training phase do not make physiological sense when considered in conjunction with data for simultaneous changes in bone mineral content (BMC). The discrepancy may be illustrated by considering athletes with daily calcium intakes higher than the mean of 2014 mg. Assume an intake at the mean plus 1 SD (approximately 2900 mg) of which no more than approximately 500 mg would likely be absorbed.[3] Mean daily sweat calcium loss averaged 844 mg (2 daily sessions, each with mean losses of 422 mg). Allowing for a modest daily urinary loss of 100 mg, this would represent a negative daily balance of more than 400 mg. Yet these athletes apparently gained an average of 26 g of bone mineral during the 10 days (or 9.6 g of calcium), reflecting a daily gain of 960 mg of calcium. This is not possible in the face of negative total body calcium balance.

Third, the authors indicate that "most" of the subjects were African American, and because many African Americans are lactose intolerant, the drink used in the calcium supplementation phase was formulated as a nondairy product. However, individuals who don't digest lactose are able to adapt to and tolerate it without noticeable adverse effects.[4,5] These athletes most likely were in this category; mean calcium intakes higher than 2000 mg per day almost undoubtedly reflect the use of substantial quantities of dairy products. Accordingly, advice to athletes should continue to emphasize the nutritional benefits of milk and other dairy products.

The authors' conclusion that balancing dermal and other calcium losses with intake is essential to maintaining or enhancing BMC is not in dispute. Additional details about the study methods are needed to allow readers to place the data in context with what we know about calcium physiology and nutrition.

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1. Klesges RC, Ward KD, Shelton ML, et al. Changes in bone mineral content in male athletes: mechanisms of action and intervention effects. *JAMA*. 1996;276:226-230. Correction: *JAMA*. 1997;277:24.
2. Tipton K, Green NR, Haymes EM, Waller M. Zinc loss in sweat of athletes exercising in hot and neutral temperatures. *Int J Sport Nutr*. 1993;3:261-271.
3. Leman J Jr. Intestinal absorption of calcium, magnesium, and phosphorus. In: Favus MJ, ed. *Primer on the Metabolic Bone Diseases and Disorders of Mineral Metabolism*. 2nd ed. New York, NY: Raven Press; 1993:46-50.
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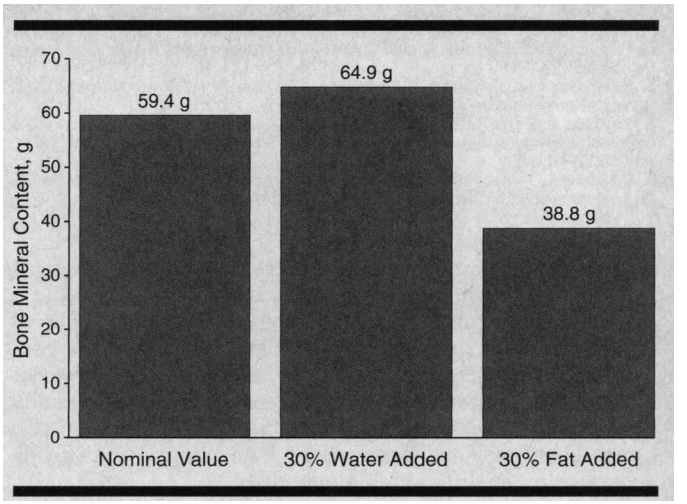
To the Editor.—Although Dr Klesges and colleagues[1] carefully assessed standardization and quality control of the dual-energy x-ray absorptiometry (DEXA) equipment used for the estimation of BMC and body composition, there is reasonable doubt that the changes in BMC they described are valid findings. It seems to be a treacherous coincidence that body calcium excretion with or without calcium supplementation impacts directly on the bone mineral status for the following reasons.

All DEXA inherently uses 2 radiation energies to resolve equations comprising at least 3 unknown variables: the attenuation coefficients of fat, water, and bone mineral. Fat and water have considerably different attenuation coefficients at low energies. In common experimental settings, such as cross-calibration efforts with invariable anthropomorphic phantoms, certain systematic errors are not detectable.[2] The influence of fat distribution on bone mass measurements with DEXA can be of considerable magnitude and ranges up to



Influence of simulated nonhomogeneous fat and water (Lucite and water) composition on the bone mineral content of lumbar vertebrae L-1 through L-4 in a spine phantom (Hologic Inc, Waltham, Mass).

10% error per 2 cm of fat.[3,4] This effect can be verified by every DEXA-user in a simple experiment as shown in 3 scans of the anthropomorphic spine phantom from Hologic Inc (Waltham, Mass) with a simulated variation in soft tissue composition, using a layer of fat- or water-equivalent material positioned on top of the vertebra: the calculated BMC varies by more than 30% (Figure). In vivo findings among our routine studies of patients with anorexia revealed an increase of 10% to 20% fat mass (relative to body weight) during their clinical course, associated with a small increase of total BMC. We found these BMC changes likely to be accounted for by systematic errors of the DEXA technology.

Large changes in fat mass at various sites have been described among female athletes and appear related to the intensity of physical activity.[5] It is not the amount of regional fat relative to total body fat that accounts for the regional body composition analysis, but the regional (precisely, pixel by pixel) relation of the tissue composition that may lead to much larger errors in the calculation of BMC. In areas in which bone mineral is detected and delimited by regions of interest, the DEXA system substitutes an average soft tissue composition value from outside of that region, assuming the same ratio inside of the region including bone. Unfortunately, Klesges et al[1] do not present the results of the fat mass in the soft tissue analysis of the athletes in their study. We strongly suspect that the described seasonal changes in BMC due to activity are also reflected in fat mass. The changes in lean tissue mass also may have contributed to an apparent change of regional BMC, because lean tissue is not homogeneously distributed in the body.

In cross-sectional studies, errors such as these may be considered negligible because they are averaged out in sufficiently large groups. However, individual test results and follow-up results can be affected considerably. This specific problem of DEXA can only be improved by a 3-energy system, capable of sufficiently resolving the minimum of a 3-compartment model, or by soft tissue and BMC analyses using a 3-dimensional method, such as quantitative computed tomography.

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1. Klesges RC, Ward KD, Shelton ML, et al. Changes in bone mineral content in male athletes: mechanisms of action and intervention effects. *JAMA*. 1996;276:226-230. Correction: *JAMA*. 1997;277:24.
2. Pearson J, Dequeker J, Henley M, et al. European semi-anthropomorphic spine

phantom for the calibration of bone densitometers: assessment of precision, stability and accuracy: the European Quantitation of Osteoporosis Study Group. *Osteoporos Int.* 1995;5:174-184.
3. Hangartner TM, Johnston CC. Influence of fat on bone measurements with dual-energy absorptiometry. *Bone Miner.* 1990;9:71-81.
4. Valkema R, Verheij LF, Blokland JAK, et al. Limited precision of lumbar spine dual photon absorptiometry by variations in the soft-tissue background. *J Nucl Med.* 1990;31:1774-1781.
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In Reply.—The authors of these letters eloquently point out that there are inherent limitations to field research and a balance in any research methodology between control and generalizability. In our article, we were critical of the generalizability of previous laboratory measurements of sweat calcium loss. Our study was conducted under actual training conditions (in which coaches will not allow interruptions), had never been previously attempted, and allowed data to be collected under difficult circumstances.

Drs Barr and Heaney question our data on calcium loss in sweat. Since we knew of no other study that examined sweat and calcium loss in a true field setting, we used the general procedures outlined by Tipton et al.[1] Barr and Heaney also suggest that the estimate of calcium loss during training may have been an overestimate due to evaporation. Some overestimation is possible, as we originally discussed. However, it is important to note that T-shirts were removed immediately at the first break during the training session to minimize evaporation. They also note an imbalance between estimated calcium loss and intake vs BMC changes. This apparent imbalance assumes perfect assessment of sweat calcium and dietary intake. The major point is that there was a dose-response relationship between calcium intake and change in BMC.

An equation we used to estimate fluid loss from weight loss contained an arithmetic error and resulted in an underestimation of average corrected weight loss and an overestimation of sweat calcium loss. However, our interpretation—that these athletes were losing excessive amounts of calcium from sweat—is not altered. To ensure integrity of all our results, data from all 3 studies were reanalyzed and verified by an independent biostatistician. Finally, our use of the calcium-fortified drink did not imply that athletes should not use dairy products. It was easier to convince these athletes to drink a "sports" beverage rather than milk.

Dr Schneider and colleagues question whether changes in BMC were invalid because of changes in fat mass. We do not believe that changes in fat mass are likely to explain our results. The fat mass changes in our study were low (12%-13%) and are unlikely to be of sufficient magnitude to explain to observed BMC changes. Furthermore, the authors used a Lunar DPX scanner (Lunar Corp, Madison, Wis), which is more dependent on fat mass in in vitro studies than the Hologic QDR-2000 used in our study.[2] Moreover, changes in fat mass did not parallel changes in BMC. Total body and leg fat masses decreased during both years. We agree that there may be more precise methods for quantifying bone mass, but these measurement issues must be balanced with such considerations as greater radiation exposure (subjects were scanned 6 or 7 times), scan time, and cost.

Although additional research is needed, it nonetheless appears that some athletes may be at risk for BMC loss, which is partially due to calcium loss in sweat, and may need supplemental calcium to restore these losses.

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1. Tipton K, Green NR, Haymes EM, Waller M. Zinc loss in sweat of athletes exercising in hot and neutral temperatures. *Int J Sport Nutr.* 1993;3:261-271.
2. Hangartner TN, Johnston CC. Influence of fat on bone measurements with dual-energy absorptiometry. *Bone Miner.* 1990;9:71-81.

CORRECTION

Incorrect Data.—In the Original Contribution entitled "Changes in Bone Mineral Content in Male Athletes: Mechanisms of Action and Intervention Effects," published in the July 17, 1996, issue of THE JOURNAL (1996;276:226-230), incorrect data appeared in the abstract, text, and Table. On page 226, the fifth line in the "Results" section of the abstract should read as follows: Dermal calcium loss averaged 247 mg per training session.

On page 227, in the right-hand column, second paragraph, 15th line, the values should be −0.08 (0.077) mmol/L [−0.32 (0.31) mg/dL]. On page 229, in the left-hand column, first paragraph, the fourth line should read as follows: Mean (SD) loss of calcium from sweat across the 3 days of training averaged 247 (94.6) mg.

Also, on page 229, the Table should be replaced with the accompanying Revised Table.

Revised Table.—Weight Change and Calcium Loss in Sweat and Urine During Intense Exercise*

Variable	Day 1	Day 2	Day 3	Mean	*P* for Linear Trend
Average corrected weight loss per training session, kg (n=9)	5.30 (0.93)	4.18 (1.04)	2.50 (1.12)	4.00 (0.42)	<.001
Sweat calcium concentration, mmol/L [mg/dL] (n=10)	2.03 (1.02) [8.14 (4.08)]	1.44 (0.61) [5.77 (2.44)]	1.39 (0.94) [5.56 (3.76)]	1.62 (0.77) [6.49 (3.08)]	.03
Estimated calcium loss in sweat, mg per training session (n=9)	401.8 (202.0)	228.2 (135.4)	111.1 (39.3)	247.0 (94.6)	.003
Urinary calcium concentration, mmol/L [mg/dL] (n=9)	1.84 (1.45) [7.36 (5.80)]	1.40 (0.77) [5.61 (3.09)]	3.20 (1.68) [12.80 (6.70)]	2.15 (0.98) [8.60 (3.94)]	.07
Estimated calcium loss in urine, mg per training session (n=9)	4.6 (6.0)	3.2 (2.4)	6.2 (5.0)	4.7 (3.1)	.5
Dietary calcium intake, mg (n=9)	...	...	...	2013.7 (879.4)	...

*Values are reported as mean (SD). Ellipses indicate not calculated.