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SHORT REPORT

Relative expansion of extracellular water in elite male athletes compared to recreational sportsmen

N. BATTISTINI, F. VIRGILI† and G. BEDOGNI

Università di Modena, Italy
†Istituto Nazionale della Nutrizione, Roma, Italy

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Summary. This study reports total body hydration and water distribution between the extracellular water (ECW) and the intracellular water (ICW) of a group of 15 elite male athletes compared with a group of 15 male subjects practising the same sport at 'amateur' level. Total body water (TBW) and ECW were assessed by means of deuterium and bromide dilution techniques respectively. Both TBW and body hydration were significantly higher in elite athletes than in non-competitive subjects ($52 \cdot 3 \pm 5 \cdot 0$ vs $46 \cdot 1 \pm 4 \cdot 2$ litres $p < 0 \cdot 001$ and $63 \cdot 2 \pm 1 \cdot 9$ vs $60 \cdot 2 \pm 1 \cdot 9$% body weight, $p < 0 \cdot 003$ respectively). Likewise, both ECW the ratio of ECW to TBW were significantly higher in athletes than in control subjects ($20 \cdot 7 \pm 2 \cdot 9$ vs $16 \cdot 1 \pm 1 \cdot 8$ litres, $p < 0 \cdot 0001$ and $0 \cdot 40 \pm 0 \cdot 06$ vs $0 \cdot 35 \pm 0 \cdot 03$, $p < 0 \cdot 005$ respectively). ICW was similar in both groups but the ICW to ECW ratio was significantly higher in the athletes compared to the recreational sportsmen ($0 \cdot 67 \pm 0 \cdot 16$ vs $0 \cdot 54 \pm 0 \cdot 07$, $p < 0 \cdot 01$). These data suggest that assumptions regarding the chemical composition of the standard human body may not be valid in elite athletes.

1. Introduction

Precise information on the body composition of athletes is important for accurate weight counselling and for optimizing training programmes. However, all methods for assessing body composition, even those perceived to be 'gold standards' (such as underwater weighing, or potassium-40 counting) rely on assumptions regarding the chemical composition of the body based on few data obtained by autoptic whole-body analysis on normal subjects. In athletes, the relationship between fat-free mass (FFM), physical activity and total fluid distribution is still unclear. Changes associated both with intensive training and nutritional factors can affect the chemical composition FFM (Forbes 1987). Thus, the assessment of body composition in athletes by methods assuming a standard composition of FFM can introduce considerable error (Sinning, Dolny, Little, Cunningham, Racaniello, Siconolfi and Sholes, 1985, Withers, Smith, Chatterton, Schultz and Gaffney 1992).

In this short report we describe a study on total body hydration and water distribution between the extracellular space and the intracellular space in a group of elite male athletes compared with a group of male subjects practising the same sport at 'amateur' level.

2. Subjects and methods

Fifteen elite male athletes were recruited from a team ('Panini, Modena') engaged in the championship of the premiere national volleyball league. These athletes follow a complex training programme of about 4 hours per day, which includes weight-lifting and power-increasing exercises. All tests were undertaken in the middle of the competitive season where the build-up phase can be considered to have been completed.

A second group of 15 subjects playing volleyball at a non-competitive level in the same club was recruited as a control. These subjects were matched for age and body mass index with the group of elite athletes, but they trained non-professionally, for a total of approximately 6–7 hours per week. Both elite athletes and controls reported a stable body weight.

Total body water (TBW) and extracellular water (ECW) were measured by deuterium oxide and sodium bromide dilution techniques respectively. All subjects were studied in fasting conditions and, after emptying the bladder, received a carefully weighed oral dose of a solution of deuterium oxide (about 5 g D_2O) plus sodium bromide (about 1·3 g NaBr). A detailed description of the method of deuterium-load body fluid collection is reported elsewhere (Battistini, Brambilla, Virgili, Simone, Bedogni, Morini and Chiumello 1992). The deuterium load was sufficient to increase the isotopic excess to approximately 500δ‰ above the background. Deuterium enrichment in sublimated plasma samples was measured by FT-IR spectrometry according to the method of Lukaski and Johnson (1985).

Three hours after the bromide load, blood was withdrawn using EDTA as anti-coagulant, and the plasma was separated by centrifugation. Protein-free plasma was obtained by ultrafiltration through membrane with a cut-off of 10,000 MW, and bromide assayed by HPLC according to Wang, Sheng, Morkenberg, Kosanovich, Clarke and Klein (1989). The final concentration of bromide in plasma was below one-tenth of the level considered toxic (6 mM) (Goodman and Gillman 1970).

Anthropometric parameters, including skinfold thickness and arm circumferences, were measures by a trained operator (G.B.) following *Anthropometric Standardization Reference Manual* methods (Lohman, Roche and Martorell 1988).

The experimental protocol was approved by the Ethical Committee of the University of Modena and informed consent of all subjects was obtained.

Statistical analysis (mean, standard deviaiton, ANOVA) was performed using a Statview package for Macintosh computers. The level of significance was set at $p < 0{\cdot}05$. All data are reported as mean ± SD.

3. Results and discussion

Table 1 reports the anthropometric parameters of both the elite athletes and the control group. The significance of differences between groups by ANOVA is also reported. Elite athletes were significantly taller and heavier than controls, but the body mass index was similar in both groups. Arm fat area was significantly less in athletes, while arm muscle area was greater in elite athletes than in recreational sportsmen. These differences probably reflect the effect of more intensive training.

Table 1. Physical characteristics of elite athletes and non-competitive subjects.

	Elite athletes ($n = 15$)	Non-competitive subjects ($n = 15$)	p (by ANOVA)
Age (years)	23·5 ± 5·7	22·4 ± 4·8	n.s.
Weight (kg)	82·8 ± 8·0	76·5 ± 6·9	0·003
Height (cm)	193·4 ± 6·8	184·6 ± 7·2	0·003
BMI (kg/m^2)	22·1 ± 1·5	22·4 ± 1·6	n.s.
AFA (cm^2)	7·5 ± 1·8	10·4 ± 3·0	0·004
AMA (cm^2)	67·5 ± 8·8	60·0 ± 7·8	0·03

BMI = Body mass index (weights/height^2); AFA = arm fat area (cm^2); AMA = arm muscle area (cm^2). AFA and AMA are not corrected for bone area.

Table 2 presents data for TBW (obtained by deuterium dilution and expressed as absolute values and as percentage of body weight) ECW (obtained by bromide dilution), and intracellular water (ICW, obtained by difference from TBW and ECW). The table also reports the ECW to TBW ratio and the ICW to ECW ratio.

Table 2. TBW (either expressed as an absolute value and as percentage of body weight), ECW and ICW (both expressed as absolute values), ECW/TBW and ICW/ECW in elite athletes and in non competitive subjects.

	Elite athletes ($n = 15$)	Non-competitive subjects ($n = 15$)	p (by ANOVA)
TBW (l) (litre)	52·3 ±5·0	46·1 ±4·2	0·001
TBW (%)	63·2 ±1·9	60·2 ±1·9	0·0003
ECW (l) (litre)	20·7 ±2·9	16·1 ±1·8	0·0001
ECW/TBW	0·40±0·06	0·35±0·03	0·005
ICW (l) (litre)	31·6 ±4·8	30·0 ±3·2	n.s.
ICW/ECW	0·67±0·16	0·54±0·07	0·01

Both TBW and body hydration were significantly higher in elite athletes than in non-competitive subjects. Likewise, both ECW and the ratio of ECW to TBW were significantly higher in athletes than in control subjects. ICW was similar in both groups but the ICW to ECW ratio was significantly higher in the athletes compared to the recreational sportsmen.

These differences may be explained by factors such as training or nutrition. Alternatively, the athletic abilities of the competitive group may have ensured that the individuals originated from a genetic pool different from that of the non-competitive group, thus introducing another possible variable into the matching procedure. Nonetheless, the important issue remains, the elite athletes may have a fluid distribution significantly different from that of the 'normal' (though trained) population.

These data suggest that assumptions regarding the chemical composition of the standard human body may not be valid in elite athletes. As a consequence, body composition models based on standard values and body composition methodologies developed for 'normal' populations would require adjustment for use in athletes.

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Address for correspondence: Nino Battistini, Cattedra di Fisiologia della Nutrizione, Università di Modena, via Campi, 287, 41100 Modena, Italy.

Zusammenfassung. In der vorliegenden Arbeit werden Daten zur Hydration des Gesamtkörpers sowie zur Differenzierung des Körperwassers in einen extrazellulären (ECW) und einen intrazellulären (ICW) Anteil mitgeteilt. Entsprechende Daten liegen für 15 männliche Hochleistungssportler vor sowie für 15 männliche Probanden, die denselben Sport auf Amateurebene betreiben. Zur Bestimmung der Gesamtwassermenge (TBW) und des ECW wurde die Deuterium- bzw. Bromid-Verdünnungstechnik herangezogen. Sowohl TBW als auch die Hydration des Körpers waren bei den Hochleistungssportlern signifikant höher als bei den nicht an Wettkämpfen teilnehmenden Individuen (52·3 ± 5·0 vs 46·1 ± 4·2 Liter, $p < 0{\cdot}001$ bzw. 63·2 ± 1·9 vs 60·2 ± 1·9% des Körpergewichts, $p < 0{\cdot}003$). Entsprechend waren sowohl ECW als auch das Verhältnis von ECW und TBW bei den Hochleistungssportlern signifikant höher als bei den Kontrollindividuen (20·7 ± 2·9 vs 16·1 ± 1·8 Liter, $p < 0{\cdot}0001$ bzw. 0·40 ± 0·06 vs 0·35 ± 0·03, $p < 0{\cdot}005$). Der ICW-Anteil war in beiden Gruppen ähnlich, das Verhältnis von ICW zu ECW war jedoch bei den Hochleistungssportlern im Vergleich zu den Freizeitsportlern signifikant höher (0·67 ± 0·16 vs 0·54 ± 0·07, $p < 0{\cdot}01$). Diese Daten legen nahe, daß Annahmen über die chemische Zusammensetzung des menschlichen Referenzkörpers für Hochleistungssportler möglicherweise nicht zutreffen.

Résumé. Ce travail analyse l'hydratation et la répartition de l'eau extra-cellulaire (EEC) et intra-cellulaire (EIC) dans un groupe de 15 athlètes de haute compétition que l'on compare à un groupe de 15 sujets pratiquant le même sport en amateurs. L'eau corporelle totale (ECT) et EEC ont été estimées respectivement au moyen des techniques de dilution du deuterium et du bromure. Aussi bien l'ECT que l'hydratation corporelle sont significativement plus élevées chez les athlètes que chez les amateurs (respectivement 52·3 ± 5·0 contre 46·1 ± 4·2 litres $p < 0{\cdot}001$ et 63·2 ± 1·9 contre 60·2 ± 1·9% du poids coporel $p < 0{\cdot}003$). De la même façon, aussi bien l'EEC que le rapport de l'EEC à l'ECT sont significativement plus élevés chez les athlètes que chez les contrôles (20·7 ± 2·9 contre 16·1 ± 1·8 litres $p < 0{\cdot}0001$ et 0·40 ± 0·06 contre 0·35 ± 0·03 $p < 0{\cdot}005$ respectivement). L'EIC est similaire dans les deux groupes, mais le rapport de l'EIC à l'EEC est significativement plus grand chez les athlètes que chez les amateurs (0·67 ± 0·16 contre 0·54 ± 0·07 $p < 0{\cdot}01$). Ces données suggèrent que les estimations concernant la composition chimique du corps humain standart, peuvent ne pas être valables chez athlètes de haute compétition.