

Bodysize Measurement Comparisons Using SAS 6.06

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INTRODUCTION

A study was conducted to compare the Navy's method of determining a member's body size with a method frequently used in the pharmaceutical industry. The interest for the study lay in the fact that particular variables may either overcompensate or underrate a sailor's dimensions. It was believed that the pharmaceutical industry may use a better approach. Early studies in drug development require lean normal human volunteers be used to determine the absorption, distribution, metabolism and excretion (ADME) profile of a drug in Phase I studies. The pharmaceutical industry is interested in lean bodies because adipose tissue (fat cells) will accumulate drugs and thereby distort the ADME profile of a drug being developed. Phase I studies are generally the first time new drugs are administered to humans. In conducting these studies, lean male bodies are desired. The Navy also has an interest in trim body shapes. Ideally, Navy personnel are in good physical condition and will be able to perform rigorous military duties whenever necessary.

METHODS AND MATERIALS

To conduct a comparison such as this required that a particular set of observations exist. The options were to conduct a specific study and collect the various body measures required at some considerable expense in terms of measurement and an extended period for enrollment of volunteers, or use a pre-existing data set that contained the various measures necessary to permit the comparison of interest. The collection of this quantity of data was extremely time consuming, since one can hardly measure more than one or two subjects per day. At this rate, it can be seen that collecting in excess of 150 subjects data is approximately a two-three month process - IF volunteers can be found. Fortunately, such a data set was located at the Naval Health Research Center in San Diego, CA. J.A. Hodgdon, PhD, kindly made his data available, for this study. Therefore, this comparison was conducted at almost no cost to the Navy, since the data existed and were readily available. This amounted to a re-examination of existing data and results using new and expanded procedures in version 6.06 of SAS.

Because the Navy has both males and females in substantial numbers, physical dimension standards for both exist, it was important that both males and females be present in the dataset. The dataset consisted of data from two studies with 115 males

and 42 females, with about 40 variables of which 16 were retained in a subset for analysis. These included STUDY\$(study), PTID\$(patient ID), SEX, AGE, WGT, HGT, HYDFAT (hydrostatic weight), NAVFAT (Navy body size), ELBWID (elbow width), NCKCIR (neck circumference), UMBCIR (umbilical circumference), WSTCIR (waist circumference), HIPCIR (hip circumference), WTRWGT (water weight), WTRTMP (water temperature) and RESVOL (residual volume). Height and weight were rounded to whole units. While these 16 variables were retained from the original dataset, body surface area ($[[WGTR^{**0.425}][HGTR^{**0.725}]*71.84/10000]$ = BODYSURR, when rounded to 0.01), body mass $[WGTR/[HGTR^{**2}]]$ = BODYMASR, when rounded to 0.01), ponderal index $([WGTR/[HGTR^{**1/3}]]$ = PONDINDR, when rounded to 0.01), water density based on water temperature per subject $([1.00093056-[[0.00004914*WTRTMP]+[0.0000042*WTRTMP^{**2}]]]$ = WTRDEN), body volume $([[WGTR-WTRWGT]/WTRDEN]-[RESVOL+0.1]$ = BODYVOLR, when rounded to 0.01) were calculated using several of the 16 variables in the subset. In addition, three metabolic body size variables $([MBS01R=WGTR^{**0.67}]$, $[MBSR02R=WGTR^{**0.72}]$ and $[MBSR03R=WGTR^{**0.75}]$) were also calculated. The Navy currently uses NCKCIR and UMBCIR for males, and NCKCIR, WSTCIR and HIPCIR for females.

The thrust of the comparison centered around the combination of height (HGTR) and elbow width (ELBWID) into a new body frame variable (FRAME). Body frame is frequently used by the pharmaceutical industry in Phase I studies to screen and select volunteers. Elbow width (ELBWID) is determined by measuring the olecranon width with the arm extended forward and the forearm upwards at a 90-degree angle; keeping the fingers straight and turn the inside of the wrist toward the body. The thumb and index finger of the other hand measure the width of the elbow; this distance can then be measured. This concept was originated in the Metropolitan Height and Weight Tables. The specific question to be answered was, "Did the new body frame variable show stronger relationships to any of the weight or body size variables than the set of variables currently in use by the Navy?" In defining the new frame variable, height and elbow width were combined to create three body frame classes: Slight, Normal and Large. One of the outcomes intended, was to be able to provide a nomogram that may be more easily interpretable and useable than a rather lengthy table.

A number of variables were calculated for use in establishing models to provide a better, simpler fit. BODYVOLR was calculated using this formula:

$$\begin{aligned} WTRDEN &= [1.00093056-[[0.00004914*WTRTMP] \\ &\quad +[0.0000042*WTRTMP^{**2}]]], \\ BODYVOLR &= [[WGTR-WTRWGT]/WTRDEN]-[RESVOL+0.1], \\ &\quad \text{rounded to 0.01.} \end{aligned}$$

Water temperature (WTRTMP) was an element of the original database. The formula for calculation of the Navy's body density (NAVFAT) were:

$$\text{Males} = -[0.191*\log_{10}(\text{UMBCIR}-\text{NCKCIR})]$$

$$\begin{aligned}
& +[0.154*\log_{10}(\text{HGT})] +1.032 \\
\text{Females} = & -[0.350*\log_{10}(\text{WSTCIR}+\text{HIPCIR}-\text{NCKCIR})] \\
& +[0.221*\log_{10}(\text{HGT})] +1.296
\end{aligned}$$

These formulae were provided in the Hodgdon & Beckett papers, for males and females. NAVFAT was not recalculated during this study. HYDFAT was determined directly for each subject, through a very involved and time-consuming procedure defined by Goldman & Buskirk with two modifications: (1) Respiratory Volume was determined outside the weighing chamber and (2) Each subject was weighed six times, and this mean of six weights was the member of the database used.

Analyses began with PROC CORR in SAS 6.04. When 6.06 became available PROC REG was used, with RQUARE and Cp options specified. The idea was to solve for a simultaneous solution between a maximum RSQUARE and minimum Cp statistic. When this occurred, the optimum solution was achieved.

RESULTS AND DISCUSSION

Early passes were broad ranging to examine any of several relationships that may have existed -- and were explorative. These included several metabolic body size calculations from seminal sources in the energy measurement field, plus several currently used in the pharmaceutical industry (i.e., body mass, ponderal index and body surface area to name a few). In the body size calculations, there are several factors used, depending on the source. These range from bodysize raised from the $\text{WGTR}^{**0.67}$, $\text{WGTR}^{**0.72}$ or $\text{WGTR}^{**0.75}$ (Cramer, Forbes & Garrigus also Kleiber). There were simultaneous plots developed to screen the better combinations. The question was to see if the relations held up, and if so were these better than the original? The idea was to improve the functionality -- have less variability, with better fit -- so that an independent duty corpsman, aboard ship, can have a better, easier and more accurate method to gauge body dimensions that are truer to the sailor's body dimension or condition.

Early in the process, several combinations of variables were discarded because of high correlations between the component terms. Those usually excluded were ones which included simple weights and certain of the circumferences used in the Navy models for males and females derived by J.A. Hodgdon.

There is also a very large body of research (Siri, Goldman & Buskirk and Wright & Wilmore) that underwater weights are the most accurate means of assessing body size or lean body mass. The availability of all of these measures in the data set made this an excellent data set for in-depth examination.

Several SAS procedures were used to make the comparisons. PROC PRINT and PROC FREQ were used to display and examine the data initially. PROC UNIVARIATE -- to assess the distributions of the variables, PROCs CORR and PLOT -- to examine the preliminary relationship between the variables, PROC STEPWISE -- to check the order of entry into a model, and PROC RSQUARE -- to measure the correlation among the model elements. In virtually every case the database was examined overall and then subset by sex, as outlined above.

A large number of variables initially entered were soon excluded, because of the correlations between multiple variables. These resolved to only three variables that were ultimately used in models: NAVFAT, HYDFAT or BODYVOLR. These too, were run on all subjects, and then separately by sex and the correlations improved. This improvement was attributed to the differences achieved because of the differences in the formulas for calculating the NAVFAT terms for males and females. No between sex comparison was made.

CONCLUSIONS

The analytical results from this study will be released elsewhere. The early findings suggest that the Navy has a better approach than the pharmaceutical industry, in that the multi-part formula in use by the Navy is a better fit than the elbow width/body frame, and is sex specific. The use of elbow width, to determine body frame size may be most effective in screening for normal, lean male bodies for Phase I studies.

Results in the form of correlations and P-values will be provided in a subsequent article. Direction and magnitude of differences in simultaneous solutions are also intended.

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