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ORIGINAL ARTICLE

Weight cycling of athletes and subsequent weight gain in middleage

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Objective: To study the effects of repeated cycles of weight loss and regain as young adults on long-term weight development.
Design: A follow-up study with questionnaires in 1985, 1995 and 2001.
Setting: Finland.
Subjects: A national cohort of 1838 male elite athletes who had represented Finland in major international sport competitions in 1920–1965, including 370 men engaged in sports in which weight-related performance classes are associated with weight cycling (boxers, weight lifters and wrestlers; further called as weight cyclers), and 834 matched control men with no athletic background.
Outcome measure: Weight change since the age of 20 years, body mass index (BMI) and prevalence of obesity and overweight.
Results: The weight cyclers gained 5.2 BMI units from age 20 years to their maximum mean weight, which was at age 58.7 years. Corresponding figures for the controls were 4.2 BMI units at 58.5 years and for other athletes 3.3 BMI units at age 62.5 years. The proportion of obese (BMI $\geqslant 30\,kg/m^2$) subjects was greatest among the weight cyclers both in 1985 and 1995. In 2001, the weight cyclers were more often obese than other athletes, but did not differ from the controls. The odds ratio for the weight cyclers to be obese compared to other athletes in 1985 was 3.18 (95% confidence intervals 2.09–4.83), and compared to the controls 2.0 (1.35–2.96). The enhanced weight gain of the weight cyclers was not accounted for by present health habits (smoking, alcohol use, use of high-fat milk or physical activity) or weight at age 20 years.
Conclusions: Repeated cycles of weight loss and regain appear to enhance subsequent weight gain and may predispose to obesity. Chronic dieting with weight cycling may be harmful for permanent weight control.
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Keywords: body weight changes; weight gain; athletics; overweight

Introduction

Chronic dieters and athletes engaged in sports with weight classes (e.g. wrestlers, weightlifters and boxers) periodically restrict their food intake to lose weight. The periods of food restriction and weight loss usually alternate with periods of unrestricted food intake and weight gain. The long-term effects of periodic dieting and weight regain on long-term weight development are still controversial.[1–3]

We therefore studied long-term weight changes in a unique population of former world-class elite athletes, including a group of men who had been active in sports with weight classes that have been linked to periodic weight reduction and regain practices. As our interest was in the development of overweight and obesity, we focused on changes in body weight in middle age. Later in life, body weight change is a function of both change in body fat and the senile decline of weight due to loss of fat-free mass, principally muscle mass.[4] Therefore, we limited our analysis to include only the age range of 20– 65 years.

Subjects and methods

The study subjects were male athletes, who had represented Finland in the Olympic Games or in other major international sport competitions between 1920 and 1965 in track and field athletics, cross-country skiing, football, ice hockey, basketball, shooting, boxing, wrestling or weightlifting. Athletes were identified from sports yearbooks and registers

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and traced through the records of local parishes, and 97.7% of them were able to be traced. The control group consisted of conscripts from the same age cohort and area of residence as the athletes, and were selected from the service register of the Finnish Defence Forces; because of universal conscription, all Finnish men are assessed for eligibility to serve. The completely healthy conscript listed in the service register living the closest geographically to each athlete was chosen as his matched control. The controls were selected in 1978–1979, and no controls for athletes traced later were obtained.

The surviving former athletes and controls were sent in 1985, 1995 and 2001 an extensive questionnaire on personal characteristics, including height, current weight, weight at the time of their military service (at age 20 years), sociodemographic factors, psychological traits, smoking and the use of alcohol, physical activity, the discontinuation of their sporting career, dietary habits, symptoms and diseases.

Relative body weight was expressed as body mass index (BMI), which is weight in kilograms divided by height in meters squared. For each questionnaire, the current age was used and the current BMI was computed using the current weight and the consensus height as determined from all answers. For the BMI at age 20 years, we used the earliest available reported weight at age 20 years and the consensus height.

Habitual physical activity at leisure was assessed by a set of questions about the type, duration and frequency of various activities. The amount of energy expended in habitual physical activities was calculated and expressed in metabolic units, as described elsewhere.[5] Alcohol consumption of all beverage types was computed as grams of alcohol per month and adjusted for body weight.[5] A detailed smoking history was used to define smoking status as a categorical variable divided into never, former and current regular smokers. The group of occasional smokers was small ($n=86$) and similar to the former smokers in BMI and age, and thus was combined with them. Type of milk used, was used as an indicator variable of fat intake.[6] Milk use was asked and used in analyses as a categorical variable with three categories: skimmed milk, medium-fat milk and high-fat milk.

Men who had been engaged in sports with mandatory weight classes (boxing, weightlifting and wrestling) in which weight reduction before a competition is common will be referred to as 'weight cyclers' in the text. The overall response rates were 83.6, 75.6 and 75.6% in 1985, 1995 and 2001, respectively. In 1985, the response rates for the controls, other athletes and the weight cyclers were respectively 91.5, 78.7 and 91.0%. In 1995, the corresponding figures were 81.6, 70.7 and 81.2%, and in 2001, 71.2, 82.3 and 78.5%. The total number of subjects aged less than 65 years in at least one questionnaire and with data on BMI at age 20 years was 2033, of which 273 (13.5%) were classified as weight cyclers, 1093 (53.7%) as other athletes and 667 (32.8%) as controls.

Validity assessment

Height and weight were measured for a sample of 87 athletes in 1992 participating in a laboratory study.[7] Self-reported height and weight agreed closely to measured height and weight (for height, $r=0.96$ (1985 questionnaire) and $r=0.98$ (1995), and for weight, $r=0.90$ (1985) and $r=0.94$ (1995)).

To analyze a possible recall bias in reporting body weight at 20 years, we examined the correlations between reported weights on different questionnaires. The correlations were greater than 0.91 between all time points.

Statistical methods

The effect of weight cycling status on weight gain and BMI was analyzed with linear regression using weight gain and BMI as outcome variables in separate models for each questionnaire. The prevalence of overweight only (BMI 25–29.9 kg/m^2) and obesity (BMI $\geqslant 30\,kg/m^2$) were age-adjusted by direct standardization to the age-distribution of the entire sample. The risk of overweight only and obesity were analyzed using logistic regression models. All the models were adjusted for age at the time of the questionnaire and BMI at age 20 years and limited to subjects aged less than 65 years. To examine if the differences in weight gain were due to differences in life habits, we adjusted the previous models for smoking, alcohol use, type of milk used and physical activity. To further examine the effect of smoking on weight gain, we used stratified models according to smoking status and weight cycling status separately, and then tested for smoking by weight cycling status interactions. As the use of alcohol and physical activity variables were highly skewed, we used a logarithmic (log + 1) transformation of them in the regression analysis. For the validity assessment, we calculated intraclass correlations between measured and reported heights and weights.

Because age was an important explanatory factor for weight gain, we examined the age dependency of BMI using information on BMI from all questionnaires in the regression models for repeated measures, again limited to age less than 65 years. In these models, the interaction between age and weight cycling status was tested comparing models with and without interaction terms with a likelihood ratio test. Based on the regression equations in these models, we estimated change in BMI from age 20 years to the age of the maximum average BMI for each study group (weight cyclers, other athletes and controls). All statistical analyses were carried out with the Stata statistical software version 8.2.[8]

Results

In 1985, the weight cyclers were older ($P<0.\,05$) than the other men, and in 1995, other athletes were younger

($P<0.005$) than the other men. In 2001, there was no longer an age difference between groups. The number of observations also varies between time points because the questionnaire was sent at every round to all surviving subjects included in the cohort independent of their previous response status (Table 1).

At age 20 years, the BMI did not significantly differ between groups. In 1985 and 1995, the age-adjusted mean BMI of the weight cyclers significantly exceeded that of the control men, which was higher than the mean BMI of the other former sportsmen. In 2001, the difference in age-adjusted mean BMI disappeared between the weight cyclers and controls, but remained statistically significant between the weight cyclers and other athletes (Table 1).

In 1985 and 1995, the weight cyclers had the greatest mean weight gain (in 1985, 15.1 kg, 95% confidence intervals (CI) 13.3–17.0) compared to other athletes (9.6 kg, 8.5–10.6) or the controls (11.8 kg, 10.5–13.1) compared to weight at age 20 years. In 2001, the weight cyclers and controls both had a mean weight gain of over 14 kg, whereas the result for other athletes was only 10.4 kg (Table 1). Stratification for smoking status did not change the results for the weight cyclers, but revealed that current smoking controls did not gain weight, whereas never and former smoker controls did ($P<0.01$ between former and current smokers, $P=0.14$ between current and never smokers) (data not shown).

The weight cyclers were significantly more likely to be obese than other athletes at all time points (odds ratio (OR) 2.35–5.05). Compared to the controls, weight cyclers were twice as likely to be obese in 1985 and 1995, but no difference was found in the relative risk of obesity in 2001 (Table 2). The evolution over time of the weight cyclers' relative risk was not due to the composition of the study group; the same result was seen when only those who had responded to all three analyses were considered. These differences in obesity were also observed when the data were stratified by smoking status (data not shown).

Table 1 The number of subjects, mean age, age-adjusted BMI and weight change since age 20 years by group in different study years of subjects aged 65 years and under at the time of the questionnaire

	Year	*Weight cyclers*	*Other athletes*	*Controls*	P-*values, weight cyclers vs other athletes*	P-*values, weight cyclers vs controls*
Number of subjects with weight data	Age 20	273	1093	667		
	1985	253	830	623		
	1995	127	700	405		
	2001	56	247	167		
Mean age	1985	52.8 (52.0–53.6)	51.7 (51.3–52.2)	51.1 (50.5–51.6)	0.025	<0.001
	1995	58.8 (57.8–59.4)	57.0 (56.5–57.3)	57.8 (57.4–58.3)	<0.001	0.025
	2001	60.3 (59.4–60.9)	60.2 (59.9–60.7)	60.3 (60.2–61.1)	0.73	0.91
Mean BMI	Age 20	22.8 (22.5–23.1)	22.6 (22.5–22.7)	22.7 (22.6–22.9)	0.13	0.67
	1985	27.8 (27.4–28.3)	25.7 (25.5–25.9)	26.5 (26.2–26.8)	<0.001	<0.001
	1995	28.1 (27.5–28.8)	25.3 (25.0–25.5)	26.9 (26.5–27.2)	<0.001	<0.001
	2001	27.4 (25.5-28.4)	26.4 (25.9–26.9)	27.4 (26.8–27.9)	0.004	0.94
Mean weight gain in kg since age 20 (95% CI)	1985	15.1 (13.9–16.3)	9.6 (8.9–10.2)	11.8 (11.0–12.6)	<0.001	<0.001
	1995	15.2 (13.4–17.0)	8.5 (7.7–9.3)	12.4 (11.4–13.5)	<0.001	0.008
	2001	14.2 (11.4–17.0)	10.4 (9.1–11.8)	14.8 (13.1–16.4)	0.020	0.76

Abbreviations: BMI, body mass index; CI, confidence intervals. 95% CI in parentheses.

Table 2 Odds ratio (95% CI) and age-adjusted prevalence for overweight (BMI 25–29.9 kg/m^2) and obesity (BMI$\geqslant$30kg/m^2), of weight cyclers vs other athletes and controls aged 65 and under at the time of the questionnaire

	Year	*Prevalence in weight cyclers %*	*Prevalence in other athletes (%)*	*Prevalence in controls (%)*	*OR, weight cyclers vs other athletes*	*OR, weight cyclers vs controls*
Overweight only, BMI 25-29.9kg/m^2	1985	50.4	44.4	50.1	1.27 (0.95-1.69)	0.95 (0.70-1.28)
	1995	53.7	52.8	51.8	1.52 (1.03-2.25)	1.0 (0.67-1.29)
	2001	45.1	53.0	49.3	0.75 (0.42-1.36)	0.85 (0.46-1.56)
Obesity BMI$\geqslant$30kg/m^2	1985	24.5	9.3	13.8	3.18 (2.09-4.83)	2.00 (1.35-2.96)
	1995	25.0	9.3	16.2	5.05 (2.96-8.60)	2.01 (1.27-3.37)
	2001	17.6	13.0	19.1	2.35 (0.99-5.55)	0.90 (0.40-1.99)

Abbreviations: BMI, body mass index; OR, odds ratio.

Some differences were seen in life habits between the groups. Between all the groups, the controls were most likely to be current or former smokers ($P<0.001$), and when the two athlete groups are compared, the weight cyclers were more likely to be current smokers than other athletes ($P<0.05$). The alcohol use of the weight cyclers did not differ from that of the controls ($P>0.05$). Other athletes were more physically active than the weight cyclers, who were more active than the controls ($P<0.05$ between groups). The weight cyclers drank high-fat milk more often than other athletes but less often compared to the controls ($P<0.05$ between groups) (Table 3). Adjustment for life habits (smoking, alcohol use, type of milk used and physical activity) did not substantially change the likelihood of obesity (e.g. OR for obesity at 1985 for the weight cyclers vs other athletes before and after adjustment: 3.18 (95% CI 2.09–4.83) vs 2.74 (1.47–5.10) or the weight cyclers compared to controls 2.0 (1.35–2.96) adjusted 1.52 (0.86–2.69)) or weight gain (detailed data not shown).

Using information from all time points, the regression of BMI on age was a quadratic function such that both age and age^2 predicted BMI (Figure 1). The mean BMI as a function of age rises for all groups, but rises more steeply for the weight cyclers, and then begins to slope downwards at the oldest ages (Figure 1). This interaction of weight cycling status and age was statistically significant ($P<0.001$). Based on the regression equations, the estimated increase in weight from age 20 years to its maximum value was 5.2 BMI units (at age 58.7 years) for the weight cyclers and 4.2 BMI units (at age 58.5 years) for the controls. The increase for other athletes was smaller (3.3 BMI units) with a maximum at a later age (62.5 years).

Discussion

Our finding of a significantly greater weight gain for the weight cyclers (boxers, wrestlers and weightlifters) at a younger age than for other sportsmen or for the control men could not be attributed to differences in current health habits, even though the lifestyle of the former athletes was much healthier[5] than that of the controls. It is therefore possible that weight loss practices during the active sporting career of the weight cyclers could have modified their subsequent weight development, increasing the propensity to weight gain after repeated cycles of weight loss and regain.

The health effects of weight cycling have been subject to active research and sometimes passionate discussion both in the scientific literature and the public media for years. A recent large population-based study (a nationally representative cohort follow-up in the US, NHANES I; $n=8479$) reported a higher all cause and cardiovascular disease (CVD) mortality of weight cyclers compared to non-obese stable weight subjects.[9] Similar results were reported by Hamm *et al.*[10] for a 25-year follow-up of a large male cohort and Lissner *et al.*[11] in a large population-based study. Studies on

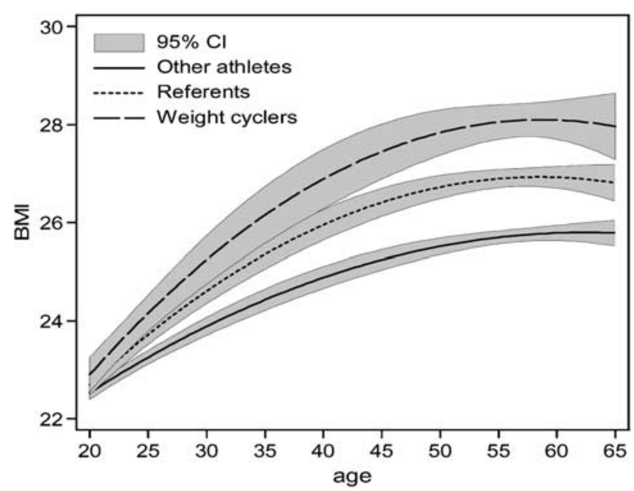

Figure 1 Mean body mass index (BMI) and 95% confidence intervals (CI) as a function of age.

Table 3 Age and health habits by weight cycling category in 1985 distributed by categories (percentages) or means (only subjects aged under 65 years)

	Weight cycling status		
	Weight cyclers n = *254*	*Other athletes* n = *832*	*Controls* n = *626*
Smoking status			
Never	52.1 % (45.6–58.5)	56.5 % (52.9–59.8)	30.2 % (26.5–34.0)
Former	26.5 % (21.0–32.5)	28.2 % (25.1–31.4)	38.4 % (34.5–42.4)
Current	21.5 % (16.5–27.2)	15.5 % (13.0–18.1)	31.5 % (27.8–35.3)
Type of milk used			
Skimmed milk	12.2 % (8.0–17.6)	13.9 % (11.1–17.0)	7.9 % (5.6–10.8)
Medium-fat milk	57.4 % (50.1–64.4)	68.1 % (64.1–71.9)	48.5 % (43.8–53.2)
High-fat milk	30.5 % (24.1–37.4)	18.0 % (14.9–21.4)	43.6 % (39.0–48.3)
Mean alcohol consumption (g/month)	485 (401–569)	445 (407–482)	439 (388–489)
Physical activity (mean MET/month)	29.1 (24.5–33.6)	36.8 (33.6–39.9)	17.7 (15.7–19.8)

Abbreviation: MET, metabolic units. 95% CI in parentheses.

smaller samples and intervention studies have contradictory results about the effect of weight cycling on CVD mortality and morbidity.[12–14]

Weight cycling has also been attributed to greater weight gain and binge eating,[15–19] psychological stress and lower general well-being[20] and unhealthier body fat distribution.[15,21] However, Prentice *et al*.[22] did not find any detrimental effects of weight cycling on body composition in a large African population-based study nor in an experimental prospective study of moderately obese women. In a cross-sectional setting of active young wrestlers aged 16 years, Steen *et al*.[23] did not find differences in body size, fat or lean body mass between weight cyclers and non-cyclers.

We could not directly assess possible weight cycling behavior during the sport career in our sample, but weight cycling and unhealthy weight control methods ('weight cutting') have been widely reported in young male athletes participating in wrestling[24–28] and other sports with weight classes.[29] Over 80% of high school[25] and college[26] wrestlers have been reported to 'cut weight', and 26.6% to cut more than 10 times per season. The effect of weight cutting is usually a loss of several kilograms, which is quickly regained.[26,27] We also did not have measurements of the body composition of our subjects and therefore could not evaluate changes in body composition over time as their weight changed. The interpretation of weight gain in the athletes over time is more complex than for non-athletes, who typically have much less muscle mass. To be able to distinguish the obese from the only overweight muscular subjects, we studied the BMI distribution in the categories of overweight only (BMI 25–29.9 kg/m^2) and obesity (BMI $\geqslant$ 30 kg/m^2). Our finding of much higher obesity prevalence in weight cyclers than other groups indicates major weight gain that cannot be attributed only to the greater muscle mass of athletes in these sports.

Limiting the data to subjects aged less than 65 years separately at each survey causes the exclusion of older cohorts from the original sample. Likewise, differential mortality due to obesity may have affected results, as the sportsmen and controls age in this cohort study; this may account for the disappearance in excess risk at the last survey (in 2001) compared to earlier time points. Taking into account the nearly 20-year time span of this study, there might be some period-specific effects on weight gain in our sample, given the general trend for gain in the entire Finnish population.[30] The rate of weight gain in adulthood has increased in men, but not in women, from 1972 to 1997.[30] Hence, the effects of the weight cycling of present-day athletes and other young adult men on future weight gain cannot be predicted with certainty. Moreover, our sample is restricted to men, and we cannot generalize to women.

Repeated cycles of weight loss and regain have in some but not in all animal studies been shown to lower resting metabolic rate[31] or feed efficiency.[2] Similarly, a lower resting metabolic rate has been observed in adolescent wrestlers engaged in weight cycling than in non-cycling wrestlers in some[23] but not in other[32] studies. A reduced metabolic rate has also been observed in women engaged in cycles of binge eating and strict dieting,[33] in restrained eaters[34] and in post-obese individuals,[35] although the findings are not unequivocal.[31]

A low metabolic rate reduces energy expenditure and together with binge eating can be expected to increase the propensity for weight gain. An increased risk of weight gain has been demonstrated in subjects with a low metabolic rate among Pima Indians, an indigenous population with a very high prevalence of obesity.[31,36] Weight cycling is associated with increased risk of binge eating,[15,18,37] but we did not have any information about the eating patterns of the men in this study. Further, binge eating is associated to greater energy intake in some[38,39] but not in all[40] studies. In our study, the weight cyclers appeared to have an enhanced preference for high-fat milk, which is in keeping with the observation that weight cycling may increase experimental animals' preference for fatty foods.[2,31] The greater than expected weight gain of the weight cycling athletes could perhaps be explained by a lower than expected basal energy expenditure, even if these men had maintained a physically active lifestyle compared to the control men. Another possible or supplementary explanation might be increased energy intake due to increased meal size and energy density associated with bingeing as a consequence of repeated weight cycle periods. Studies on eating behavior of athletes would be needed to further elucidate this problem.

The weight cycling behavior of the former athletes engaged in power sports at a young age resembles that of young dieters who lose weight temporarily and soon regain it. The present observations concerning the enhanced weight gain of these athletes raise the concern that the repeated cycles of weight loss and regain caused by dieting at a young age could similarly affect weight in the long term. For many young persons with perceived rather than real excess weight, a temporary success in the relentless pursuit for thinness may predict an ever increasing problem with weight maintenance as well as an increased risk of eating disorders. The discouragement of unnecessary weight control measures may be one of the means to prevent obesity and eating disorders.

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