.6-1.9
	Night	0.4-1.0	Night	0.4-1.0

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