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The effect of posture on blood hemoglobin measurements with Ember in athletes and active individuals

Summary

Posture is known to affect the concentrations of substances and cells in human blood because of shifts in plasma volume, although the available data are rather limited because of the need to sample blood repeatedly within short intervals. The aims of this study were to determine (i) differences among body positions in the blood hemoglobin concentration ([Hgb]), as measured bloodlessly with Ember, and (ii) the time needed for [Hgb] to stabilize upon transition from one position to the other. Sixty-five healthy male and female athletes and physically active individuals of a wide age range (18-61) were measured in supine, sitting, and standing positions in sequence and in random order until their [Hgb] readings stabilized. Values were lowest in supine position (13.4 g/dL), higher in sitting position (13.8 g/dL, up by 3.2%), and highest in standing position (14.8 g/dL, up by 10.2% from supine and 6.7% from sitting). Athletes had smaller variation from one position to another than active persons, suggesting better homeostasis and fitness. The time needed for [Hgb] to stabilize upon transition from one position to the other averaged 10 minutes. Our findings show that persons interested in monitoring their [Hgb] should pay attention to posture, as differences are of considerable magnitude (such that could either mask or exaggerate the effects of other factors, like training and altitude exposure, on [Hgb]). To avoid variances in hemoglobin [Hgb] measurements due to posture changes, an Ember user should maintain the same posture for 10 minutes prior to taking each measurement, then continue that posture for the approximate 30 seconds required to take the measurement.

Background

Ember is a new product, developed at Cercacor, which measures the blood hemoglobin concentration ([Hgb]) noninvasively. Ember uses a sensor placed at a fingertip. The sensor is connected to a device, which processes the sensor's signal and produces a reading that is calibrated to the hemoglobin concentration in venous blood. The accuracy of the system is high,[1] and its reproducibility is excellent.[2]

Many factors affect the measurement of [Hgb] like kind of blood (arterial, venous, capillary), site of sampling, time of blood collection,˚and posture.[3] The latter is known to affect [Hgb] (among a number of blood parameters) because the plasma volume reacts dynamically to modifications of gravitational force and hydrostatic pressure. In particular, prolonged standing increases the venous pressure in the legs, thus generating an enhancement of capillary pressure, which ultimately leads to ultrafiltration of plasma in the interstitial space. In this process of plasma extravasation, larger and nondiffusible plasma components, such as erythrocytes containing hemoglobin, remain entrapped within the blood vessels, resulting in a rise in [Hgb].[4]

Lippi and coworkers[4] reported a 2.3% increase in [Hgb] from supine to sitting position, 7.1% from supine to standing, and 4.8% from sitting to standing in a small sample (n = 19) of middle-aged (44 ± 11 years), non-athletic individuals. These differences are of considerable magnitude in sport setting and may lead to false conclusions if no attention is paid to posture. However, they need to be verified in a more relevant sample. In addition, information is scarce on how long one has to stay in one position in order to obtain a reliable [Hgb] measurement. In the aforementioned report,[4] the volunteers stayed in each position for 20-25 min but it was not determined whether such time is sufficient or excessive. This lack of information may be due to the need to sample blood repeatedly within short intervals (say, every few minutes), which not only is uncomfortable but may affect the [Hgb] measurement as well if a considerable blood volume is removed. This problem, however, is eliminated by the use of a bloodless hemoglobin monitor such as Ember.

Thus, the aims of the present study were (i) to examine differences in Ember's [Hgb] readings in athletes and active people depending on posture (supine vs sitting vs standing), and (ii) to determine how long it takes for the Ember reading to stabilize after a person has assumed a specific position.

Methods

Participants and Procedure

The study included 65 volunteers (38 male and 27 female), aged 18-61, who participated in a variety of sports and athletic activities, that is, cycling, gymnastics, running, swimming, and water polo. Depending on the frequency and intensity of participation in these activities, the participants were divided into two activity levels: athletes if they practiced at least four times per week with high training volume and took part in competition regularly (n = 29) and active if they were involved in athletic activities one to three times per week with moderate training volume without participation in athletic events (n = 36). All participants provided written informed consent. As this was deemed to be a low-risk study, involving no invasive measurements, no Institutional Review Board approval was required.

Participants were asked to arrive at the testing station without having exercised during the past two hours, well hydrated, and comfortably clothed. An Ember sensor was placed at the ring finger of their non-dominant hand, and [Hgb] values were recorded every minute. Participants were switched among the three positions, supine, sitting, and standing, in random, counterbalanced order. (It was impossible to test all possible transitions from one posture to another on the same individual, as originally planned, because this took too long for the participant to bear.) They stayed in each position for at least ten minutes (which was found in pilot tests to be necessary for eliminating any random fluctuations) and until three identical measurements (with one decimal figure) were obtained in a row.

Data Analysis

For data analysis, we used the initial [Hgb] value, which we flagged as "mixed" (as this was influenced by the posture of the participant on the way to the testing station, which was mainly a mix of sitting and standing), and the three stable values at the supine, sitting, and standing positions. We also used the time from the moment a person assumed a particular position until the first of the three identical [Hgb] measurements appeared as the time needed for the [Hgb] reading to stabilize. There were nine transitions: mixed→supine, mixed→sitting, mixed→standing, supine→sitting, supine→standing, sitting→supine, sitting→standing, standing→supine, and standing→sitting.

The normality of distribution of the study variables was examined by the Shapiro-Wilk test. Variables whose distribution did not differ significantly from normal are reported as the mean and sd, whereas variables whose distribution differed significantly from normal are reported as the median and range.

The comparison of [Hgb] values was performed by three-way ANOVA (posture x gender x activity level) with repeated measures on posture. The comparison of the time needed for the [Hgb] reading to stabilize was analyzed by three-way ANOVA (transition x gender x activity level). The level of statistical significance was set at $\alpha = 0.05$. Statistical analysis was performed in the SPSS, v. 23.

Results and Discussion

Demographic and anthropometric data of the participants are presented in **Table 1.**

Table 1. Demographic and anthropometric characteristics of the participants

Characteristic	Male		Female	
	Athletes (*n* = 18)	Active (*n* = 20)	Athletes (*n* = 11)	Active (*n* = 16)
Age (y)*	23 (19-61)	40 (21-60)	19 (19-51)	30 (18-49)
Body weight (kg)**	80.6 (9.6)	81.7 (9.3)	58.9 (6.5)	60.6 (8.7)
Body height (m) **	1.82 (0.06)	1.79 (0.07)	1.67 (0.06)	1.68 (0.07)
Body mass index (kg/m^2) **	24.3 (1.8)	25.6 (1.9)	21.0 (1.5)	21.4 (2.6)

*Median and range. **Mean and SD.

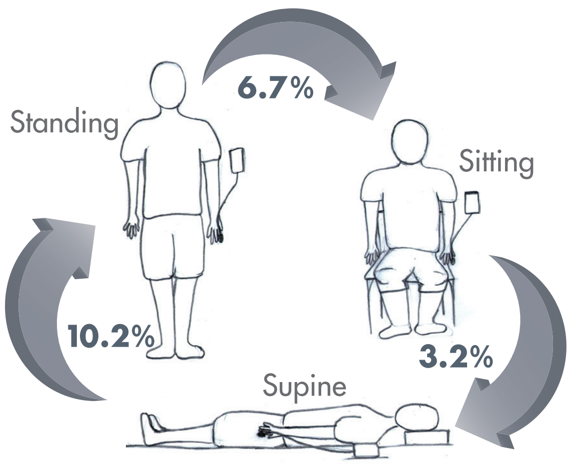
Participants' [Hgb] data according to posture, gender and activity level are presented in **Table 2.** Three-way ANOVA showed a significant main effect of posture ($p < 0.001$), meaning that [Hgb] differed from one position to another, and a significant interaction of posture and activity level ($p = 0.013$), meaning that the [Hgb] of athletes and active persons responded differently to changes in posture.

Table 2. Blood hemoglobin concentration (g/dL, Mean and SD) according to posture, gender and activity level of the participants

	Posture	Mixed	Supine	Sitting	Standing
Male	Athletes	14.9 (1.4)	14.2 (1.3)	14.7 (1.1)	15.4 (1.3)
	Active	14.9 (1.4)	14.1 (1.1)	14.5 (1.1)	15.4 (1.2)
Female	Athletes	13.1 (0.9)	12.5 (1.0)	12.7 (0.8)	13.4 (0.9)
	Active	13.7 (1.6)	12.3 (1.3)	12.8 (1.3)	14.1 (1.3)

To further explore the effect of posture on [Hgb], that is, to find out which body positions differed significantly from which, we performed analysis of simple contrasts, which showed significant differences between all positions ($p < 0.001$). [Hgb] was lowest in supine position (mean 13.4 g/dL), higher in sitting position (13.8 g/dL), and highest in standing position (14.8 g/dL). The mean value in the starting, mixed position was 14.3 g/dL, that is, intermediate between sitting and standing. There was a 3.2% increase from supine to sitting position, 10.2% from supine to standing, and 6.7% from sitting to standing (**Figure 1**). These values are higher than those reported by Lippi and coworkers[4] by approximately 40%.

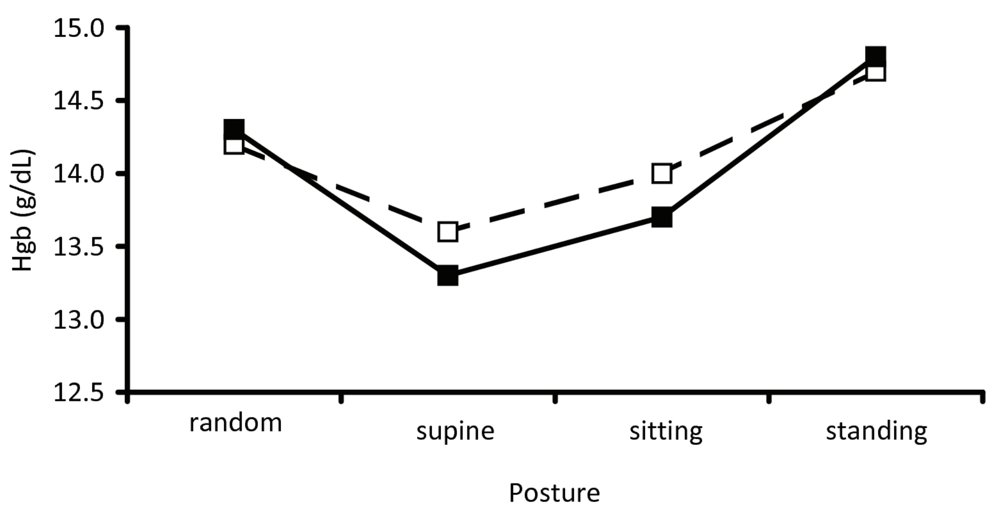
Figure 1. Percentage changes in [Hgb] from one posture to another.



To further explore the interaction of posture and activity level, that is, to find out what was different in the response of athletes and active persons to changes in posture, we drew **Figure 2,** which shows an intersection of the lines connecting the mixed and supine positions, and an intersection of the lines connecting the sitting and standing positions. In both cases, athletes had smaller changes from one position to another than active persons. This smaller variation of the athletes' values suggests that athletes had lower water shifts from the vascular system to the interstitial space when changing body positions. This may be an indication of better homeostasis and fitness.

Three-way ANOVA of the time needed for the [Hgb] reading to stabilize showed neither significant main effects nor significant interactions, suggesting a uniform time regardless of transition, gender, or activity level. The median value was 10 min, with a range of 0 (meaning that there were cases in which the reading did not change at all between positions) to 22 min.

Figure 2. Mean hemoglobin concentration in each body position for athletes (■) and active persons (□).



Conclusions

- Ember displayed notable changes in [Hgb] from one body position to another, which were lower in athletes than physically active persons.
- Because these changes are of such magnitude that could either mask or exaggerate the effects of other factors (like training and altitude exposure) on [Hgb], posture and fitness level should be taken into account for the evaluation of [Hgb] measurements.
- It is important for a person to stay in a particular position for 10 minutes in order to stabilize [Hgb], and it is important to compare values obtained in the same position.

Acknowledgement

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References

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