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Anthropometric change: implications for office ergonomics

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Abstract. Well-designed office workspaces require good anthropometric data in order to accommodate variability in the worker population. The recent obesity epidemic carries with it a number of anthropometric changes that have significant impact on design. We examine anthropometric change among US civilians over the last 50 years, and then examine that change in a subset of the US population – the US military – as military data sets often have more ergonomic dimensions than civilian ones. The civilian mean stature increased throughout the period 1962 to 2006 for both males and females. However, the rate of increase in mean weight was considerably faster. As a result, the male obesity rate changed from 10.7% in 1962 to 31.3% in 2006. The female change for the same period was 15.8% to 33.2%. In the Army, the proportion of obesity increased from 3.6% to 20.9%, in males. In the absence of national US ergonomic data, we demonstrate one approach to tracking civilian change in these dimensions, applying military height/weight regression equations to the civilian population estimates. This approach is useful for population monitoring but is not suitable for establishing new design limits, as regression estimates likely underestimate the change at the ends of the distribution.

Keywords: anthropometry, secular trend, obesity, workspace design

1. Introduction

Well-designed office workspaces require good anthropometric data in order to accommodate variability in the worker population. Historically, anthropometric changes in human populations, at least in developed countries, were a function of gradual increases in body height, or stature – the secular trend. More recently, an obesity epidemic is becoming a worldwide phenomenon. This epidemic carries with it a number of anthropometric changes that have significant impact on the design of office workspaces. We examine anthropometric change among US civilians over the last 50 years, and then examine that change in a subset of the US population – the US military. We conclude by exploring the impact of those changes on the standards used by office furniture manufacturers to design their products.

2. Method

We examined national probability samples of US anthropometry from 1962 through 2006, using data from the National Health Examination Survey (1962) [12] and the series of National Health and Nutrition Examination Surveys [7]. A 2007-2008 update of NHANES data has been released, but samples were smaller than in the 2003-2006 four-year cycle. We use the 2006 data here because the next four-year cycle sample, 2007-2010, has not yet been released. In addition to mean height and weight, we calculated obesity prevalence rates as a measure of population change. We followed the US Centers for Disease Control definition of obesity, which is a Body Mass Index (BMI) greater than 30. The BMI is calculated as weight (in kg)/stature (in meters)^2.

Because few ergonomic dimensions are available in the US national probability samples, many designers and standards developers use US military data, where ergonomic dimensions are abundant. In order to examine military samples over a similar time period, we took data from US Army soldiers in measured in 1966 (6,682 males) [13], 1987-1988 (1774 males; 2208 females) [4] and again in 2006-2007 (2811 males; 651 females) [2, 5]. Obesity rates for these samples were calculated as well.

3. Results

The civilian mean stature increased throughout the period 1962 to 2006 for both males and females. However, the rate of increase in mean weight was considerably faster (Figure 1).
As a result of body weight increasing more rapidly than stature, the male obesity rate changed from 10.7% in 1962 to 31.3% in 2006. The female change for the same period was 15.8% to 33.2% (Table 1). In the Army, the proportion of obesity increased from 3.6% to 20.9%, in males. We had insufficiently representative data to get reliable estimates for the females in the 2006-2007 study. Figures 2 and 3 show the increase in stature and weight, respectively, during the comparative time period for both US civilian males and US Army males. Table 2 shows the prevalence of obesity for these populations over the same time period.

Our most comparable military data sets are from 1987-1988 and 2006-2007. Examining those two data sets in particular, mean values increased for a number of important ergonomic dimensions in approximately 20 years (Table 3). For example, male biacromial (shoulder) breadth increased 12.7 mm; male bideltoid (upper arm) breadth increased 8.1 mm, while male torso circumferences – all important in personal protective equipment – increased 40 mm or more.

4. Discussion

Military populations are different from the civilian population in that the demographic distributions are different, it is not a random sample from the civilian population, and physical fitness requirements ensure that, in general, military populations are more

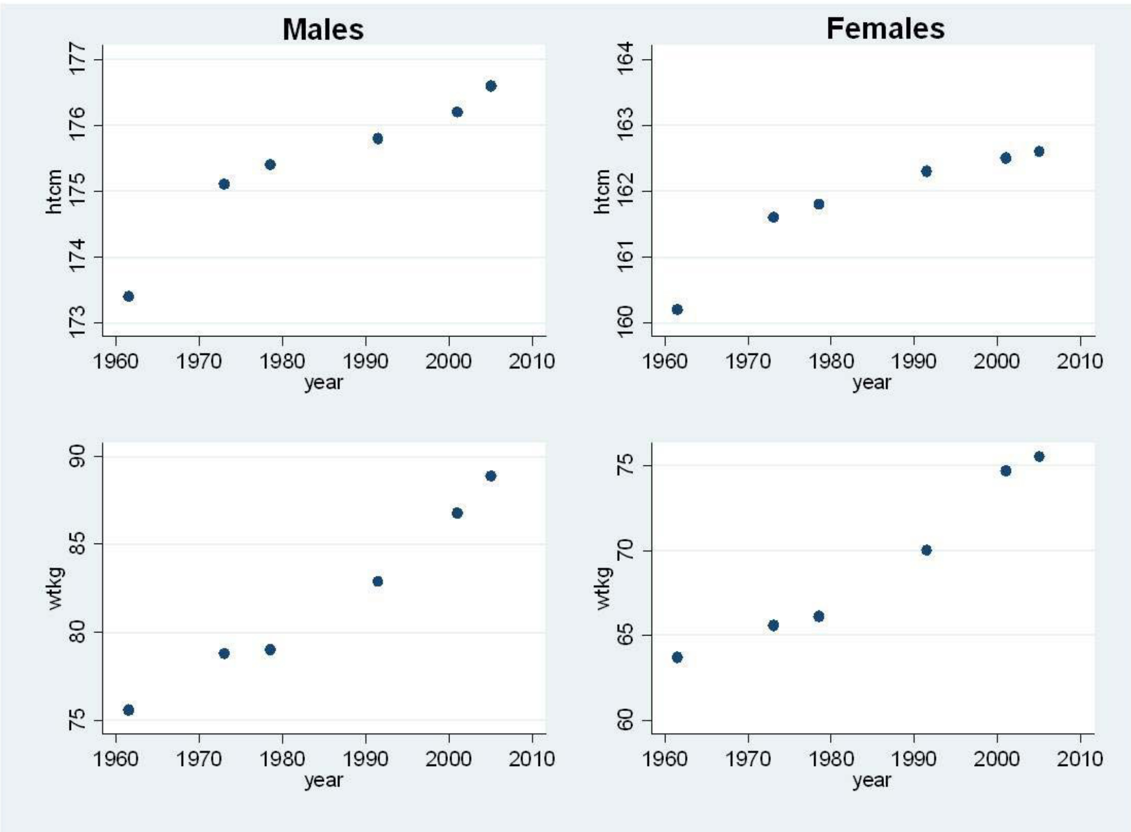

Fig 1. Changes in Mean Stature & Weight for U.S. Civilians, 20-74 yrs of age: 1962-2006 (Stature and Weight means are taken from Ogden et al [9], McDowell et al [6], and calculated from the NHANES 2003-04 and 2005-06 data releases [7]).

Table
Prevalence of Obesity (BMI>30) Among US Adults

	1960-62	1971-74	1976-80	1988-94	1999-2000	2001-02	2003-04	2005-06
Males	**10.70%**	**12.10%**	**12.70%**	**20.60%**	**27.70%**	**27.80%**	**31.10%**	**33.30%**
Females	**15.80%**	**16.60%**	**17.00%**	**25.90%**	**34.00%**	**33.30%**	**33.20%**	**35.30%**

*1960- 2000 Prevalence data from Flegal et al [3] based on adults 20 -74 years of age;
2001- 2006 Prevalence data from Ogden et al [10, 11] based on adults aged 20 years and older.

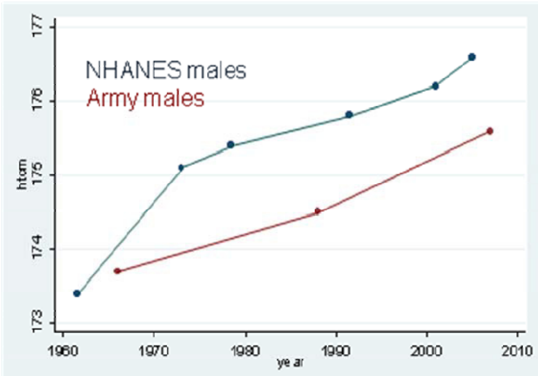

Fig 2. Mean stature for US civilian and US Army males: 1962 – 2007.

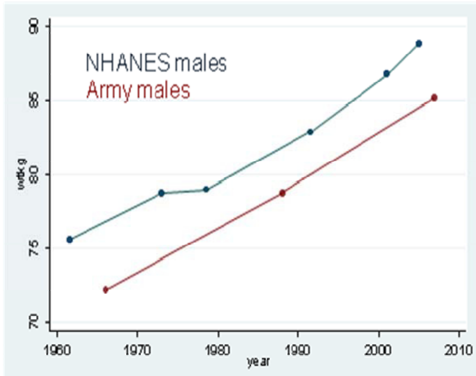

Fig 3. Mean body weight for US civilians and US Army males: 1960 – 2007.

Table 2
Prevalence of Obesity (BMI>30) Among US Adult Males and US Civilian Males.

	1960-62	1966	1988	1988-94	2005-06	2006-07
US Males	**10.70%**			**20.60%**	**33.30%**	
Army Males		**3.60%**	**7.00%**			**20.90%**

Table 3
Change in Mean Values for Selected Ergonomic Dimensions among US Army Active Duty Males: 1987-1988 vs 2006-2007 (values in mm).

Males	1987-1988 N=1774	2006-2007 N=1475	Difference	Probability	Observer Error
Stature	1755.8	1760.2	4.4	ns	5
Sitting Height*	913.9	922.5	8.5	**P<.001**	5.7
Biacromial Breadth	397	409.7	12.7	**P<.001**	7.8
Crotch Height	837.2	836	-1.2	ns	6.8
Knee Height Sitting	558.8	557.9	-0.9	ns	1.8
Weight (kg)	78.5	83.7	5.2	**P<.001**	0.2
Bideltoid Breadth	491.8	499.8	8.1	**P<.001**	7.9
Chest Circumference	991.4	1037.1	45.7	**P<.001**	15
Waist Circumference	862.4	921.9	59.5	**P<.001**	12.4
Buttock Circumference	983.7	1023.3	39.7	**P<.001**	11.7
Hip Breadth Sitting	366.8	371.6	4.9	**P<.001**	6.4

* Table taken from Gordon et al [5]: Anthropometric Change in the US Army: 1987-2007. P values reflect 5% probability with the Bonferroni adjustment for 11 tests. Observer error refers to the largest expert mean absolute difference in ANSUR trials, reported in Gordon et al [4]. Boldface dimensions have P values less than 0.001, and differences larger than the observer error.

physically fit than the civilian pool. Yet, because important ergonomic dimensions are not routinely measured in the civilian surveys, military data are sometimes used in designing office furniture and workstations, as well as in ergonomic standards, such as ANSI/HFES 100 [1].

A solution to the problem of having insufficient dimensions on the population of interest is to estimate the impact of stature and weight changes on ergonomic parameters using regression equations taken from a military data set. Specifically, we propose to use the 1987-1988 US Army data base (which has sufficiently representative males and females) to calculate regression equations (Table 4) that predict ergonomic dimensions from stature and weight. This data base is ideally suited for this purpose because it is large and demographically diverse.

Table 4
Stature/Weight Regressions* for Workstation Dimensions: 1987-1988 US Army.

	Males (n=5057)				Females (n=3479)			
	Stature (mm)	Weight (kg)	Constant	R2	Stature (mm)	Weight (kg)	Constant	R2
Abdominal Extension Depth, Sitting	-0.1564	2.5624	317.5268	0.67	-0.1452	3.1675	268.4026	0.7
Buttock Knee Length	0.2936	0.7959	36.1595	0.74	0.2483	1.3066	96.7072	0.71
Buttock Popliteal Length	0.2868	0.3716	-34.1074	0.67	0.252	0.6708	24.8726	0.6
Elbow Rest Height	*-0.0059*	0.6841	191.3705	0.08	0.0552	0.2545	124.0556	0.05
Foot Length	0.1167	0.2038	47.8473	0.55	0.1079	0.2707	49.5019	0.5
Forearm-Forearm Breadth	-0.1875	3.5895	592.445	0.62	-0.1327	3.6779	459.5629	0.66
Forearm-Hand Length	0.2515	0.0985	32.5818	0.62	0.2449	0.1454	28.2582	0.59
Hip Breadth, Sitting	-0.0094	1.9894	228.6642	0.74	-0.0425	3.0035	273.331	0.68
Knee Height, Sitting	0.3416	0.2446	-61.3784	0.81	0.3273	0.3472	-44.5135	0.78
Popliteal Height	0.3466	-0.442	-141.454	0.76	0.3506	-0.7835	-138.214	0.69
Sitting Height	0.3865	0.1764	223.871	0.61	0.4162	*-0.0428*	184.9214	0.64
Thigh Clearance	-0.0455	1.0353	164.8534	0.66	-0.0391	1.1609	147.7685	0.56

*Regression equations were estimated from the ANSUR research database, with subjects (18-65 yrs) weighted to match Census 2000 age/race distributions. All regression equations were statistically significant at P<.0001. However, coefficients in grey are not significantly different from zero.

By using the stature change and weight change as input values to the regression equation, and ignoring the constant, the equation can estimate the mean change in the civilian ergonomic dimension (Figure 4).

We made these calculations for 12 sample dimensions. Table 5 shows the changes in stature and weight that were used as input values for the regression equations. Table 6 shows the resulting estimates for changes in ergonomic dimensions.

For many of the stature-related dimensions, the change was inconsequential for design. But for many of the weight related dimensions, the changes were substantial. For example, male Forearm-Forearm Breadth increased by 33.9 mm (49.0 mm for females) and male Hip Breadth Sitting increased by 20.0 mm (39.9 mm for females).

The estimation method described here is based on known changes in the mean values of stature and weight. We applied it to some of the algorithms in ANSI/HFES 100 [1] for workstation design and found similar changes to those design parameters – 40.00 mm in seat pan width, for example. We note that these changes at the mean likely underestimate changes at the tails of the anthropometric distribution, especially at the large end. Design decisions are often based on values at the tails of the anthropometric distribution.

Eq. 1 Workstation Dimension (Time2) = a * (Stature Time2) + b* (Weight Time2) + constant

Eq. 2 Workstation Dimension (Time1) = a * (Stature Time1) + b* (Weight Time1) + constant

Eq. 3 Workstation Δ (T2 - T1) = a * (Stature2 - Stature1) + b* (Weight2 – Weight1)

Fig 4. Equations for estimating mean change in ergonomic dimensions.

Table 5
Changes in Stature and Weight: 1987-1988 vs 2005-2006 (values in kg and mm).

	Males		Females	
	Stature	Weight	Stature	Weight
US Army 87-88	1755.8	78.49	1629.4	62.01
NHANES 2006	1768.6	88.6	1628.7	75.3
Change	12.8	10.11	-0.7	13.29

Table 6
Expected Changes in Workstation Dimensions* (values in mm).

	Males	Females	Obs Error
Abdominal Extension Depth, Sitting	23.9	42.2	10.4
Buttock Knee Length	11.81	17.19	6.1
Buttock Popliteal Length	7.43	8.74	7.3
Elbow Rest Height	6.84	3.34	9.8
Foot Length	3.55	3.52	3
Forearm-Forearm Breadth	33.89	48.97	17.3
Forearm-Hand Length	4.22	1.76	3.9
Hip Breadth, Sitting	19.99	39.95	6.4
Knee Height, Sitting	6.85	4.38	1.8
Popliteal Height	-0.03	-10.66	6.7
Sitting Height	6.73	-0.86	5.7
Thigh Clearance	9.88	15.46	3.3

5. Conclusion

US national probability samples have shown little recent increase in stature, while showing substantial increase in weight, and the trend is apparent in US Army data as well. The US lacks a systematic tool for gathering anthropometric data useful for ergonomic design. The changes in probability samples suggest that ergonomic dimensions related to body weight have likely increased substantially in recent years. In the absence of national US ergonomic data, one approach to tracking civilian change in these dimensions is to apply stature/weight regression equations derived from a data base rich in such dimensions, to the civilian population estimates where ergonomic dimensions are generally not available.

This approach gives a rough sense of the average change in dimensions, and is useful for population monitoring. However, this method is not suitable for establishing new design limits, as regression estimates likely underestimate the change at the ends of the distribution, where design limits are often established.

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