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Changes in waist circumference independent of weight: Implications for population level monitoring of obesity

Emma Gearon[a,b,*], Stephanie K. Tanamas[c], Christopher Stevenson[d], Venurs H.Y. Loh[e], Anna Peeters[a,b]

[a] Global Obesity Centre, Deakin University, Locked Bag 20000, Geelong, Victoria 3220, Australia
[b] School of Public Health and Preventive Medicine, Monash University, Melbourne, Locked Bag 20000, Geelong, Victoria 3220, Australia
[c] Department of Epidemiology and Clinical Research Section, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, 1550 E. Indian School Rd., Phoenix, AZ 85014, United States
[d] School of Health and Social Development, Deakin University, Locked Bag 20000, Geelong, Victoria 3220, Australia
[e] Institute for Health and Ageing, Australian Catholic University, Level 6, 215 Spring Street, Melbourne, Victoria 3000, Australia

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ABSTRACT

Population monitoring of obesity is most commonly conducted using body mass index (BMI). We test the hypothesis that because of increases in waist circumference (WC) independent of increases in weight, BMI alone detects an increasingly smaller proportion of the population with obesity.

Methods: Australian adults with measured height, weight, and WC were selected from three nationally representative cross-sectional surveys (1989, 1999–2000, 2011–12; n = 8313, 5903 & 3904). Participants were defined as having obesity using classifications for an obese BMI (≥ 30 kg·m^{-2}) and substantially-increased-risk WC (≥ 88 cm [women], ≥ 102 cm [men]). Age-standardised prevalence of obesity according to BMI and/or WC, and the proportion of these detected by BMI and by WC were compared across surveys.

Findings: Between 1989 and 2011–12, weight and WC increased by 5.4 kg and 10.7 cm (women), and by 7.0 kg and 7.3 cm (men). For women and men, 63% and 38% of increases in WC were independent of increases in weight. Over this period, the prevalence of obesity according to BMI and/or WC increased by 25.3 percentage-points for women (18.9% to 44.3%) and 21.1 percentage-points for men (17.1% to 38.2%). The proportion of these detected by BMI decreased for women by 20 percentage-points (77% to 57%) with no change for men. The proportion of these detected by WC increased for women and men by 10 percentage-points (87% to 97%) and 6 percentage-points (85% to 91%) respectively.

Conclusion: BMI alone is detecting a decreasing proportion of those considered obese by BMI and/or WC. Renewed discussion regarding how we monitor obesity at the population level is required.

1. Introduction

Accurate population monitoring of risk factors for key non-communicable diseases provides the foundation for their effective prevention and management (World Health Organization, 2013). As obesity is a leading contributor to the global burden of disease (Collaborators GBDRF, 2017), it is important to accurately and effectively monitor obesity prevalence at the population level. Internationally, body mass index (BMI, a measure of weight for height) and waist circumference (WC) are the two most common anthropometric classifications of obesity (World Health Organization, 2011). While it is established that there is imperfect overlap in categorisation of obesity according to BMI and WC, as individuals can be obese according to one indicator but not another (Lahti-Koski et al., 2007; Park et al., 2008; Lean et al., 1995), population obesity monitoring primarily relies on BMI alone (NCD Risk Factor Collaboration, 2016). This domination of BMI over other anthropometric markers of obesity has been attributed to recommendation by the World Health Organization (2011), and to a perceived

Abbreviations: AusDiab, Australian Diabetes, Obesity and lifestyle Study. A survey conducted in the year 1999–2000 representative of the Australian population; BMI, body mass index, an index of weight for height (kg·m^{-2}) used as an indicator of adiposity; NNPAS, National Nutrition Physical Activity Survey. A survey conducted in the year 2011–12 representative of the Australian population; RFPS, National Heart Foundation Risk Factor Prevalence Study. A survey conducted in the year 1989 representative of the urban Australian population; WC, waist circumference, the circumference around an individual's waist, used as an indicator of adiposity

* Corresponding author at: Deakin University, Locked Bag 20000, Geelong, Victoria 3220, Australia.
E-mail addresses: Emma.Gearon@deakin.edu.au (E. Gearon), sktanamas@gmail.com (S.K. Tanamas), Christopher.Stevenson@deakin.edu.au (C. Stevenson), venurshuiyee.loh@myacu.edu.au (V.H.Y. Loh), Anna.Peeters@deakin.edu.au (A. Peeters).

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redundancy in measuring both BMI and WC (NCD Risk Factor Collaboration, 2016), given their similar discriminative ability to predict cardio-metabolic risk factors and diseases (Huxley et al., 2010; Cheong et al., 2015; Seo et al., 2017).

However, there is some indication that the nature of obesity is changing to one of greater abdominal adiposity, indicated in part by greater increases in WC over time than would be expected based on increases in body weight (Stern et al., 2014; Janssen et al., 2012; Elobeid et al., 2007; Freedman and Ford, 2015; Albrecht et al., 2015; Walls et al., 2011a). We have previously demonstrated in the Mongolian context that as WC has increased independent of increases in body weight, BMI is detecting an increasingly smaller proportion of the population with obesity, as categorised by BMI or WC (Chimeddamba et al., 2017). However the implications in other countries have not been analysed. Given that current population monitoring initiatives rely on BMI, it is imperative that the extent to which BMI may be underestimating the level of population risk is quantified.

The first aim of this study was to firstly quantify the discordance in changes to WC and weight for urban Australian adults between 1989 and 2011–12. The second aim was to describe trends in classification of obesity according to BMI and WC, between 1989 and 2011–12.

We stratify all analyses by smoking status, body mass index category, highest educational attainment and age to both identify subgroups of interest and assess the potentially modifying effect of these factors.

2. Methods

2.1. Data source

Three nationally representative cross-sectional surveys were used: the 1989 National Heart Foundation Risk Factor Prevalence Study (RFPS); the 1999–2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab); and the 2011–12 National Nutrition and Physical Activity Survey (NNPAS), the details of which have been described previously (National Heart Foundation of Australia, 2001; Dunstan et al., 2002; Australian Bureau of Statistics, 2013). Briefly, the 1989 RFPS was a random selection of 9279 Australian adults (response rate 65%) aged 25–69 residing in State or Territory capital cities conducted between June and December of 1989 (National Heart Foundation of Australia, 2001). AusDiab was a multi-stage household based survey of all adult residents aged over 25 years from 11,479 private dwellings (response rate after sample loss: 70%) across Australia conducted over a 21 month period between 1999 and 2000, with biomedical information on 11,247 participants (Dunstan et al., 2002). The 2011–12 NNPAS was a multi-stage household-based survey of 9519 private dwellings (response rate after sample loss: 77%) across Australia from June 2011 to June 2011–12 with one randomly selected adult and (where applicable) one child (2–18 years) selected from each dwelling, totalling 12,153 participants (Australian Bureau of Statistics, 2013).

2.2. Outcome variables

Height and weight were obtained through similar methodology at all three time points. Trained interviewers measured participants' height (using a stadiometer, to the nearest 0.1 cm [2011 − 12] or 0.5 cm [1989, 1999–2000]), weight (using digital scales, to the nearest 0.1 kg) and WC (using a flexible steel measuring tape, to the nearest 0.1 cm [2011–12] or 0.5 cm [1989, 1999–2000]) after participants were instructed to remove shoes and bulky clothing. In AusDiab (1999–2000) and NNPAS (2011 − 12), where multiple measures were taken, the mean of the two closest measurements was used. There was variation in measurement of waist circumference across the three surveys. Measurements were taken at the narrowest point between the ribs and hips (1989), the mid-point between the iliac crest and lowest palpable rib (1999–2000), and the umbilicus (2011–12).

For the first aim, weight and WC were used as continuous variables.

For the second aim, WC was categorised as not-obese (< 88 cm for women, < 102 cm for men) and obese (≥ 88 cm for women, ≥ 102 cm for men) (World Health Organization, 2000), and BMI ($kg{\cdot}m^{-2}$) was calculated as weight (kg) × $height^{-2}$ (m) and categorised as not-obese (BMI < 30 $kg{\cdot}m^{-2}$) and obese (BMI ≥ 30 $kg{\cdot}m^{-2}$) (World Health Organization, 2000). We then examined classification of obesity according to the following BMI and WC combinations: obese according to BMI and/or WC (WC ≥ 88 cm (women), ≥ 102 cm (men) or BMI ≥ 30 $kg{\cdot}m^{-2}$); obese according to WC but not BMI (WC ≥ 88 cm (women), ≥ 102 cm (men) and BMI < 30 $kg{\cdot}m^{-2}$); obese according to BMI but not WC (WC < 88 cm (women), < 102 cm (men) and BMI ≥ 30 $kg{\cdot}m^{-2}$); obese according to BMI and WC (WC ≥ 88 cm (women), ≥ 102 cm (men) and BMI ≥ 30 $kg{\cdot}m^{-2}$); and not-obese (WC < 88 cm (women), < 102 cm (men) and BMI < 30 $kg{\cdot}m^{-2}$).

2.3. Potential effect modifiers

All analyses were conducted for women and men separately, and further stratified by smoking status, BMI category, highest educational attainment and age. BMI category was calculated from measured height and weight as specified above, and categorised as: normal weight (BMI ≥ 18.5 to < 25 $kg{\cdot}m^{-2}$); overweight (BMI ≥ 25 to < 30 $kg{\cdot}m^{-2}$); and obese (BMI ≥ 30 $kg{\cdot}m^{-2}$) (World Health Organization, 2011). Smoking status, education group and age group were self-reported in each survey, and categorised for ease of interpretation: age-group (25–34, 35–44, 55–64, 65–69), education group (dichotomised at completion of secondary school), and smoking status (never or ever smoker).

2.4. Exclusion Criteria

Of the 32,679 potential subjects across the three surveys (1989, 1999–2000, 2011–12), participants were ineligible for this analysis if they resided outside of capital cities (n = 0, 4336, 4365; to maximise comparability across the three surveys), were aged < 25 or > 69 years (n = 778, 787, 3107; to account for the inaccuracy of BMI at older ages (Prentice and Jebb, 2001)), or were pregnant at the time of the survey (n = 85, 57, NA). We further excluded participants who were missing information on height, weight or WC (n = 103, 70, 777) or other variables of interest (n = 0, 94, 0). Our final analytical populations comprised 8, 313 (1989), 5903 (1999–2000) and 3904 (2011–12) women and men.

2.5. Statistical analyses

Descriptive statistics were calculated for all study populations. All further analyses were age-standardised to the 2012 mid-year Australian population using the direct method (Bell, 1999), and survey weighted, where a person-level weight reflecting the Australian population distribution of age, sex and locale at the time of each survey was applied. Survey weights are calibrated by 'State by Part of State' (including urban areas), by sex and by age group, allowing us to make valid inferences about the urban Australian population from our analytic population classified by age and sex (Australian Bureau of Statistics, 2013).

To facilitate comparability with available data from the 2011–12 NNPAS, *group jackknife* variance estimation was used for all analyses (Bell, 1999). For the 1999–2000 AusDiab and the 1989 RFPS, where jackknife variance estimates were unavailable, they were created using cluster level information. For the RFPS we used postcode information to form pseudo-clusters, and these were used to create jackknife replicate.

We present key results in figures and tables, and include all results in appendices.