Weight change, survival time and cause of death in Dutch elderly *

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Summary

Weight change, subsequent survival time and cause of death are reported from the Dutch Longitudinal Study among the Elderly. Data consist of a national sample of persons aged 65-99 years. Six hundred and fifty-eight subjects were examined in the baseline years 1955-1957 and were re-examined 5 years later. Vital status and cause of death were ascertained for 604 of these subjects through 1983.

Those subjects who experienced a decline in body mass index (BMI, kg/m²) during the period of observation, were likely to be in poorer health and have a shorter survival time than those subjects with stable weight, regardless of initial BMI. Weight gain was associated with shorter survival time only in the age group 65-74 and in those with heart disease. Weight loss, on the other hand, was most likely to result in decreased survival time among those ultimately dying of stroke, pneumonia/influenza or heart disease. As such, weight loss may be an indicator of the severity of disease.

The noted associations remained, even when those surviving less than two years were omitted from the analyses. Thus, in longer survivors, weight loss may be associated with decreased vitality and decreased ability to survive once a disease becomes apparent.

Causes of death; Body mass index (BMI); Longevity; Longitudinal study; Old age

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Introduction

Excessive body weight is a well documented risk factor for poor health as measured by the presence of chronic disease as well as by shortened life expectancy. Among middle-aged adults, it is a widely reported risk factor for increased cardiovascular morbidity and mortality (Hubert et al., 1983; Garrison and Castelli, 1985; Johnson et al., 1986; Seidell et al., 1986). Weight loss among middle-aged adults has been shown to have a positive effect on physiologic parameters such as systolic blood pressure, serum cholesterol and blood glucose (Noppa, 1980; Borkan et al., 1986).

Among older adults, however, the relationship between body weight and health status, survival time and cause-specific mortality is ambiguous (Andres, 1980; Waaler, 1984; Manson et al., 1987). Clinical studies of older adults have provided evidence indicating that weight loss is a sign of approaching death (Marton et al., 1981; Dwyer et al., 1987). This evidence gives rise to the question of whether weight loss in older persons in any situation should be regarded as positive.

The present study is based on longitudinal data on weight change and subsequent survival in a Netherlands national probability sample of the elderly. The following questions are addressed: (1) What is the relationship between body weight change and physician-rated health status among older adults? (2) Is weight change a risk factor for decreased longevity among older adults? (3) Does change in weight differentially affect survival time across separate causes of death?

Materials and Methods

Design of the study

In 1955–1957, a probability sample of the older Dutch population was examined in the first cycle of the Dutch Longitudinal Study among the Elderly. The sample consisted of 3149 persons and was sex- and age-stratified, such that the 65–69, 70–74, 75–79 and 80–99 age groups contained equal numbers of men and women. The study was initiated and conducted by Dr. R.J. Van Zonneveld with the Netherlands Organization for Applied Scientific Research (TNO). The subjects were examined by their own general practitioner; a total of 374 general practitioners cooperated.

The initial study objective was to describe the health status of a cross-section of Dutch elderly as well as related psycho-social factors (Van Zonneveld, 1961). The physical examination data included height and weight. In 1960, sufficient interest existed among the examining general practitioners to re-examine the survivors of the original survey. From 1960–1962 through 1974–1975, there were six follow-up cycles, in which traceable subjects were re-examined longitudinally. Vital status and causes of death were ascertained up to 1983.

In the 1960–1962 cycle, of the 1602 known survivors 658 subjects were traced and re-examined. Of 604 of these, vital status was ascertained in 1983. These
subjects comprise the present study sample (38% of all survivors in 1960–62). The key variable of interest in this report, change in body mass index, was calculated when measures of weight at both examinations as well as height at follow-up were available. The present analyses were based on those subjects who fulfill this criterion \((n = 512)\). As will be shown later, these subjects' baseline characteristics pertinent to the current study were not appreciably different from the baseline characteristics of those subjects who survived for five years but were not re-examined. All subjects were 70 years of age or over at the time of the second cycle.

**Measurements**

*Weight change*

Weight and height were measured by the examining general practitioner. Body mass index (BMI) was used as a measure of weight, because of its known correlation with weight, independent of height (Kholsa and Lowe, 1967). BMI is a ratio of weight to height, defined as weight (in kilograms) divided by height (in meters) squared. BMI change was calculated as the difference between attained BMI (at follow-up or cycle two) and initial BMI (at baseline or cycle one). This value represents change in weight adjusted for height. Follow-up data on height were used to calculate both baseline and follow-up BMI, so that BMI change did not represent height change but rather weight change. For example, a BMI change of 2.0 kg/m\(^2\) translates to a weight change of 7.2 kg for a person of height 1.90 m, while for a person of height 1.50 m it translates to a weight change of 4.5 kg.

*Health status*

The measure of health status was the assessment by the examining physician of the subject's overall health, based on comprehensive physical examination (Van Zonneveld, 1961). The outcome was summarized as good, moderate or poor. This measure proved to be the strongest independent predictor of longevity in this sample (Deeg et al., 1989a). The study design did not provide for assessments of inter-rater reliability, and therefore inter-rater reliability of health status assessment could not be checked. However, at follow-up, the baseline assessment was available to the examining physician for comparison in order to reduce intra-rater variability.

*Causes of death*

The causes of death of deceased subjects were recorded by their general practitioner who had also examined them earlier in the study. If the causes of death were not established by the general practitioner himself, they were reported to him by the treating physician. (This is routine practice in the Dutch health care system.) One or more causes of death were known for 96% of the deceased subjects. The average number of causes of death known per deceased subject was 1.7. Considering this multiplicity of causes of death, and in view of the difficulties involved when information is limited to only one (underlying) cause of death (Israel et al., 1986; White et al., 1989), the decedents were grouped by cause of death based on both
first and second cause listed on their death record. Thus, one subject could appear in at most two groups.

The four leading causes of death were, then, heart disease (9th International Classification of Diseases codes 393-398, 410-429), CVA or stroke (ICD-9 codes 430-438), cancer (ICD-9 codes 140-239) and pneumonia/influenza (ICD-9 codes 460-466, 480-487), with frequencies of 42, 20, 16 and 15%, respectively. The subjects dying from one of these four causes together constituted 80% of the total sample. Other causes of death occurred in too small numbers to draw conclusions. Causes of death of a 10% sample of subjects examined at baseline and deceased subsequently were checked against official death records. A 71% agreement was found on those four causes of death discussed here. Especially with respect to heart disease, the records obtained in the study appeared to be more accurate than the official records (Deeg et al., 1985).

The measure of survival time

The concept of longevity is expressed as the realized probability of dying (RPD), a function of survival time, sex and age at baseline (Deeg et al., 1989b). This function is designed to make the survival times of sample subjects of different sex and age comparable. The RPD compares each individual subject’s survival time with the survival curve of that part of those age and sex peers in the total population who were still alive at the time of the baseline examination. Possible values of the realized probability of dying are between 0 and 1. These values introduce a rank order among all sample subjects. For example, the value of an individual’s RPD is 0.7, if at the time of his or her death 70% of his or her cohort is still alive. For those subjects still alive at the end of the study in 1983 (2% of this study sample, n = 10), a value of the realized probability of dying is imputed. If the RPD is uniformly distributed, the sample survival time represents the survival time of the entire Dutch population. For the present analyses, the survival curves were based on the Dutch population mortality rates in the successive years following baseline through 1983; the RPD was calculated to reflect survival from follow-up onward. The RPD was indeed uniformly distributed (mean = 0.49, S.D. = 0.29).

Statistical analysis

The relationship between BMI change and RPD was first examined graphically by observation of mean RPD across categories of magnitudes of BMI change (≤ -2.5, -2.5/-0.5, -0.5/+0.5, +0.5/+2.5, and ≥ +2.5 kg/m², respectively) within quartiles of baseline BMI. Further examination included observation of mean RPD across BMI change categories by sex, by age at baseline (65-74 and 75+ years), and by cause of death (heart disease, stroke, cancer and pneumonia/influenza).

Tests of significance were obtained by means of regression models with the logit of the RPD (LRPD) as the dependent variable. Since the RPD itself was uniformly distributed in the sample at follow-up, its logit was approximately normally distributed with mean 0. Separate analyses were performed, with BMI change conditional
TABLE I
Comparison of baseline characteristics of subjects examined in cycle 1 and surviving but not re-examined in cycle 2 with subjects examined in cycle 1 and re-examined in cycle 2 with complete and with incomplete BMI measurements

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Subjects surviving but not re-examined (n = 998)</th>
<th>Subjects re-examined BMI complete (n = 512)</th>
<th>Subjects re-examined BMI incomplete (n = 92)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age in years</td>
<td>73.9</td>
<td>73.7</td>
<td>76.7 *</td>
</tr>
<tr>
<td>% Females</td>
<td>49.3</td>
<td>46.3</td>
<td>62.2 *</td>
</tr>
<tr>
<td>% Low income</td>
<td>22.7</td>
<td>21.1</td>
<td>18.9</td>
</tr>
<tr>
<td>% Cigarette smokers</td>
<td>15.1</td>
<td>13.7</td>
<td>13.6</td>
</tr>
<tr>
<td>Mean height in m</td>
<td>1.63</td>
<td>1.62</td>
<td>1.60</td>
</tr>
<tr>
<td>Mean weight in kg</td>
<td>69.2</td>
<td>69.2</td>
<td>68.6</td>
</tr>
<tr>
<td>% Good health status</td>
<td>80.1</td>
<td>79.0</td>
<td>61.8 *</td>
</tr>
</tbody>
</table>

* These values are significantly different (p < 0.05) from the other values.

In order to examine the possible selection bias of the study sample, baseline characteristics of those subjects surviving but not re-examined and those subjects re-examined at follow-up with complete BMI measurements were compared. No significant differences in characteristics pertinent to the study were found (Table I, first two columns). Thus, the latter subjects can be considered to be representative of the original sample with respect to relevant aspects. Likewise, the baseline characteristics of those 92 subjects examined twice with incomplete BMI measurements showed no significant differences with the two former groups in income, smoking habit, height and weight (Table I, last column). However, significantly more subjects of older age, of female sex and in poorer health did not have complete BMI measurements at follow-up. In the results to be presented, however, this will not introduce significant bias, as the study sample itself can be considered representative.

Results

Thirty percent of all subjects exhibited no weight change after 5 years (magnitude of BMI change less than 0.5 kg/m²: Table II). Another 50% showed a weight change of magnitude greater than 0.5 but less than 2.5 kg/m². Interestingly, the low baseline quartile had the largest proportion of persons with stable weight or little weight change (87% vs. 72% in the high quartile). Fifteen percent of persons in the sample lost considerable weight while only 4% gained weight (magnitude of BMI...
TABLE II
Distribution of individuals across categories of BMI change within quartiles of baseline BMI (BM1)

<table>
<thead>
<tr>
<th>BM1 quartile (kg/m²)</th>
<th>BMI change (kg/m²)</th>
<th>&lt; -2.5</th>
<th>-2.5/-0.5</th>
<th>-0.5/0.5</th>
<th>0.5/2.5</th>
<th>≥ 2.5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 23.8</td>
<td></td>
<td>9</td>
<td>38</td>
<td>42</td>
<td>32</td>
<td>8</td>
<td>129</td>
</tr>
<tr>
<td>23.8–28.9 a</td>
<td></td>
<td>36</td>
<td>68</td>
<td>79</td>
<td>63</td>
<td>11</td>
<td>257</td>
</tr>
<tr>
<td>≥ 29.0</td>
<td></td>
<td>32</td>
<td>37</td>
<td>34</td>
<td>20</td>
<td>3</td>
<td>126</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>77</td>
<td>143</td>
<td>155</td>
<td>115</td>
<td>22</td>
<td>512</td>
</tr>
</tbody>
</table>

* Median BM1 at 25.9 kg/m².

change ≥ 2.5 kg/m²). The Spearman rank correlation between baseline BMI and BMI change was ~0.58.

The association of weight change and change in health status

At baseline, 76.5% of all persons were assessed by their general practitioners to be in good health. The remainder of persons were judged to be in moderate (23.2%) or poor health (0.3%). At follow-up, 59.6% of persons were assessed to be in good health, 95.9% of which were also in good health at baseline. Thirty-five percent were judged to be in moderate and 5.4% in poor health.

Baseline health status was not significantly correlated with baseline BMI (r = -0.07). However, there was an association between change in health status and change in weight for the entire cohort. The association was such that those subjects losing weight were more likely to show a decline in health status than those gaining weight (Table III). Of those losing over 0.5 kg/m² weight, 62.6% declined in health, whereas of those gaining over 0.5 kg/m² weight only 22.1% showed a decline in health status. The partial correlation between weight change and health status change, holding BMI at cycle 1 constant, was -0.20. This association held across age groups (65–74 and 75 + years at baseline) and for each sex.

TABLE III
Association of BMI change with health status change

<table>
<thead>
<tr>
<th>Health status</th>
<th>BMI change (kg/m²)</th>
<th>≤ -2.5</th>
<th>-2.5/-0.5</th>
<th>-0.5/0.5</th>
<th>0.5/2.5</th>
<th>≥ 2.5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved</td>
<td></td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>No change</td>
<td></td>
<td>106</td>
<td>127</td>
<td>96</td>
<td>20</td>
<td>392</td>
<td></td>
</tr>
<tr>
<td>Declined</td>
<td></td>
<td>33</td>
<td>22</td>
<td>15</td>
<td>2</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>76 a</td>
<td>143</td>
<td>154 a</td>
<td>115</td>
<td>22</td>
<td>510</td>
</tr>
</tbody>
</table>

* One observation is missing.
The association of weight change and survival time

When BMI changes over 5 years were related to survival time over the next 22 years, a U-shaped pattern emerged for each baseline quartile of BMI (Fig. 1a–c). However, the lowest point or 'nadir' of each U within a baseline quartile group varied. For example in Fig. 1a, it can be seen that persons in the low BMI quartile at baseline (BMI < 23.8 kg/m²) had the best probability of survival (c.q. the lowest RPD) if their BMI increased 0.5 to 2.5 kg/m², corresponding to a gain in weight of approximately 1–7 kg. Figure 1c shows that the nadir of the curve for those persons in the high BMI quartile (> 29 kg/m²) at baseline was associated with a BMI decline of 0.5–2.5 kg/m². For those persons who were in the middle quartiles (Fig. 1b), a stable weight or a loss of 0.5–2.5 kg/m² was also associated with the lowest RPD. Overall, persons with a stable BMI in all baseline quartile groups had an average or lower RPD indicating an average or longer survival time. The U-shaped or quadratic association of BMI change and survival time appeared to be significant over all baseline BMI quartiles when tested in regression models (p < 0.05, two-sided).

![Graph showing association of BMI change with RPD by quartile BMI at baseline (time 1)](image-url)
The association of weight change and survival time controlling for initial BMI

The regression model including both BMI change and baseline BMI showed only borderline significance (0.05 < \( p < 0.10 \), two-sided) of baseline BMI in the total sample. This small, independent effect of baseline BMI was linear and negative, indicating a shorter average survival time for those in the lower BMI range and a longer average survival time in the higher BMI range.

Again, age- and sex-specific models demonstrated variable effects. In a model including BMI change, baseline BMI showed neither a linear nor a quadratic
significant association with survival time for ages 75 and over and in men. For ages 65–74, a small, independent effect of baseline BMI on survival time was noted (borderline significant), in addition to the larger effect of BMI change. This association of baseline BMI with survival time was quadratic, indicating that a higher baseline BMI corresponded to a shorter survival time, and that both a medium and a lower baseline BMI corresponded to a longer survival time (reversed J-shaped association). Women, finally, were the only group in which there appeared to be a (borderline significant) linear effect of baseline BMI on survival time, while there was no evidence of an independent effect of BMI change. In women, a lower BMI at baseline was associated with a higher RPD or a shorter survival time, while a higher baseline BMI was associated with a longer survival time.

The regression models which combined BMI change and BMI attained at follow-up did not show any independent effect of attained BMI on survival time. In

| TABLE IV | Distribution of individuals across categories of BMI change by quartile BMI at baseline (BMI1) and for four causes of death |
|-----------------------------------------------|
| BMI change (kg/m²) | < -2.5 | -2.5/-0.5 | -0.5/0.5 | 0.5/2.5 | > 2.5 | Total |
| Heart disease |
| BMI1 quartile (kg/m²) | |
| < 23.8 | 2 | 16 | 17 | 15 | 2 | 52 |
| 23.8–28.9 | 12 | 24 | 34 | 21 | 5 | 96 |
| ≥ 29.0 | 22 | 18 | 19 | 7 | 1 | 67 |
| Total | 36 | 58 | 70 | 43 | 8 | 215 |
| CVA |
| BMI1 quartile (kg/m²) | |
| < 23.8 | 1 | 7 | 6 | 5 | 3 | 22 |
| 23.8–28.9 | 6 | 13 | 20 | 16 | 1 | 56 |
| ≥ 29.0 | 4 | 8 | 6 | 4 | 1 | 23 |
| Total | 11 | 28 | 32 | 25 | 5 | 101 |
| Cancer |
| BMI1 quartile (kg/m²) | |
| < 23.8 | 0 | 7 | 8 | 5 | 1 | 21 |
| 23.8–28.9 | 4 | 14 | 10 | 16 | 2 | 46 |
| ≥ 29.0 | 3 | 5 | 3 | 4 | 0 | 15 |
| Total | 7 | 26 | 21 | 25 | 3 | 82 |
| Pneumonia / influenza |
| BMI1 quartile (kg/m²) | |
| < 23.8 | 2 | 9 | 5 | 4 | 2 | 22 |
| 23.9–28.9 | 4 | 12 | 13 | 7 | 1 | 37 |
| ≥ 29.0 | 5 | 5 | 5 | 1 | 1 | 17 |
| Total | 11 | 26 | 23 | 12 | 4 | 76 |
summary, BMI change dominated initial BMI as well as attained BMI in relation to subsequent survival time.

The association of weight change and survival time in those surviving 2 or more years

The analyses omitting those subjects surviving less than 2 years showed somewhat attenuated associations. Still, the quadratic relationship of BMI change with survival time was borderline significant ($0.05 < p < 0.10$) for the total sample. The effects, although smaller, were in the same direction as in the total sample. In models including BMI change, any (borderline) significant associations of initial or attained BMI alone and survival time could not be demonstrated.

Cause of death-specific associations of BMI change and survival time

The occurrence of each of the four causes of death by baseline BMI and BMI change is presented in Table IV. Subjects dying of the most frequent cause of death, heart disease (42% of the sample), had a relatively high baseline BMI, and lost weight more frequently compared to those dying of other causes. The occurrence of

![Graphs showing association of BMI change with realized probability of dying by cause of death.](image)

Fig. 3. Association of BMI change with Realized Probability of Dying by cause of death. (a) Heart disease; (b) CVA; (c) cancer; (d) pneumonia/influenza.
stroke (in 20% of the sample) was not found to be related to either baseline BMI or BMI change. Cancer, ranking third as a cause of death (16% of the sample), occurred slightly more often in subjects with low baseline BMI. Those dying of cancer were not found to experience weight change more frequently than those dying of other causes. A fourth cause of death, pneumonia and/or influenza (15% of the sample), was not associated with baseline BMI or BMI change.

The cause of death-specific relationships between BMI change and RPD are shown in Fig. 3a–d. In those subjects dying of heart disease, BMI change appeared to have a significant, quadratic association with survival time, indicating that weight gain as well as weight loss was associated with a greater RPD or, conversely, with a shorter survival time. In those subjects dying of stroke, weight loss was associated with a slightly shorter survival time (0.05 < p < 0.10, two-sided). This association between BMI change and survival time, however, disappeared in a regression model including BMI attained at follow-up: in those dying of stroke, a low BMI at follow-up appeared to be somewhat more strongly predictive of a shorter survival time than weight loss. Among those subjects dying of cancer, persons who lost weight were slightly more likely to die sooner than those who did not lose weight. This association, however, was not significant (p > 0.10). Among those dying of pneumonia/influenza, those who either lost or gained weight were likely to have a shorter survival time (U-shaped curve, p < 0.05).

When analyses were restricted to those surviving 2 years or longer, the proportions of each of the four causes of death in the sample remained unchanged. A significant quadratic relationship of BMI change and survival time held up only in those dying of heart disease. Other relationships no longer showed, possibly due to insufficient numbers.

Discussion

This study focuses on the relationship between BMI change, change in health status, and survival time as a function of both total and cause-specific mortality. The findings suggest that a stable BMI is associated with a relatively favorable health status and survival time in older persons. Evidence is presented of a U or J shape to the association between survival time and change in BMI, regardless of initial BMI.

The present analyses are based on only 512 of the initially examined subjects. The possibility that the observed associations may be due to selection bias should, therefore, be considered. Although this possibility cannot be fully ruled out, we consider it unlikely for the following reasons. First, the main reason for the attrition was that a number of general practitioners who had collaborated in the study by examining sample members were no longer available. It is unlikely that factors which contributed to the discontinuation of the physicians' collaboration were associated selectively with individual patients' BMI or longevity. Second, the 512 subjects with complete weight measurements through cycle two and therefore included in these analyses were found to be not different from the general popula-
tion with respect to survival time. Third, comparison of relevant baseline characteristics between the 512 subjects included in this analysis and those 998 subjects who were examined at baseline, survived 5 years, but were not re-examined at follow-up, revealed no major differences (Table I).

In our sample, persons with incomplete height or weight measurements were more likely to be female, older and in poorer health. It is worth noting, then, that the associations found might have proved stronger had complete measurements been available in the full sample.

The arguments given above support the view that the present findings are not due to selection bias. However, the generalizability of the findings may be limited by another feature of the study design. Only subjects who survived at least 5 years were included in the present analyses. By comparison, 39% of the initial sample had died by cycle two. With only one measurement available for the majority of those who died, there is no way of determining how their weight changed and how this change was related to their longevity. In analogy with the smaller effect of weight change on survival time found in the subsample of those surviving at least 2 years subsequent to follow-up compared to the full study sample, it seems warranted to assume that the magnitude of change observed in the study sample is likely to be an underestimation of the magnitude of change experienced by the total sample examined at baseline.

While a U-shaped relationship between BMI as measured at a single point in time and subsequent mortality has been fairly well established (Bray et al., 1972; Lew and Garfinkel, 1979; Andres, 1980; Sorlie et al., 1980; Larsson et al., 1981; Jarrett et al., 1982; Waaler, 1984; Manson et al., 1987; Rissanen et al., 1989), the relationship between weight change and subsequent mortality has received only little attention. In two reports addressing the relationship between both weight at one point in time and weight change and mortality, the latter association appeared to be weaker than the association of baseline weight and mortality (Sidney et al., 1987; Harris et al., 1988). This difference may be due presumably to the younger age of these samples compared to the average age of the sample studied in the present paper.

Several previous reports also show differential cause-specific mortality across the distribution of baseline BMI. For example, a high baseline BMI has been described as a risk factor for cardiovascular mortality. Conversely, an association between low baseline BMI and cancer mortality has also been described (Jarrett et al., 1982; Sidney et al., 1987; Harris et al., 1988; Rissanen et al., 1989). The latter reports describe continued excess mortality in the lowest BMI group after removing the first two years of deaths and/or controlling for several confounding factors (systolic blood pressure, cholesterol and smoking). One study shows evidence of a negative association of BMI change and cancer incidence, again in persons not older than 68 years at baseline (Nomura et al., 1985). Non-clinical studies considering the association between change in weight and subsequent mortality in the age group 70 and over have, as far as we are aware, not been reported in literature.

Smoking habit has been observed to be a confounder of the relationship between body weight and longevity: smokers on the average weigh less than nonsmokers and
at the same time have a greater risk of death than nonsmokers. However, the literature provides evidence that the association between a low baseline weight and subsequent mortality remains significant after controlling for smoking (Harris et al., 1988; Rissanen et al., 1989). In previous reports from our study, it was observed the smoking habit was only very weakly associated with longevity (Deeg et al., 1985). Since our concern is with the relationship between weight change and longevity, however, this discussion is only partly pertinent. Smoking can be a confounder of this relationship if it is associated with weight change. According to the studies by Nomura et al. (1985) and Harris et al. (1989), the association between weight loss and decreased survival time is evident regardless of smoking habit. The association between weight change and decreased survival time appears not to be fully explained by smoking habit. This is confirmed in our own data, in which there was no statistically significant association between the smoking habit and weight change. Furthermore, neither the (negative) correlation between BMI change and health status change nor that between BMI change and longevity showed any alteration when controlling for the smoking habit.

The causes of death determined by a physician are subject to inaccuracy and variability especially in the elderly. For example, the multiplicity of causes of death, common among elderly persons, gives rise to problems of interpretation when studying cause of death-specific data. In the analyses presented, one subject, dying of multiple causes of death, can only be considered in one cause of death group at a time. An association of weight or weight change with survival time, demonstrated for one cause of death, may in fact be partially due to another disease contributing to death. The noted relation between weight gain and death of pneumonia or influenza, for instance, may appear somewhat counter-intuitive. Pneumonia or influenza most likely manifest themselves as a cause of death in very old and frail (hence non-overweight) persons. However, they are not likely to be the single cause of death in these persons. In our sample, it turned out that in 60 of the 76 (i.e., 79%) subjects dying of pneumonia or influenza, one of the other three causes of death studied were also present. The majority (45%) had heart disease recorded as an additional cause of death, while stroke and cancer were noted in 24% and 11% of all subjects dying of pneumonia/influenza, respectively. Thus, the presence of other causes of death related to weight or weight change obscures the true relationship of weight or weight change to survival time in those subjects dying of pneumonia or influenza. The co-existence of other causes of death was not as pronounced in those dying of heart disease, stroke or cancer (respectively in 34, 47 and 31%).

In this study, pre-morbid weight gain was associated with a shortened survival time only among those ultimately dying of heart disease or pneumonia/influenza. This effect remained statistically significant only for heart disease after removing the first 2 years of deaths. As noted above, the observed association between weight gain and death of pneumonia or influenza is presumably due to the fact that almost half of those with cause of death pneumonia/influenza, also had heart disease among their causes of death. Clinically, in subjects with heart failure, weight gain due to edema is a well described phenomenon and could explain the relationship between weight gain and death from heart disease. More detailed study of the
mortality risk associated with weight change for persons with established heart
disease is needed before definite conclusions can be drawn.

Pre-morbid weight loss, by contrast, is associated with a shortened survival time
for all four causes of death examined. Weight loss has been reported to be an
indicator of the severity of disease, if a disease is present (Marton et al., 1981).
Another study of weight decline over a 12 month period among persons with cancer
and heart disease suggests that loss of predominantly skeletal and some visceral
protein stores may be at the root of this change (Heymsfield and McManus, 1982).
The present study did not demonstrate a significant relationship between weight
loss and subsequent death from cancer. A follow-up in months instead of years
might have provided information on acute weight loss within a few months before
death.

The value of the present study lies in its evidence of a long-term prognostic
significance of weight change. As its results show, the relationship between weight
loss and decreased survival time holds, even when those subjects who survive less
than two years are left out of the analyses. The results presented, then, suggest that
weight decline is not a feature of normal aging but instead accompanies decreasing
health. Weight loss may be an indicator of the severity of present disease. Alterna-
tively, if no disease is apparent, weight loss may be associated with decreased
vitality and decreased ability to survive once a disease becomes apparent. Finally,
weight change in either direction may be interpreted in terms of a decreased
capability to maintain homeostasis.

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