BMMD CALIBRATION REPORT
(BLIND STUDY)

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The objective of this study is to obtain the calibration curve equation for the data collected from the Body Mass Measurement Device (BMMD). The numerical technique used to obtain the equation is the **interpolation** with the **divided difference method.**

DIVIDED DIFFERENCE METHOD

The treatment of divided difference table assumes that a function, f(x), is known at several distinct values for x:

x_0 f_0

x_1 f_1

x_2 f_2

x_3 f_3 and so on.

The x's are not assumed to be evenly spaced nor the values are arranged in any particular order (in the case of BMMD, the x's are readings and f's are masses).

DEFINITION OF INTERPOLATING POLYNOMIAL: Consider the nth degree polynomial:

$$P_n(x) = a_0 + (x - x_0)\, a_1 + (x - x_0)(x - x_1)\, a_2 + \dots\dots$$
$$+ (x - x_0)(x - x_1) \dots\dots (x - x_{n-1})\, a_n.$$

If we choose a_i so that $P_n(x)$ equals f(x) at the n +1 known points, $x_0, x_1, \dots\dots, x_n$, then $P_n(x)$ is an interpolating polynomial. Also, for the interpolating polynomial, it must match the table for all n + 1 entries:

$$P_n(x_i) = f_i \quad \text{for } i = 0, 1, 2, \dots\dots, n.$$

It can be shown that the above a_i are readily determined by using what are called the divided differences of the tabulated values. A special notation is used for divided differences:

$f[x_0, x_1] = (f_1 - f_0)/(x_1 - x_0)$ is called the first divided difference between x_0 and x_1. The second and higher order divided differences are defined in terms of lower order difference. For example:

$$f[x_0, x_1, x_2] = \{f[x_1, x_2] - f[x_0 - x_1]\}/(x_2 - x_0).$$

$$f[x_0, x_1, \ldots\ldots x_n] = \{f[x_1, x_2, \ldots\ldots, x_i] - f[x_0, x_1, \ldots\ldots\ldots, x_{i-1}]\}/(x_i - x_0).$$

This concept is extended to a zero order difference : $f[x_s] = f_s$. Using this notation, a divided difference table, in symbolic form, is shown below.

x_i	f_i	$f[x_i, x_{i+1}]$	$f[x_i, x_{i+1}, x_{i+2}]$	$f[x_i, x_{i+1}, x_{i+2}, x_{i+3}]$
x_0	f_0			
		$f[x_0, x_1]$		
x_1	f_1		$f[x_0, x_1, x_2]$	
		$f[x_1, x_2]$		$f[x_0, x_1, x_2, x_3]$
x_2	f_2		$f[x_1, x_2, x_3]$	
		$f[x_2, x_3]$		$f[x_1, x_2, x_3, x_4]$
x_3	f_3		$f[x_2, x_3, x_4]$	
		$f[x_3, x_4]$		
x_4	f_4			

Using the definition of interpolating polynomial, the polynomial obtained will be,

$$P_3(x) = f_0 + (x - x_0)\, f[x_0, x_1] + (x - x_0)(x - x_1)\, f[x_0, x_1, x_2] + \ldots\ldots\ldots\ldots$$

$$\ldots\ldots + (x - x_0)(x - x_1)\ldots\ldots\ldots\ldots(x - x_3)\, f[x_0, x_1, x_2, x_3].$$

Similarly, for n + 1 data points, the polynomial will be,

$$P_n(x) = f_0 + (x - x_0)\, f[x_0, x_1] + (x - x_0)(x - x_1)\, f[x_0, x_1, x_2] + \ldots\ldots\ldots\ldots$$

$$+ (x - x_0)(x - x_1)\ldots\ldots\ldots\ldots(x - x_{n-1})\, f[x_0, x_1, \ldots\ldots\ldots x_{n-1}].$$

BMMD DATA ANALYSIS: The BMMD data were obtained with no mass (zero reading), 29.67 lbs, 59.29 lbs, subject alone, subject + 29.67, and subject + 59.29. Thus, six data points are known. But, for the calibration purposes, the subject weight must be assumed to be unknown. Hence, this data point was eliminated from the data set and the interpolating polynomial of fourth order was obtained from known five data points. Ten calibration equations were obtained. Ten subjects alone also took the readings. Their readings were substituted in the calibration curve equations to predict their masses. The following tables show the results. It is noted here that the values under column D, the difference, is obtained by subtracting the actual mass from the predicted mass. Whereas the percentage difference (column E) is the ratio of difference and the actual mass. The results show that the differences obtained are within the 2.25 lb limit (or within 1%) except for the subject with 133.33 lbs when predicted from the calibration curve used from the readings taken for the subject with a 117.381 lbs. The predicted mass for this case is 134.67 lbs and the % difference is negligibly higher than 1 % (1.003%). Thus, it can be concluded that the interpolation technique utilizing the divided differences is a suitable tool to generate the calibration equation and subsequently, to predict the mass from the data taken for the BMMD.

BMMD TABULATED RESULTS

	A	B	C	D	E
1					
2	READING	ACTUAL MASS	PREDICTED MASS	DIFFERENCE	% DIFFERENCE
3		(LBS)	(LBS)	(LBS)	
4	BJECT #1 CALIBRATION EQUATION :		157.261 LBS		
5	5.93261	133.33	134.0973028	0.7673028	0.575491487
6	6.76327	182.466	183.6073337	1.1413337	0.625504861
7	5.63984	117.56	117.9817562	0.4217562	0.358758251
8	6.91293	191.793	193.0788644	1.2858644	0.670443864
9	6.52479	167.926	168.8483943	0.9223943	0.549286174
10	6.59123	171.867	172.9179858	1.0509858	0.61151111
11	6.28027	153.314	154.1613111	0.8473111	0.552663879
12	6.59984	172.239	173.4477813	1.2087813	0.701804644
13	7.11703	205.025	206.2438464	1.2188464	0.594486721
14	5.58313	114.307	114.945311	0.638311	0.55841812
15					
16					
17					
18	BJECT #2 CALIBRATION EQUATION :		159.704 LBS		
19	5.93261	133.33	134.0421966	0.7121966	0.534160804
20	6.76327	182.466	183.452804	0.986804	0.540815275
21	5.63984	117.56	117.9442557	0.3842557	0.326859221
22	6.91293	191.793	192.894795	1.101795	0.574470914
23	6.52479	167.926	168.7323413	0.8063413	0.480176566
24	6.59123	171.867	172.7921837	0.9251837	0.538313754
25	6.28027	153.314	154.0755293	0.7615293	0.496712172
26	6.59984	172.239	173.3206634	1.0816634	0.62800144
27	7.11703	205.025	206.0116712	0.9866712	0.481244336
28	5.58313	114.307	114.9105691	0.6035691	0.528024618
29					
30					
31	BJECT #3 CALIBRATION EQUATION :		154.735 LBS		
32	5.93261	133.33	133.6388295	0.3088295	0.231627916
33	6.76327	182.466	182.9875241	0.5215241	0.285819879
34	5.63984	117.56	117.5408166	0.0191834	0.016317965
35	6.91293	191.793	192.3844542	0.5914542	0.308381536
36	6.52479	167.926	168.3092092	0.3832092	0.228201231
37	6.59123	171.867	172.360358	0.493358	0.287058016
38	6.28027	153.314	153.669671	0.355671	0.231988599
39	6.59984	172.239	172.8875556	0.6485556	0.376543988
40	7.11703	205.025	205.4090667	0.3840667	0.187326765
41	5.58313	114.307	114.5080631	0.2010631	0.175897452
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	A	B	C	D	E
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47	READING	ACTUAL MASS	PREDICTED MASS	DIFFERENCE	% DIFFERENCE
48		(LBS)	(LBS)	(LBS)	
49	JECT #4 CALIBRATION EQUATION :		107.311 LBS		
50	5.93261	133.33	134.0736307	0.7436307	0.557736968
51	6.76327	182.466	183.4862898	1.0202898	0.559167078
52	5.63984	117.56	117.9913728	0.4313728	0.366938414
53	6.91293	191.793	192.9457372	1.1527372	0.601031946
54	6.52479	167.926	168.7520597	0.8260597	0.491918881
55	6.59123	171.867	172.8142421	0.9472421	0.55114833
56	6.28027	153.314	154.0943856	0.7803856	0.50901131
57	6.59984	172.239	173.343103	1.104103	0.641029616
58	7.11703	205.025	206.1003478	1.0753478	0.52449594
59	5.58313	114.307	114.960747	0.653747	0.571922105
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63	BJECT #5 CALIBRATION EQUATION :		139.812 LBS		
64					
65	5.93261	133.33	134.0797822	0.7497822	0.562350709
66	6.76327	182.466	183.536794	1.070794	0.586845769
67	5.63984	117.56	117.9708699	0.4108699	0.349498044
68	6.91293	191.793	192.99022	1.19722	0.624225076
69	6.52479	167.926	168.8002648	0.8742648	0.520625037
70	6.59123	171.867	172.8643325	0.9973325	0.580293192
71	6.28027	153.314	154.1294257	0.8154257	0.531866431
72	6.59984	172.239	173.3933735	1.1543735	0.670216095
73	7.11703	205.025	206.1245585	1.0995585	0.536304597
74	5.58313	114.307	114.9353098	0.6283098	0.549668699
75					
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78	BJECT #6 CALIBRATION EQUATION :		128.472 LBS		
79	5.93261	133.33	133.9471372	0.6171372	0.462864472
80	6.76327	182.466	183.3428295	0.8768295	0.480544047
81	5.63984	117.56	117.8751139	0.3151139	0.268045168
82	6.91293	191.793	192.8012432	1.0082432	0.52569343
83	6.52479	167.926	168.6115309	0.6855309	0.408233924
84	6.59123	171.867	172.6727371	0.8057371	0.468814316
85	6.28027	153.314	153.958506	0.644506	0.420383005
86	6.59984	172.239	173.2014805	0.9624805	0.558805207
87	7.11703	205.025	205.9554217	0.9304217	0.453808901
88	5.58313	114.307	114.8466927	0.5396927	0.472143176
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	A	B	C	D	E
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93	READING	ACTUAL MASS	PREDICTED MASS	DIFFERENCE	% DIFFERENCE
94		(LBS)	(LBS)	(LBS)	
95	BJECT #7 CALIBRATION EQUATION :		142.494 LBS		
96	5.93261	133.33	134.0625342	0.7325342	0.549414385
97	6.76327	182.466	183.4869385	1.0209385	0.559522596
98	5.63984	117.56	117.9573901	0.3973901	0.338031728
99	6.91293	191.793	192.9269378	1.1339378	0.591230024
100	6.52479	167.926	168.7656448	0.8396448	0.500008813
101	6.59123	171.867	172.8261255	0.9591255	0.55806263
102	6.28027	153.314	154.1045714	0.7905714	0.515655061
103	6.59984	172.239	173.3546673	1.1156673	0.647743717
104	7.11703	205.025	206.0368732	1.0118732	0.493536496
105	5.58313	114.307	114.9224867	0.6154867	0.538450576
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109	BJECT #8 CALIBRATION EQUATION :		108.962 LBS		
110	5.93261	133.33	134.3371701	1.0071701	0.75539646
111	6.76327	182.466	183.3091802	0.8431802	0.462102638
112	5.63984	117.56	118.2340867	0.6740867	0.57339801
113	6.91293	191.793	192.5582712	0.7652712	0.399008932
114	6.52479	167.926	168.8104221	0.8844221	0.526673713
115	6.59123	171.867	172.8180842	0.9510842	0.553383838
116	6.28027	153.314	154.2911731	0.9771731	0.637367168
117	6.59984	172.239	173.3392876	1.1002876	0.638814438
118	7.11703	205.025	205.3330786	0.3080786	0.150263919
119	5.58313	114.307	115.1942703	0.8872703	0.776216942
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123	BJECT #9 CALIBRATION EQUATION :		117.381 LBS		
124	5.93261	133.33	134.6679039	1.3379039	1.003453011
125	6.76327	182.466	183.5709228	1.1049228	0.605549965
126	5.63984	117.56	118.4939652	0.9339652	0.794458319
127	6.91293	191.793	192.7281525	0.9351525	0.487584271
128	6.52479	167.926	169.1562514	1.2302514	0.7326152
129	6.59123	171.867	173.1472962	1.2802962	0.744934281
130	6.28027	153.314	154.6610506	1.3470506	0.878622044
131	6.59984	172.239	173.6659857	1.4269857	0.828491631
132	7.11703	205.025	205.3182085	0.2932085	0.143011096
133	5.58313	114.307	115.4384693	1.1314693	0.989851278
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	A	B	C	D	E
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139	READING	ACTUAL MASS	PREDICTED MASS	DIFFERENCE	% DIFFERENCE
140		(LBS)	(LBS)	(LBS)	
141	JECT #10 CALIBRATION EQUATION :		144.469 LBS		
142	5.93261	133.33	134.449388	1.119388	0.839561989
143	6.76327	182.466	184.0117353	1.5457353	0.847136069
144	5.63984	117.56	118.2742772	0.7142772	0.607585233
145	6.91293	191.793	193.4573333	1.6643333	0.867775831
146	6.52479	167.926	169.2662149	1.3402149	0.798098508
147	6.59123	171.867	173.3351081	1.4681081	0.854211745
148	6.28027	153.314	154.5652385	1.2512385	0.816128012
149	6.59984	172.239	173.8646525	1.6256525	0.94383531
150	7.11703	205.025	206.560188	1.535188	0.74878088
151	5.58313	114.307	115.2255601	0.9185601	0.803590419
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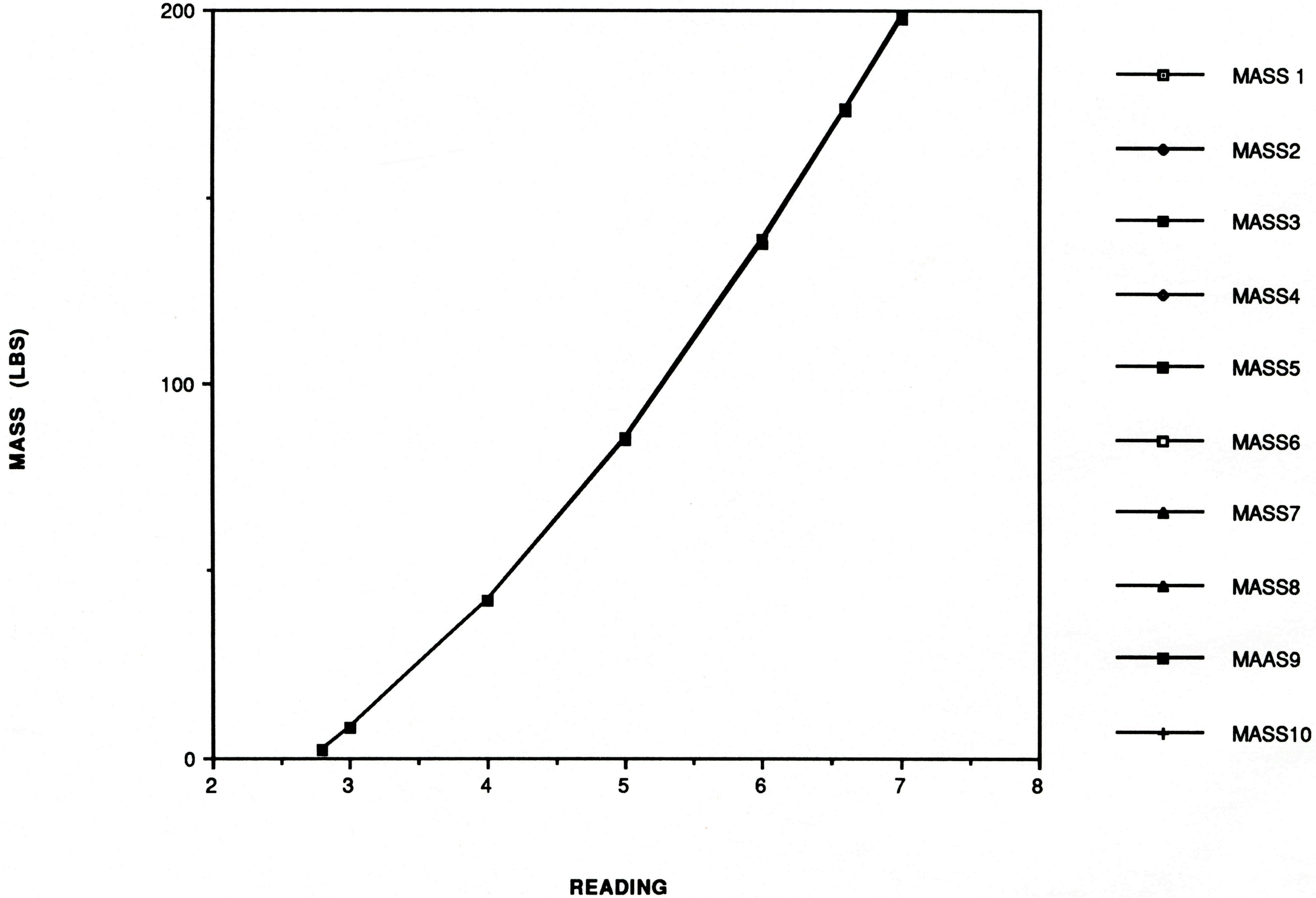
BLIND STUDY CAL EQUATION CURVES (TEN)



CALIBRATION EQUATIONS FROM BLIND STUDY (OCT '92)

CAL EQN BASED ON SUBJECT#1:

y = (x-2.70593)*30.88566+(x-2.70593) (x-3.66657)*4.752144
+ (x-2.70593) (x-3.66657) (x-4.42499) *(-0.04981263)
+(x-2.70593) (x-3.66657) (x-4.42499) (x-6.83242) *(-0.024357993)

CAL EQN. BASED ON SUBJECT#2:

y = (x-2.70602)*30.89723831 + (x-2.70602) (x-3.66630) *4.736262145
+(x-2.70602) (x-3.66630) (x-4.42503) * (-0.051263035)
+ (x-2.70602) (x-3.66630) (x-4.42503) (x-6.875512) * (-0.027024517)

CAL EQN. BASED ON SUBJECT # 3:

y= (x-2.706044)*30.89315259 + (x-2.706044) (x-3.666451) *4.56652349
+(x-2.706044) (x-3.666451) (x-4.430486) * (0.007410326)
+(x-2.706044) (x-3.666451) (x-4.430486) (x-6.7989925)*(-0.05134891)

CAL EQN. BASED ON SUBJECT # 4:

y = (x-2.70577) *30.91107986 +(x-2.70577)(x-3.66562) *4.759190578
+(x-2.70577) (x-3.66562) (x-4.42344) *(-0.045210185)
+(x-2.70577) (x-3.66562) (x-4.42344) (x-5.99615) *(-0.018736277)

CAL EQN. BASED ON SUBJECT # 5:

y = (x-2.70629) *30.89916894 + (x-2.70629) (x-3.66651) * 4.741844172
+(x-2.70629) (x-3.66651) (x-4.42504) (-0.0417715281)
+ (x-2.70629) (x-3.66651) (x-4.42504) (x-6.5493) * (-0.026655905)

CAL EQN. BASED ON SUBJECT # 6:

y = (x-2.70628) *30.90431848 +(x-2.70628) (x-3.66634) *4.740597853
+(x-2.70628) (x-3.66634) (x-4.42483) (-0.046780969)
+ (x-2.70628) (x-3.66634) (x-4.42483) (x-6.37053) *(-0.019335521)

CAL EQN. BASED ON SUBJECT # 7:

y = (x-2.70581) * 30.91558908 + (x-2.70581) (x-3.66552) * 4.710170103
+(x-2.70581) (x-3.66552) (x-4.42477) *(-0.033932645)
+(x-2.70581) (x-3.66552) (x-4.42477) (x-6.58906) *(-0.030577471)

CAL EQN. BASED ON SUBJECT # 8:

$$y = (x-2.70576) * 30.90689389 + (x-2.70576)(x-3.66574) * 4.763891327 + (x-2.70576)(x-3.66574)(x-4.42348) *(-0.027091221) + (x-2.70576)(x-3.66574)(x-4.42348)(x-6.02807) *(-0.054254941)$$

CAL EQN. BASED ON SUBJECT # 9:

$$y = (x-2.70590) * 30.91204601 + (x-2.70590)(x-3.66572) * 4.754776284 + (x-2.70590)(x-3.66572)(x-4.42366) *(0.006299436) + (x-2.70590)(x-3.66572)(x-4.42366)(x-6.17017) * (-0.081598626)$$

CAL EQN. BASED SUBJECT # 10:

$$y = (x-270587) *30.91494483 + (x-2.70587)(x-3.66560) * 4.762522147 + (x-2.70587)(x-3.66560)(x-4.42326) *(-0.038329713) + (x-2.70587)(x-3.66560)(x-4.42326)(x-6.621904) *(-0.036791118)$$

NOTE: y = predicted mass and x = BMMD reading
This blind study data were collected during the month of October (1992) Ten subjects worked with the cal weights and obtained readings to help generate ten cal equations. Additional ten subjects obtained readings by themselves only. Their readings were substituted in each of the ten cal equations to predict their masses. The comparison was made between the predicted masses and their scale weights (See report on BLIND STUDY DATA analysis)