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Standardizing anthropometric measures in children and adolescents with functions for egen: Update

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Abstract. In this article, we describe an extension to the `egen` functions `zanthro()` and `zbmicat()` (Vidmar et al., 2004, *Stata Journal* 4: 50–55). All functionality of the original version remains unchanged. In the 2004 version of `zanthro()`, z scores could be generated using the 2000 U.S. Centers for Disease Control and Prevention Growth Reference and the British 1990 Growth Reference. More recent growth references are now available. For measurement-for-age charts, age can now be adjusted for gestational age. The `zbmicat()` function previously categorized children according to body mass index (weight/height^2) as normal weight, overweight, or obese. "Normal weight" is now split into normal weight and three grades of thinness. Finally, this updated version uses cubic rather than linear interpolation to calculate the values of L, M, and S for the child's decimal age between successive ages (or length/height for weight-for-length/height charts).

Keywords: dm0004_1, zanthro(), zbmicat(), z scores, LMS, egen, anthropometric standards

1 Introduction

Comparison of anthropometric data from children of different ages is complicated by the fact that children are still growing. We cannot directly compare the height of a 5-year-old with that of a 10-year-old. Clinicians and researchers are often interested in determining how a child compares with other children of the same age and sex: Is the child taller, shorter, or about the same height as the average for his or her age and sex?

The growth references available to `zanthro()` tabulate values obtained by the LMS method, developed by Cole (1990) and Cole and Green (1992). The LMS values are used to transform raw anthropometric data, such as height, to standard deviation scores (z scores). These are standardized to the reference population for the child's age and sex (or for length/height and sex). Two sets of population-based reference data that were widely used at the time `zanthro()` was initially developed are the 2000 Centers for Disease Control and Prevention (CDC) Growth Reference in the United States (Kuczmarski et al. 2000) and the British 1990 Growth Reference (Cole, Freeman, and Preece 1998). Since then, the following population-based reference data have been released and are now available in `zanthro()`: the WHO Child Growth Standards, the WHO Reference 2007, the UK-WHO Preterm Growth Reference, and the UK-WHO Term Growth Reference.

1.1 WHO Child Growth Standards

The WHO Child Growth Standards (World Health Organization 2006, 2007) are the result of the Multicentre Growth Reference Study (MGRS) undertaken by the World Health Organization (WHO) between 1997 and 2003. They replace the 1977 National Center for Health Statistics (NCHS)/WHO Growth Reference created by the U.S. NCHS and WHO. The 1977 reference underestimated levels of low weight-for-age (underweight) for breast-fed infants. A number of specific limitations were noted by the WHO working group in 1995: "1) the sample was limited to Caucasian infants from mostly middle-income families; 2) data were collected every three months rather than monthly, which limited the accuracy of developing the growth curve, particularly from 0–6 months of age; and 3) the majority of the infants in the sample were bottle-fed, and if they were breast-fed it was only for a short duration (typically less than three months)" (Binagwaho, Ratnayake, and Smith Fawzi 2009).

WHO concluded that new growth curves were necessary, a recommendation endorsed by the World Health Assembly. The MGRS collected primary growth data and related information on 8,440 healthy breast-fed infants and young children in Brazil, Ghana, India, Norway, Oman, and the United States. It combined a longitudinal follow-up from birth to 24 months and a cross-sectional survey of children aged 18–71 months. "The MGRS is unique in that it was purposely designed to produce a standard by selecting healthy children living under conditions likely to favor the achievement of their full genetic growth potential" (World Health Organization 2006). The WHO Child Growth Standards can be used to assess the growth and development of children from 0–5 years.

1.2 WHO Reference 2007

The WHO Reference 2007 (de Onis et al. 2007) is a modification of the 1977 NCHS/WHO Growth Reference for children and adolescents aged 5–19 years. It was merged with data from the cross-sectional sample of children aged 18–71 months to smooth the transition at 5 years. The WHO Reference 2007 can be used for children and adolescents aged 5–19 years. It complements the WHO Child Growth Standards.

1.3 UK-WHO Growth References

In 2007, the Scientific Advisory Committee on Nutrition recommended that a modified WHO chart be adopted in the UK. Two composite UK-WHO data files (Cole et al. 2011), one for preterm and the other for term births, were launched in May 2009. Both comprise three sections:

- A birth section based on the British 1990 Growth Reference. Acknowledgment statements for these data should specify the data source as "British 1990 Growth Reference, reanalyzed 2009".
- A postnatal section from 2 weeks to 4 years copied from the WHO Child Growth Standards.
- The 4–20 years section from the British 1990 Growth Reference.

Term infants are those born at 37 completed weeks' gestation and beyond. The UK-WHO Term Growth Reference can be used for these infants. For infants born before 37 completed weeks' gestation, the UK-WHO Preterm Growth Reference can be used, with gestationally corrected age.

1.4 Additional growth charts available in zanthro()

The WHO and composite UK-WHO growth data are now available in `zanthro()`. In addition, two new measurements have been added to the British 1990 Growth Reference: waist-for-age and percentage body fat–for-age (based on Tanita body composition analyzer/scales).

1.5 Categorizing children into grades of thinness and overweight

Body mass index (BMI) cutoffs are used to define categories of thinness (Cole et al. 2007) and overweight (Cole et al. 2000) in children and adolescents aged 2–18 years. BMI data were obtained from nationally representative surveys of children in Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. The thinness cutoffs correspond to equivalent adult BMI cutoff points endorsed by WHO of 16, 17, and 18.5 kg/m^2. `zbmicat()` now categorizes children into these three thinness grades as well as normal weight, overweight, or obese according to international cutoff points.

1.6 Comparison with LMSgrowth

LMSgrowth is a Microsoft Excel add-in to convert measurements to and from United States, UK, WHO, and composite UK-WHO reference z scores. It can be downloaded via this link: http://www.healthforallchildren.com/index.php/shop/product/Software/Gr5yCsMCONpF39hF/0. z scores can only be calculated for the range of ages within a growth chart. Where the age ranges for the two programs do not overlap (table 1), only one of `zanthro()` and LMSgrowth will generate z scores.

Table 1. Differences in age ranges for `zanthro()` and LMSgrowth

Chart	Age range for `zanthro()`	Age range for LMSgrowth
CDC: Weight	0–20 years	0–19.96 years
CDC: Height	2–20 years	1.96–19.96 years
CDC: BMI	2–20 years	1.96–19.96 years

Each growth reference is summarized by three numbers, called L, M, and S, which represent the skewness, median, and coefficient of variation of the measurement as it changes with age (or length and height). For age, L, M, and S values are generally tabulated at monthly intervals. For length and height, these parameters are tabulated at 0.5 or 1 cm intervals. Where a child's age, length, and height occur within these intervals, values of L, M, and S are obtained via cubic interpolation except at the endpoints of the charts, where linear interpolation is used. (The BMI cutoff points are tabulated at 6 monthly intervals. The cutoff point where a child's age occurs within these intervals is also obtained via cubic interpolation—or linear interpolation from 2–2.5 years and 17.5–18 years.) Minor discrepancies in the z scores calculated by `zanthro()` and LMSgrowth will be caused by different segment lengths and methods of interpolation for a segment (figure 1). Even so, the z scores generated by the two programs should agree within one decimal place.

CDC: Weight

Age (years)	0	0.04	...	19.88	19.96	20
Age (months)	0	0.5	...	238.5	239.5	240
`zanthro()`	+	+	...	+	+	+
	linear				linear	
LMSgrowth	+	+	...	+	+	-
	linear			linear		

CDC: Height and BMI

Age (years)	1.96	2	2.04	...	19.88	19.96	20
Age (months)	23.5	24	24.5	...	238.5	239.5	240
`zanthro()`	-	+	+	...	+	+	+
		linear				linear	
LMSgrowth	+	-	+	...	+	+	-
	linear				linear		

Figure 1. Use of linear interpolation for charts with different age ranges

2 Syntax

`egen` [*type*] *newvar* `= zanthro(`*varname*`,`*chart*`,`*version*`)` [*if*] [*in*]`,`
`xvar(`*varname*`)` `gender(`*varname*`)` `gencode(male=`*code*`, female=`*code*`)`
[`ageunit(`*unit*`)` `gestage(`*varname*`)` `nocutoff`]

`egen` [*type*] *newvar* `= zbmicat(`*varname*`)` [*if*] [*in*]`,` `xvar(`*varname*`)`
`gender(`*varname*`)` `gencode(male=`*code*`, female=`*code*`)` [`ageunit(`*unit*`)`]

`by` cannot be used with either of these functions.

3 Functions

`zanthro(`*varname*`,`*chart*`,`*version*`)` calculates z scores for anthropometric measures in children and adolescents according to United States, UK, WHO, and composite UK-WHO reference growth charts. The three arguments are the following:

varname is the variable name of the measure in your dataset for which z scores are calculated (for example, `height`, `weight`, or `BMI`).

chart; see tables 3–7 for a list of valid chart codes.

version is `US`, `UK`, `WHO`, `UKWHOpreterm`, or `UKWHOterm`. `US` calculates z scores by using the 2000 CDC Growth Reference; `UK` uses the British 1990 Growth Reference; `WHO` uses the WHO Child Growth Standards and WHO Reference 2007 composite data files as the reference data; and `UKWHOpreterm` and `UKWHOterm` use the British and WHO Child Growth Standards composite data files for preterm and term births, respectively.

`zbmicat(`*varname*`)` categorizes children and adolescents aged 2–18 years into three thinness grades—normal weight, overweight, and obese—by using BMI cutoffs (table 2). BMI is in kg/m^2. This function generates a variable with the following values and labels:

Table 2. Values and labels for grades of thinness and overweight

Value	Grade/Label	BMI range at 18 years
-3	Grade 3 thinness	<16
-2	Grade 2 thinness	16 to <17
-1	Grade 1 thinness	17 to <18.5
0	Normal wt	18.5 to <25
1	Overweight	25 to <30
2	Obese	30+

Note that since the previous version of `zbmicat()`, the value label for BMI category has been changed from `1` = Normal wt, `2` = Overweight, and `3` = Obese.

4 Options

`xvar(`*varname*`)` specifies the variable used (along with gender) as the basis for standardizing the measure of interest. This variable is usually age but can also be length or height when the measurement is weight; that is, weight-for-age, weight-for-length, and weight-for-height are all available growth charts.

`gender(`*varname*`)` specifies the gender variable. It can be string or numeric. The codes for `male` and `female` must be specified by the `gencode()` option.

`gencode(male=`*code*`, female=`*code*`)` specifies the codes for `male` and `female`. The gender can be specified in either order, and the comma is optional. Quotes around the codes are not allowed, even if the gender variable is a string.

`ageunit(`*unit*`)` gives the unit for the age variable and is only valid for measurement-for-age charts; that is, omit this option when the chart code is `wl` or `wh` (see section 5). The *unit* can be `day`, `week`, `month`, or `year`. This option may be omitted if the *unit* is `year`, because this is the default. Time units are converted as follows:

1 year = 12 months = 365.25/7 weeks = 365.25 days
1 month = 365.25/84 weeks = 365.25/12 days
1 week = 7 days

Note: Ages cannot be expressed to full accuracy for all units. The consequence of this will be most apparent at the extremes of age in the growth charts, where z scores may be generated when the age variable is in one unit and missing for some of those same ages when they have been converted to another unit.

`gestage(`*varname*`)` specifies the gestational age variable in weeks. This option enables age to be adjusted for gestational age. The default is 40 weeks. If gestational age is greater than 40 weeks, the child's age will be corrected by the amount over 40 weeks. A warning will be given if the gestational age variable contains a nonmissing value over 42. As with the `ageunit()` option, this option is only valid for measurement-for-age charts.

`nocutoff` forces calculation of all z scores, allowing for extreme values in your dataset. By default, any z scores with absolute values greater than or equal to 5 (that is, values that are 5 standard deviations or more away from the mean) are set to missing.

The decision to have a default cutoff at 5 standard deviations from the mean was made as a way of attempting to capture extreme data entry errors. Apart from this and setting to missing any z scores where the measurement is a nonpositive number, these functions will not automatically detect data errors. As always, please check your data!

5 Growth charts

Growth charts available in `zanthro()` are presented in tables 3–7. Note: Where `xvar()` is outside the permitted range, `zanthro()` and `zbmicat()` return a missing value.

Table 3. 2000 CDC Growth Charts, version `US`

chart	Description	Measurement unit	`xvar()` range
`la`	length-for-age	cm	0–35.5 months
`ha`	height-for-age	cm	2–20 years
`wa`	weight-for-age	kg	0–20 years
`ba`	BMI-for-age	kg/m^2	2–20 years
`hca`	head circumference–for-age	cm	0–36 months
`wl`	weight-for-length	kg	45–103.5 cm
`wh`	weight-for-height	kg	77–121.5 cm

Table 4. British 1990 Growth Charts, version `UK`

chart	Description	Measurement unit	`xvar()` range
`ha`	length/height-for-age	cm	0–23 years
`wa`	weight-for-age	kg	0–23 years
`ba`	BMI-for-age	kg/m^2	0–23 years
`hca`	head circumference–for-age	cm	Males: 0–18 years Females: 0–17 years
`sha`	sitting height–for-age	cm	0–23 years
`lla`	leg length–for-age	cm	0–23 years
`wsa`	waist-for-age	cm	3–17 years
`bfa`	body fat–for-age	%	4.75–19.83 years

Length/height and BMI growth data are available from 33 weeks gestation. Weight and head circumference growth data are available from 23 weeks gestation.

Table 5. WHO Child Growth Charts and WHO Reference 2007 Charts, version `WHO`

chart	Description	Measurement unit	`xvar()` range
`ha`	length/height-for-age	cm	0–19 years
`wa`	weight-for-age	kg	0–10 years
`ba`	BMI-for-age	kg/m^2	0–19 years
`hca`	head circumference–for-age	cm	0–5 years
`aca`	arm circumference–for-age	cm	0.25–5 years
`ssa`	subscapular skinfold–for-age	mm	0.25–5 years
`tsa`	triceps skinfold–for-age	mm	0.25–5 years
`wl`	weight-for-length	kg	45–110 cm
`wh`	weight-for-height	kg	65–120 cm

Table 6. UK WHO Preterm Growth Charts, version `UKWHOpreterm`

chart	Description	Measurement unit	`xvar()` range
`ha`	length/height-for-age	cm	0–20 years
`wa`	weight-for-age	kg	0–20 years
`ba`	BMI-for-age	kg/m^2	0.038–20 years
`hca`	head circumference–for-age	cm	Males: 0–18 years Females: 0–17 years

Length/height growth data are available from 25 weeks gestation. Weight and head circumference growth data are available from 23 weeks gestation.

Table 7. UK WHO Term Growth Charts, version `UKWHOterm`

chart	Description	Measurement unit	`xvar()` range
`ha`	length/height-for-age	cm	0–20 years
`wa`	weight-for-age	kg	0–20 years
`ba`	BMI-for-age	kg/m^2	0.038–20 years
`hca`	head circumference–for-age	cm	Males: 0–18 years Females: 0–17 years

Length/height, weight, and head circumference growth data are available from 37 weeks gestation.

6 Examples

Below is an illustration with data on a set of British newborns. The British 1990 Growth Reference is used; the variable `sex` is coded `male = 1`, `female = 2`; and the variable `gestation` is "completed weeks gestation".

```
. use zwtukeg

. list, noobs abbreviate(9)
```

sex	ageyrs	weight	gestation
1	.01	3.53	38
2	.073	5.05	40
2	.115	4.68	42
1	.135	4.89	36
2	.177	2.75	28

To compare the weight of the babies in this sample, for instance, with respect to socioeconomic grouping, we can convert weight to standardized z scores. The z scores are created using the following command:

```
. egen zwtuk = zanthro(weight,wa,UK), xvar(ageyrs) gender(sex)
> gencode(male=1, female=2)
(Z values generated for 5 cases)
(gender was assumed to be coded male=1, female=2)
(age was assumed to be in years)
```

In the command above, we have assumed all are term births. If some babies are born prematurely, we can adjust for gestational age as follows.

```
. egen zwtuk_gest = zanthro(weight,wa,UK), xvar(ageyrs) gender(sex)
> gencode(male=1, female=2) gestage(gestation)
(Z values generated for 5 cases)
(gender was assumed to be coded male=1, female=2)
(age was assumed to be in years)
```

Here are the results for both of the above commands:

```
. list, noobs abbreviate(10)
```

sex	ageyrs	weight	gestation	zwtuk	zwtuk_gest
1	.01	3.53	38	-.2731358	.6329474
2	.073	5.05	40	1.696552	1.696552
2	.115	4.68	42	.2438011	-.4162439
1	.135	4.89	36	-.3017253	1.204823
2	.177	2.75	28	-4.707812	-.2137314

Note that at `gestation` = 40 weeks, the z score is the same whether or not the `gestage()` option is used. The formula for gestationally corrected age is

$$\text{actual age} + (\text{gestation at birth} - 40)$$

where "actual age" and "gestation at birth" are in weeks.

Gestational age may be recorded as weeks and days, as in the following example:

gestwks	gestdays
38	3
40	6
42	0
36	2
28	1

These variables first need to be combined into a single `gestation` variable, which can then be used with the `gestage()` option:

```
. generate gestation =  gestwks + gestdays/7
```

Here we use the UK-WHO Term Growth Reference for term babies:

```
. egen zwtukwho = zanthro(weight,wa,UKWHOterm), xvar(ageyrs) gender(sex)
> gencode(male=1, female=2)
(Z values generated for 5 cases)
(gender was assumed to be coded male=1, female=2)
(age was assumed to be in years)
```

Here we use the UK-WHO Preterm Growth Reference for preterm babies, adjusting for gestational age:

```
. egen zwtukwho_pre = zanthro(weight,wa,UKWHOpreterm), xvar(ageyrs) gender(sex)
> gencode(male=1, female=2) gestage(gestation)
(Z values generated for 5 cases)
(gender was assumed to be coded male=1, female=2)
(age was assumed to be in years)
```

Note: Where the gestationally corrected age is from 37 to 42 weeks, the UK-WHO preterm and term growth charts generate different z scores. For example, the gestationally corrected age of a 2-week-old baby girl who was born at 37 weeks gestation is 39 weeks. If her weight is 3.34 kg, the following z scores are generated using the UK-WHO preterm and term growth charts:

```
. use zwtukwhoeg, clear

. egen zpreterm = zanthro(weight,wa,UKWHOpreterm), xvar(agewks) gender(sex)
> gencode(male=1, female=2) ageunit(week) gestage(gestation)
(Z value generated for 1 case)
(gender was assumed to be coded male=1, female=2)
(age was assumed to be in weeks)

. egen zterm = zanthro(weight,wa,UKWHOterm), xvar(agewks) gender(sex)
> gencode(male=1, female=2) ageunit(week) gestage(gestation)
(Z value generated for 1 case)
(gender was assumed to be coded male=1, female=2)
(age was assumed to be in weeks)
```

```
. list, noobs abbreviate(9)
```

sex	weight	agewks	gestation	zpreterm	zterm
2	3.34	2	37	.2403702	-.0422754

To determine the proportion of children who are thin, normal weight, overweight, and obese, we can categorize each child by using the following command:

```
. use zbmicateg, clear
. egen bmicat = zbmicat(bmi), xvar(ageyrs) gender(sex)
> gencode(male=1, female=2)
./zbmicat.dta
(BMI categories generated for 10 cases)
(gender was assumed to be coded male=1, female=2)
(age was assumed to be in years)
```

Here are the results:

```
. list, noobs
```

sex	ageyrs	bmi	bmicat
1	5.95	13.01	Grade 2 thinness
1	9.46	16.43	Normal wt
2	6.71	20.62	Obese
2	6.89	13.45	Grade 1 thinness
2	8.63	18.96	Overweight
1	8.48	17.45	Normal wt
1	7.08	15.65	Normal wt
2	7.56	11.54	Grade 3 thinness
2	9.78	19.56	Normal wt
2	8.25	20.58	Overweight

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