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Original Contribution

Changes in Body Weight and Health-Related Quality of Life: 2 Cohorts of US Women

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Studies have shown that body weight is a determinant of health-related quality of life (HRQoL). However, few studies have examined long-term weight change with changes in HRQoL. We followed 52,682 women aged 46–71 years in the Nurses' Health Study (in 1992–2000) and 52,587 women aged 29–46 years in the Nurses' Health Study II (in 1993–2001). Body weight was self-reported, HRQoL was measured by the Medical Outcomes Study's 36-Item Short Form Health Survey, and both were updated every 4 years. The relationship between changes in weight and HRQoL scores was evaluated at 4-year intervals by using a generalized linear regression model with multivariate adjustment for baseline age, ethnicity, menopausal status, and changes in comorbidities and lifestyle factors. Weight gain of 15 lbs (1 lb = 0.45 kg) or more over a 4-year period was associated with 2.05-point lower (95% confidence interval: 2.14, 1.95) physical component scores, whereas weight loss of 15 lbs or more was associated with 0.89-point higher (95% confidence interval: 0.75, 1.03) physical component scores. Inverse associations were also found between weight change and physical function, role limitations due to physical problems, bodily pain, general health, and vitality. However, the relations of weight change with mental component scores, social functioning, mental health, and role limitations due to emotional problems were small.

body weight; health-related quality of life; prospective cohort study; women

Abbreviations: BMI, body mass index; HRQoL, health-related quality of life; MCS, mental component score; NHS, Nurses' Health Study; NHS II, Nurses; Health Study II; PCS, physical component score; SF-36, 36-Item Short Form Health Survey.

Health-related quality of life (HRQoL) is an individual's subjective perception of both positive and negative aspects of life that are influenced by health status. It is a multidimensional concept that usually includes subjective evaluations of physical functioning, mental health, and social/role functioning. Mounting evidence from cross-sectional studies has demonstrated that obesity is associated with worse HRQoL in different populations (1–6), especially in the physical dimensions (1–3) and among women (4–6). However, cross-sectional studies are limited to examining temporal relations and are subject to reverse causation. Therefore, longitudinal analyses have been conducted to partly overcome this limitation. Findings from several prospective cohort studies have consistently shown that baseline higher body mass index (BMI) (calculated as weight (kg)/height $(m)^2$) is related to mobility disability (7, 8), lower self-rated health (8), lower HRQoL (9), and greater decline of HRQoL (10, 11). Several studies have also shown that weight gain over time was associated with lower HRQoL or with larger declines in HRQoL than having a stable weight (12–18). Nevertheless, the sample sizes in some studies were relatively small (13–15, 17, 18), and some studies did not include the full dimensions of HRQoL (12, 16). Furthermore, few studies have tested changes in body weight and concurrent impact on HRQoL. For example, if obesity is related to worse physical functioning, could weight loss improve function? Meanwhile, because many community-dwelling individuals gain weight gradually over time, does HRQoL worsen along with weight gain?

To answer these questions, we analyzed data from 2 cohort studies—the Nurses' Health Study (NHS) and the Nurses'

Table 1. Baseline Characteristics of US Women in the Nurses' Health Study (in 1992) and the Nurses' Health Study II (in 1993)

Baseline Characteristic	Total ($n = 105,269$)		NHS ($n = 52,682$)		NHS II ($n = 52,587$)	
	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%
Age, years	48.2 (11.4)		57.9 (7.0)		38.4 (4.6)	
Body mass index[a]	25.6 (5.3)		26.0 (4.9)		25.2 (5.7)	
Physical activity, MET-hours/week	20.1 (24.7)		19.8 (23.1)		20.4 (26.1)	
Alcohol intake, g/day	4.2 (8.0)		5.2 (9.5		3.2 (6.2)	
AHEI score[b]	50.8 (11.2)		52.8 (10.9)		48.7 (11.0)	
White race		97.7		98.2		97.1
Current smoker		11.3		12.5		10.0
Menopausal status						
Premenopausal		58.4		23.1		93.9
Postmenopausal + never hormone user		14.4		28.5		0.3
Postmenopausal + past hormone user		8.4		16.4		0.4
Postmenopausal + current hormone user		17.9		31.5		4.3
Missing data		0.8		0.5		1.2
Currently married		83.4		82.8		83.9
Living alone		9.9		10.8		9.1
Comorbidities						
Cancer		7.2		12.6		1.9
Cardiovascular disease		6.3		9.1		3.4
Diabetes		2.8		4.5		1.1
Hypercholesterolemia		32.2		45.7		18.7
Hypertension		20.0		32.3		7.8
Respiratory diseases		10.4		11.2		9.5
Baseline health-related quality of life						
Bodily pain	75.9 (19.5)		74.5 (20.1)		77.4 (18.8)	
General health	80.2 (17.4)		80.1 (17.5)		80.3 (17.2)	
Mental component score	50.0 (9.2)		52. 0 (8.5)		47.9 (9.4)	
Mental health	74.4 (14.9)		77.1 (14.2)		71.7 (15.1)	
Physical component score	51.7 (8.4)		50.2 (8.8)		53.1 (7.7)	
Physical functioning	89.1 (15.8)		86.3 (17.2)		91.9 (13.8)	
Role limitations–emotional	82.8 (29.8)		84.2 (28.8)		81.4 (30.7)	
Role limitations–physical	79.8 (33.0)		76.3 (35.1)		83.4 (30.2)	
Social functioning	87.9 (18.9)		89.5 (18.2)		86.4 (19.4)	
Vitality	59.8 (19.2)		64.2 (18.1)		55.4 (19.2)	

Abbreviations: AHEI, Alternative Health Eating Index; MET, metabolic equivalent; NHS, Nurses' Health Study; NHS II, Nurses' Health Study II; SD, standard deviation.

[a] Weight (kg)/height $(m)^2$.

[b] A diet score was calculated on the basis of the 2010 Alternative Healthy Eating Index (28), where a higher score denotes better overall dietary quality.

Health Study II (NHS II)—in which we collected measurements of HRQoL, as well as body weight, demographic characteristics, lifestyle factors, and medical history every 4 years on 3 occasions during 8 years of follow-up. These repeated measurements and the long duration of follow-up enabled us to investigate the association of dynamic changes in body weight and HRQoL.

METHODS

Study population

The NHS consists of 121,700 female registered nurses, aged 30–55 years, who completed a baseline questionnaire about lifestyle and medical history in 1976. The NHS II was established in 1989 and comprised 116,671 younger female

Table 2. Baseline Characteristics of Women in the Nurses' Health Study (in 1992) and the Nurses' Health Study II (in 1993) According to Weight-Change Pattern During the First 4 Years of Follow-up

Baseline Characteristic	Weight-Change Pattern									
	Lost ≥15 lbs		Lost 5–14.9 lbs		Relatively Stable (−4.9–4.9 lbs)		Gained 5–14.9 lbs		Gained ≥15 lbs	
	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%
Nurses' Health Study										
No. of subjects	2,589[a]		7,749[a]		21,180[a]		15,632[a]		5,539[a]	
Age, years	59.0 (7.1)		59.4 (7.0)		58.6 (7.0)		57.0 (6.9)		55.5 (6.6)	
Body mass index[b]	30.8 (6.3)		26.9 (5.0)		24.8 (4.4)		25.7 (4.4)		27.6 (5.3)	
Body weight change, lbs[c]	−23.7 (12.2)		−7.9 (2.7)		0.3 (2.2)		8.1 (2.7)		22.5 (10.2)	
Physical activity, MET-hours/week	14.5 (21.3)		18.3 (22.4)		21.1 (23.6)		19.9 (23.0)		18.6 (23.1)	
Alcohol intake, g/day	4.7 (10.3)		5.2 (9.9)		5.5 (9.4)		5.1 (9.2)		4.4 (9.2)	
AHEI score[d]	51.6 (10.7)		52.4 (10.8)		53.4 (10.9)		52.6 (10.8)		52.2 (11.0)	
White race		99.0		98.1		98.1		98.1		98.2
Current smoker		13.2		13.4		11.3		12.4		16.2
Premenopausal status		19.5		18.1		20.3		26.7		32.0
Currently married		81.3		81.8		84.0		83.4		79.0
Living alone		11.2		11.9		10.3		10.2		12.0
Comorbidity										
Cancer		14.0		13.9		12.6		11.8		12.3
Cardiovascular disease		13.4		11.1		8.3		8.3		9.9
Diabetes		10.1		6.6		3.7		3.4		5.0
Hypercholesterolemia		49.3		47.1		45.3		45.4		44.0
Hypertension		46.9		37.3		29.2		30.6		34.9
Respiratory diseases		15.1		12.1		10.5		10.2		13.5
Changes in SF-36 score										
Bodily pain	0.1 (21.2)		−0.5 (19.9)		−0.9 (18.5)		−1.6 (19.0)		−3.7 (20.7)	
General health	−0.2 (17.7)		−0.6 (15.5)		−0.7 (14.2)		−1.2 (14.8)		−3.8 (16.5)	
Physical component score	−1.3 (9.1)		−1.4 (8.1)		−1.4 (7.4)		−2.0 (7.7)		−3.7 (8.7)	
Mental component score	1.7 (9.2)		1.6 (8.5)		1.6 (7.6)		2.1 (8.2)		2.5 (9.2)	
Mental health	2.4 (14.0)		2.2 (12.9)		2.5 (11.8)		3.1 (12.5)		2.9 (14.0)	
Physical functioning	−3.9 (19.4)		−4.3 (16.7)		−3.9 (15.2)		−4.8 (15.5)		−8.5 (17.8)	
Role limitations–emotional	1.1 (35.5)		0.7 (33.6)		1.3 (30.3)		2.1 (32.2)		2.6 (35.3)	
Role limitations–physical	−2.5 (40.5)		−1.3 (39.1)		−1.4 (35.7)		−2.1 (36.9)		−5.7 (40.0)	
Social functioning	0.7 (24.0)		1.2 (21.2)		1.6 (18.0)		2.2 (19.1)		2.2 (21.6)	
Vitality	3.2 (17.7)		2.2 (16.0)		1.3 (14.3)		0.8 (15.1)		−1.1 (17.2)	

Table continues

registered nurses, aged 25–42 years, who responded to a baseline questionnaire similar to the NHS questionnaire. Detailed descriptions of the cohorts can be found elsewhere (19, 20). In both cohorts, questionnaires were administered at baseline and biennially thereafter to update information on lifestyle (e.g., body weight, smoking, physical activity) and occurrence of chronic diseases. The cumulative follow-up rates in the 2 cohorts exceeded 90% of potential person-years.

In the current analysis, we used the 1992 wave of the NHS ($n = 104{,}064$) and the 1993 wave of the NHS II ($n = 107{,}721$) as the baseline, when we first assessed HRQoL by using the Medical Outcomes Study's 36-Item Short Form Health Survey (SF-36), version 1. The SF-36 was administered again in 1996 and 2000 in the NHS and in 1997 and 2001 in the NHS II. Because we conducted a complete case analysis, we excluded women who responded only to the short-version surveys, which did not include the SF-36, on any of the 3 occasions ($n = 47{,}365$ in the NHS, and $n = 43{,}457$ in the NHS II). The shorter survey was sent to women who had not responded to several mailings of the main long-version questionnaire. Women who were excluded because of missing HRQoL data (mostly those who completed the shorter version of the survey) were somewhat older, heavier, and more sedentary, on average, than those who completed the longer

Table 2. Continued

Baseline Characteristic	Weight-Change Pattern									
	Lost ≥15 lbs		Lost 5–14.9 lbs		Relatively Stable (−4.9–4.9 lbs)		Gained 5–14.9 lbs		Gained ≥15 lbs	
	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%
Nurses' Health Study II										
No. of subjects	2,544[a]		5,598[a]		18,105[a]		17,092[a]		9,248[a]	
Age, years	38.8 (4.5)		38.5 (4.6)		38.3 (4.6)		38.5 (4.6)		38.3 (4.6)	
Body mass index[b]	31.9 (7.4)		26.2 (5.7)		23.5 (4.8)		24.4 (4.9)		27.3 (5.9)	
Body weight change, lbs[c]	−26.4 (15.5)		−8.1 (2.8)		0.6 (2.2)		8.4 (2.8)		24.3 (11.2)	
Physical activity, MET-hours/week	16.6 (24.3)		20.3 (26.2)		21.9 (27.2)		20.3 (26.3)		18.9 (24.0)	
Alcohol intake, g/day	2.7 (6.0)		3.2 (6.3)		3.4 (6.1)		3.2 (6.2)		2.8 (6.1)	
AHEI score[d]	48.2 (11.3)		48.8 (11.1)		49.2 (11.1)		48.3 (10.9)		48.6 (11.0)	
White race		97.7		97.0		96.9		97.2		97.5
Current smoker		10.8		11.1		8.8		9.5		12.3
Premenopausal status		91.7		93.7		94.6		93.9		93.1
Currently married		79.1		84.3		86.2		84.8		79.1
Living alone		11.3		8.2		8.0		8.7		12.2
Comorbidities										
Cancer		1.9		2.6		1.7		1.9		1.8
Cardiovascular disease		5.4		3.7		3.0		2.9		4.5
Diabetes		3.2		1.6		0.9		0.8		1.1
Hypercholesterolemia		26.8		20.6		15.9		17.8		22.3
Hypertension		15.8		9.1		5.5		6.8		11.0
Respiratory diseases		13.4		9.5		8.5		9.1		11.2
Changes in SF-36 score										
Bodily pain	0.8 (21.8)		−0.5 (20.1)		−1.5 (18.8)		−2.1 (19.2)		−4.1 (21.1)	
General health	3.3 (16.7)		1.0 (15.2)		0.2 (13.4)		−0.8 (14.0)		−4.3 (16.2)	
Mental component score	1.3 (10.7)		1.2 (10.0)		1.2 (9.2)		1.3 (9.5)		1.4 (10.6)	
Mental health	2.2 (16.6)		1.7 (15.4)		1.7 (14.1)		2.0 (14.6)		2.0 (16.1)	
Physical component score	1.2 (8.6)		0.1 (7.9)		−0.5 (7.1)		−1.0 (7.4)		−2.6 (8.7)	
Physical functioning	3.2 (16.4)		0.9 (14.1)		−0.1 (12.3)		−0.7 (13.1)		−3.4 (16.3)	
Role limitations–emotional	−0.1 (35.8)		0.3 (34.9)		1.5 (32.9)		2.0 (34.1)		1.2 (37.5)	
Role limitations–physical	2.4 (38.0)		0.3 (35.9)		−0.6 (33.0)		−1.0 (34.2)		−5.3 (38.6)	
Social functioning	2.7 (25.0)		2.2 (22.1)		1.7 (19.7)		2.0 (20.5)		1.3 (24.0)	
Vitality	7.9 (20.9)		4.4 (18.9)		2.5 (17.4)		0.8 (17.7)		−2.1 (19.3)	

Abbreviations: AHEI, Alternative Health Eating Index; MET, metabolic equivalent; SD, standard deviation; SF-36, Medical Outcomes Study's 36-Item Short Form Health Survey.

[a] Value expressed as number of subjects.

[b] Weight (kg)/height $(m)^2$.

[c] 1 lb = 0.45 kg.

[d] A diet score was calculated on the basis of the 2010 Alternative Healthy Eating Index (28), where a higher score denotes better overall dietary quality.

survey in the NHS. However, there was substantial overlap in the distributions of these responses (data not shown). No significant differences were found in the NHS II. This indicates that our analyses are unlikely to be substantially biased by the type of survey returned. We further excluded women who had missing information on body weight on any of the 3 occasions ($n = 4,557$ in the NHS, and $n = 6,658$ in the NHS II). In the NHS II, we also excluded women who reported that they were pregnant at the time of returning any of the 3 questionnaires ($n = 5,019$). After exclusions, data from 52,682 women in the NHS and 52,587 women in the NHS II were available. The study protocol was approved by the institutional review boards of Brigham and Women's Hospital and the Harvard School of Public Health.

Table 3. Changes in Physical and Mental Component Scores[a] of Women in the Nurses' Health Study (in 1992–2000) and the Nurses' Health Study II (in 1993–2001) According to Weight-Change Pattern

HRQoL Measure by Study[b]	Weight-Change Pattern[c]							
	Lost ≥15 lbs		Lost 5–14.9 lbs		Gained 5–14.9 lbs		Gained ≥15 lbs	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Physical component score								
Nurses' Health Study	0.33	0.14, 0.52	0.17	0.04, 0.30	−0.59	−0.70, −0.48	−2.12	−2.28, −1.96
Nurses' Health Study II	1.57	1.37, 1.77	0.47	0.32, 0.61	−0.46	−0.57, −0.36	−2.02	−2.15, −1.90
Pooled analysis	0.89	0.75, 1.03	0.30	0.20, 0.39	−0.52	−0.60, −0.45	−2.05	−2.14, −1.95
Mental component score								
Nurses' Health Study	−0.60	−0.79, −0.41	−0.28	−0.41, −0.15	0.42	0.31, 0.52	0.66	0.50, 0.81
Nurses' Health Study II	0.02	−0.23, 0.26	−0.06	−0.24, 0.12	0.19	0.07, 0.32	0.41	0.26, 0.56
Pooled analysis	−0.33	−0.49, −0.18	−0.21	−0.32, −0.10	0.35	0.27, 0.43	0.56	0.46, 0.67

Abbreviations: CI, confidence interval; HRQoL, health-related quality of life.

[a] The multivariate linear regression model is adjusted for baseline age, race, menopausal status, changes in marital status (remained nonmarried, nonmarried to married, remained married, or married to nonmarried), living status (remained living alone, living alone to living with others, remained living with others, or living with others to living alone), smoking status (remained never smoker, from never to current smoker, remained past smoker, past to current smoker, current to past smoker, remained current smoker, or missing indicator status), changes in comorbidities (no disease, new-onset disease, or remained diseased (comorbidities were diabetes, hypertension, hypercholesterolemia, cardiovascular disease, cancer, and respiratory diseases)), quintile of change in physical activity, alcohol intake, and Alternative Health Eating Index (28) score.

[b] Reference group is subjects whose weight was relatively stable (change of −4.9–4.9 lbs).

[c] 1 lb = 0.45 kg.

Assessment of HRQoL

The self-administered SF-36 questionnaire was used to assess the following 8 domains of HRQoL (21): 1) physical functioning, 2) role limitations due to physical health problems (herein, role limitations–physical), 3) bodily pain, 4) general health perceptions, 5) vitality, 6) social functioning, 7) role limitations due to emotional problems, and 8) mental health. The first 4 components are considered to reflect the physical dimensions, and the last 4 components, the mental dimensions of HRQoL. Each domain was scored separately from 0 (lowest level of functioning) to 100 (highest level of functioning), with higher scores reflecting better HRQOL. Two component summary scores capturing the overall physical and mental health (physical component score (PCS) and mental component score (MCS)) were calculated from the 8 subscale scores and transformed so that a mean score of 50 (standard deviation, 10) reflects the mean in the general US population (22). The instrument has been validated extensively within the Medical Outcomes Study (23) and in other settings (24–26). It has been demonstrated to have good construct validity (25, 26), as well as high internal consistency (24–26) and high test-retest reliability (24).

Assessment of body weight

Subjects were asked for their body height and weight on the baseline questionnaires, and body weight was subsequently reported on each biennial questionnaire in the 2 cohorts. BMI was calculated as the weight in kilograms divided by the square of height in meters. The validity of self-reported weight has been established previously (27): 184 women were weighed by technicians 6–12 months after completing a mailed questionnaire, and self-reported weight was highly correlated with measured weight (Spearman $r = 0.96$). Participants were categorized into the following 5 weight-change groups according to their patterns of weight change over the 4-year period: those who lost 15 lbs or more (1 lb = 0.45 kg), those who lost 5–14.9 lbs, women whose 4-year weight change remained within 4.9 lbs, those who gained 5–14.9 lbs, and those who gained 15 lbs or more.

Covariates

In the follow-up questionnaires, we obtained updated information on the following characteristics: age, ethnicity, marital status, living status, menopausal status, postmenopausal hormone use, cigarette smoking, alcohol intake, physical activity, and history of comorbid diseases (i.e., diabetes, hypertension, hypercholesterolemia, cardiovascular disease, cancer, respiratory diseases, and other major diseases). Dietary information (including alcohol intake) was collected by a validated food frequency questionnaire in 1990 for the NHS and in 1991 for the NHS II and was updated every 4 years through similar food frequency questionnaires. To reduce the potential variables in the model and to reflect overall diet quality, we calculated a diet score on the basis of the 2010 Alternative Healthy Eating Index (28), where a higher score denotes better overall dietary quality.

Statistical analysis

We examined the relation between 4-year changes in weight and covariates with the concurrent changes in HRQoL

Table 4. Changes in 8 Domains of Health-Related Quality of Life[a] of Women in the Nurses' Health Study (in 1992–2000) and the Nurses' Health Study II (in 1993–2001) According to Weight-Change Pattern

Measure of HRQoL Domains[b]	Weight-Change Pattern[c]							
	Lost ≥15 lbs		Lost 5–14.9 lbs		Gained 5–14.9 lbs		Gained ≥15 lbs	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Pooled analysis								
Bodily pain	1.48	1.14, 1.82	0.55	0.32, 0.79	−0.70	−0.88, −0.51	−2.60	−2.84, −2.37
General health	1.43	1.16, 1.69	0.29	0.11, 0.47	−0.68	−0.82, −0.54	−3.36	−3.54, −3.18
Mental health	−0.39	−0.63, −0.15	−0.45	−0.61, −0.28	0.50	0.38, 0.63	0.58	0.41, 0.74
Physical functioning	1.51	1.23, 1.79	0.22	0.02, 0.41	−0.96	−1.11, −0.81	−4.09	−4.29, −3.90
Role limitations–emotional	−1.09	−1.66, −0.52	−0.62	−1.02, −0.22	0.84	0.53, 1.15	0.68	0.29, 1.08
Role limitations–physical	1.04	0.41, 1.67	0.47	0.03, 0.90	−0.44	−0.77, −0.10	−3.39	−3.83, −2.96
Social functioning	−1.11	−1.47, −0.76	−0.51	−0.76, −0.27	0.36	0.17, 0.55	−0.27	−0.52, −0.03
Vitality	2.76	2.47, 3.06	1.04	0.83, 1.24	−0.75	−0.90, −0.59	−2.84	−3.05, −2.64
Nurses' Health Study								
Bodily pain	1.09	0.63, 1.55	0.54	0.24, 0.85	−0.69	−0.94, −0.43	−2.49	−2.87, −2.12
General health	−0.15	−0.51, 0.22	−0.09	−0.33, 0.15	−0.50	−0.70, −0.30	−2.58	−2.87, −2.28
Mental health	−0.81	−1.11, −0.52	−0.57	−0.76, −0.37	0.54	0.37, 0.70	0.50	0.26, 0.74
Physical functioning	0.39	−0.02, 0.80	−0.11	−0.39, 0.16	−1.29	−1.52, −1.06	−4.89	−5.22, −4.55
Role limitations–emotional	−1.37	−2.12, −0.62	−0.52	−1.02, −0.01	0.78	0.36, 1.19	0.33	−0.29, 0.95
Role limitations–physical	−0.18	−1.08, 0.71	0.37	−0.23, 0.97	−0.64	−1.13, −0.14	−3.54	−4.27, −2.81
Social functioning	−2.39	−2.85, −1.92	−0.87	−1.18, −0.56	0.52	0.27, 0.78	0.16	−0.21, 0.54
Vitality	1.39	1.02, 1.76	0.60	0.35, 0.84	−0.66	−0.86, −0.45	−2.57	−2.87, −2.27
Nurses' Health Study II								
Bodily pain	2.01	1.50, 2.51	0.61	0.24, 0.97	−0.77	−1.03, −0.51	−2.74	−3.05, −2.43
General health	3.30	2.91, 3.68	0.84	0.57, 1.12	−0.86	−1.06, −0.66	−3.82	−4.06, −3.59
Mental health	0.16	−0.23, 0.54	−0.22	−0.49, 0.06	0.34	0.14, 0.54	0.48	0.25, 0.71
Physical functioning	2.87	2.49, 3.25	0.65	0.37, 0.93	−0.66	−0.86, −0.47	−3.70	−3.94, −3.47
Role limitations–emotional	−0.66	−1.54, 0.21	−0.64	−1.27, −0.01	0.64	0.19, 1.09	0.57	0.04, 1.11
Role limitations–physical	2.51	1.62, 3.39	0.64	0.00, 1.28	−0.45	−0.90, 0.00	−3.58	−4.12, −3.04
Social functioning	0.51	−0.03, 1.05	0.06	−0.33, 0.45	0.08	−0.19, 0.36	−0.66	−0.99, −0.33
Vitality	4.37	3.91, 4.84	1.71	1.38, 2.05	−0.99	−1.23, −0.75	−3.19	−3.47, −2.90

Abbreviations: CI, confidence interval; HRQoL, health-related quality of life.

[a] The multivariate linear regression model is adjusted for baseline age, race, menopausal status, changes in marital status (remained nonmarried, nonmarried to married, remained married, or married to nonmarried), living status (remained living alone, living alone to living with others, remained living with others, or living with others to living alone), smoking status (remained never smoker, from never to current smoker, remained past smoker, past to current smoker, current to past smoker, remained current smoker, or missing indicator status), changes in comorbidities (no disease, new-onset disease, or remained diseased (comorbidities were diabetes, hypertension, hypercholesterolemia, cardiovascular disease, cancer, and respiratory diseases)), quintile of change in physical activity, alcohol intake, and Alternative Health Eating Index (28) score.

[b] Reference group is subjects whose weight was relatively stable (change of −4.9–4.9 lbs).

[c] 1 lb = 0.45 kg.

scores. In this analysis, the 4-year changes in HRQoL scores (PCS, MCS, and the 8 domains) were used as the outcomes (i.e., changes from 1992/1993 to 1996/1997 and changes from 1996/1997 to 2000/2001). We used 4-year weight change (5 categories) as the predictor and adjusted for baseline age, race, postmenopausal status, and menopausal hormone use. We also adjusted for 4-year changes in other covariates including marital status (remained nonmarried, nonmarried to married, remained married, or married to nonmarried); living status (remained living alone, living alone to living with others, remained living with others, or living with others to living alone); smoking status (remained never smoker, never to current smoker, remained past smoker, past to current smoker, current to past smoker, remained current smoker, or missing indicator status); changes in comorbidities including diabetes, hypertension, hypercholesterolemia, cardiovascular disease, cancer, and respiratory diseases (no disease, new-onset disease, or remained diseased); and quintile of changes in continuous variables of physical activity, alcohol intake, and Alternative Healthy Eating Index score. We stratified

the analysis by baseline body weight (normal weight, overweight, or obesity) and history of abovementioned comorbidities, because those characteristics could substantially influence weight change and HRQoL.

All analyses were performed using SAS, version 9.2, software (SAS Institute, Inc., Cary, North Carolina) with significance indicated by a 2-tailed *P* value of 0.05. We used multivariate linear regression (the GENMOD procedure in SAS) starting from an unstructured correlation matrix to account for the correlated nature of within-person repeated measurements, and we present the model-based covariance estimates. The 2 cohorts were analyzed separately and also combined because of similar study design, characteristics, and follow-up strategies. There is still debate about the clinical significance of HRQoL scores (29), but to be consistent with our previous publications, we used 0.25 standard deviations as the threshold to determine minimally important changes in PCS and MCS (19). In our study, the standard deviations were approximately 8.0 and 9.0 for changes in PCS and MCS, respectively; thus, we used 2.0 as the cutoff point for minimally important changes. Considering only statistically significant differences was deemed to be misleading because of the large sample size.

RESULTS

Table 1 shows the baseline characteristics in the 2 cohorts. The mean ages were 57.9 years (standard deviation, 7.0; range, 46–71) in the NHS and 38.4 years (standard deviation, 4.6; range, 29–46) in the NHS II. Women in the NHS had higher prevalence of metabolic disorders than those in the NHS II. As for SF-36 components, women in the NHS reported worse PCS, physical functioning, bodily pain, and role limitations–physical than those in the NHS II. This was expected because of the higher age of women in the NHS. Interestingly, women in the NHS had better MCS, social functioning, mental health, and vitality, as well as fewer role limitations due to emotional functioning compared with women in the NHS II. Women in the 2 cohorts had similar self-perceived general health.

Table 2 shows the characteristics according to changes in body weight during the first 4 years of follow-up. Weight gain was related to younger age in the NHS but not in the NHS II. Compared with the stable weight group, both weight gain and weight loss were related to higher prevalence of smoking, diabetes, hypertension, cardiovascular disease, and respiratory diseases.

In the pooled multivariate analysis (Table 3), weight gain of 15 lbs or more was associated with a decrease in PCS of 2.05 points (95% CI: 1.95, 2.14), whereas weight loss of 15 lbs or more was associated with an increase in PCS of 0.89 points (95% CI: 0.75, 1.03). Again, the relation between weight change and MCS was modest. Weight gain was associated with a concurrent decrease in physical dimensions (physical functioning, role limitations–physical, bodily pain, and general health) and vitality, whereas weight loss was associated with modestly higher scores in those components (Table 4).

Weight gain was associated with lower PCS regardless of baseline obesity status, although the relation was stronger with higher initial BMI; however, weight loss was associated with higher PCS among overweight/obese women but not among women of normal weight (Web Table 1 available at http://aje.oxfordjournals.org/). The association between weight change and PCS was not significantly different in women with or without comorbidities (Web Table 2), except among women with prevalent or incident cancers, for whom weight loss was related to modestly lower PCS.

DISCUSSION

HRQoL has received increasing attention as an important outcome measure for disease burden, health service research, and evaluation of intervention effectiveness. In these 2 large prospective cohorts of US women, we found an inverse association between weight gain and changes in physical health in the dimensions of physical functioning, role limitations–physical, bodily pain, general health, and vitality. The association between weight gain and mental health was more modest and not clinically significant.

Obesity is consistently related to a range of adverse HRQoL outcomes examined in cross-sectional studies (1–6). However, cross-sectional studies are subject to reverse causation (i.e., the association could result from poor health leading to obesity rather than obesity and weight gain causing worse health). Therefore, prospective design has the advantage of identifying the correct temporal sequence, and a number of longitudinal studies have been reported to date. Studies have found that higher BMI at baseline is related to mobility disability (7, 8) and self-rated health (8) in US adults. However, other domains of HRQoL were not assessed. A recent study by Daviglus et al. (9) found that obesity at midlife (ages 36–64 years) was associated with lower HRQoL scores in all components measured by the Medical Outcomes Study's 12-Item Short Form Health Survey at older ages in a 26-year follow-up study among 6,766 US adults. Another study of 3,014 US adults aged 18–30 years found an inverse association between baseline BMI and PCS but not MCS after 20 years of follow-up (14). Two other studies also found that baseline obesity was associated with a greater deterioration in quality of life in 8,609 Canadian adults (10) and 5,985 Australian adults (11).

One important advantage of our study over the previous investigations is that we were able to examine changes in body weight in relation to concurrent changes in HRQoL. This "change-on-change" analysis approach builds on the repeated measurements and long-term follow-up periods in the 2 cohorts. This method has the feature of a quasi-experimental design, although it lacks randomization as in a clinical trial. Our findings are consistent with those of a number of intervention studies in which the effects of weight loss programs on the changes of HRQoL have been evaluated. A recent meta-analysis (30) summarized data from 53 trials and found that weight loss may be associated with modest improvements in physical, but not mental, health. The weight loss interventions were conducted primarily among obese individuals with a variety of weight loss strategies (i.e., drugs, diet, physical activity, education, or combinations of these), and the sample sizes were generally small (30). In a large study, Ackermann et al. (31) used data from

the Diabetes Prevention Program ($n = 3,046$) and found that each 5 kg of weight loss was associated with a 0.64-point increase in PCS after 1 year (31). This is consistent with our results in which weight loss of 5–14.9 lbs was related to an approximately 0.54-point increase in PCS among overweight and obese women during a 4-year period.

However, clinical trials can only evaluate the effects of weight loss on HRQoL, and the findings may not be directly applied to community-dwelling individuals. Therefore, studies with repeated measurements of weight and HRQoL are crucial to test the impact of weight gain and changes in HRQoL. Our previous analysis of the NHS (in 1992–1996) reported that weight gain was associated with lower scores in physical functioning, bodily pain, and vitality after 4 years of follow-up (32). Thus, our current analysis extended the findings to a younger cohort of women with longer follow-up duration and assessed change in HRQoL as the outcome of interest. Our results are also consistent with those of several other studies reporting that weight gain is associated with lower physical HRQoL over follow-up compared with those of stable weight (12–18). For example, in the study by León-Muñoz et al. (15), weight gain over 2 years was associated with worse HRQoL scores in older Spanish adults, and the associations were stronger in women who were obese at baseline. In another study of 2,414 Dutch women with a mean age of 50.6 years, Verkleij et al. (18) found that each 1-kg increase in body weight was associated with a 0.10-point reduction in PCS.

In our study, the relations of weight change with MCS and mental domains were very modest and generally below the clinically significant level. Previous studies have also found inconsistent results between obesity and mental components (3). Clinical trials have found no significant improvement in mental domains with weight loss (30). Our results are also consistent with those of Kozak et al. (14) and Verkleij et al. (18), in that weight change was associated with null or clinically insignificant changes in MCS. This may be due to the complexity of weight loss, including whether it is intentional or unintentional. In the older population, weight loss is more likely to be unintentional, being caused by the presence of preclinical, subthreshold, or established chronic diseases, which may be accompanied by worsening mental health. For example, in our study, a modest decrease in MCS related to weight loss was found in older women in the NHS, whereas no change was found in younger women in the NHS II. Furthermore, the impact of obesity on mental health domains may also reflect the social stigma experienced by overweight/obese individuals (33).

The strengths of the current study include a large sample size, high follow-up rates, and repeated assessments of weight and HRQoL variables during a long time period. To the best of our knowledge, this is the largest prospective study investigating the association of weight gain and loss with changes in HRQoL. Although randomized clinical trials may better address the causal relationship, the effect depends on the modality for weight loss, and the results are not generalizable to free-living individuals. Our "change-on-change" analysis approach is, to some extent, a natural experiment, in which individuals gained or lost weight by themselves; thus, the results may be more externally generalizable compared with the results from a well-controlled experimental setting.

We also acknowledge several limitations. First, our study populations consisted primarily of educated white US women. Although the homogeneity of socioeconomic status helps reduce confounding, the results may not be generalizable to men or to other ethnic and socioeconomic groups. Some studies have suggested that there might be sex-specific associations between weight gain and HRQoL (5, 12, 13, 15). Second, we did not ascertain the underlying reasons for weight change during the follow-up period. Some people may intentionally lose weight, and some may lose weight unintentionally because of underlying medical conditions. This may attenuate the association between weight loss and changes in HRQoL. Third, some degree of measurement error in the assessment of exposure and outcome is inevitable. We adjusted for changes of multiple lifestyle factors and comorbidities; however, residual and unmeasured confounding from other lifestyle behaviors or factors is still possible. For example, we did not collect the information on diagnosis of depression, and studies have shown that some antidepressants may have the side effect of weight gain (34). Finally, most changes in HRQoL outcomes varied by only a few points, and although some were in the range of minimally important changes, the clinical and public health implications are yet unclear.

CONCLUSIONS

In these 2 cohorts of US women, we found that weight gain over a 4-year period was associated with worse HRQoL in the physical functioning domains. Among overweight and obese women, weight loss was associated with improved physical health. Our results confirm the association between body weight and HRQoL and add further evidence that avoiding weight gain among all weight groups, as well as losing weight in overweight and obese women, improves HRQoL.

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REFERENCES

1. Fontaine KR, Barofsky I. Obesity and health-related quality of life. *Obes Rev*. 2001;2(3):173–182.
2. Kim D, Kawachi I. Obesity and health-related quality of life. In: Hu FB, ed. *Obesity Epidemiology*. New York, NY: Oxford University Press; 2008:234–260.
3. Ul-Haq Z, Mackay DF, Fenwick E, et al. Meta-analysis of the association between body mass index and health-related quality of life among adults, assessed by the SF-36. *Obesity (Silver Spring)*. 2013;21(3):E322–E327.
4. Larsson U, Karlsson J, Sullivan M. Impact of overweight and obesity on health-related quality of life—a Swedish population study. *Int J Obes Relat Metab Disord*. 2002;26(3): 417–424.
5. Bentley TG, Palta M, Paulsen AJ, et al. Race and gender associations between obesity and nine health-related quality-of-life measures. *Qual Life Res*. 2011;20(5):665–674.
6. Lynch CP, McTigue KM, Bost JE, et al. Excess weight and physical health-related quality of life in postmenopausal women of diverse racial/ethnic backgrounds. *J Womens Health (Larchmt)*. 2010;19(8):1449–1458.
7. Launer LJ, Harris T, Rumpel C, et al. Body mass index, weight change, and risk of mobility disability in middle-aged and older women. The epidemiologic follow-up study of NHANES I. *JAMA*. 1994;271(14):1093–1098.
8. Damush TM, Stump TE, Clark DO. Body-mass index and 4-year change in health-related quality of life. *J Aging Health*. 2002;14(2):195–210.
9. Daviglus ML, Liu K, Yan LL, et al. Body mass index in middle age and health-related quality of life in older age: the Chicago Heart Association Detection Project in Industry Study. *Arch Intern Med*. 2003;163(20):2448–2455.
10. Garner RE, Feeny DH, Thompson A, et al. Bodyweight, gender, and quality of life: a population-based longitudinal study. *Qual Life Res*. 2012;21(5):813–825.
11. Cameron AJ, Magliano DJ, Dunstan DW, et al. A bi-directional relationship between obesity and health-related quality of life: evidence from the longitudinal AusDiab Study. *Int J Obes (Lond)*. 2012;36(2):295–303.
12. Stafford M, Hemingway H, Marmot M. Current obesity, steady weight change and weight fluctuation as predictors of physical functioning in middle aged office workers: the Whitehall II Study. *Int J Obes Relat Metab Disord*. 1998;22(1): 23–31.
13. Burns CM, Tijhuis MA, Seidell JC. The relationship between quality of life and perceived body weight and dieting history in Dutch men and women. *Int J Obes Relat Metab Disord*. 2001; 25(9):1386–1392.
14. Kozak AT, Daviglus ML, Chan C, et al. Relationship of body mass index in young adulthood and health-related quality of life two decades later: the Coronary Artery Risk Development in Young Adults Study. *Int J Obes (Lond)*. 2011;35(1):134–141.
15. León-Muñoz LM, Guallar-Castillón P, Banegas JR, et al. Changes in body weight and health-related quality-of-life in the older adult population. *Int J Obes (Lond)*. 2005;29(11): 1385–1391.
16. Williams LT, Young AF, Brown WJ. Weight gained in two years by a population of mid-aged women: How much is too much? *Int J Obes (Lond)*. 2006;30(8):1229–1233.
17. de Hollander EL, Picavet HS, Milder IE, et al. The impact of long-term body mass index patterns on health-related quality of life: the Doetinchem Cohort Study. *Am J Epidemiol*. 2013; 178(5):804–812.
18. Verkleij SP, Adriaanse MC, Wendel-Vos GC, et al. Longitudinal relation between weight change and quality of life in a community-based population: a prospective cohort study. *Eur J Public Health*. 2013;23(2):285–290.
19. Sarna L, Bialous SA, Cooley ME, et al. Impact of smoking and smoking cessation on health-related quality of life in women in the Nurses' Health Study. *Qual Life Res*. 2008;17(10): 1217–1227.
20. Mozaffarian D, Hao T, Rimm EB, et al. Changes in diet and lifestyle and long-term weight gain in women and men. *N Engl J Med*. 2011;364(25):2392–2404.
21. Ware JE Jr, Snow KK, Kosinski M, et al. *SF-36 Health Survey: Manual and Interpretation Guide*. Boston, MA: The Health Institute, New England Medical Center; 1993.
22. Ware JE Jr, Kosinksi M, Keller SD. *SF-36 Physical and Mental Health Summary Scales: A User's Manual*. Boston, MA: The Health Institute, New England Medical Center; 1994.
23. Stewart AL, Ware JE Jr, eds. *Measuring Functioning and Well-Being: The Medical Outcomes Study Approach*. Durham, NC: Duke University Press; 1992.
24. Brazier JE, Harper R, Jones NM, et al. Validating the SF-36 health survey questionnaire: new outcome measure for primary care. *BMJ*. 1992;305(6846):160–164.
25. McHorney CA, Ware JE Jr, Rogers W, et al. The validity and relative precision of MOS short- and long-form health status scales and Dartmouth COOP charts. Results from the Medical Outcomes Study. *Med Care*. 1992;30(5 suppl): MS253–MS265.
26. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care*. 1992;30(6):473–483.
27. Rimm EB, Stampfer MJ, Colditz GA, et al. Validity of self-reported waist and hip circumferences in men and women. *Epidemiology*. 1990;1(6):466–473.
28. Chiuve SE, Fung TT, Rimm EB, et al. Alternative dietary indices both strongly predict risk of chronic disease. *J Nutr*. 2012;142(6):1009–1018.
29. Sloan JA, Cella D, Hays RD. Clinical significance of patient-reported questionnaire data: another step toward consensus. *J Clin Epidemiol*. 2005;58(12):1217–1219.
30. Warkentin LM, Das D, Majumdar SR, et al. The effect of weight loss on health-related quality of life: systematic review and meta-analysis of randomized trials. *Obes Rev*. 2014;15(3): 169–182.
31. Ackermann RT, Edelstein SL, Narayan KM, et al. Changes in health state utilities with changes in body mass in the Diabetes Prevention Program. *Obesity (Silver Spring)*. 2009;17(12): 2176–2181.
32. Fine JT, Colditz GA, Coakley EH, et al. A prospective study of weight change and health-related quality of life in women. *JAMA*. 1999;282(22):2136–2142.
33. Taylor VH, Forhan M, Vigod SN, et al. The impact of obesity on quality of life. *Best Pract Res Clin Endocrinol Metab*. 2013; 27(2):139–146.
34. Schwartz TL, Nihalani N, Jindal S, et al. Psychiatric medication-induced obesity: a review. *Obes Rev*. 2004;5(2): 115–121.