



## Updating ICRP 70 Skeleton Weight vs. Body Height Equation

Maia Avtandilashvili & Sergei Y. Tolmachev

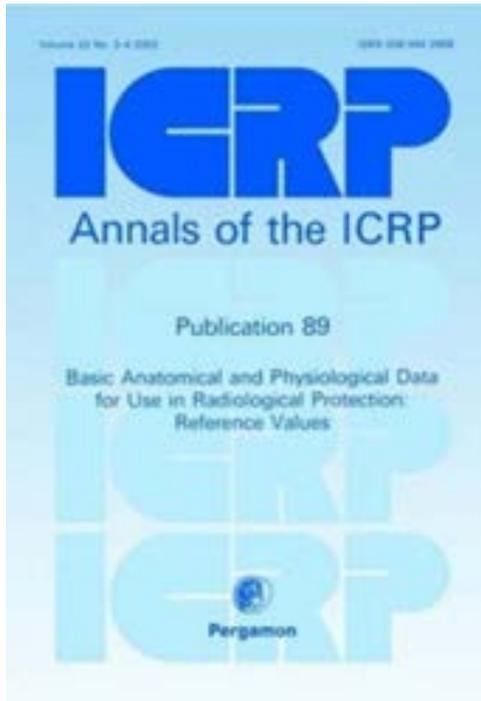
*US Transuranium and Uranium Registries*  
*College of Pharmacy, Washington State University*  
*Richland, WA*

“Learning from Plutonium  
and Uranium Workers”





# Motivation



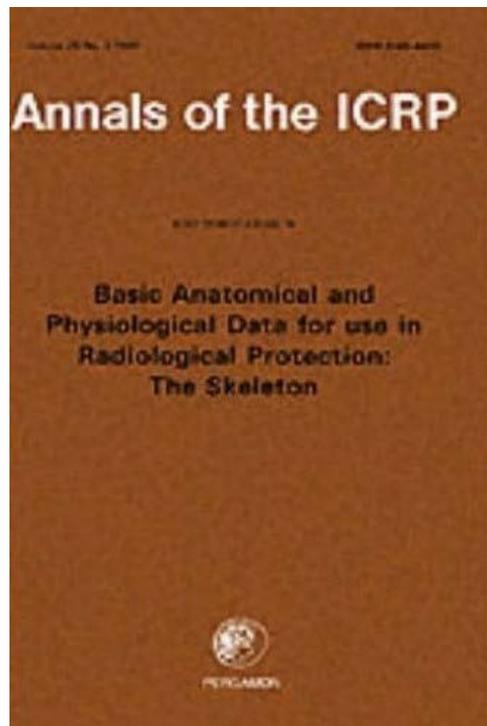
*“Reference values for selected anatomical and physiological features of the skeleton ... useful for the development of biokinetic and dosimetric models for radionuclides”*

ICRP 89 (2002)

# ICRP Reference Man: Skeleton Weight

## ICRP Publication 70 (1995)

- Reference Adult Male: 10.5 kg
- Data from 44 subjects including two USTUR donors



RADIOLOGICAL PROTECTION DATA: THE SKELETON 9

Table 1. Skeletal weights of adult males

Investigator	Age (y)	Weight (kg)	Height (cm)	Skeletal weight	
				kg	% of TB
Bischoff, 1863	33	69.7	168	11.1	15.9
Dursy, 1863	36	50.5	163	7.6	15.0
Dursy, 1863	42	65.3	172	9.8	15.0
Volkmann, 1873*	38	64.5		7.9	12.2
Volkmann, 1873*	45	63.0		7.5	11.9
Volkmann, 1874*		62.5		10.2	16.3
von Liebig, 1874	30-45	55.7		11.5	20.6
von Liebig, 1874	30-45	76.5		13.9	18.2
Mechanik, 1926	25	60.2		8.1	13.5
Mechanik, 1926	28	63.2		9.3	14.7
Mechanik, 1926	32	65.0		9.3	14.3
Mechanik, 1926	50	60.0		8.3	13.8
Mechanik, 1926	50	60.1		9.2	15.3
Mechanik, 1926	51	59.6		8.0	13.4
Mechanik, 1926	55	61.5		8.4	13.7
Mechanik, 1926	58	61.9		6.9	11.1
Mitchell <i>et al.</i> , 1945	35	70.6	183	10.5	14.8
Forbes <i>et al.</i> , 1953	46	53.8	169	9.5	17.6
Forbes <i>et al.</i> , 1956	48	62.0	169	10.3	16.7
Forbes <i>et al.</i> , 1956	60	73.5	172	11.0	15.0
Borisov and Marei, 1974	37-50	66	168	8.3	12.6
Borisov and Marei, 1974	37-50	74	174	8.9	12.0
Borisov and Marei, 1974	37-50	73	172	9.6	13.2
Borisov and Marei, 1974	37-50	67	170	9.7	14.5
Borisov and Marei, 1974	37-50	76	174	10.1	13.3
Borisov and Marei, 1974	37-50	73	174	10.1	13.9
Borisov and Marei, 1974	37-50	74	177	10.4	14.1
Borisov and Marei, 1974	37-50	79	183	10.9	13.8
Borisov and Marei, 1974	37-50	77	178	12.7	16.4
Borisov and Marei, 1974	37-50	79	181	13.4	17.0
Clarys <i>et al.</i> , 1984	73	52.8	156	7.4	13.9
Clarys <i>et al.</i> , 1984	78	70.4	163	8.9	12.7
Clarys <i>et al.</i> , 1984	78	71.5	167	11.7	16.4
Clarys <i>et al.</i> , 1984	70	58.5	159	7.9	13.5
Clarys <i>et al.</i> , 1984	83	51.7	168	9.8	19.0
Clarys <i>et al.</i> , 1984	72	65.1	166	9.6	14.8
Clarys <i>et al.</i> , 1984	65	54.8	166	8.8	16.1
Clarys <i>et al.</i> , 1984	59	76.8	173	10.1	13.1
Clarys <i>et al.</i> , 1984	81	61.0	177	8.7	14.3
Clarys <i>et al.</i> , 1984	73	85.1	172	10.3	12.1
Clarys <i>et al.</i> , 1984	73	57.7	164	7.3	12.7
Clarys <i>et al.</i> , 1984	55	88.9	187	11.1	12.5
McInroy <i>et al.</i> , 1985	49	64.9	182	9.0	13.9
McInroy <i>et al.</i> , 1991	62	75.0	173	8.7	11.6

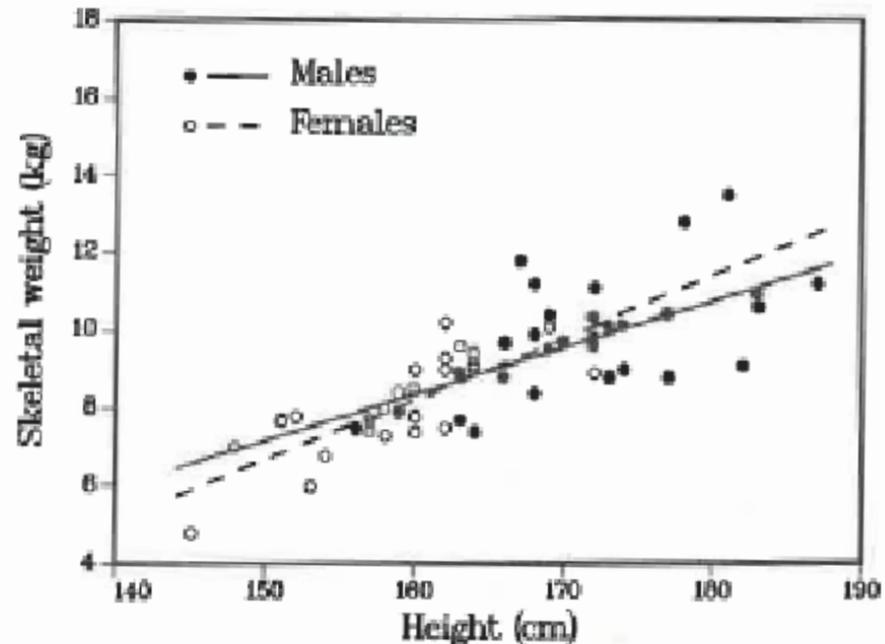
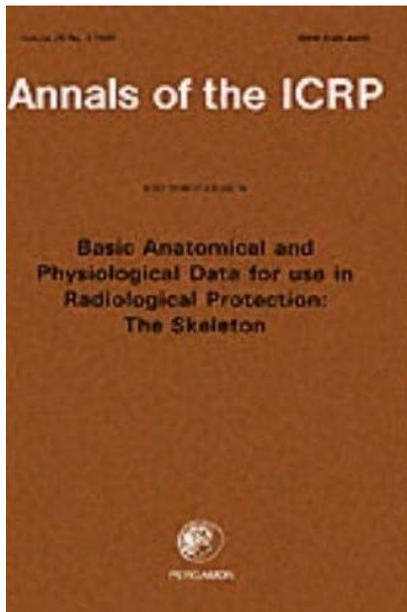
\* From Vierordt (1906), Muehlmann (1927), Clarys *et al.* (1984).



# ICRP Study

## ICRP Publication 70 (1995)

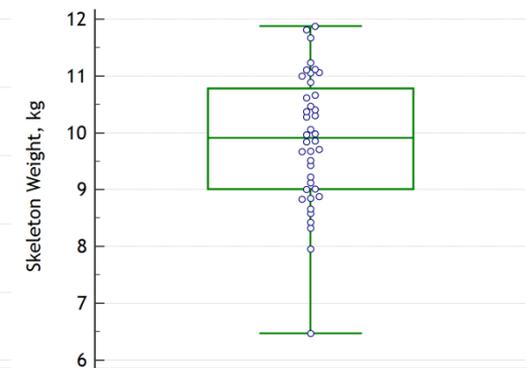
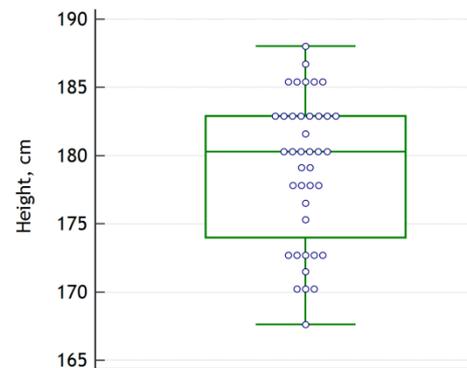
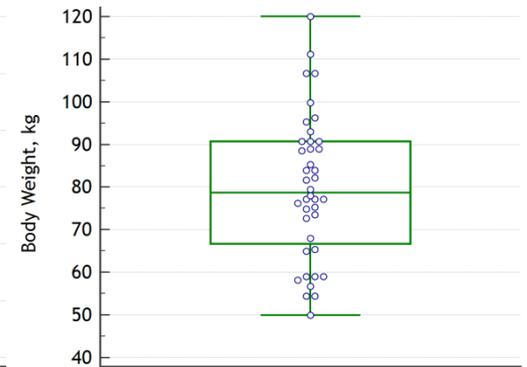
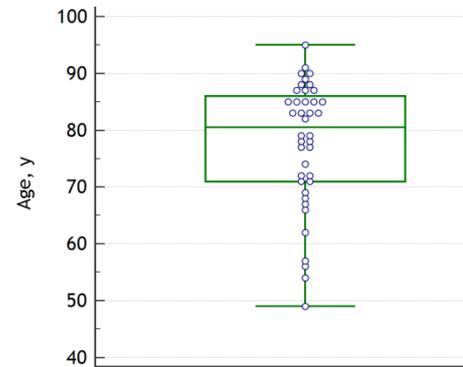
- Correlation between skeleton weight and body height
- Number of cases: 31
- $W_{skel} \text{ (kg)} = -10.7 + 0.119 \times H \text{ (cm)}; R = 0.60$





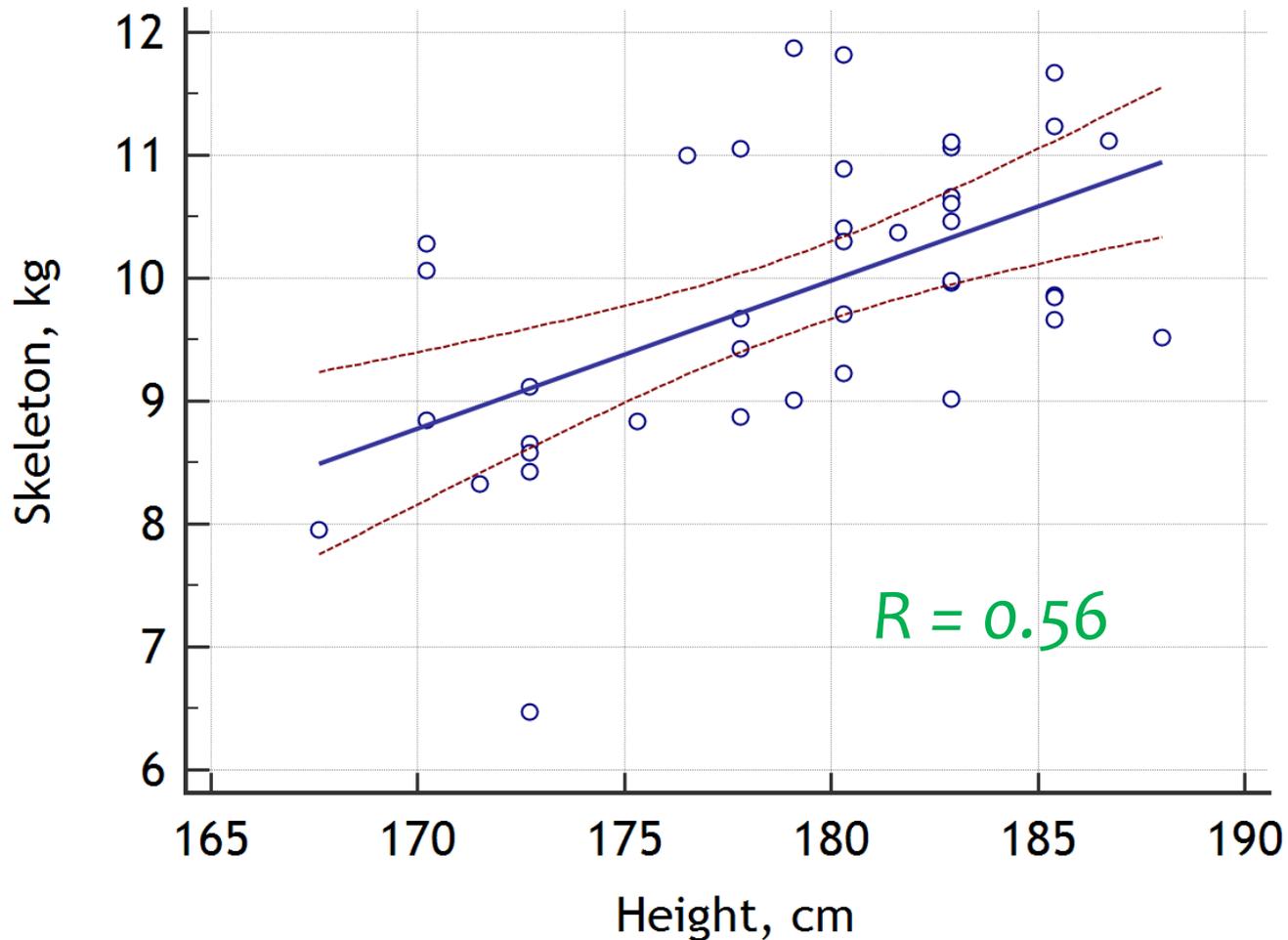
# This Study

- USTUR whole-body donors
- Number of cases: 40
  - ✓ Age:  $78 \pm 11$  y
  - ✓  $W_{\text{body}}$ :  $80 \pm 17$  kg
  - ✓ H:  $179 \pm 5$  cm
  - ✓  $W_{\text{skel}}$ :  $9.9 \pm 1.2$  kg





# USTUR: Linear Regression Fit

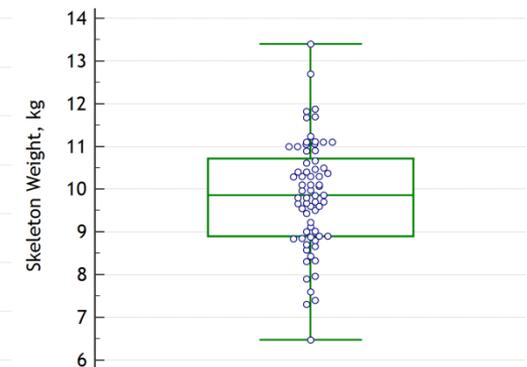
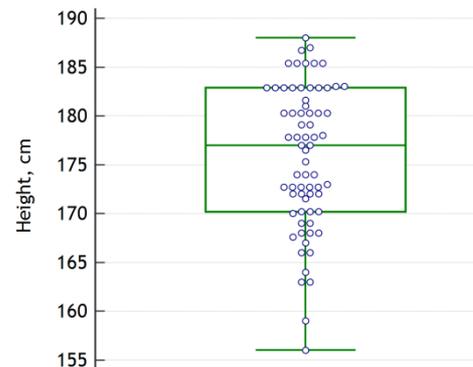
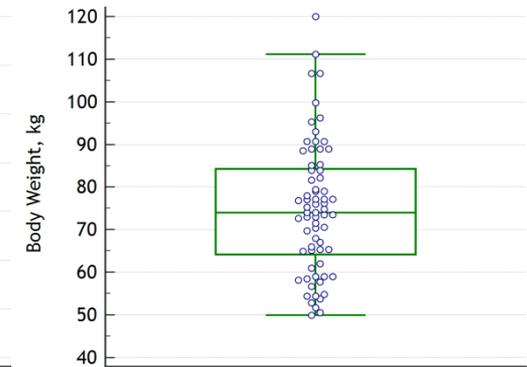
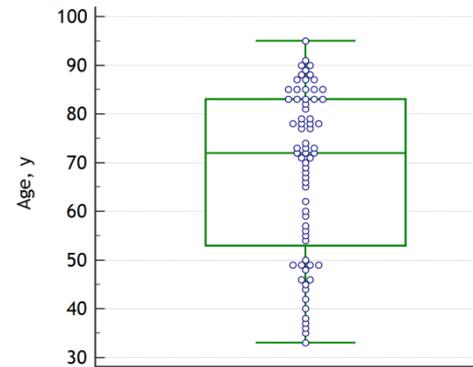


$$W_{skel} \text{ (kg)} = -11.70 + 0.120 \times H \text{ (cm)}$$



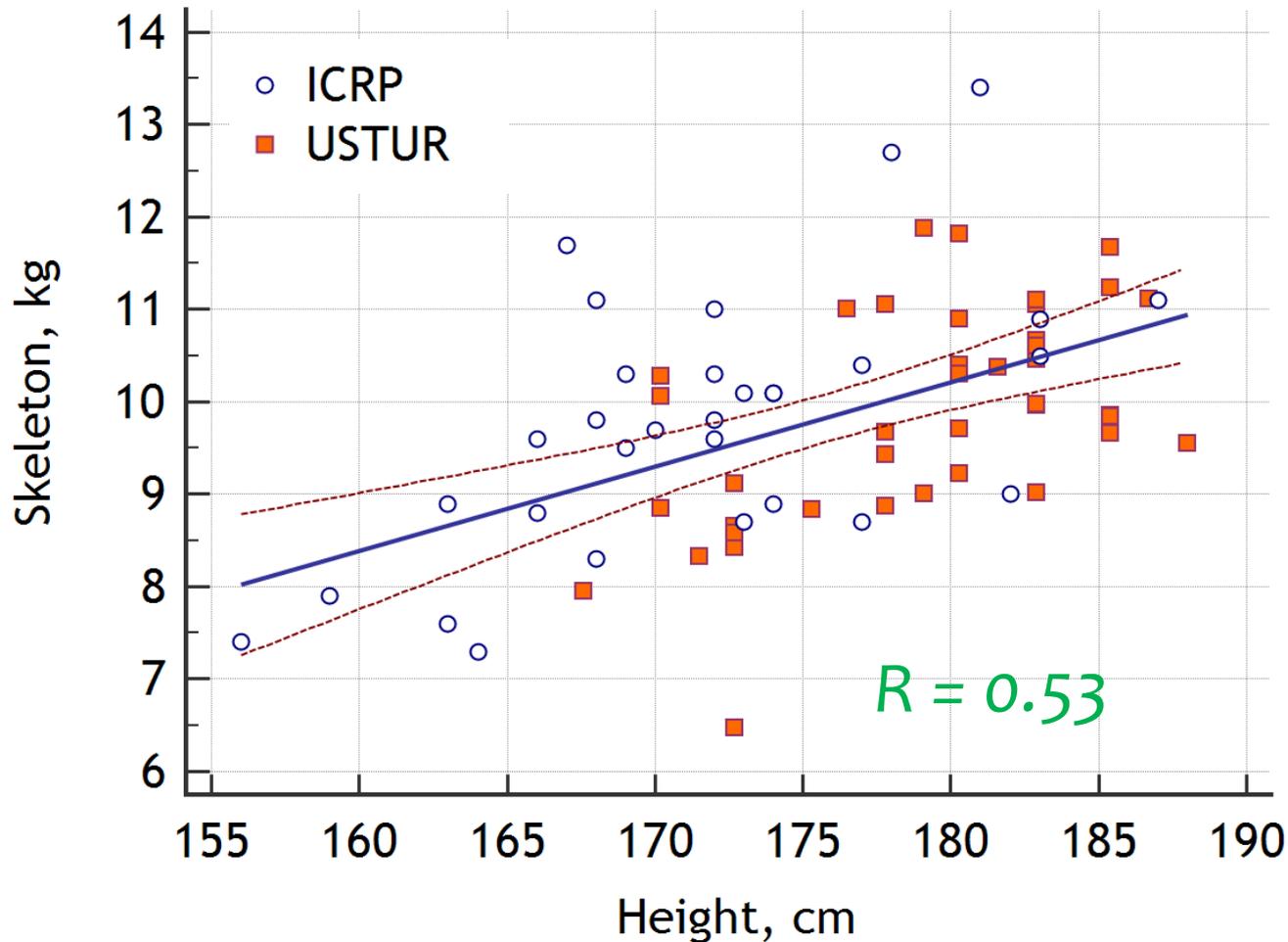
# Combined Population

- ICRP + USTUR
- Number of cases: 69
  - ✓ Age:  $68 \pm 17$  y
  - ✓  $W_{\text{body}}$ :  $75 \pm 15$  kg
  - ✓ H:  $176 \pm 7$  cm
  - ✓  $W_{\text{skel}}$ :  $9.9 \pm 1.3$  kg





# Combined: Linear Regression Fit



$$W_{skel} \text{ (kg)} = -6.49 + 0.093 \times H \text{ (cm)}$$



# Linear Regression Parameters

Study	n	$W_{skel} = a \times H + b$		R	Residual St. Dev.
		$a \pm \sigma_a$	$b \pm \sigma_b$		
ICRP	31*	$0.119 \pm 0.029$	$-10.67 \pm 5.04$	0.60	1.16
USTUR	40*	$0.120 \pm 0.029$	$-11.70 \pm 5.20$	0.56	0.98
Combined	69	$0.093 \pm 0.018$	$-6.49 \pm 3.21$	0.53	1.10

\* Two common subjects



# Multiple Regression

- Skeleton Weight =  $f(\text{Height, Body Weight, Age})$

$$W_{skel}(\text{kg}) = a + b \times H(\text{cm}) + c \times W_{body}(\text{kg}) + d \times A(\text{y})$$

Predictor	Regression Coefficient	P-value
Constant	-1.77	
Height	0.058 ± 0.020	0.0047
Body Weight	0.036 ± 0.009	0.0140
Age	-0.018 ± 0.007	0.0003
Correlation Statistics		
Correlation Coefficient, $R$	0.66	
Residual Standard Deviation	0.98	



# Summary

- ICRP 70 skeleton weight vs. height equation for male adults updated using data from 40 USTUR whole-body donors
- Linear regression fit:

$$W_{skel}(\text{kg}) = -6.49 + 0.093 \times H(\text{cm})$$

- ✓ Updated ICRP 70 equation

- Multiple regression fit:

$$W_{skel}(\text{kg}) = -1.77 + 0.058 \times H(\text{cm}) + 0.036 \times W_{body}(\text{kg}) - 0.018 \times A(y)$$

- ✓ Recommended for skeleton weight calculation



*Questions?*