4. **Villafuerte FC, Cardenas R, and Monge CC.** Optimal hemoglobin concentration at high altitude: a theoretical approach for Andean men at rest. *J Appl Physiol* 96: 1581–1588, 2004.
5. **Wehrlin JP and Marti B.** Live high-train low associated with increased haemoglobin mass as preparation for 2003 world championships in two native european world-class runners. *Br J Sports Med.* [doi: 10.1136/bjsm.2005.019729.]

Alfredo Gamboa
1Vanderbilt University
Nashville, Tennessee
e-mail: alfredo.gamboa@vanderbilt.edu

Jorge L. Gamboa
2Department of Physiology
University of Kentucky
Lexington, Kentucky

To the Editor: Both the point and the counterpoint side (3) cited our congress abstract (4), which reported increased hemoglobin mass (Hb_{mass}), red cell volume (RCV), $\dot{V}O_{2\,max}$, and a correlation coefficient (r) of ~0.7 between ΔHb_{mass} and $\Delta\dot{V}O_{2\,max}$ for female and male athletes. Yet this correlation has to be put into perspective by the limited number of athletes (5 females and 5 males). When females and males were taken together, r was reduced to 0.35. However, our experiences (including actual unpublished data) with national team (4) and world class athletes (5) support the findings of Levine and Stray-Gundersen (2), namely that an adequate hypoxic dose increases Hb_{mass} and RCV, and this may positively affect aerobic performance. This coherence may be diminished by a series of confounding factors such as an inadequate hypoxic dose, an inadequate training stimulus, measurement error of RCV and Hb_{mass} determination (1), different individual responses to altitude, medical problems, and difficulties of timing the performance after the LHTL training camp. However, we agree with Dr. Gore that one of the most important aspects in this debate is measurement error of RCV and Hb_{mass} (1, 3) and that further studies in this field are needed. To our knowledge, there has been no controlled LHTL study with elite endurance athletes that used an estimated high enough natural hypoxic dose, measured Hb_{mass} with the carbon monoxide rebreathing method, controlled for blood doping, and related the changes of Hb_{mass} in relation to measured error of Hb_{mass} measurement.

REFERENCES

1. **Gore CJ, Hopkins WG, and Burge CM.** Error of measurement for blood volume parameters: a meta analysis. *J Appl Physiol* 99: 1745–1758, 2005.
2. **Levine BD and Stray-Gundersen J.** "Living high-training low": effect of moderate-altitude acclimatization with low-altitude training on performance. *J Appl Physiol* 83: 102–112, 1997.
3. **Levine BD and Stray-Gundersen J; Gore CJ and Hopkins WG.** Point: Counterpoint: Positive effects of intermittent hypoxia (live high:train low) on exercise are/are not mediated primarily by augmented red cell volume. *J Appl Physiol* 99: 2053–2058, 2005.
4. **Wehrlin JP, Zuest P, Clénin G, Hallén J, and Marti B.** 24 days live high:train low increases red cell volume, running performance and VO2max in Swiss national team orienteers. In: *Book of Abstracts, 8th Annual Congress of the European College of Sport Science*, edited by Müller E, Schwameder H, Zallinger G, and Fastenbauer V). Salzburg: Institute of Sport Sciences, University of Salzburg, 2003, p. 375–376.

Jon Peter Wehrlin
Section for Elite Sport
Swiss Federal Institute of Sports
Magglingen, Switzerland
e-mail: jon.wehrlin@baspo.admin.ch

To the Editor: The arguments presented for and against the potential influence of augmented red cell volume on exercise performance (2) are based primarily on the classic dimensions of "exercise performance," namely maximum oxygen uptake in the laboratory and running time for endurance events on the track (3). The underlying hypothesis is that a major determinant of "performance" is oxygen transport. Hence augmenting red cell volume should increase oxygen transport by increasing the oxygen carrying capacity of the arterial blood and/or increasing maximum cardiac output by increasing blood volume. However, data on these basic parameters of oxygen transport are conspicuously absent. For example, during performance at low altitude, is oxygen carrying capacity (hemoglobin concentration) actually higher after altitude exposure? Hemoglobin concentration is highly dependent on changes in plasma volume, and just as hemoconcentration follows ascent to altitude, so hemodilution promptly follows descent; hemoglobin concentration has been shown to fall >1 g/100 ml I within 24 h. Is maximum cardiac output significantly altered after altitude exposure? Hemodilution (plasma volume expansion) should increase blood volume and, when added to augmented red cell volume, ventricular filling pressures should be higher, enhancing stroke volume. Are stroke volumes larger at sea level after altitude exposure? Is there any change in the fraction of the cardiac output distributed to the exercising muscles? Pulmonary diffusing capacity has been reported to increase during a sojourn at altitude (1). Is there any measurable improvement in arterial blood oxygenation (oxygen content) during maximal exertion at low altitude after exposure to moderate altitude?

REFERENCES

1. **Dempsey JA, Reddan WG, Birnbaum MIster HV, Thoden JS, Grover RF, and Rankin J.** Effects of acute through life-long hypoxic exposure on exercise pulmonary gas exchange. *Respir Physiol* 13: 62–89, 1971.
2. **Levine BD and Stray-Gundersen J; Gore CJ and Hopkins WG.** Point: Counterpoint: Positive effects of intermittent hypoxia (live high:train low) on exercise are/are not mediated primarily by augmented red cell volume *J Appl Physiol* 99: 2053–2058, 2005.
3. **Reeves JT, Grover RF, and Cohn JE.** Regulation of ventilation during exercise at 10,200 ft in athletes born at low altitude. *J Appl Physiol* 22: 546–554, 1967.

Robert F. Grover
e-mail: drgrover@charter.net

To the Editor: There is common agreement that erythropoiesis is stimulated during altitude exposure and that an increase in red cell volume (RCV) causes improved aerobic capacity (5). However, Gore and Hopkins suggest that the 5-8% increase in