Cluster analysis of behavioural weight management strategies and associations with weight change in young women: a longitudinal analysis

C D Madigan, A J Daley, E Kabir, P Aveyard, W Brown

Cite this article as: C D Madigan, A J Daley, E Kabir, P Aveyard, W Brown, Cluster analysis of behavioural weight management strategies and associations with weight change in young women: a longitudinal analysis, *International Journal of Obesity* accepted article preview 22 June 2015; doi: 10.1038/ijo.2015.116.

Received 30 January 2015; revised 27 May 2015; accepted 12 June 2015; Accepted article preview online 22 June 2015

Cluster analysis of behavioural weight management strategies and associations with weight change in young women: a longitudinal analysis

Claire D Madigan PhD[1], Amanda J Daley PhD[1], Enamul Kabir PhD[2,4], Paul Aveyard PhD[3]Wendy Brown PhD[4]

[1]School of Health and Population Sciences, University of Birmingham, UK

[2] School of Agricultural, Computational and Environmental Sciences, University of Southern Queensland, Australia.

[3] Nuffield Department of Primary Care Health Sciences, University of Oxford, UK

[4] School of Human Movement and Nutrition Sciences, University of Queensland, Australia

Conflicts of interests – None

Corresponding author

Claire Madigan

Health and Population Sciences

University of Birmingham

Birmingham

B15 2TT

UK
c.d.madigan@bham.ac.uk

Word count: 3303

ABSTRACT

Background/Objectives: Maintaining a healthy weight is important for the prevention of many chronic diseases. Little is known about the strategies used by young women to manage their weight, or the effectiveness of these in preventing weight gain. We aimed to identify clusters of weight control strategies used by women and determine the average annual weight change among women in each cluster from 2000 to 2009.

Methods: Latent cluster analysis of weight control strategies reported by 8125 participants in the Australian Longitudinal Study of Women's Health. Analyses were performed in March-November 2014.

Results: Weight control strategies were used by 79% of the women, and four unique clusters were found. The largest cluster group (39.7%) was named *dieters* as 90% had been on a diet in the past year, and half of these women had lost 5 kg on purpose. Women cut down on size of meals, fats and sugars and took part in vigorous physical activity. Additionally 20% had used a commercial programme. The next largest cluster (30.2%) was the *healthy living* group who followed the public health messages of 'eat less and move more'. The *do nothing* group (20%) did not actively control their weight whereas the *perpetual dieters* group (10.7%) used all strategies, including unhealthy behaviours. On average women gained 700 g per year (over nine years), however the *perpetual dieter*s group gained significantly more weight (210g) than the *do nothing* group ($p<0.001$).

Conclusions: Most women are actively trying to control their weight. The most successful approach was to follow the public health guidelines on health eating and physical activity.

INTRODUCTION

In the last 20 years there has been a shift in the distribution of adult BMI, with populations getting heavier across all BMI categories. Weight gain has been particularly marked in young adults, who, on average, gain more than 0.6 kg per year when they are in their twenties and thirties(1, 2). Much more is known about strategies used to maintain weight after a period of weight loss, than about strategies used for the primary prevention of weight gain. This is because information about strategies used for weight loss maintenance is available from the

National Weight Control Registry (NWCR), a cohort of over 10,000 US adults who have successfully lost ≥13.6 kg of weight and maintained this loss for a minimum of one year(3). Those who maintained weight loss most commonly reported high levels of physical activity, eating breakfast, consuming low-energy/low fat diets, a high level of dietary restraint and weighed themselves regularly(4).

Population approaches to weight control have been less well studied(5). A systematic review of trials and observational studies found the strength of evidence is low for all weight gain prevention strategies, but effective strategies may include: low-fat diets, eating fewer meals prepared away from home, eating more fruits and vegetables, monitoring heart rate during exercise, and participation in group lifestyle sessions with reminder text messages(5).This review did not, however focus on people who may also want to lose weight. One small Australian study (n=1335) has reported that 50% of people visiting a GP surgery (aged ≥18 years) had tried to lose weight in the past 12 months(6). Of those, 72% reported changing their diet, 54% increased exercise, 7.5% consulted a professional weight loss programme, 6.5% used over the counter supplements and 1.7% used medication(6). Whether participants used single strategies or a combination of strategies, or whether they successfully lost weight, was not assessed.

Only one study has examined strategies for weight control using a population based prospective cohort. In it, the Australian Longitudinal Study of Women's Health (ALSWH) researchers found 74% of mid-age women (45-52 years) actively used at least one strategy to manage their weight(7). One combination of practices was associated with preventing weight gain two years later, this included decreasing food quantity, cutting down on fats and sugars, using a commercial weight loss programme, and exercise(7).

There is little information about the weight control strategies that are being used by younger adult women, or their efficacy in preventing weight gain. Rates of weight gain are high in this population group(2), possibly because young women do not engage in weight control strategies, or because the strategies they do adopt are ineffective. A better understanding of the strategies currently used by young adult women, and their effectiveness, could be used to guide behavioural advice on weight control.

The primary aim of this study was to identify clusters of weight management behaviours in the younger cohort of the ALSWH, who were aged 22-27 in 2000. Additional aims were to assess the characteristics of women in each cluster, and determine the average rate of weight change in each cluster, over nine years from 2000 to 2009.

METHODS

The ALSWH is a prospective study of factors shaping the health and well-being of three cohorts of Australian women (born in 1973–1978, 1946–1951, and 1921–1926), recruited from the national health insurance database. The focus of this paper is on the 1973–1978 cohort who completed mailed surveys in 1996, 2000, 2003, 2006 and 2009 (surveys 1 to 5). Women were aged 22-27 years at survey 2 (year 2000) and aged 31-36 years at survey 9. More details can be found at http://www.alswh.org.au. The study was approved by the Universities of Newcastle and Queensland Ethical Review Committees and all participating women provided informed consent. The women were asked about their weight control practices in Survey 2. Additional demographic, health and behavioural information was extracted from the same survey (unless stated otherwise), and weight change was assessed over nine years using data from Survey 2 and the following three surveys.

Cluster analysis variables

Women were asked how often they had dieted in the past year and the number of times they had lost 5 kg or more on purpose. Women who answered 'yes' to the question: 'Have you used a weight control practice in the past 12 months?' were asked to indicate which of the nine weight control practices they had used (yes/no) in the past 12 months. The strategies are listed in the results tables.

Descriptive variables

Almost all the demographic (age, education), behavioural (physical activity, sitting time, alcohol use) and health (BMI, weight satisfaction, stress and depression) variables were assessed at survey 2. Marital status, parity and smoking status (smoker/ex-smoker) were assessed at survey five, and included in the weight gain analysis, as getting married, having a baby and quitting smoking are known to be associated with weight gain(8, 9). BMI was calculated as weight (kg)/height^2(m^2) and categorized in accordance with WHO recommendations(10).

Physical activity was assessed using questions developed for national surveillance of physical activity in Australia(11, 12). Women reported time spent walking briskly and in moderate-intensity and vigorous leisure activities in the last week. Responses were used to calculate total physical activity in MET·minutes per week ((min/week in walking and moderate PA*3.33)+ (min/week in vigorous PA*6.66)). Average daily sitting time was calculated from reported time spent sitting on weekdays and weekend days and reported as a continuous variable. Alcohol intake was coded as: non-drinker, low-risk (up to two drinks/day), or risky drinker (more than two drinks/day)(13). Women were categorised as ex-smokers or not ex-smokers at Survey 5. In survey 3 women completed a food frequency questionnaire and the data were used to estimate daily energy intake(14).

The Center for Epidemiologic Studies Depression Scale (CESD-10) was used to measure depressive symptoms (15), with scores of ≥10 indicating depressive symptoms(15). A measure of stress was developed for the ALWSH study and details have been reported elsewhere(16). The scores range from zero to four, with four indicating extremely stressed. Women were asked how dissatisfied they felt with their weight and how much they would like to weigh now. They were also asked whether there had been times when they felt that they had eaten what other people would regard as an unusually large amount of food given the circumstances, and if they felt a loss of control over their eating.

Weight was reported at each survey to the nearest kg. Validation research with a subsample of the ALSWH mid age cohort has shown that self-reported weight is reasonably accurately reported in ALSWH women, but This finding is supported by other research with Australian adults(18). A regression line through each woman's weight at each survey point was used to provide a weight trajectory over nine years; the coefficient represented weight change in kg per year. Women were classified as weight maintainers (+/-2 kg change/year), weight losers (≥-2 kg change/year) or weight gainers (≥2 kg change/year).

Statistical analysis

Analyses were conducted in March-November 2014 using SPSS (Version 21) and R. Data were available for 9688 women who completed survey 2. Women were excluded if they had missing data for: weight control variables (n=203); weight at three or more surveys (n=1045); BMI at survey 1 or 2 (n=254); and if they were pregnant between surveys two to five, with only one non pregnant weight (n=61). Data from 8125 women were included in the analysis.

The cluster analysis variables (see above and in Table 2) were inputted for latent class cluster analysis (LCA) using poLCA (developed by Linzer and Lewis(19)). We used LCA, a model-based approach that allows for mixed measurement levels and enables independent and dependent variables to be considered and clustered together. It also allows estimation of latent class clusters for polytomous outcome variables. The LCA model is estimated in R by the poLCA () function. It is necessary to specify the selected variables, the data, and the number of clusters. The function returns results including the BIC, the AIC, the likelihood function, the G^2 (Likelihood ratio/deviance statistic), the Chi-square statistic, number of estimated parameters, the estimated class-conditional response probabilities, and a matrix containing each observation's posterior class membership probabilities. The latent class model does not automatically determine the number of latent classes in a given data set; but it does offer a variety of parsimony and goodness of fit statistics that researchers may use to make a theoretically and empirically sound assessment(20). Generally, the goal is to select models that maximize the likelihood, minimize the BIC, Chi-square or G^2, while retaining a parsimonious model. To obtain the best classification, we estimated models for two to 15 latent clusters. For each cluster selection, the model was repeated 10 times so that the parameter estimates corresponded to the model producing the greatest log-likelihood.

Measures of central tendency were used to describe the characteristics of women included and excluded from the analysis and in each of the clusters. Linear regression was used to compare weight change in those women who reported not actively managing their weight (i.e the *do nothing* group) and those in the other cluster groups. Within the model the following confounding variables were taken into account: sitting time, education, BMI, partnered/un-partnered, children/no children, ex-smoker/not ex-smoker. These variables were based on the determinants of change reported in previous ALSWH papers (9, 21, 22) If there were

missing data on confounders, these were imputed with the mean score in order to include data from as many women as possible in the analysis.

RESULTS

A comparison of selected characteristics of the included and excluded women is shown in Table 1. The women who were excluded due to missing data had slightly higher depressive symptom scores and were less likely to be university educated, but other characteristics were similar. On average the included women were 24.1 years of age, with a BMI of 23.9 kg/m^2. Just over half did not have a university education.

Initially, the cluster analyses offered 4, 5 or 6 cluster solutions. However, after considering both model fit and parsimony(23) we found the optimal BIC value (112964, log likelihood -56067, *chi^2 7287283*) with four clusters, which were named: *dieters, healthy living, do nothing* or *perpetual dieters*. The weight management strategies used by women in each cluster are shown in Table 2, and their demographic, behavioural and health characteristics are shown in Table 3.

Strategies used

Seventy-nine per cent of women reported using at least one strategy to control their weight, with the majority of women using two or three strategies (45.7%). Only 3.2% of women reported using six or more strategies.

Dieters

This was the largest cluster, with 39.7% of the women; their average BMI was 25.4 kg/m^2. More than 90% had been on a diet in the past year, and more than half of these reported losing 5 kg on purpose. Women in this cluster tended to use healthy weight management

strategies, such as vigorous exercise, cutting down on size of meals and cutting down on fats/sugars to manage their weight. Approximately 20% of this group had used a commercial programme to manage their weight and fewer than 5% reported using unhealthy strategies such as smoking and laxatives/diuretics.

Fewer than 10% of women in this cluster were happy with their weight (7.3%), almost one quarter reported having lost control of their eating. Median physical activity was 719 MET.Minutes/week (equates to about 30 minutes of moderate activity every day), and average sitting time was on average 6.4 hours per day. Few women in this cluster were classified as risky drinkers. Overall 72% of women were partnered, and 41.1% had university education. These women were classified as somewhat stressed but had low scores for depressive symptoms.

Healthy living

This was the second largest cluster (30.2% of the sample) with an average BMI of 22.8 kg/m^2. Very few women in this cluster had been on a diet to lose weight in the past year, and only one in five had ever lost 5 kg on purpose. The three most popular weight control strategies were: vigorous exercise, cutting down on the size of meals and cutting down on fats and sugars. Very few women in this cluster reported using commercial weight loss programmes, meal replacements, vomiting or smoking.

Although the average BMI of women in this cluster was in the healthy range, almost three quarters said they would like to weigh less. However, very few had ever dieted. One quarter were happy with their weight. Almost half women in this cluster had a university education and stress and depressive symptoms were low.

Do nothing

Twenty percent of the sample was included in this cluster, which had the lowest mean BMI. These women did not use any of the nine weight management strategies and very few reported dieting to lose weight in the past year (5.3%) or having ever purposefully lost 5 kg (7%) (Table 2).

Eighty percent of women in this cluster were either not at all, or only slightly, dissatisfied with their weight, indicating the highest satisfaction with weight of any of the clusters. The proportions of women who reported eating a large amount of food or losing control of eating were low in this group. Physical activity scores were low and daily energy intake was high. About one third were university educated, and had low stress and depressive symptom scores.

Perpetual dieters

This was the smallest cluster, comprising 10.7% of women, with an average BMI of 25.5 kg/m^2.Three quarters of women in this cluster had purposefully lost at least 5 kg (one third had done this three times or more) and only 1% had never been on a diet in the past year. Use of all the weight control strategies was highest in this group, including healthy strategies such as cutting down on meal sizes, fats and sugars, and vigorous exercise, as well as unhealthy weight control strategies such as smoking, vomiting and using laxatives/diuretics. Very few women in this cluster were happy with their weight (2.8%) and eating large amounts and losing control of eating were more common than in the other clusters. This group reported the highest amount of physical activity and lowest energy intake. The proportion of ex-smokers was high in this cluster group. Stress and depressive score were also high.

Nine year weight change (2000 to 2009)

Most women in this sample were in the healthy BMI range in 2000. Overall, there was an average rate of weight gain of 700 (SD 1300) g/year but 1.5% of the women were categorised

as weight losers; 87.3% as maintainers, and only 11.2% as gainers. There were no statistically significant differences in rate of weight gain in three of the clusters (Table 4), but the *perpetual dieters* gained 210g/year more ($p<0.001$) than women in the *do nothing cluster* (adjusted for covariates). The proportion of women who were classified as weight gainers was highest in the *perpetual dieters* and *dieter groups*.

DISCUSSION

As rates of weight gain are increasing rapidly in young adults, it is important to explore the strategies used for weight control in this population(2). The ALSWH study provided an opportunity to investigate these strategies in a large sample of young adult women. On average, women gained 700 g per year, which equates to 6.3 kg across the nine years, in line with previous research that suggests populations are getting heavier (24, 25). However, only 11% were classified as weight gainers (gaining >2 kg/year). The majority of women (79.9%) reported using at least one strategy to control their weight and we found four distinct clusters of women, based on their weight control behaviours. The largest group, *the dieters* used a variety of strategies to control their weight. The *healthy living* group followed public health messages of 'eat less and move more' and gained a similar amount of weight. The *do nothing* group did not actively manage their weight, and on average gained 600 g per year. The *perpetual dieters* gained significantly more weight than the *do nothing* group, and on average gained 8.1 kg in nine years.

The majority of women actively control their weight, however on average women gained weight. Both the *dieters* and *perpetual dieter* groups used a variety of strategies, but still struggled with their weight, and included the highest proportion classified as weight gainers. It could be hypothesised that, as these women were on average overweight at baseline, they

perhaps struggled more with their weight. This is similar to findings of the NWCR, who found a cluster group that had continuously struggled with weight since childhood(26). Similar to the NWCR cohort, women in the *dieters* and *perpetual dieter* groups relied on the greatest number of strategies to control their weight and reported higher levels of stress and depressive symptoms. It is concerning that a high proportion of the perpetual dieters used unhealthy strategies to manage their weight, as these strategies are associated with eating disorders and weight cycles of loss and regain, which may be harmful for health(27, 28). Although the overall percentage of women using these strategies was low, there may be potential for public health messages to discourage using these harmful strategies.

The *healthy living* group appears to include women who actively try to maintain their weight, by using strategies such as vigorous exercise, cutting down on size of meals and cutting down on fats and sugars. This reflects current public health messages and appears to work for these women, whose average BMI was in the middle of the healthy weight range. The *do nothing* group may represent women with higher self-regulation competence as they had the lowest average BMI, but appeared to do little to control their weight. Previous research with adolescents has shown that higher self-regulation competence is associated with lower consumption of unhealthy snacks(29).

There was some evidence to suggest that psychological well-being differed between the clusters, with low scores in the *dieters* and *perpetual dieters* clusters. There could be two reasons for this. Firstly, trying and failing to control weight may be associated with decreases in psychological well-being.(30) Secondly, lower psychological well-being may be associated with weight gain(31). Further research is required to clarify the complex inter-relationships between perpetual dieting, weight gain and well-being.

The strengths of the study include the large representative sample of young adult women and the longitudinal study design. Limitations of the study design include a reliance on self-reported data. Less accurate reporting of weight by obese women (17) would have affected our estimates of both weight and weight gain, especially in the *dieters group*, which had the greatest proportion of obese women.

Questions about behavioural weight management strategies were included in surveys two and five, but as the questions used in survey five were different, we were unable to assess whether these weight management strategies changed over time. To our knowledge, no surveys have investigated the stability of weight control practices in a general population sample, but we suspect that those who are unsuccessful at weight loss maintenance do not adhere to behavioural regimens, which suggests that weight control practices could vary over time, particularly in those trying to lose weight(32). Another limitation is that although several important weight management strategies were examined, women may have used other strategies that were not reported. A final limitation is that we have no information about the potential metabolic and genetic differences between these clusters.

In summary, 79% of the women used at least one strategy to control their weight, and yet, on average, they still gained weight. We identified four main clusters of weight management strategies; the most successful approach was following current guidelines for a healthy diet and physical activity. The findings confirm that the use of unhealthy strategies to control weight may not be helpful. Further research should examine the optimal combination of weight management strategies and their relationships with both long term weight control and well-being.

Acknowledgements

The research on which this paper is based was conducted as part of the Australian Longitudinal Study on Women's Health, The University of Newcastle and The University of Queensland. We are grateful to the Australian Government Department of Health for funding and to the women who provided the survey data. The authors also thank Professor Graham Giles of the Cancer Epidemiology Centre of Cancer Council Victoria, for permission to use the Dietary Questionnaire for Epidemiological Studies (Version 2), Melbourne: Cancer Council Victoria, 1996."

All authors declare no conflict of interest.

All authors declare no financial reimbursements.

References

1. Norman J, Bild D, Lewis C, Liu K, West D, Study C. The impact of weight change on cardiovascular disease risk factors in young black and white adults: the CARDIA study. Int J Obes Relat Metab Disord. 2003;27(3):369-76.
2. Allman-Farinelli MA, Chey T, Bauman AE, Gill T, James WPT. Age, period and birth cohort effects on prevalence of overweight and obesity in Australian adults from 1990 to 2000. Eur J Clin Nutr. 2007;62(7):898-907.
3. Klem ML, Wing RR, McGuire MT, Deagel HM, Hill JO. A descriptive study of individuals successful at long-term maintenance of substantial weight loss. American Journal of Clinical Nutrition. 1997;66:239-46.
4. Wing R, Hill J. Successful weight loss maintenance. Annual Review of Nutrition. 2001;21:323-41.
5. Hutfless S, Gudzune KA, Maruthur N, Wilson RF, Bleich SN, Lau BD, et al. Strategies to Prevent Weight Gain in Adults: A Systematic Review. American Journal of Preventive Medicine. 2013;45(6):e41-e51.
6. Yoong S, Carey M, Sanson-Fisher R, D'Este C. A cross-sectional study assessing the self-reported weight loss strategies used by adult Australian general practice patients. BMC Family Practice. 2012;13(48).
7. Williams L, Germov J, Young A. Preventing weight gain: a population cohort study of the nature and effectiveness of mid-age women's weight control practices. International Journal of Obesity. 2007;31(6):1978-86.
8. Aubin H-J, Farley A, Lycett D, Lahmek P, Aveyard P. Weight gain in smokers after quitting cigarettes: meta-analysis. BMJ. 2012;345.
9. Brown W, Hockey R, Dobson A. Effects of Having a Baby on Weight Gain. American Journal of Preventive Medicine. 2010;38(2):163-70.

10. World Health Organisation. Obesity 2011. Available from: http://www.who.int/topics/obesity/en/.
11. Armstrong T, Bauman A, Davies J. Physical activity patterns of Australian adults. Results of the 1999 National Physical Activity Survey Canberra: 2000.
12. Brown W, Burton N, Marshall A, Miller Y. Reliability and validity of a modified self administered version of the Active Australia physical activity survey in a sample of mid-age women. Aust N Z J Public Health. 2008;32(6):535-41.
13. National Health and Medical Research Council. Australian alcohol guidelines. Canberra: 2001.
14. Hodge A, Patterson A, Brown W, Ireland P, Giles G. The anti cancer council of Victoria FFQ: relative validity of nutirient intakes compared with weighed food records in young to middle-aged women in a study of iron supplementation. Aust N Z J Public Health. 2000;24:576-83.
15. Andresen E, Malmgren J, Carter W, Patrick D. Screening for depression in well older adults: evaluation of a short form of the CES-D (Center for Epidemiologic Studies Depression Scale). American Journal of Preventive Medicine. 1994;10:77-84.
16. Bell S, Lee C. Perceived stress revisited: the Women's Health Australia project Younger cohort Psychology, Health and Medicine. 2003;8(3):343-53.
17. Burton NW, Brown W, Dobson A. Accuracy of body mass index estimated from self-reported height and weight in mid-aged Australian women. Australian and New Zealand Journal of Public Health. 2010;34(6):620-3.
18. Dhaliwal S, Howat P, Bejoy T, Welborn T. Self-Reported Weight and Height for Evaluating Obesity Control Programs. American Journal of Health Behavior. 2010;34(4):489-99.
19. Linzer D, Lewis J. poLCA: Polytomous Variable Latent Class Analysis. R package version 142013.
20. Linzer D, Lewis J. "poLCA: an R Package for Polytomous Variable Latent Class Analysis. Journal of Statistical Software. 2011;42(10):1-29.
21. Ball K, Brown W, Crawford D. Who does not gain weight? Prevalence and predictors of weight maintenance in young women. International Journal of Obesity. 2002;26:1570-8.
22. Ball K, Crawford D. An investigation of psychological, social and environmental correlates of obesity and weight gain in young women. International Journal of Obesity. 2006;30(8):1240-9.
23. Haughton D, Legrand P, Woolford S. Review of three latent class cluster analysis packages: latent gold, poLCA, and MCLUST. The American Statistician. 2009;63(1):81-91.
24. NOO. Change in adult BMI distribution. Public Health England; 2013.
25. Lee J, Pilli S, Gebremariam A, Keirns C, Davis M, Vijan S, et al. Getting heavier, younger: trajectories of obesity over the life course. International Journal of Obesity. 2010;34(4):614-23.
26. Ogden L, Stroebele N, Wyatt H, Catenacci V, Peters J, Stuht J, et al. Cluster Analysis of the National Weight Control Registry to Identify Distinct Subgroups Maintaining Successful Weight Loss. Obesity. 2012;20(10):2039-47.
27. Neumark-Sztainer D, Wall M, Story M, Standish A. Dieting and unhealthy weight control behaviors during adolescence: associations with 10-year changes in body mass index. J Adolesc Health. 2012;50(1):80-6.
28. Neumark-Sztainer DR, Wall MM, Haines JI, Story MT, Sherwood NE, van den Berg PA. Shared Risk and Protective Factors for Overweight and Disordered Eating in Adolescents. American Journal of Preventive Medicine. 2007;33(5):359-69.
29. Stok F, De Vet E, J W, Chu M, De Wit J, De Ridder D. Navigating the obesogenic environment: How psychological sensitivity to the food environment and self-regulatory

competence are associated with adolescent unhealthy snacking. Eating Behaviors. 2015;17:19-22.
30. Elfhag K, Rössner S. Who succeeds in maintaining weight loss? A conceptual review of factors associated with weight loss maintenance and weight regain. Obesity Reviews. 2005;6(1):67-85.
31. Räikkönen K, Matthews KA, Kuller LH. Depressive Symptoms and Stressful Life Events Predict Metabolic Syndrome Among Middle-Aged Women: A comparison of World Health Organization, Adult Treatment Panel III, and International Diabetes Foundation definitions. Diabetes Care. 2007;30(4):872-7.
32. MacLean PS, Wing RR, Davidson T, Epstein L, Goodpaster B, Hall KD, et al. NIH working group report: Innovative research to improve maintenance of weight loss. Obesity. 2015;23(1):7-15.

Table 1: Baseline characteristics of the excluded and included women (Mean (SD) unless stated otherwise)

	Participants with missing data n = 1563	**Included in the analyses n=8125**	**P value**
Age	24.2 (1.5)	24.1 (1.5)	0.20
Education n (%)			
University degree	393 (25.1)	3375 (41.5)	<0.00
No university degree	1088 (69.7)	4482 (55.2)	
BMI kg/m^2	23.8 (5.1)	23.9 (4.9)	0.66
Mean stress score[a]	0.9 (0.6)	0.9 (0.6)	0.31
Mean depression score[b]	8.4 (5.6)	7.5 (5.6)	<0.01
Satisfaction with weight n (%)			
Happy as I am	357 (24.0)	1633 (20.1)	
1-5kg more	56 (3.8)	264 (3.3)	
Over 5kg more	13 (0.9)	42 (0.5)	
1-5 kg less	449 (30.6)	3090 (38.0)	
6-10 kg less	306 (20.9)	1712 (21.1)	
Over 10 kg less	282 (19.0)	1350 (16.7)	

[a](1= somewhat stressed; 4=extremely stressed) [b] >10 indicative of depression

Table 2: Weight control strategies by cluster group

		Dieters	Healthy Living	Do nothing	Perpetual dieters
Percentage of total sample		3224 39.7	2450 30.2	1632 20.0	819 10.1
		n (%)	n (%)	n (%)	n (%)
How often have you been on a diet to lose weight during the last year?	Never	46 (1.4)	2417 (98.7)	1544 (94.6)	8 (1.0)
	1-4 times	2628 (81.5)	32 (1.3)	72 (4.4)	264 (32.2)
	5-10 times	190 (5.9)	0	8 (0.5)	148 (18.1)
	More than 10 times	99 (3.1)	0	4 (0.2)	91 (11.1)
	Always	254 (7.9)	0	3 (0.2)	303 (37.0)
	Missing	7 (0.2)	1 (0)	1 (0.1)	5 (0.6)
Lost ≥5 kg on purpose	Never	1350 (41.9)	1978 (80.7)	1519 (93.1)	198 (24.1)
	1-2 times	1630 (50.6)	423 (17.3)	102 (6.3)	363 (44.3)
	3 or more times	244 (7.6)	49 (2.0)	11 (0.7)	258 (31.5)
Vigorous exercise	Yes	1919 (59.5)	1460 (59.6)	0 (100)	639 (78.0)
Vomited on purpose	Yes	61 (1.9)	43 (1.8)	0 (100)	289 (35.3)
Used laxatives, diuretics, slimming pills	Yes	105 (3.3)	25 (1.0)	0 (100)	369 (45.1)
Used commercial weight loss programme	Yes	612 (19.0)	4 (0.2)	0 (100)	197 (24.1)
Used meal replacements/ slimming products	Yes	194 (6.0)	31 (1.3)	0 (100)	210 (25.6)
Cut down on size of meals	Yes	2616 (81.1)	1289 (52.6)	0 (100)	746 (91.1)
Cut down fats/sugars	Yes	2655 (82.4)	1498 (61.1)	0 (100)	729 (89.0)
Fasting/cut out meals	Yes	431 (13.4)	166 (6.8)	0 (100)	595 (72.6)
Smoked	Yes	179 (5.6)	191 (7.8)	0 (100)	360 (44.0)
Do not actively manage weight	Yes	0 (100)	0 (100)	1632 (100)	0 (100)

Table 3: Characteristics of women in the total sample and by cluster group

Mean (SD) unless otherwise stated.	Total sample	Dieters	Healthy living	Do nothing	Perpetual dieters
Weight variables					
Dissatisfied about weight n (%)					
Not at all	1335 (16.4)	156 (4.8)	491 (20.0)	675 (41.4)	13 (1.6)
Slightly	2777 (34.0)	961 (29.8)	1076 (43.9)	625 (38.3)	115 (14.1)
Moderately	1953 (24.0)	981 (30.5)	552 (22.6)	200 (12.2)	220 (15.7)
Markedly	2041 (25.2)	1122 (34.8)	324 (13.2)	125 (7.7)	470 (57.4)
Missing	20 (0.2)	4 (0.1)	7 (0.3)	7 (0.4)	1 (0.1)
How much would you like to weigh n (%)					
Happy as I am	1633 (20.1)	236 (7.3)	621 (25.3)	753 (46.1)	23 (2.8)
Weigh more than 1 kg	306 (3.7)	18 (0.6)	67 (2.7)	214 (13.2)	6 (0.7)
1-5 kg less	3090 (38.0)	1277 (39.6)	1123 (45.8)	417 (25.6)	273 (33.3)
6-10 kg less	1712 (21.1)	907 (28.1)	423 (17.3)	125 (7.7)	257 (31.4)
Over 10 kg less	1350 (16.6)	775 (24.0)	206 (8.4)	114 (7.0)	255 (31.1)
Missing	34 (0.4)	10 (0.3)	10 (0.4)	9 (0.6)	5 (0.6)
Ever eaten a large amount n (%)					
Yes	3386 (41.6)	1538 (47.7)	869 (35.5)	424 (26.0)	555 (67.8)
Missing	41 (0.5)	18 (0.6)	10 (0.4)	6 (0.4)	7 (0.9)
Lost control of eating n (%)					
Yes	1501 (18.5)	719 (22.3)	293 (12.0)	77 (4.7)	412 (50.3)
Missing	57 (0.7)	30 (0.9)	14 (0.6)	6 (0.4)	7 (0.9)
Demographic characteristics					
Marital status n (%)					
Un partnered	1827 (22.5)	729 (22.6)	516 (21.1)	388 (23.8)	194 (23.7)
Partnered	5897 (71.8)	2322 (72.0)	1801 (73.5)	1153 (70.6)	561 (68.5)
Missing	461 (5.7)	173 (5.4)	133 (5.4)	91 (5.6)	64 (7.8)
Education n (%)					
Less than University	3375 (41.5)	1777 (55.1)	1217 (49.7)	996 (61.0)	492 (60.1)
University	4482 (55.2)	1325 41.1)	1161(47.4)	592 (36.3)	297 (36.3)
Missing	268 (3.3)	122 (3.8)	72 (2.9)	44 (2.7)	30 (3.7)
BMI (kg/m^2)	23.9 (4.9)	25.4 (5.2)	22.8 (3.9)	21.5 (4.0)	25.5 (5.5)
Underweight n (%)	521 (6.4)	52 (1.6)	160 (6.5)	285 (17.5)	24 (2.9)
Healthy weight	5134 (63.2)	1808 (56.1)	1782 (72.7)	1113(68.2)	431 (52.6)
Overweight	1621 (20.0)	855 (26.5)	377 (15.4)	156 (9.6)	233 (28.4)
Obese	849 (10.4)	509 (15.8)	131 (5.3)	78 (4.8)	131 (16.0)
Health Behaviours					
Physical activity median met minutes/week	699.3 (n=7933)	716.0 (n=3183)	799.2 (n=2399)	499.5 (n=1602)	899.1 (n=809)
Sitting time (hours/day)	6.4 (2.8)	6.4 (2.8) (n=3127)	6.4 (2.7) (n=2367)	6.3 (2.8) (n=1576)	6.5 (2.9) (n=776)
Alcohol status NHMRC n (%)					
None	672 (8.3)	232 (7.2)	184 (7.5)	221 (13.5)	35 (4.3)
Low	7109 (87.5)	2856 (88.6)	2172 (88.7)	1364 (83.6)	717 (87.5)
Risky	294 (3.6)	117 (3.7)	76 (3.1)	38 (2.3)	63 (7.7)
High	50 (0.6)	19 (0.6)	18 (0.7)	9 (0.6)	4 (0.5)
Ex-smoker	1835 (22.6)	735 (22.8)	510 (20.8)	326 (21.0)	264 (32.2)
Non ex-smoker	5832 (71.8)	2310 (71.7)	1811 (73.9)	1220 (74.8)	491 (60.0)
Daily Energy intake (KJ) per day	6936.0 (2780.0) (n=7243)	6736.1 (2870.3) (n=2878)	6979.4 (2620.3) (n=2189)	7402.5 (2780.7) (n=1471)	6644.1 (2964.1) (n=705)
Health variables					
Stress score	0.9 (0.6)	1.0 (0.6) (n=3212)	0.9 (0.5) (n=2441)	0.8 (0.5) (n=1621)	1.3 (0.7) (n=809)
Depression score	7.5 (5.6)	7.5 (5.3) n=3170	6.7 (5.1) n=2398	6.9 (5.2) n=1599	10.6 (6.4) n=809

Table 4: Percentage of weight maintainers, weight losers and weight gainers in each cluster, and average rates of annual weight gain from 2000 to 2009.

	Dieters	Healthy living	Do nothing	Perpetual dieters
	3224	2450	1632	819
Weight change categories:				
Weight loser's %	1.7	1.4	1.0	2.1
Weight maintainer's %	84.1	90.9	90.8	82.4
Weight gainers %	14.2	7.8	8.2	15.5
Average annual weight change (g, SD)	730 (1400)	580 (1110)	640 (1210)	880 (1560)
Mean difference in weight gain(g)[a] (95% CI)	80 (2, 20)	-70 (-150, 10)	--	230 (130, 340)
p value	0.045	0.104		<0.0001
Mean difference in weight gain[a,b] (95% CI)	80 (-3,160)	-50 (-13, 40)	--	210 (100, 320)
p value	0.06	0.266		0.000

[a] compared with the contented cluster

[b] adjusted for BMI, sitting time and education at survey 2 and whether women were living with/married to a partner, had children, or were ex-smokers, at survey 5.

Cluster analysis of behavioural weight management strategies and associations with weight change in young women: a longitudinal analysis

Claire D Madigan PhD[1], Amanda J Daley PhD[1], Enamul Kabir PhD[2,4], Paul Aveyard PhD[3]Wendy Brown PhD[4]

[1]School of Health and Population Sciences, University of Birmingham, UK

[2] School of Agricultural, Computational and Environmental Sciences, University of Southern Queensland, Australia.

[3] Nuffield Department of Primary Care Health Sciences, University of Oxford, UK

[4] School of Human Movement and Nutrition Sciences, University of Queensland, Australia

Conflicts of interests – None

Corresponding author

Claire Madigan

Health and Population Sciences

University of Birmingham

Birmingham

B15 2TT

UK

c.d.madigan@bham.ac.uk

Word count: 3303

ABSTRACT

Background/Objectives: Maintaining a healthy weight is important for the prevention of many chronic diseases. Little is known about the strategies used by young women to manage their weight, or the effectiveness of these in preventing weight gain. We aimed to identify clusters of weight control strategies used by women and determine the average annual weight change among women in each cluster from 2000 to 2009.

Methods: Latent cluster analysis of weight control strategies reported by 8125 participants in the Australian Longitudinal Study of Women's Health. Analyses were performed in March-November 2014.

Results: Weight control strategies were used by 79% of the women, and four unique clusters were found. The largest cluster group (39.7%) was named *dieters* as 90% had been on a diet in the past year, and half of these women had lost 5 kg on purpose. Women cut down on size of meals, fats and sugars and took part in vigorous physical activity. Additionally 20% had used a commercial programme. The next largest cluster (30.2%) was the *healthy living* group who followed the public health messages of 'eat less and move more'. The *do nothing* group (20%) did not actively control their weight whereas the *perpetual dieters* group (10.7%) used all strategies, including unhealthy behaviours. On average women gained 700 g per year (over nine years), however the *perpetual dieter*s group gained significantly more weight (210g) than the *do nothing* group ($p<0.001$).

Conclusions: Most women are actively trying to control their weight. The most successful approach was to follow the public health guidelines on health eating and physical activity.

INTRODUCTION

In the last 20 years there has been a shift in the distribution of adult BMI, with populations getting heavier across all BMI categories. Weight gain has been particularly marked in young adults, who, on average, gain more than 0.6 kg per year when they are in their twenties and thirties(1, 2). Much more is known about strategies used to maintain weight after a period of weight loss, than about strategies used for the primary prevention of weight gain. This is because information about strategies used for weight loss maintenance is available from the

National Weight Control Registry (NWCR), a cohort of over 10,000 US adults who have successfully lost ≥13.6 kg of weight and maintained this loss for a minimum of one year(3). Those who maintained weight loss most commonly reported high levels of physical activity, eating breakfast, consuming low-energy/low fat diets, a high level of dietary restraint and weighed themselves regularly(4).

Population approaches to weight control have been less well studied(5). A systematic review of trials and observational studies found the strength of evidence is low for all weight gain prevention strategies, but effective strategies may include: low-fat diets, eating fewer meals prepared away from home, eating more fruits and vegetables, monitoring heart rate during exercise, and participation in group lifestyle sessions with reminder text messages(5).This review did not, however focus on people who may also want to lose weight. One small Australian study (n=1335) has reported that 50% of people visiting a GP surgery (aged ≥18 years) had tried to lose weight in the past 12 months(6). Of those, 72% reported changing their diet, 54% increased exercise, 7.5% consulted a professional weight loss programme, 6.5% used over the counter supplements and 1.7% used medication(6). Whether participants used single strategies or a combination of strategies, or whether they successfully lost weight, was not assessed.

Only one study has examined strategies for weight control using a population based prospective cohort. In it, the Australian Longitudinal Study of Women's Health (ALSWH) researchers found 74% of mid-age women (45-52 years) actively used at least one strategy to manage their weight(7). One combination of practices was associated with preventing weight gain two years later, this included decreasing food quantity, cutting down on fats and sugars, using a commercial weight loss programme, and exercise(7).

There is little information about the weight control strategies that are being used by younger adult women, or their efficacy in preventing weight gain. Rates of weight gain are high in this population group(2), possibly because young women do not engage in weight control strategies, or because the strategies they do adopt are ineffective. A better understanding of the strategies currently used by young adult women, and their effectiveness, could be used to guide behavioural advice on weight control.

The primary aim of this study was to identify clusters of weight management behaviours in the younger cohort of the ALSWH, who were aged 22-27 in 2000. Additional aims were to assess the characteristics of women in each cluster, and determine the average rate of weight change in each cluster, over nine years from 2000 to 2009.

METHODS

The ALSWH is a prospective study of factors shaping the health and well-being of three cohorts of Australian women (born in 1973–1978, 1946–1951, and 1921–1926), recruited from the national health insurance database. The focus of this paper is on the 1973–1978 cohort who completed mailed surveys in 1996, 2000, 2003, 2006 and 2009 (surveys 1 to 5). Women were aged 22-27 years at survey 2 (year 2000) and aged 31-36 years at survey 9. More details can be found at http://www.alswh.org.au. The study was approved by the Universities of Newcastle and Queensland Ethical Review Committees and all participating women provided informed consent. The women were asked about their weight control practices in Survey 2. Additional demographic, health and behavioural information was extracted from the same survey (unless stated otherwise), and weight change was assessed over nine years using data from Survey 2 and the following three surveys.

Cluster analysis variables

Women were asked how often they had dieted in the past year and the number of times they had lost 5 kg or more on purpose. Women who answered 'yes' to the question: 'Have you used a weight control practice in the past 12 months?' were asked to indicate which of the nine weight control practices they had used (yes/no) in the past 12 months. The strategies are listed in the results tables.

Descriptive variables

Almost all the demographic (age, education), behavioural (physical activity, sitting time, alcohol use) and health (BMI, weight satisfaction, stress and depression) variables were assessed at survey 2. Marital status, parity and smoking status (smoker/ex-smoker) were assessed at survey five, and included in the weight gain analysis, as getting married, having a baby and quitting smoking are known to be associated with weight gain(8, 9). BMI was calculated as weight (kg)/height^2(m^2) and categorized in accordance with WHO recommendations(10).

Physical activity was assessed using questions developed for national surveillance of physical activity in Australia(11, 12). Women reported time spent walking briskly and in moderate-intensity and vigorous leisure activities in the last week. Responses were used to calculate total physical activity in MET·minutes per week ((min/week in walking and moderate PA*3.33)+ (min/week in vigorous PA*6.66)). Average daily sitting time was calculated from reported time spent sitting on weekdays and weekend days and reported as a continuous variable. Alcohol intake was coded as: non-drinker, low-risk (up to two drinks/day), or risky drinker (more than two drinks/day)(13). Women were categorised as ex-smokers or not ex-smokers at Survey 5. In survey 3 women completed a food frequency questionnaire and the data were used to estimate daily energy intake(14).

The Center for Epidemiologic Studies Depression Scale (CESD-10) was used to measure depressive symptoms (15), with scores of ≥10 indicating depressive symptoms(15). A measure of stress was developed for the ALWSH study and details have been reported elsewhere(16). The scores range from zero to four, with four indicating extremely stressed. Women were asked how dissatisfied they felt with their weight and how much they would like to weigh now. They were also asked whether there had been times when they felt that they had eaten what other people would regard as an unusually large amount of food given the circumstances, and if they felt a loss of control over their eating.

Weight was reported at each survey to the nearest kg. Validation research with a subsample of the ALSWH mid age cohort has shown that self-reported weight is reasonably accurately reported in ALSWH women, but This finding is supported by other research with Australian adults(18). A regression line through each woman's weight at each survey point was used to provide a weight trajectory over nine years; the coefficient represented weight change in kg per year. Women were classified as weight maintainers (+/-2 kg change/year), weight losers (≥-2 kg change/year) or weight gainers (≥2 kg change/year).

Statistical analysis

Analyses were conducted in March-November 2014 using SPSS (Version 21) and R. Data were available for 9688 women who completed survey 2. Women were excluded if they had missing data for: weight control variables (n=203); weight at three or more surveys (n=1045); BMI at survey 1 or 2 (n=254); and if they were pregnant between surveys two to five, with only one non pregnant weight (n=61). Data from 8125 women were included in the analysis.

The cluster analysis variables (see above and in Table 2) were inputted for latent class cluster analysis (LCA) using poLCA (developed by Linzer and Lewis(19)). We used LCA, a model-based approach that allows for mixed measurement levels and enables independent and dependent variables to be considered and clustered together. It also allows estimation of latent class clusters for polytomous outcome variables. The LCA model is estimated in R by the poLCA () function. It is necessary to specify the selected variables, the data, and the number of clusters. The function returns results including the BIC, the AIC, the likelihood function, the G^2 (Likelihood ratio/deviance statistic), the Chi-square statistic, number of estimated parameters, the estimated class-conditional response probabilities, and a matrix containing each observation's posterior class membership probabilities. The latent class model does not automatically determine the number of latent classes in a given data set; but it does offer a variety of parsimony and goodness of fit statistics that researchers may use to make a theoretically and empirically sound assessment(20). Generally, the goal is to select models that maximize the likelihood, minimize the BIC, Chi-square or G^2, while retaining a parsimonious model. To obtain the best classification, we estimated models for two to 15 latent clusters. For each cluster selection, the model was repeated 10 times so that the parameter estimates corresponded to the model producing the greatest log-likelihood.

Measures of central tendency were used to describe the characteristics of women included and excluded from the analysis and in each of the clusters. Linear regression was used to compare weight change in those women who reported not actively managing their weight (i.e the *do nothing* group) and those in the other cluster groups. Within the model the following confounding variables were taken into account: sitting time, education, BMI, partnered/un-partnered, children/no children, ex-smoker/not ex-smoker. These variables were based on the determinants of change reported in previous ALSWH papers (9, 21, 22) If there were

171 missing data on confounders, these were imputed with the mean score in order to include data
172 from as many women as possible in the analysis.
173
174 **RESULTS**
175 A comparison of selected characteristics of the included and excluded women is shown in
176 Table 1. The women who were excluded due to missing data had slightly higher depressive
177 symptom scores and were less likely to be university educated, but other characteristics were
178 similar. On average the included women were 24.1 years of age, with a BMI of 23.9 kg/m^2.
179 Just over half did not have a university education.
180
181 Initially, the cluster analyses offered 4, 5 or 6 cluster solutions. However, after considering
182 both model fit and parsimony(23) we found the optimal BIC value (112964, log likelihood -
183 56067, *chi^2 7287283*) with four clusters, which were named: *dieters, healthy living, do*
184 *nothing* or *perpetual dieters*. The weight management strategies used by women in each
185 cluster are shown in Table 2, and their demographic, behavioural and health characteristics
186 are shown in Table 3.
187 **Strategies used**
188 Seventy-nine per cent of women reported using at least one strategy to control their weight,
189 with the majority of women using two or three strategies (45.7%). Only 3.2% of women
190 reported using six or more strategies.
191
192 *Dieters*

193 This was the largest cluster, with 39.7% of the women; their average BMI was 25.4 kg/m^2.
194 More than 90% had been on a diet in the past year, and more than half of these reported
195 losing 5 kg on purpose. Women in this cluster tended to use healthy weight management

196 strategies, such as vigorous exercise, cutting down on size of meals and cutting down on
197 fats/sugars to manage their weight. Approximately 20% of this group had used a commercial
198 programme to manage their weight and fewer than 5% reported using unhealthy strategies
199 such as smoking and laxatives/diuretics.

200 Fewer than 10% of women in this cluster were happy with their weight (7.3%), almost one
201 quarter reported having lost control of their eating. Median physical activity was 719
202 MET.Minutes/week (equates to about 30 minutes of moderate activity every day), and
203 average sitting time was on average 6.4 hours per day. Few women in this cluster were
204 classified as risky drinkers. Overall 72% of women were partnered, and 41.1% had university
205 education. These women were classified as somewhat stressed but had low scores for
206 depressive symptoms.

207 *Healthy living*

208 This was the second largest cluster (30.2% of the sample) with an average BMI of 22.8
209 kg/m^2. Very few women in this cluster had been on a diet to lose weight in the past year, and
210 only one in five had ever lost 5 kg on purpose. The three most popular weight control
211 strategies were: vigorous exercise, cutting down on the size of meals and cutting down on fats
212 and sugars. Very few women in this cluster reported using commercial weight loss
213 programmes, meal replacements, vomiting or smoking.

214 Although the average BMI of women in this cluster was in the healthy range, almost three
215 quarters said they would like to weigh less. However, very few had ever dieted. One quarter
216 were happy with their weight. Almost half women in this cluster had a university education
217 and stress and depressive symptoms were low.

218 *Do nothing*

Twenty percent of the sample was included in this cluster, which had the lowest mean BMI. These women did not use any of the nine weight management strategies and very few reported dieting to lose weight in the past year (5.3%) or having ever purposefully lost 5 kg (7%) (Table 2).

Eighty percent of women in this cluster were either not at all, or only slightly, dissatisfied with their weight, indicating the highest satisfaction with weight of any of the clusters. The proportions of women who reported eating a large amount of food or losing control of eating were low in this group. Physical activity scores were low and daily energy intake was high. About one third were university educated, and had low stress and depressive symptom scores.

Perpetual dieters

This was the smallest cluster, comprising 10.7% of women, with an average BMI of 25.5 kg/m^2.Three quarters of women in this cluster had purposefully lost at least 5 kg (one third had done this three times or more) and only 1% had never been on a diet in the past year. Use of all the weight control strategies was highest in this group, including healthy strategies such as cutting down on meal sizes, fats and sugars, and vigorous exercise, as well as unhealthy weight control strategies such as smoking, vomiting and using laxatives/diuretics. Very few women in this cluster were happy with their weight (2.8%) and eating large amounts and losing control of eating were more common than in the other clusters. This group reported the highest amount of physical activity and lowest energy intake. The proportion of ex-smokers was high in this cluster group. Stress and depressive score were also high.

Nine year weight change (2000 to 2009)

Most women in this sample were in the healthy BMI range in 2000. Overall, there was an average rate of weight gain of 700 (SD 1300) g/year but 1.5% of the women were categorised

as weight losers; 87.3% as maintainers, and only 11.2% as gainers. There were no statistically significant differences in rate of weight gain in three of the clusters (Table 4), but the *perpetual dieters* gained 210g/year more ($p<0.001$) than women in the *do nothing cluster* (adjusted for covariates). The proportion of women who were classified as weight gainers was highest in the *perpetual dieters* and *dieter groups*.

DISCUSSION

As rates of weight gain are increasing rapidly in young adults, it is important to explore the strategies used for weight control in this population(2). The ALSWH study provided an opportunity to investigate these strategies in a large sample of young adult women. On average, women gained 700 g per year, which equates to 6.3 kg across the nine years, in line with previous research that suggests populations are getting heavier (24, 25). However, only 11% were classified as weight gainers (gaining >2 kg/year). The majority of women (79.9%) reported using at least one strategy to control their weight and we found four distinct clusters of women, based on their weight control behaviours. The largest group, *the dieters* used a variety of strategies to control their weight. The *healthy living* group followed public health messages of 'eat less and move more' and gained a similar amount of weight. The *do nothing* group did not actively manage their weight, and on average gained 600 g per year. The *perpetual dieters* gained significantly more weight than the *do nothing* group, and on average gained 8.1 kg in nine years.

The majority of women actively control their weight, however on average women gained weight. Both the *dieters* and *perpetual dieter* groups used a variety of strategies, but still struggled with their weight, and included the highest proportion classified as weight gainers. It could be hypothesised that, as these women were on average overweight at baseline, they

perhaps struggled more with their weight. This is similar to findings of the NWCR, who found a cluster group that had continuously struggled with weight since childhood(26). Similar to the NWCR cohort, women in the *dieters* and *perpetual dieter* groups relied on the greatest number of strategies to control their weight and reported higher levels of stress and depressive symptoms. It is concerning that a high proportion of the perpetual dieters used unhealthy strategies to manage their weight, as these strategies are associated with eating disorders and weight cycles of loss and regain, which may be harmful for health(27, 28). Although the overall percentage of women using these strategies was low, there may be potential for public health messages to discourage using these harmful strategies.

The *healthy living* group appears to include women who actively try to maintain their weight, by using strategies such as vigorous exercise, cutting down on size of meals and cutting down on fats and sugars. This reflects current public health messages and appears to work for these women, whose average BMI was in the middle of the healthy weight range. The *do nothing* group may represent women with higher self-regulation competence as they had the lowest average BMI, but appeared to do little to control their weight. Previous research with adolescents has shown that higher self-regulation competence is associated with lower consumption of unhealthy snacks(29).

There was some evidence to suggest that psychological well-being differed between the clusters, with low scores in the *dieters* and *perpetual dieters* clusters. There could be two reasons for this. Firstly, trying and failing to control weight may be associated with decreases in psychological well-being.(30) Secondly, lower psychological well-being may be associated with weight gain(31). Further research is required to clarify the complex inter-relationships between perpetual dieting, weight gain and well-being.

The strengths of the study include the large representative sample of young adult women and the longitudinal study design. Limitations of the study design include a reliance on self-reported data. Less accurate reporting of weight by obese women (17) would have affected our estimates of both weight and weight gain, especially in the *dieters group*, which had the greatest proportion of obese women.

Questions about behavioural weight management strategies were included in surveys two and five, but as the questions used in survey five were different, we were unable to assess whether these weight management strategies changed over time. To our knowledge, no surveys have investigated the stability of weight control practices in a general population sample, but we suspect that those who are unsuccessful at weight loss maintenance do not adhere to behavioural regimens, which suggests that weight control practices could vary over time, particularly in those trying to lose weight(32). Another limitation is that although several important weight management strategies were examined, women may have used other strategies that were not reported. A final limitation is that we have no information about the potential metabolic and genetic differences between these clusters.

In summary, 79% of the women used at least one strategy to control their weight, and yet, on average, they still gained weight. We identified four main clusters of weight management strategies; the most successful approach was following current guidelines for a healthy diet and physical activity. The findings confirm that the use of unhealthy strategies to control weight may not be helpful. Further research should examine the optimal combination of weight management strategies and their relationships with both long term weight control and well-being.

Acknowledgements

The research on which this paper is based was conducted as part of the Australian Longitudinal Study on Women's Health, The University of Newcastle and The University of Queensland. We are grateful to the Australian Government Department of Health for funding and to the women who provided the survey data. The authors also thank Professor Graham Giles of the Cancer Epidemiology Centre of Cancer Council Victoria, for permission to use the Dietary Questionnaire for Epidemiological Studies (Version 2), Melbourne: Cancer Council Victoria, 1996."

All authors declare no conflict of interest.

All authors declare no financial reimbursements.

References

1. Norman J, Bild D, Lewis C, Liu K, West D, Study C. The impact of weight change on cardiovascular disease risk factors in young black and white adults: the CARDIA study. Int J Obes Relat Metab Disord. 2003;27(3):369-76.
2. Allman-Farinelli MA, Chey T, Bauman AE, Gill T, James WPT. Age, period and birth cohort effects on prevalence of overweight and obesity in Australian adults from 1990 to 2000. Eur J Clin Nutr. 2007;62(7):898-907.
3. Klem ML, Wing RR, McGuire MT, Deagel HM, Hill JO. A descriptive study of individuals successful at long-term maintenance of substantial weight loss. American Journal of Clinical Nutrition. 1997;66:239-46.
4. Wing R, Hill J. Successful weight loss maintenance. Annual Review of Nutrition. 2001;21:323-41.
5. Huttfless S, Gudzune KA, Maruthur N, Wilson RF, Bleich SN, Lau BD, et al. Strategies to Prevent Weight Gain in Adults: A Systematic Review. American Journal of Preventive Medicine. 2013;45(6):e41-e51.
6. Yoong S, Carey M, Sanson-Fisher R, D'Este C. A cross-sectional study assessing the self-reported weight loss strategies used by adult Australian general practice patients. BMC Family Practice. 2012;13(48).
7. Williams L, Germov J, Young A. Preventing weight gain: a population cohort study of the nature and effectiveness of mid-age women's weight control practices. International Journal of Obesity. 2007;31(6):1978-86.
8. Aubin H-J, Farley A, Lycett D, Lahmek P, Aveyard P. Weight gain in smokers after quitting cigarettes: meta-analysis. BMJ. 2012;345.
9. Brown W, Hockey R, Dobson A. Effects of Having a Baby on Weight Gain. American Journal of Preventive Medicine. 2010;38(2):163-70.

10. World Health Organisation. Obesity 2011. Available from: http://www.who.int/topics/obesity/en/.
11. Armstrong T, Bauman A, Davies J. Physical activity patterns of Australian adults. Results of the 1999 National Physical Activity Survey Canberra: 2000.
12. Brown W, Burton N, Marshall A, Miller Y. Reliability and validity of a modified self administered version of the Active Australia physical activity survey in a sample of mid-age women. Aust N Z J Public Health. 2008;32(6):535-41.
13. National Health and Medical Research Council. Australian alcohol guidelines. Canberra: 2001.
14. Hodge A, Patterson A, Brown W, Ireland P, Giles G. The anti cancer council of Victoria FFQ: relative validity of nutirient intakes compared with weighed food records in young to middle-aged women in a study of iron supplementation. Aust N Z J Public Health. 2000;24:576-83.
15. Andresen E, Malmgren J, Carter W, Patrick D. Screening for depression in well older adults: evaluation of a short form of the CES-D (Center for Epidemiologic Studies Depression Scale). American Journal of Preventive Medicine. 1994;10:77-84.
16. Bell S, Lee C. Perceived stress revisited: the Women's Health Australia project Younger cohort Psychology, Health and Medicine. 2003;8(3):343-53.
17. Burton NW, Brown W, Dobson A. Accuracy of body mass index estimated from self-reported height and weight in mid-aged Australian women. Australian and New Zealand Journal of Public Health. 2010;34(6):620-3.
18. Dhaliwal S, Howat P, Bejoy T, Welborn T. Self-Reported Weight and Height for Evaluating Obesity Control Programs. American Journal of Health Behavior. 2010;34(4):489-99.
19. Linzer D, Lewis J. poLCA: Polytomous Variable Latent Class Analysis. R package version 142013.
20. Linzer D, Lewis J. "poLCA: an R Package for Polytomous Variable Latent Class Analysis. Journal of Statistical Software. 2011;42(10):1-29.
21. Ball K, Brown W, Crawford D. Who does not gain weight? Prevalence and predictors of weight maintenance in young women. International Journal of Obesity. 2002;26:1570-8.
22. Ball K, Crawford D. An investigation of psychological, social and environmental correlates of obesity and weight gain in young women. International Journal of Obesity. 2006;30(8):1240-9.
23. Haughton D, Legrand P, Woolford S. Review of three latent class cluster analysis packages: latent gold, poLCA, and MCLUST. The American Statistician. 2009;63(1):81-91.
24. NOO. Change in adult BMI distribution. Public Health England; 2013.
25. Lee J, Pilli S, Gebremariam A, Keirns C, Davis M, Vijan S, et al. Getting heavier, younger: trajectories of obesity over the life course. International Journal of Obesity. 2010;34(4):614-23.
26. Ogden L, Stroebele N, Wyatt H, Catenacci V, Peters J, Stuht J, et al. Cluster Analysis of the National Weight Control Registry to Identify Distinct Subgroups Maintaining Successful Weight Loss. Obesity. 2012;20(10):2039-47.
27. Neumark-Sztainer D, Wall M, Story M, Standish A. Dieting and unhealthy weight control behaviors during adolescence: associations with 10-year changes in body mass index. J Adolesc Health. 2012;50(1):80-6.
28. Neumark-Sztainer DR, Wall MM, Haines JI, Story MT, Sherwood NE, van den Berg PA. Shared Risk and Protective Factors for Overweight and Disordered Eating in Adolescents. American Journal of Preventive Medicine. 2007;33(5):359-69.
29. Stok F, De Vet E, J W, Chu M, De Wit J, De Ridder D. Navigating the obesogenic environment: How psychological sensitivity to the food environment and self-regulatory

competence are associated with adolescent unhealthy snacking. Eating Behaviors. 2015;17:19-22.
30. Elfhag K, Rössner S. Who succeeds in maintaining weight loss? A conceptual review of factors associated with weight loss maintenance and weight regain. Obesity Reviews. 2005;6(1):67-85.
31. Räikkönen K, Matthews KA, Kuller LH. Depressive Symptoms and Stressful Life Events Predict Metabolic Syndrome Among Middle-Aged Women: A comparison of World Health Organization, Adult Treatment Panel III, and International Diabetes Foundation definitions. Diabetes Care. 2007;30(4):872-7.
32. MacLean PS, Wing RR, Davidson T, Epstein L, Goodpaster B, Hall KD, et al. NIH working group report: Innovative research to improve maintenance of weight loss. Obesity. 2015;23(1):7-15.

Table 1: Baseline characteristics of the excluded and included women (Mean (SD) unless stated otherwise)

	Participants with missing data n = 1563	Included in the analyses n=8125	P value
Age	24.2 (1.5)	24.1 (1.5)	0.20
Education n (%)			
University degree	393 (25.1)	3375 (41.5)	<0.00
No university degree	1088 (69.7)	4482 (55.2)	
BMI kg/m^2	23.8 (5.1)	23.9 (4.9)	0.66
Mean stress score[a]	0.9 (0.6)	0.9 (0.6)	0.31
Mean depression score[b]	8.4 (5.6)	7.5 (5.6)	<0.01
Satisfaction with weight n (%)			
Happy as I am	357 (24.0)	1633 (20.1)	
1-5kg more	56 (3.8)	264 (3.3)	
Over 5kg more	13 (0.9)	42 (0.5)	
1-5 kg less	449 (30.6)	3090 (38.0)	
6-10 kg less	306 (20.9)	1712 (21.1)	
Over 10 kg less	282 (19.0)	1350 (16.7)	

[a](1= somewhat stressed; 4=extremely stressed) [b] >10 indicative of depression

Table 2: Weight control strategies by cluster group

		Dieters	Healthy Living	Do nothing	Perpetual dieters
Percentage of total sample		3224 39.7	2450 30.2	1632 20.0	819 10.1
		n (%)	n (%)	n (%)	n (%)
How often have you been on a diet to lose weight during the last year?	Never	46 (1.4)	2417 (98.7)	1544 (94.6)	8 (1.0)
	1-4 times	2628 (81.5)	32 (1.3)	72 (4.4)	264 (32.2)
	5-10 times	190 (5.9)	0	8 (0.5)	148 (18.1)
	More than 10 times	99 (3.1)	0	4 (0.2)	91 (11.1)
	Always	254 (7.9)	0	3 (0.2)	303 (37.0)
	Missing	7 (0.2)	1 (0)	1 (0.1)	5 (0.6)
Lost ≥5 kg on purpose	Never	1350 (41.9)	1978 (80.7)	1519 (93.1)	198 (24.1)
	1-2 times	1630 (50.6)	423 (17.3)	102 (6.3)	363 (44.3)
	3 or more times	244 (7.6)	49 (2.0)	11 (0.7)	258 (31.5)
Vigorous exercise	Yes	1919 (59.5)	1460 (59.6)	0 (100)	639 (78.0)
Vomited on purpose	Yes	61 (1.9)	43 (1.8)	0 (100)	289 (35.3)
Used laxatives, diuretics, slimming pills	Yes	105 (3.3)	25 (1.0)	0 (100)	369 (45.1)
Used commercial weight loss programme	Yes	612 (19.0)	4 (0.2)	0 (100)	197 (24.1)
Used meal replacements/ slimming products	Yes	194 (6.0)	31 (1.3)	0 (100)	210 (25.6)
Cut down on size of meals	Yes	2616 (81.1)	1289 (52.6)	0 (100)	746 (91.1)
Cut down fats/sugars	Yes	2655 (82.4)	1498 (61.1)	0 (100)	729 (89.0)
Fasting/cut out meals	Yes	431 (13.4)	166 (6.8)	0 (100)	595 (72.6)
Smoked	Yes	179 (5.6)	191 (7.8)	0 (100)	360 (44.0)
Do not actively manage weight	Yes	0 (100)	0 (100)	1632 (100)	0 (100)

Table 3: Characteristics of women in the total sample and by cluster group

Mean (SD) unless otherwise stated.	Total sample	Dieters	Healthy living	Do nothing	Perpetual dieters
Weight variables					
Dissatisfied about weight n (%)					
Not at all	1335 (16.4)	156 (4.8)	491 (20.0)	675 (41.4)	13 (1.6)
Slightly	2777 (34.0)	961 (29.8)	1076 (43.9)	625 (38.3)	115 (14.1)
Moderately	1953 (24.0)	981 (30.5)	552 (22.6)	200 (12.2)	220 (15.7)
Markedly	2041 (25.2)	1122 (34.8)	324 (13.2)	125 (7.7)	470 (57.4)
Missing	20 (0.2)	4 (0.1)	7 (0.3)	7 (0.4)	1 (0.1)
How much would you like to weigh n (%)					
Happy as I am	1633 (20.1)	236 (7.3)	621 (25.3)	753 (46.1)	23 (2.8)
Weigh more than 1 kg	306 (3.7)	18 (0.6)	67 (2.7)	214 (13.2)	6 (0.7)
1-5 kg less	3090 (38.0)	1277 (39.6)	1123 (45.8)	417 (25.6)	273 (33.3)
6-10 kg less	1712 (21.1)	907 (28.1)	423 (17.3)	125 (7.7)	257 (31.4)
Over 10 kg less	1350 (16.6)	775 (24.0)	206 (8.4)	114 (7.0)	255 (31.1)
Missing	34 (0.4)	10 (0.3)	10 (0.4)	9 (0.6)	5 (0.6)
Ever eaten a large amount n (%)					
Yes	3386 (41.6)	1538 (47.7)	869 (35.5)	424 (26.0)	555 (67.8)
Missing	41 (0.5)	18 (0.6)	10 (0.4)	6 (0.4)	7 (0.9)
Lost control of eating n (%)					
Yes	1501 (18.5)	719 (22.3)	293 (12.0)	77 (4.7)	412 (50.3)
Missing	57 (0.7)	30 (0.9)	14 (0.6)	6 (0.4)	7 (0.9)
Demographic characteristics					
Marital status n (%)					
Un partnered	1827 (22.5)	729 (22.6)	516 (21.1)	388 (23.8)	194 (23.7)
Partnered	5897 (71.8)	2322 (72.0)	1801 (73.5)	1153 (70.6)	561 (68.5)
Missing	461 (5.7)	173 (5.4)	133 (5.4)	91 (5.6)	64 (7.8)
Education n (%)					
Less than University	3375 (41.5)	1777 (55.1)	1217 (49.7)	996 (61.0)	492 (60.1)
University	4482 (55.2)	1325 41.1)	1161(47.4)	592 (36.3)	297 (36.3)
Missing	268 (3.3)	122 (3.8)	72 (2.9)	44 (2.7)	30 (3.7)
BMI (kg/m^2)	23.9 (4.9)	25.4 (5.2)	22.8 (3.9)	21.5 (4.0)	25.5 (5.5)
Underweight n (%)	521 (6.4)	52 (1.6)	160 (6.5)	285 (17.5)	24 (2.9)
Healthy weight	5134 (63.2)	1808 (56.1)	1782 (72.7)	1113(68.2)	431 (52.6)
Overweight	1621 (20.0)	855 (26.5)	377 (15.4)	156 (9.6)	233 (28.4)
Obese	849 (10.4)	509 (15.8)	131 (5.3)	78 (4.8)	131 (16.0)
Health Behaviours					
Physical activity median met minutes/week	699.3 (n=7933)	716.0 (n=3183)	799.2 (n=2399)	499.5 (n=1602)	899.1 (n=809)
Sitting time (hours/day)	6.4 (2.8)	6.4 (2.8) (n=3127)	6.4 (2.7) (n=2367)	6.3 (2.8) (n=1576)	6.5 (2.9) (n=776)
Alcohol status NHMRC n (%)					
None	672 (8.3)	232 (7.2)	184 (7.5)	221 (13.5)	35 (4.3)
Low	7109 (87.5)	2856 (88.6)	2172 (88.7)	1364 (83.6)	717 (87.5)
Risky	294 (3.6)	117 (3.7)	76 (3.1)	38 (2.3)	63 (7.7)
High	50 (0.6)	19 (0.6)	18 (0.7)	9 (0.6)	4 (0.5)
Ex-smoker	1835 (22.6)	735 (22.8)	510 (20.8)	326 (21.0)	264 (32.2)
Non ex-smoker	5832 (71.8)	2310 (71.7)	1811 (73.9)	1220 (74.8)	491 (60.0)
Daily Energy intake (KJ) per day	6936.0 (2780.0) (n=7243)	6736.1 (2870.3) (n=2878)	6979.4 (2620.3) (n=2189)	7402.5 (2780.7) (n=1471)	6644.1 (2964.1) (n=705)
Health variables					
Stress score	0.9 (0.6)	1.0 (0.6) (n=3212)	0.9 (0.5) (n=2441)	0.8 (0.5) (n=1621)	1.3 (0.7) (n=809)
Depression score	7.5 (5.6)	7.5 (5.3) n=3170	6.7 (5.1) n=2398	6.9 (5.2) n=1599	10.6 (6.4) n=809

Table 4: Percentage of weight maintainers, weight losers and weight gainers in each cluster, and average rates of annual weight gain from 2000 to 2009.

	Dieters	Healthy living	Do nothing	Perpetual dieters
	3224	2450	1632	819
Weight change categories:				
Weight loser's %	1.7	1.4	1.0	2.1
Weight maintainer's %	84.1	90.9	90.8	82.4
Weight gainers %	14.2	7.8	8.2	15.5
Average annual weight change (g, SD)	730 (1400)	580 (1110)	640 (1210)	880 (1560)
Mean difference in weight gain(g)[a] (95% CI)	80 (2, 20)	-70 (-150, 10)	--	230 (130, 340)
p value	0.045	0.104		<0.0001
Mean difference in weight gain[a,b] (95% CI)	80 (-3,160)	-50 (-13, 40)	--	210 (100, 320)
p value	0.06	0.266		0.000

[a] compared with the contented cluster

[b] adjusted for BMI, sitting time and education at survey 2 and whether women were living with/married to a partner, had children, or were ex-smokers, at survey 5.