RECOMMENDATIONS FOR THE TRUNCATION OF BODY MASS INDEX IN POPULATION DATA

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Background

Body Mass Index (BMI) is a simple, efficient and accurate method for determining health risk related to body weight. The calculation of BMI for large scale population surveys is largely reliant on self-reported measures of height and weight as surrogate measures of actual height and weight. Although self-reported height and weight have been shown to be less valid than objective measures, the feasibility of conducting objective measurements for very large samples is limited by inconvenience and cost. Misreporting extreme values of height or weight may impact on the calculation of BMI and cause changes in the distribution of BMI, although the possible effect of BMI outliers that result from misreporting has not been systematically explored across surveys.

Some population surveys in Australia and overseas have applied truncation rules for height, weight, and/or BMI from self-reported data, and others have not. The rules and methods for truncation are not consistent across surveys. The Australian Bureau of Statistics applied truncation rules for self-reported height and weight to data collected from the 1995 and 2001 National Health Surveys. Height was truncated such that all cases less than or equal to 145 cms are coded as 145 cm and cases equal to or above 200cm are coded as 200cm. The rules that have been applied to weight are inconsistent across the two surveys. The upper limits for weight were defined as 130 kgs in 1995 and 145 kgs in 2001, and the lower limits were 35kgs in 1995 and 40 kgs in 2001. Extreme values were truncated to the nearest acceptable value (rather than coded as missing) for both height and weight, so no records with reported height and weight are removed.

The Australian Longitudinal Study of Women's Health (ALSWH) collects self-reported health information by mailed survey from more than 40 000 women. At baseline in 1996, the sample comprised 14 799 young participants (aged 18-23 years), 14099 mid-aged (40-45 years) and 12 940 older women (70-75 years) (sampled across Australia from the Medicare database). Specific truncation rules for each variable and for each age group are applied to the ALSWH data. For height, the lower limit is 120cms and the upper limit is 200cms for young women and 190cms for mid-aged and older women. The lower limit for weight is 30kgs across all ages and the upper limit is 140kgs for young and mid-aged women and 120kgs for older women. BMI is limited to a minimum of 14 across all age groups and a maximum of 55 in younger and mid-aged women and 50 in older. These limits were set after examining the extreme values in the distribution of each variable, checking hard-copies of surveys to ensure data had been entered as reported (and correcting extremes that were due to data entry errors), then determining the plausibility of reported relative height and weight. Values in all three variables that fell outside these ranges are coded as missing, rather than being truncated to the closest acceptable value, because of an inability to distinguish between extreme values that actually exist and those based on inaccurate reporting (Ball, 2002).

A useful indication of the true range of height, weight and BMI among Australians comes from physical measurements taken in the 1995 National Nutrition Survey (McLennan & Podger, 1998). Although minimum and maximum values were not reported, 90% of the sample aged 19 years and over had a calculated BMI between 19.8 and 34.9. Among men, heights were recorded from 140-149 cms to 190 cms or more, and 90% were between 163 and 186.7 cms tall. Among women, recorded heights ranged from 130-139 cms to 180-189 cms, and 90% had heights between 150.3 and 172.6 cms. Adult males weighed between 45-49 and 130 kg or more, and 90% weighed between 61.6 and 106.6 kilograms. The lowest weights recorded for adult women were 35-39 kgs, and some female participants were also categorised as weighing 130 kg or more. The most extreme 5% of female adult weights were less than 49.1 kgs at the lower end, or more than 95.2 kgs at the upper end of the distribution.

In the United States, the National Health Interview Survey (NHIS) is conducted by the National Center for Health Statistics (Centers for Disease Control and Prevention) using personal household interviews similar to those used in the Australian NHS. The Behavioral Risk Factor Surveillance System (BRFSS), which is the largest, continuously conducted, telephone survey internationally, is conducted by US states under the guidance of Center for Disease Control and Prevention. The BRFSS survey is designed to identify and monitor behavioural risk factors for chronic diseases and other leading causes of death. Currently, neither of these survey programs apply any exclusion criteria to extreme values of height and weight and include BMI for every case with reported height and weight (Yore M, CDC Physical Activity and Nutrition Branch, Personal Communication, 23rd August, 2003).

In Canada, the National Population Health Survey (NPHS) is a longitudinal study that conducts data collection every two years via face-to-face interview. For persons aged 20-64 years, limits for height are employed at a minimum of 3 feet (91.44cms) and a maximum of 7 feet (213.36cms). Respondents reporting height outside these values are excluded from calculation and analysis of BMI (Health Canada, 1996). The Canadian Community Health Survey (CCHS, 2000) uses a computer-assisted telephone interview (CATI) to survey approximately 130,000 Canadians. For respondents aged between 20 and 64 years (excluding pregnant women), BMI is truncated to a minimum value of 14 and a maximum value of 48, and available information suggests that values outside these parameters are re-coded to the closest acceptable value (Health Canada, 2000).

The examples above indicate a lack of consistency across data collection surveys in their management of self-reported height, weight and BMI, which makes comparison across surveys (and in the case of the NHS, even over time for the same survey) problematic. In addition, where truncation rules are used, the variability in managing cases outside the parameters of those rules further affects comparability and validity of the data. Truncation of height and weight that re-codes values of those outside the parameters to the closest acceptable value may misclassify people based on resulting BMI. For example, if the height of a case is valid but outside the upper limits and is recoded to the upper limit, the resulting BMI based on the truncated height and reported weight would be inflated. The possibility of such threats to validity due to truncation of self-reported height, weight and BMI must therefore be weighed against the likely advantages of employing such truncation rules.

This exploratory analysis was conducted to examine the distribution of Body Mass Index (BMI) and self-reported height and weight in three Australian National Health Surveys (1989, 1995, and 2001) and two New South Wales Health Surveys (1997-98 and 2002). The purpose of the analysis was comparison of the distribution of BMI values across data sets and the examination of outliers, with the aim of providing recommendations for the management of extreme and unlikely BMI values in future population surveys that collect self-reported height and weight. The exploratory nature of these analyses attempts to identify population sub groups or segments where measurement or misclassification error may occur and to learn from such analyses if any further refinement of cutpoints for BMI truncation are possible or warranted.

Methods

Adults (all those aged 16 years or over) were selected from each of the data sets described above. Each of the data sets recorded participant's self-reported weight and height. BMI was calculated as weight (kg)/height $(m)^2$. Cases with missing values for either height or weight were excluded from the analysis.

Descriptive analysis was conducted for height (cm), weight (kg) and BMI. Respondents were categorized as having extremely low (BMI <15), low (15≤ BMI <18), normal (18≤ BMI ≤35), high (35< BMI≤ 40) or extremely high (BMI>40) calculated BMI. The characteristics of respondents from each survey in each of these BMI categories was examined by gender (male vs. female), age, and country of birth (Australia vs. other). The reported height and weight for respondents whose BMI fell outside truncation rules being used for BMI (less than 14 or greater than 48; employed by the CCHS in Canada) in the NSW Health surveys and the 1989 NHS (who have not employed any truncation rules) were examined for plausibility to determine whether the most extreme BMI values had realistic values of relative height and weight. The reported height and weight for these extreme BMI values were considered, and compared against truncation rules being applied to height and weight variables for other population wide surveys that sample both men and women.

The most extreme truncation rules being applied elsewhere (from those discussed previously) to height and weight across surveys were used as a reference – those with a reported height of less than 145 or more than 200cms (from the 1995 and 2001 NHSs), or a reported weight of less than 30 or more than 130 kgs (from the 1995 NHS).

Results

A comparison of the mean, standard deviation and range for height, weight and BMI across the different surveys is shown in Table 1. Interestingly, the mean height, weight, and BMI were almost equal across surveys, despite considerable differences in the range of values. Slightly higher mean weight in the 2002 NSW Health survey and the 2001 NHS may be due to real increases in the weight of the population over time since the earlier surveys. The trends in reported body weight across the three national health surveys suggest a consistent increase of around 2kg per person in the adult Australian population each quinquennium. The lowest 1% of cases fell below a BMI of about 17, with very little variation in the 1st percentile cut-point across surveys. The highest one percentile cut-point based on BMI was slightly more variable across surveys, but clustered around a BMI of 40.

Approximately 2.5% of cases in each survey were categorized as having ‘extremely low’ or ‘low’ BMI, although the proportion was slightly higher in the sample from the 1989 NHS (3.4%). Again, this could be due to higher actual prevalence rates of the ‘low BMI’ category in 1989, with a trend towards a reduction in underweight in the population. The extremely low category was too small to show much variation among surveys.

The proportion of respondents categorized as having ‘extremely high’ or ‘high’ BMI was more variable across surveys. It was lowest in the earlier surveys (2% and 2.4% in the 1989 and 1995 NHS respectively), and slightly higher in most recent surveys (4.4% in the 2001 NHS and 4.9% in the 2002 NSW Health Survey).

Table 1: Descriptive characteristics for height, weight, and BMI from each survey

		TELEPHONE SURVEY				
		1997-8 NSW Health Survey	**2002 NSW Health Survey**	**1989 National Health Survey**	**1995 National Health Survey**	**2001 National Health Survey**
N		33 297	11 997	39 866	37 328	17 375
Height (cm)	**Mean**	168.92	168.68	169.06	169.75	169.53
	Std. Dev.	10.21	10.40	10.42	10.05	10.24
	Min-Max	122-213	100-231	55-208	145-200	145-200
Weight (kg)	**Mean**	72.09	73.57	69.40	71.68	73.48
	Std. Dev.	15.86	16.71	14.50	14.96	16.52
	Min-Max	25-195	26-190	30-210	35-130	40-145
BMI	**Mean**	25.19	25.81	24.27	24.79	25.49
	Std. Dev.	4.76	5.29	5.30	4.34	5.04
	Minimum	9.49	8.02	10.02	10.75	12.34
	Maximum	76.82	101.00	244.63	52.86	68.97
	1st percentile	17.03	16.95	16.65	16.98	17.02
	99th percentile	39.88	42.68	37.64	37.91	40.57
BMI category (%)	**Extremely low (BMI<15)**	0.2	0.2	0.2	0.1	0.1
	Low (15≤ BMI <18)	2.3	2.1	3.2	2.5	2.4
	High (35< BMI≤ 40)	2.5	3.3	1.4	1.9	3.3
	Extremely High (BMI>40)	1.0	1.6	0.6	0.5	1.1

The demographic characteristics of respondents from each survey that were categorized as having ‘extremely low’ or ‘low’ BMI are shown in Table 2. The small numbers in each group of extreme values (ranges from 19 to 63 persons) limits the extent of interpretation of these analysis by demographic characteristics.

The largest proportion of respondents with low BMI were aged between 16 and 29 years in all surveys, and this age group also made up the largest proportion of respondents with extremely low BMI in the NHS data from all years. In the 97-98 and 2002 NSW Health surveys, those with extremely low BMI were more evenly distributed across age groups. The proportion of those with both low and extremely low BMI who were male was similar across surveys, although a greater proportion of those with extremely low BMI were male in the 2001 NHS compared with other surveys. The majority of respondents with low and extremely low BMI were born in Australia, although a lower proportion of those with extremely low BMI from the 1995 NHS were Australian-born compared with other surveys.

The demographic characteristics of those with ‘high’ and ‘extremely high’ BMI in each survey are shown in Table 3. The number of participants that fell within the extreme BMI categories at the upper end of the distribution (Table 3) was much greater than those in extreme value categories at the lower end for BMI (Table 2). The majority of those categorized as having extremely high and high BMI were aged between 30 and 54 years, although among those with high BMI from the 2002 NSW Health Survey there was a slightly lower proportion aged 30-54 years (43.8%) and a slightly higher proportion aged 55-74 years (44.2%) compared with other surveys. The proportion of those with high BMI that were male was quite similar across surveys, with a slightly lower proportion of males among those with high BMI from the 2002 NSW Health Survey. Among those with extremely high BMI, the NSW Health Survey samples and the 1989 NHS sample had very similar proportions of men, with lower representation of males in the other two NHS samples. The proportion of those categorized as having high or extremely high BMI that were born in Australia was similar across surveys, and similar to the proportion of Australian-born in low and extremely low BMI categories (Table 2).

Table 2: Demographic characteristics of respondents within extreme low BMI categories (%) from each survey

		TELEPHONE SURVEY				
		1997-8 NSW Health Survey	**2002 NSW Health Survey**	**1989 National Health Survey**	**1995 National Health Survey**	**2001 National Health Survey**
EXTREMELY LOW BMI (BMI<15)						
N		55	26	63	50	19
		%	%	%	%	%
AGE (years)	**16-29**	20.0	15.4	49.2	38.0	42.1
	30-54	32.8	26.8	14.3	14.0	21.1
	55-74	27.4	26.9	9.5	30.0	10.5
	75+	20.0	30.8	26.9	18.0	26.3
SEX	**Male**	34.5	23.1	28.6	30.0	42.1
COUNTRY OF BIRTH						
	Australia	83.6	84.6	85.7	62.0	78.9
LOW BMI (15≤ BMI <18)						
N		**755**	**246**	**1293**	**938**	**410**
		%	%	%	%	%
AGE (years)	**16-19**	40.1	37.4	55.7	60.7	54.9
	30-54	35.6	22.8	24.8	23.9	25.9
	55-74	12.6	23.2	12.2	9.2	9.7
	75+	11.7	16.6	7.4	6.0	9.5
SEX	**Male**	20.9	20.7	28.2	29.3	26.1
COUNTRY OF BIRTH						
	Australia	79.1	82.1	77.0	73.9	76.6

Table 3: Demographic characteristics of respondents within extreme high BMI categories (%) from each survey

		TELEPHONE SURVEY				
		1997-8 NSW Health Survey	2002 NSW Health Survey	1989 National Health Survey	1995 National Health Survey	2001 National Health Survey
HIGH BMI (35< BMI≤ 40)						
N		822	401	546	727	574
		%	%	%	%	%
AGE (years)	**16-29**	8.7	8.2	14.2	15.6	11.5
	30-54	55.0	43.8	57.0	56.9	58.1
	55-74	33.3	44.2	27.7	25.2	26.4
	75+	2.9	3.7	1.2	2.5	4.0
SEX	**Male**	33.8	23.1	34.2	37.7	38.5
COUNTRY OF BIRTH						
	Australia	85.5	81.8	72.9	75.4	77.7
EXTREMELY HIGH BMI (BMI >40)						
N		326	192	233	181	197
		%	%	%	%	%
AGE (years)	**16-29**	11.0	4.6	20.6	13.8	13.1
	30-54	55.8	56.8	55.8	61.3	53.2
	55-74	30.0	33.3	18.9	22.1	24.9
	75+	3.0	5.2	4.7	2.8	8.6
SEX	**Male**	31.6	34.9	34.8	19.3	24.4
COUNTRY OF BIRTH						
	Australia	81.0	78.1	73.0	79.0	78.7

If the most extreme truncation rules being applied elsewhere to BMI only (a lower limit of 14 and an upper limit of 48) were applied to the data from the ‘97-‘98 and ‘02 NSW Health Surveys and the 1989 NHS (ie. those that do not currently truncate height, weight or BMI), then 21, 17 and 20 respondents respectively would be affected at the lower end. Applied at the upper end, 78 respondents from the 1997-8 NSW Health Survey, 57 from the 2002 NSW Health Survey, and 91 respondents from the 1989 NHS would be affected. All of the cases that would be excluded at the lower end of BMI across all surveys had reported values of height and weight that were realistic (given that these were extreme cases by selection). That is, the heights reported by these potentially excluded cases ranged from 147 to 231 cms across all surveys, and the reported weights ranged from 25 to 70 kgs.

Reported heights and weights for cases excluded at the upper end of BMI had much greater inconsistency in terms of reported combinations of height and weight that were realistic. Although some of the cases had reported heights and weights in combinations that were plausible, many were clearly the result of misreporting. Extreme underreporting of height (range of reported values across surveys was 55-188 cms) was especially apparent. Such extreme underreporting of height was generally accompanied by a plausible report of weight in kilograms, which then resulted in an inflated calculation of their BMI value (above the parameters set at the upper end).

Discussion

Similarity in the mean and 1st and 99th percentiles for BMI across different surveys suggest that the distribution of BMI is quite similar across different survey methods. The demographic characteristics of respondents with extreme BMI values were very similar across surveys, and there were no subgroups with systematically marked differential classification in different surveys. Such consistency would indicate that the truncation of extreme values would not systematically affect the estimated BMI values among particular groups of respondents when using different survey methods.

The low representation of males compared with females, which was consistent across surveys and across categories of extreme BMI at both the upper and lower ends of the distribution, seems to be in contrast with findings that BMI shows a strong association with gender. Based on findings from the 2002 NSW Health survey that men were more likely than women to be overweight or obese (55.7% and 45.1% respectively), and expectations that young women may be more likely to be underweight, we might have expected patterns suggesting that truncation at either or both ends of the BMI distribution would differentially impact on the resulting distribution of BMI for men and women.

Higher representation of women in the extreme high categories of BMI used for this analysis may be due to different classification compared with the binomial categorization as ‘overweight or obese’ (BMI ≥25) and ‘not overweight or obese’ generally used. Data from the 2002 NSW Health survey showed that among men who were overweight or obese (n = 2883), 7.1% were included in the categories of high or extremely high BMI used in this analysis, compared with 12.7% of women who were overweight or obese (n = 3074). Among men who were not overweight or obese, 2.5% were included in the categories of extremely low or low BMI, compared with 5.7% of women who were not overweight or obese. This suggests that although a lower proportion of all women are classified as overweight or obese compared with men, women may be more highly represented at the extremes of both overweight and obese binomial categories. If this is the case, they may also be differentially affected by truncation rules that re-code a significant number of extreme values at either end of the distribution. However, the absolute numbers here are small, and the proportions assigned to at risk (overweight/obese) categories in the population will not be substantially influenced by these outlier date points.

Although findings were similar across surveys, there are a number of methodological factors that may have influenced the comparability across surveys. Mostly, this relates to differences in data collection methods and data handling between the NSW Health Survey Program and the National Health surveys conducted by the Australian Bureau of Statistics (ABS). The survey modes utilized for the National Health surveys and the NSW Health surveys are different. The NSW Health Survey Program uses a computer-assisted telephone interview (CATI) system, while the ABS National Health Surveys were conducted using personal interview surveys (paper copies) in the respondent's household. Although the questions related to self-reported height and weight are the same in both surveys, the personal interview mode used for National Surveys allows those administering the survey to prompt for more exact reporting if the respondent seemed to be 'rounding' either measurement, and in some cases, to offer to measure or weigh respondents if they were unsure of their weight or height. In addition, the face-to-face nature of the interview is likely to reduce intentional misreporting (since the attributes being reported are visibly evident) (Rowland, 1990). These factors may improve the validity of reported values from the National Health Surveys. Nonetheless, in spite of these differences in survey methods, the prevalence of extreme over weight and underweight categories were very similar.

As previously discussed, the 1995 and 2001 National Health Survey data that was available in a format with the self-reported height and weight already truncated by the ABS. The reasons or rationale for the truncations used in those data were not available. Raw data from these national surveys are unavailable, which may limit their comparability with data from NSW Health surveys. However, the consistencies between findings from these two surveys and the other surveys analysed here would suggest that the truncation rules being used do not significantly affect the distribution of BMI.

Certainly, the number of cases affected by the re-coding of height and weight were small for the 2001 NHS (information on number of cases top-coded in the 1995 NHS was not available). For height, 42 respondents were recoded at the lower end and 21 respondents at the upper end. For weight, 36 respondents were re-coded at the lower end and 62 respondents at the upper end (Evans D, Australian Bureau of Statistics (Health section), Personal Communication, 9th September, 2003).

Inconsistencies across survey types in the management and coding of missing values for height and weight, as well as the truncation discussed above, resulted in greater-than-anticipated time invested for the secondary comparative analysis presented here. In addition, insufficient reporting of the data management strategies used for the publicly-available data sets used in this analysis (for example, top-coding and truncation rules) resulted in a great deal of investigative work required to clarify the comparability across surveys and increase the ability to distinguish between real and manufactured differences (for example, in the range of values).

Recommendations

This descriptive analysis suggests that application of conservative truncation rules similar to those being applied elsewhere would not systematically affect subgroups in the distribution. Furthermore, the prevalence of at risk groups (overweight/obese) would not be substantively influenced by any such truncation. However, the relatively small number of cases at each extreme suggests that the distribution of BMI as it results from self-reported height and weight is unlikely to be affected by extreme outliers that result from misreporting. Consequently, there appears to be no real rationale for future truncation of extreme values of BMI (or truncation of the contributing self-reported height and weight variables) in population surveys. Lack of truncation would ensure ease of comparability with other data sets, as well as simplicity of data coding processes. In addition, study of those cases that would be affected by current truncation rules being applied to BMI suggests that they may exclude values that are likely to be valid, especially at the lower end. Although the number of such cases is relatively small, if the true distribution of body mass continues to widen over time then exclusion of these valid cases in current and recent data sets may impact upon the validity of analyzing changes in the distribution of BMI through comparison with future population data.

Separate to the issue of excluding invalid cases for BMI, truncation may be required to preserve the anonymity of participants who may be easily identifiable due to their extreme BMI levels. If this is the case, then consistency over time within survey programs, as well as consistency between survey programs, would be sensible. The implementation of different truncation rules to different variables makes it necessary to truncate all data according to the most extreme truncation rules that have been applied to allow comparison between surveys. Certainly, where truncation results in the top-coding of extreme values, it is essential that these processes are transparent and adequately reported so that secondary analysis (especially for the purpose of comparison between different surveys) may be conducted without unnecessary and time-intensive attempts to uncover the methods used.

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