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LETTER TO THE EDITOR

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Population ranges for the volume of distribution (V_d) of alcohol for use in forensic alcohol calculations

Editor,

As the pharmacokinetics of alcohol (ethanol) are well understood, equations, such as the Widmark equation (Equation 1) can be used by forensic practitioners to estimate either (a) the blood alcohol concentration of an individual consuming a known amount of alcohol or (b) the amount of alcohol consumed from a measured blood alcohol concentration [1]

$$C_t = \frac{100\, v\, z\, d}{V_d M} - \beta\, t \quad (1)$$

C_t = blood alcohol concentration at time t (mg/100 mL); M = mass of the subject (kg); V_d = volume of distribution of alcohol (L/kg); β = alcohol elimination rate (mg/100 mL/h); t = time since the drinking began (h); v = volume of alcoholic beverage consumed (mL); z = strength of alcoholic beverage (% v/v); d = density of alcohol (g/mL).

Previous work has demonstrated that the variables in the Widmark equation that contribute most to the uncertainty of the final calculated result are the apparent volume of distribution of alcohol (V_d) and the alcohol elimination rate (β) [2, 3]. As alcohol only dissolves in water, if the total body water (TBW) of an individual is measured or determined using a suitable anthropometric equation, the volume of distribution of alcohol can be calculated using Equation 2

$$V_d = \frac{TBW}{M\, F_w} \quad (2)$$

V_d = volume of distribution of alcohol (L/kg); TBW = total body water (L), M = mass of the subject (kg); F_w = water content of blood (0.825% w/v in males and 0.838% w/v in females [2, 4]).

The most accurate method of determining V_d or TBW is either via controlled drinking or isotope dilution studies with an accuracy of ~1.5% [5]. In isotope dilution studies, a known dose of isotope (deuterium/tritium) labeled water is given to the individual. After a known amount of time when the isotope-labeled water has equilibrated with the individual's body water, a blood or saliva sample can be taken and the concentration of the isotope measured. From these data, the individual's TBW can be determined [8]. The second-best method of estimating V_d/TBW is the use of anthropometric equations, with the Watson equation giving an accuracy of ~9.1%–12.8% [6, 7]. In some cases, it is not possible to either experimentally determine V_d/TBW or calculate it, so in this case population data ranges could be used to give the best estimation for V_d/TBW for an individual. This may be as an overall range, by sex, or by subdivision of the sex ranges by body mass index (BMI being a person's weight in kilograms divided by the individual's height in meters squared). It is important to remember that the use of an average or single value for V_d/TBW is not appropriate. To date, there have been no studies in the literature that have presented these data ranges.

Using a previously collected data set of TBW measured using isotope dilution we have been able to calculate the V_d of everyone in the study [5] by converting TBW to V_d using Equation 2. These data comprised 1466 individuals of African American, Asian, Caucasian, Hispanic, and Puerto Rican ethnic backgrounds (884 women and 582 men) that had a BMI of between 17 and 80 kg/m^2 (women) and 17 and 67 kg/m^2 (men) with ages from 18 and 90 years. From these data, the relative frequency distribution of the V_d for males and females was determined and is shown in Figure 1.

As expected, due to physiological differences between males and females the median V_d of males (0.71 L/kg) is higher than that of females (0.58 L/kg), although it can be seen there is a large overlap between males and females. The 95% range for males is 0.58–0.83 L/kg and 0.43–0.73 L/kg for females. The 95% range for the entire data set are 0.45–0.81 L/kg. The use of a 95% range gives a better representation of the values of V_d that may be seen in a population as this excludes any potentially extreme values that are not typical of the population. As the BMI of the individuals was recorded in the study, it was possible to look at the 95% range based on Sex and BMI. The BMI ranges were determined according to the World Health Organisation WHO classifications [9]. These data are shown in Figure 2 and Table 1.

Using the analysis presented in this study, it is possible, if only the sex of an individual is known, to give suitable ranges for the V_d in forensic alcohol calculations. In transgender individuals undergoing gender-affirming hormone therapy (GAHT) there are alterations in TBW [10] and in this case, if it is known that the individual is receiving GAHT, then the best approach would be to use the 95% range for the entire data set (see Table 1).

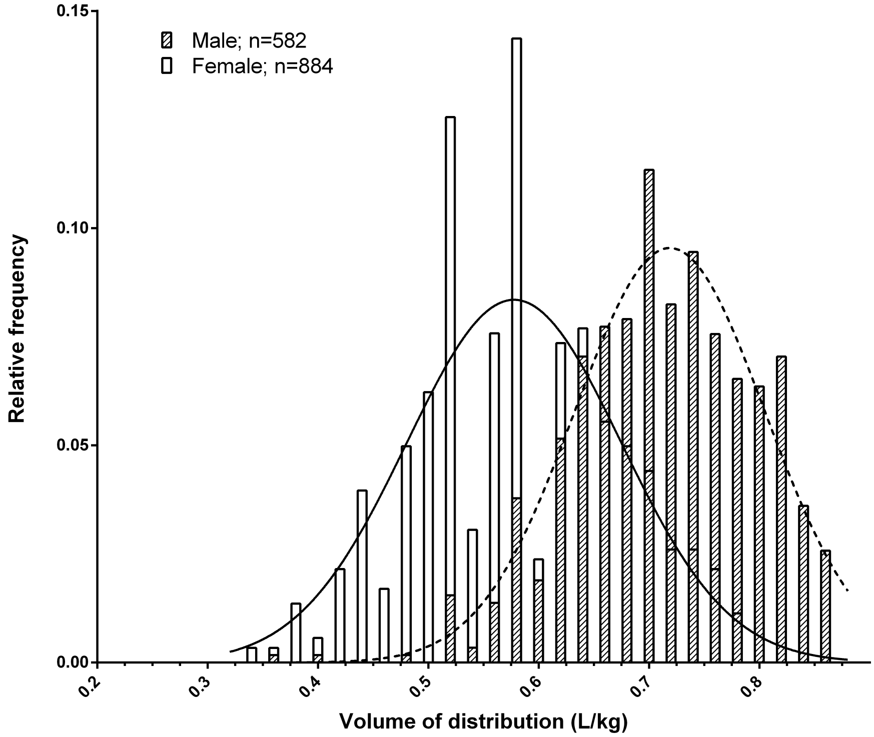

FIGURE 1 Relative frequency distributions of the volume of distribution (V_d) of alcohol in 1466 individuals of African American, Asian, Caucasian, Hispanic, and Puerto Rican ethnic backgrounds (884 women and 582 men).

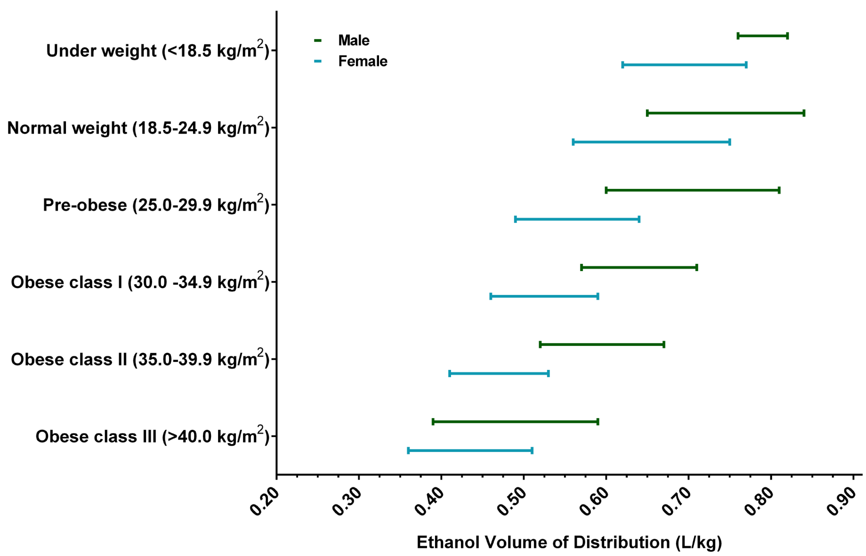

FIGURE 2 Graphical representation of the 5th–95th percentile distribution of the volume of distribution (V_d) of alcohol for males and females in relation to a person's obesity as reflected in a body mass index (BMI).

TABLE 1 Table of maximum to minimum and 5th–95th percentile distribution of the volume of distribution (V_d) of alcohol for males and females in relation to a person's obesity as reflected in a body mass index (BMI).

		Ethanol volume of distribution (L/kg)														
		Male					Female					All				
Classification of obesity	BMI (kg/m²)	*n*	Min	Max	5th	95th	*n*	Min	Max	5th	95th	*n*	Min	Max	5th	95th
Underweight	<18.5	3	0.76	0.82	0.76	0.82	26	0.61	0.78	0.62	0.77	29	0.61	0.82	0.62	0.78
Normal weight	18.5–24.9	275	0.60	0.86	0.65	0.84	380	0.45	0.78	0.56	0.75	655	0.45	0.86	0.57	0.82
Overweight	25.0–29.9	212	0.51	0.85	0.60	0.81	239	0.43	0.74	0.49	0.64	451	0.43	0.85	0.50	0.78
Obese class I	30.0–34.9	60	0.51	0.75	0.57	0.71	98	0.42	0.66	0.46	0.59	158	0.42	0.75	0.47	0.68
Obese class II	35.0–39.9	19	0.52	0.68	0.52	0.67	69	0.35	0.57	0.41	0.53	88	0.35	0.68	0.42	0.62
Obese class III	>40	13	0.36	0.61	0.39	0.59	72	0.33	0.53	0.36	0.51	85	0.33	0.61	0.36	0.56

Although this letter gives V_d ranges that can be used in forensic alcohol calculations it is important to remind readers that outside of experimental studies, the best method of estimating the V_d of an individual is using the Watson et al. equation (see [6, 7]), and this is the recommended approach when the relevant information (age, weight and sex) is available.

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