Calculation of percentage changes in volumes of blood, plasma, and red cells.

By Chuck Matthews, MS, PhD

A well-known thermoregulatory adaptation to heat stress, derived either from ambient exposures and/or during physical activity, is an expansion of blood/plasma volume. Conversely, exposure to cold temperatures may result in a contraction of blood/plasma volume. Blood volume can change as a result of changes in either of the two the basic constituents of blood, red cell volume or plasma volume. Plasma volume is not a fixed volume and it changes due to fluctuations in hydration status and minute-to-minute changes in the distribution of fluid between the circulatory system and interstitial spaces. Acute physical activity and postural changes can result in up to a 10-20% change in plasma volume. Errors introduced into “measures” of blood parameters via these mechanisms have been termed “pre-analytic” errors.

Blood constituents, such as total cholesterol and hemoglobin, that are too large to leave the circulatory system and enter interstitial spaces, will vary in their concentration with the volume of blood/plasma in circulation. That is, a 5% increase in plasma volume would reduce total cholesterol by 5%, because the absolute mass of the lipoprotein will be diluted.

Calculations have been developed to estimate the relative change (from baseline) in blood, red cell, and plasma volumes. These calculations, utilizing the blood parameters hemoglobin (mg/dl) and hematocrit (%), were originally intended for use in estimating acute changes in blood volumes in exercise and dehydration studies. They have also been employed in longitudinal studies of blood volume changes over several days, and several months.

In accordance with Dill & Costill (1974), the subscripts for “baseline” (b) and “after” (a) dehydration (or over time) are retained below and in the Seasons data set (in the intermediate variables). When the baseline value is not measured directly, baseline blood volume is assumed to be 100%.

Calculations employed in the Seasons study use the one-year average of hemoglobin (hemo_m) and hematocrit (hct_m) as the referent (or “baseline” (b)) value. The values employed in the quarter specific calculations (or “after” (a)) were (hemoglobin (hemo) and hematocrit (hct).

Finally, estimates of change in blood, red cell, and plasma volumes were estimated as percent changes in a give quarter from the one-year average values (referent).
Blood volume\(^1\)
\[ \text{BV}_b = 100\% \]
\[ \text{BV}_a = \text{BV}_b \times \left( \frac{\text{hemo}_m}{\text{hemo}} \right) \]

Red cell volume\(^2\)
\[ \text{CV}_b = \text{BV}_b \times \left( \frac{\text{hct}_m}{100} \right) \]
\[ \text{CV}_a = \text{BV}_a \times \left( \frac{\text{hct}}{100} \right) \]

Plasma volume\(^2\)
\[ \text{PV}_b = \text{BV}_b - \text{CV}_b \]
\[ \text{PV}_a = \text{AV}_a - \text{CV}_a \]

Percent changes
\[ ^1\text{BV}_\text{pct} = 100 \times \left( \frac{\text{BV}_a - \text{BV}_b}{\text{BV}_b} \right) \]
\[ ^2\text{CV}_\text{pct} = 100 \times \left( \frac{\text{CV}_a - \text{CV}_b}{\text{CV}_b} \right) \]
\[ ^2\text{PV}_\text{pct} = 100 \times \left( \frac{\text{PV}_a - \text{PV}_b}{\text{PV}_b} \right) \]

\(^1\) available for all Seasons subjects
\(^2\) available only for Blood Sub-study subjects

These variables may be useful for:

1) quantifying the potential effect of seasonal variation in blood volume on seasonal change in cholesterol levels
2) quantifying and/or adjusting for pre-analytic error in the blood cholesterol values (i.e., \(\text{TC}_{\text{adjusted}} = \text{TC} \times \frac{\text{pv}_\text{pct}}{\text{bv}_\text{pct}}\)).

References

