Application of Bioelectric Impedance Methodology to Determine the BEC

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INTRODUCTION

The calculation of the BEC according to given quantities of alcoholic beverages is accomplished by the application of Widmark's formula. Two variable factors are to be considered, namely the so-called resorption deficit and Widmark's distribution-factor "r". Widmark defined "r" to be the ratio of total body ethanol concentration and BEC (Widmark, 1932). According to close relations between the ethanol content and the water content of organs, tissues and body fluids "r" also corresponds to the ratio of total body water content and blood water content (Brettel, 1986).

Due to considerable physiological and pathological fluctuations of the total body water (TBW) the application of rigid values for "r" (i.e. 0.6 for women, 0.7 for men) does not entirely reflect the real situation. Since the TBW and the blood water content in the individual case are hardly attainable (Brettel, 1986), it was tried to determine the individual TBW using anthropometric data, which are easily obtained (Watson, 1981). Ulrich, Cramer and Zink presented an individual distribution factor "ri", which is also in foro applicable (Ulrich, 1987). However, this factor applies only to men, short drinking times and low to average alcohol consumption.

Up until now, the determination of TBW and body fat has been a long venture, burdening to the volunteers. In particular hydrodensitometry, although a method of high accuracy, it is also costly, time consuming and not tolerated by some volunteers. The body fat analyzer TBF-305 of the Japanese company Tanita* is easy to use and does not burden the volunteer. Weight, body fat, TBW and LBM (lean body mass) are measured by bioelectric impedance analysis (BIA) with high accuracy. Comparisons of TBF-305 with

* We are obliged to Tanita Europe for making a body fat analyzer TBF-305 available to us.
hydrodensitometry yielded a high correlation ($r=0.868$) on a statistically significant level ($p<0.001$; Fig.1). This appliance was used for the determination of individual Widmark factors.

**Fig.1: Correlation of body fat measurements by Tanita BIA and by hydrodensitometry (source: Tanita)**

**METHODOLOGY**

In the drinking experiment, 46 volunteers participated. 16 women and 30 men took part with an average age of 28 years. Within a 2 hours time period, the volunteers consumed beer or wine in quantities determined by themselves. During the test there was no intake of food. For the first 10 volunteers, 3 measurements with TBF-305 were taken. The first before the start of the drinking experiment, the second at the BEC maximum level and the third in the elimination phase. Two blood samples were taken to determine the water content BWC by gravimetry. Because fluctuations in each parameter were slight, just one TBF measurement as well as one determination of blood water content (BWC) were performed for the remaining 36 volunteers.

Two tests with intravenous ethanol intake ($n=6$) were performed as a control of the experimentally determined distribution factors. The quantity of ethanol was increased...
from 0.2g ethanol/kg body weight for the first test to 0.7g ethanol/kg body weight for the second test.

The BEC graph was controlled with the SIEMENS Alkomat™. During the drinking experiments, two blood samples (the first after completion of the maximum stage, the second in the late elimination phase) were taken and the BEC was measured by GC/MS. During the intravenous ethanol intake tests, 4 blood samples were taken in the maximum stage and in the elimination phase to determine the BEC by GC/MS. The blood water content was measured by gravimetry.

RESULTS

The measurement with the body fat analyzer yielded clear sex-specific differences in weight, fat weight, lean body mass (LBM) and total body water (TBW). Fig. 2 shows, that the absolute values of these 4 parameters are higher among men than among women. Except for fat weight, these differences are statistically significant. The fat ratio, however, was higher among women, with a mean of 27%, than among men at 21.5%. Reciprocal ratios are found in reference to the body water ratio (Fig. 3).

Fig. 2: Sex specific differences in weight, body fat, LBM and TBW

Fig. 3: Sex specific differences in body fat ratio and body water ratio
The value of the distribution factor "r" varies considerably depending on which calculation method is used (Fig. 4). However, the differences between the sexes are proven to be statistically significant for all calculation methods. If one calculates "r" as the ratio of body water content to blood water content, a value of 0.75 (SD 0.07) is found for men and 0.67 (SD 0.04) for women. Similar values are calculated for "ri" according to Ulrich, Cramer and Zink with a mean value of 0.73 (SD 0.08). Assuming the consumed alcohol would be distributed exclusively in the total body water TBW, clearly lower values of 0.59 (SD 0.06) for men and 0.54 (SD 0.03) for women are obtained. If ethanol is assumed to be distributed in the entire fat-free body mass LBM, significantly higher values for "r" [0.81 for men (SD 0.08) and 0.73 (SD 0.05) for women] were determined.

Fig. 4: Value of "r" according to different calculation methods

Naturally, the results of calculated BECs are influenced by such differing reduction factors. If one calculates expected values with the different reduction factors in the drinking experiment, the following deviations occur (Fig. 5): On average, slight deviations above the measured values are found when determining "r" from the ratio of total body water content to blood water content. This also applies to the factor "ri". On average, greater deviations above measured value result from the application of standard values for "r" (0.7 for men, 0.6 for women). Massive deviations above measured values are found when the total body water TBW is inserted in the Widmark formula. On average slight deviations below measured values are found when the lean body mass LBM is inserted in the Widmark formula.
To control the plausibility of these results, tests were conducted by administering an ethanol charge intravenously (Fig. 6). Here again, the slightest deviations were found between calculated and measured BECs by applying "r" as the ratio of total body water content to blood water content (mean deviation -0.01 o/oo, SD 0.03).

**Fig. 5: Deviations between calculated and measured BEC's (ethanol intake: orally)**

**Fig. 6: Deviations between calculated and measured BEC's (ethanol intake: intravenous)**

**DISCUSSION**

The measurements with the body fat analyzer TBF-305 confirm, that the average body fat content of women is significantly higher than of men. The application of rigid Widmark factors also accommodates this circumstance. However, our investigations show, that the most frequently used values (0.6 for women and 0.7 for men) are too low for both sexes. By calculating the distribution factor (as defined by Widmark) as the ratio of body water content to blood water content, the accumulated test results occurrences emerge as presented in fig 7. The figure shows, that just 12.5% of the women had an "r" value of 0.6 or lower, but 18% had a value of more than 0.7. On the other hand, 16% of the men had an "r" value under 0.7 and 23% had an "r" of more than 0.8.

The determination of "r" from the ratio of body water- to blood water content yields a "reduced body weight", which allows the most exact calculation of BECs, when applying
Widmark’s formula. This reduced body weight is neither identical to the total body water (TBW) nor to the fat-free body mass (LBM), but lies between these two.

The distribution factor "ri" (ULRICH, 1987) correlates well with the experimentally calculated Widmark factor "r" (fig. 8). Since, in foro, neither an analysis of body water content nor blood water content may be available, the application of "ri" may be used for men. This method is constrained to the circumstances noted by the authors (short drinking time, low to medium ethanol quantities).

LITERATURE


