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Physical Activity Patterns in the National Weight Control Registry

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Abstract

Objective—The National Weight Control Registry (NWCR) was established in 1993 to examine the characteristics of those who are successful at weight loss: individuals maintaining a 13.6-kg weight loss for >1 year. The size of the registry has increased substantially since the early descriptions of this group a decade ago. The purpose of this study was to describe in detail the weekly physical activity habits of NWCR members, to examine the relationship between amount of activity and demographic characteristics, and to determine if changes in activity parameters have occurred over time.

Methods and Procedures—Participants were 887 men and 2,796 women who enrolled in the NWCR between 1993 and 2004. Physical activity was evaluated at registry entry using the Paffenbarger Physical Activity Questionnaire.

Results—NWCR entrants report an average of $2,621 \pm 2,252$ kcal/week in physical activity. There is considerable variability in the amount of activity reported: 25.3% report <1,000 kcal/week and 34.9% report >3,000 kcal/week. Activity level on registry entry is related to the magnitude but not the duration of weight loss. The amount of activity reported by men has

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DISCLOSURE

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decreased over time while no significant change was observed in women. Changes in the types of activities most frequently reported were also observed.

Discussion—Overall, NWCR participants are an extremely physically active group. However, the amount of activity reported is highly variable, making it difficult to develop a single recommendation for the optimum amount of physical activity for weight loss maintenance. A better understanding of individual-specific determinants of how much activity is required for weight loss maintenance ought to be a high research priority.

INTRODUCTION

In many studies, regular physical activity has been found to be associated with long-term weight loss maintenance (1–4). It is less clear how much exercise is needed, and whether particular types of exercise are better than others for weight loss maintenance. Given the weight loss and maintenance success of members of the National Weight Control Registry (NWCR), an understanding of their activity patterns including the amount of activity reported and their activity preferences, might lead to some insight regarding the amount and types of activity common to individuals who are successful at long-term weight loss maintenance.

The NWCR was established in 1993 to investigate the characteristics and behaviors of individuals who have been successful at long-term weight loss maintenance (5). With ~5,000 participants, the NWCR is the largest longitudinal prospective study of individuals successful at long-term maintenance of weight loss. To qualify for NWCR entry, individuals must have lost a minimum of 13.6 kg (30 lb) and have maintained that amount of weight loss for at least 1 year.

The physical activity habits of the initial 784 who were successful at weight loss (of those who had enrolled in the registry between 1994 and 1997) were previously described ~10 years ago in an initial descriptive analysis by Klem *et al.* (5). Initial registry entrants were predominantly female, white, married, and well educated. These initial entrants far exceeded the minimum criteria for registry entry: participants lost an average of 30 kg (66 lb) and maintained the minimum 13.6-kg weight loss for an average of 5.5 years. Physical activity seemed to be a key to success in this group—approximately 90% of registry entrants reported using a combination of diet plus exercise to both lose weight and maintain weight loss. The self-reported data provided by registry members about levels of current activity also suggested that initial entrants were highly physically active. On average, subjects reported expending ~2,827 kilocalories/week (kcal/week) in physical activity—roughly the equivalent of walking 28 miles/week (5). The physical activity data from this initial report of those successful at weight loss in the NWCR has been referenced in several recent reviews and position statements regarding the role of physical activity in weight loss maintenance (3,6–12).

The size of the registry has increased more than fivefold since early descriptions of this group nearly a decade ago, and thus we are interested in re-examining the weight loss and maintenance behaviors of individuals entering the registry. We recently evaluated whether the macronutrient composition of the diet reported by NWCR members has shifted over the

past decade (13). Over the past decade there have been substantial changes in physical activity recommendations, both for the general public and for overweight and obese individuals in particular. These recommendations may potentially impact the amount of physical activity reported by NWCR entrants and/or the amount of weight loss that entrants report on registry entry.

The purpose of the present study was to update and describe in more detail the physical activity patterns of the now ~5,000 members of the NWCR. Specifically, this study examines the amount of activity reported by NWCR members, the variability in the amount of activity reported by NWCR members, and the relationship between self-reported physical activity levels and demographic factors such as age, gender, weight loss magnitude, and weight loss duration. In addition, we describe the most frequent types of activities reported by NWCR members. Furthermore, we compare data from initial registry entrants (1993–1996, $n = 1,191$) to more recent entrants (2001–2004; $n = 1,149$) to determine if changes in physical activity patterns reported on registry entry have occurred since the registry was started nearly a decade ago.

METHODS AND PROCEDURES

Subjects

Participants were 887 men and 2,796 women who had enrolled in the registry between 1993 and 2004 ($N = 3,683$). We also compared the following two groups: (i) initial NWCR entrants: those enrolled between 1993 and 1996 ($N = 1,191$, 237 men and 954 women) and (ii) recent NWCR entrants: those enrolled from 2001 to 2004 ($N = 1,149$, 220 men and 819 women). To be eligible for enrollment in the NWCR, an individual should be 18 years old, and have maintained a weight loss of at least 30 lb for at least 1 year.

Procedures

Prospective participants were recruited through coverage of the NWCR provided by local and national media sources describing the registry and its entry criteria, physician and dietitian referrals, mailings sent by several commercial weight loss programs to their current members, and articles placed in health newsletters and magazines. Interested participants were directed to call a 1–800 number or visit the study website to receive NWCR enrollment information. Consent form and questionnaire packets were then sent to these subjects. Entry into the registry was based on self-reported height, weight and weight change. To increase the veracity of self-reported weight change, subjects were asked to provide documentation of weight loss with either “before and after” photographs or names of individuals able to verify the weight loss. Approximately 80% of subjects provided this information. All participants volunteered to participate in the registry and were not compensated for participation in this study. For the purpose of the present study we excluded subjects who had undergone weight loss surgery.

Measures

All data used in the present study were collected on initial entry into the NWCR. In particular, the following data were used for the analyses in this study.

Demographic and weight history—Participants were asked to provide basic demographic information (age, gender, ethnicity, education level, and marital status) and details about weight history (current weight and current height, maximum adult weight, duration of maintenance of required minimum 13.6-kg weight loss). Using this information, current and maximum BMIs (in kg/m^2) were calculated. In addition, we were able to calculate weight change (magnitude of weight loss) as the maximum pre-enrollment weight minus the enrollment weight for each subject. The reliability and validity of self-reported weight information by NWCR subjects have been documented previously (14).

Physical activity patterns—To assess the current level of physical activity, participants were asked to complete the Paffenbarger Physical Activity Questionnaire (15) on registry entry. This questionnaire has been validated as a tool to assess the planned weekly, and lifestyle-associated, physical activity (16). The three major components of the Paffenbarger Questionnaire are (i) stairs climbed, (ii) walking, and (iii) sports and recreation. Subjects are asked to report their physical activity for the previous week. If the previous week was “unusual,” they are asked to report data for a “typical” week. Specifically they are asked to quantify how many flights of stairs they climbed on average each day and how many blocks they walked on average each day. In addition, they are asked to list any sports or recreational activities they participated in during the past week and to give the number of times they engaged in the activity as well as the time spent engaged in the activity.

From this questionnaire, an estimate of the weekly energy expended through leisure time physical activity was calculated using the scoring system devised for this questionnaire, as described by Paffenbarger and colleagues (15). In brief, kilocalorie scores for blocks and flights are computed as follows: 1 city block = 8 kcal, 1 flight of stairs = 4 kcal. Reported sports and recreational activities were coded into three levels of intensity according to the Paffenbarger Questionnaire coding scheme and values are assigned by the Paffenbarger scoring system as follows: low intensity activities are assigned 5 kcal/min, medium intensity activities are assigned 7.5 kcal/min, and heavy intensity activities are assigned 10 kcal/min. Contemporary forms of physical activity not included in the original Paffenbarger activity coding scheme were coded similarly to the activity that was most closely comparable. For example, elliptical type machines were coded similarly to stationary cycling, snowshoeing was coded similarly to cross country skiing, and Versaclimber was coded similarly to Stairmaster. Total estimated kilocalories per week are obtained by the following formula: (flights of stairs/day \times 7 day/week \times 4 kcal/flight) + (blocks/day \times 7 days/week \times 8 kcal/block) + for each activity reported (activity intensity kcal/min \times min/episode \times episodes/week). A limitation of the Paffenbarger questionnaire is that the kilocalorie values assigned for blocks, flights and recreational activities are derived from a 68 kg (150 lb) male, and there is no correction factor for gender or body weight. Thus the calculation of Paffenbarger activity kilocalories per week is the same for all individuals regardless of body weight.

We also used data from this questionnaire to divide subjects into four roughly equal levels of self-reported physical activity on registry entry as follows: low (<1,000 kcal/week, $n = 910$), moderate (1,000 to <2,500 kcal/week, $n = 934$), high (2,250 to <3,500 kcal/week, $n = 779$) and very high (3,500 + kcal/week, $n = 968$). This allowed us to compare subject characteristics across these four levels of activity.

In addition, we used data from this questionnaire to determine the types of sports and recreational activities most frequently reported by NWCR entrants. To be consistent with other reports on the NWCR (13), we used a Statistical Package for the Social Sciences syntax file with predetermined cut-off values to eliminate implausible data points from the Paffenbarger data. This file excluded eight subjects who reported either total kcal/week >23,000, kcal/week from stairs >10,000, kcal/week from blocks >7,000, kcal/week from light activities >10,000, kcal/week from medium activities >15,000, kcal/week from heavy activities >20,000. The range of physical activity that remained after these exclusions was from 0 to 22,844 kcal/week.

Statistical analysis

Data analyses were performed using Statistical Package for the Social Sciences (Statistical Package for the Social Sciences for Windows, release 14 February 2006. Chicago: SPSS). Results are presented as mean \pm s.d., or percentage of participants. Differences between men and women and initial vs. more recent entrants were compared using independent sample *t*-tests for difference in means and chi-square tests for difference in proportions.

Although reported physical activity in kilocalories per week was not normally distributed, bootstrapped samples of 237 (the size of our smallest group) from the larger sample of 3,683 suggest that the sample mean is normally distributed at this sample size and thus the central limit theorem can be assumed to hold, and parametric methods (e.g., *t*-tests) are thus appropriate.

Pearson's chi-square tests were used for an overall comparison of demographic characteristics (ethnicity, marital status, education level) across groups reporting different levels of activity at enrollment. General linear models with polynomial contrasts were used for testing linear trends across groups reporting different levels of activity at enrollment. Enrollment weight and BMI, maximum weight and BMI, weight change and weight maintenance duration were adjusted to the sample mean age and proportion in males.

RESULTS

Characteristics of subjects

Demographics and weight history of NWCR entrants: 1993–2004—The demographic characteristics of the 3,683 NWCR members (887 men, 2,796 women) who entered the registry between 1993 and 2004 are shown in Table 1. Average age of entrants is 51.6 ± 12.7 years in men and 45.4 ± 12.0 years in women ($P < 0.001$). Overall, 95.5% of subjects were white; there were no significant differences in ethnicity between men and women. The majority of NWCR entrants are married, and highly educated. BMI reported at registry entry was 26.1 ± 4.5 in men and 24.6 ± 4.6 in women ($P < 0.001$); maximum BMI was 36.5 ± 8.3 in men and 36.3 ± 8.1 in women ($P = 0.637$). Weight loss reported on registry entry was 33.4 ± 18.5 kg in men and 32.0 ± 16.1 kg in women ($P = 0.017$) and weight maintenance duration (of 13.6-kg minimum weight loss) was 5.7 years and was not significantly different between men and women.

Changes in demographics and weight history of NWCR entrants: initial entrants (1993–1996) vs. recent entrants (2001–2004)—The average age of NWCR entrants has risen slightly from 45.5 for initial NWCR entrants (1993–1996) to 46.8 for more recent NWCR entrants (2001–2004) ($P = 0.009$). The percentage of male NWCR entrants also rose from 19.9 to 28.7% ($P < 0.001$). No significant changes have occurred in ethnicity. Over time, more female NWCR entrants report having obtained graduate or professional degrees (26.8% of initial entrants vs. 36.3% of more recent entrants, $P < 0.001$); and more male NWCR entrants are married (66.2% of initial entrants vs. 74.2% of more recent entrants, $P = 0.029$).

Maximum (pre-weight loss) BMI reported by NWCR subjects on registry entry rose from 35.8 ± 7.3 to 37.2 ± 8.5 in men ($P = 0.40$) and from 35.1 ± 7.6 to 37.4 ± 8.1 in women ($P < 0.001$); maximum (pre-weight loss) body weight reported on registry entry rose from 116.1 ± 25.4 to 120.9 ± 31.2 kg in men ($P = 0.54$) and from 96.1 ± 21.9 to 102.6 ± 23.4 kg in women ($P < 0.001$). Current BMI reported on registry entry rose from 25.5 ± 3.6 to 26.5 ± 5.1 in men ($P = 0.011$) and from 24.0 ± 4.2 to 25.1 ± 4.6 in women ($P < 0.001$); current weight on registry entry rose from 82.7 ± 14.0 to 85.9 ± 19.0 kg in men ($P = 0.029$) and 65.6 ± 12.2 to 68.7 ± 13.4 kg in women ($P = 0.037$). The weight loss reported by female NWCR entrants has increased from 30.4 ± 15.7 to 33.9 ± 16.3 kg ($P < 0.001$), while weight loss reported by male NWCR entrants has not statistically changed (33.4 ± 17.8 vs. 35.0 ± 19.0 kg, $P = 0.317$). The duration of weight loss maintenance has decreased from 91.1 ± 106.7 to 47.7 ± 69.5 months in men ($P < 0.001$) and 76.2 ± 91.2 to 55.9 ± 71.4 months in women ($P < 0.001$).

Physical activity patterns

Physical activity patterns of NWCR entrants: 1993–2004—Average weekly physical activity reported by all 3,683 NWCR members who entered the registry between 1993 and 2004 is $2,621 \pm 2,252$ kcal/week. Men reported significantly more activity than women: men averaged $2,903 \pm 2,509$ kcal/week vs. $2,532 \pm 2,156$ kcal/week in women ($P < 0.001$). Overall, 85.3% of men and 89.6% of women ($P < 0.001$) report using physical activity as part of their weight loss strategy. The percentage of participants reporting various levels of physical activity is shown in Table 2. Most NWCR entrants report high levels of physical activity: 75% report expending $>1,000$ kcal/week in physical activity, about half (54%) report expending $>2,000$ kcal/week and 35% expend $>3,000$ kcal/week. However, it is important to note that $\sim 25\%$ of entrants report $<1,000$ kcal/week and 15% report <500 kcal/week.

The activity breakdown in kilocalories per week expended in blocks walked, stairs climbed, light, medium and heavy activities are shown in Table 3. Subjects reported expending an average of 757 ± 930 kcal/week in blocks walked, 174 ± 209 kcal/week in flights of stairs climbed, 165 ± 542 kcal/week in light intensity activity (~ 33 min/week), $632 \pm 1,079$ kcal/week in medium intensity activity (~ 84 min/week), and $892 \pm 1,479$ kcal/week in heavy intensity activity (~ 89 min/week). Men expended significantly more kilocalories/week in heavy activities than women ($1,114 \pm 1,648$ kcal/week vs. $822 \pm 1,439$ kcal/week, P

<0.001); there were no significant differences between men and women in the other four categories (blocks, stairs, light, and medium activities).

Most frequently reported types of activity: 1993–2004—The most frequently reported types of activity in male and female NWCR entrants are shown in Table 4. Walking was defined as treadmill walking, unspecified treadmill use other than running, and power walking (all ascertained from the sports and recreation component of the Paffenbarger questionnaire) and/or walking ≥ 1 mile/day outdoors (ascertained from the walking component of the Paffenbarger). Using this definition, walking was the most commonly reported activity with 52.2% of NWCR members reporting walking as part of their weekly physical activity. The number of women reporting walking was slightly higher than the number of men (53.4% vs. 48.6%, $P = 0.13$). Data using alternative definitions of walking are also presented in Table 4. Resistance training was the second most commonly reported activity (29.2% of NWCR members); there were no significant differences between the percentages of men and women reporting resistance training. Only 8.1% of those who report using resistance exercise report it as the only activity. In men, cycling (23.7%), running (22.3%) and cardiovascular exercise machines (12.7%) rounded out the top five most frequently reported activities while in women these activities were aerobics (19.2%), cycling (16.6%) and cardiovascular exercise machines (15.2%). Using the same definition of walking discussed above, 15.9% of NWCR members report walking as their only activity, 36.3% report walking plus other activities, 29.9% report other activities only and 17.9% report walking < 1 mile outdoors per day and no other activities. There were significant differences between men and women with more men reporting other activities only (36.0% vs. 28.0%, $P < 0.001$) and more women reporting walking plus other activities (33.3% vs. 37.3%, $P = 0.030$) and walking < 1 mile outdoors per day and no other activities (15.4% vs. 18.6%, $P = 0.31$).

Relationship between activity level at registry entry and subject characteristics (1993–2004)—We also used data from the Paffenbarger questionnaire to categorize subjects into four levels of physical activity on registry entry with roughly equal numbers of subject per groups as follows: low ($< 1,000$ kcal/week, $n = 910$), moderate (1,000 to $< 2,500$ kcal/week, $n = 934$), high (2,250 to $< 3,500$ kcal/week, $n = 779$) and very high (3,500 + kcal/week, $n = 968$). We found significant differences in subject characteristics within these four levels of activity (see Table 5). There was a higher percentage of male subjects (P for trend < 0.0001) and a lower average age of subjects (P for trend 0.002) as activity level category increased. There were also higher percentages of unmarried and never married subjects as activity level category increased. There were no significant differences in ethnicity across activity level category. Maximum pre-enrollment BMI and body weight (adjusted for age and gender) were not significantly different across activity level category ($P = 0.553$). However, weight change (maximum pre-enrollment body weight minus enrollment body weight) was significantly greater in subjects reporting higher levels of activity (P for trend < 0.0001). Those subjects reporting very high levels of activity (3,500 + kcal/week) were maintaining on average a 4.2 kg greater weight loss than those reporting low levels of activity ($< 1,000$ kcal/week) after adjustment for age and gender. Enrollment BMI and body weight (adjusted for age and gender) was also significantly lower in subjects

reporting higher levels of activity (P for trend <0.0001). Enrollment body weight in subjects reporting very high levels of activity (3,500 + kcal/week) was on average 3.4 kg lower than those reporting low levels of activity ($<1,000$ kcal/week) after adjustment for age and gender. There were no significant differences in weight maintenance duration across activity category.

Changes in physical activity pattern of NWCR entrants: initial entrants (1993–1996) vs. recent entrants (2001–2004)—When initial registry entrants were compared to more recent entrants, we noted some differences in weekly activity patterns over time (see Table 6). In men, weekly activity was higher in subjects enrolled between 1993 and 1996 ($3,215 \pm 2,765$ kcal/week) compared to those subjects enrolled between 2001 and 2004 ($2,682 \pm 2,198$ kcal/week, $P = 0.012$). There were no significant differences in the breakdown of kilocalories derived from blocks, flights, light, medium, and heavy activities in men. In women, initial registry entrants also reported higher weekly levels of activity ($2,635 \pm 2,344$ vs. $2,526 \pm 2,029$ kcal/week); however, this difference was not statistically significant ($P = 0.308$). When the activity breakdown was analyzed in women, initial registry entrants reported higher kilocalories from blocks walked ($818 \pm 1,012$ vs. 673 ± 814 kcal/week, $P = 0.001$) without significant changes in the other activity components (stairs, light, medium, and heavy activities).

The types of activities most commonly reported by NWCR entrants have also changed over time. There were significantly higher percentages of both men (25.3% vs. 37.0%, $P = 0.003$) and women (22.9% vs. 36.6%, $P < 0.001$) reporting resistance training in more recent entrants as compared to initial entrants. Walking remained the most commonly reported activity in the NWCR; there was no significant difference over time in the number of subjects reporting walking (defined as walking 1 mile/day outdoors, treadmill and/or power walking). However, there were fewer recent women entrants reporting outdoor walking >1 mile (45.3% vs. 39.2%, $P = 0.004$) and fewer subjects overall reporting outdoor walking >3 miles (14.3% vs. 11.1%, $P = 0.020$).

In both men and women, there were fewer recent entrants reporting Nordic Track use (4.7% vs. 1.7%, $P < 0.001$) and more recent entrants reporting the use of cardiovascular exercise machines other than Nordic Track and Stairmaster/Lifestep (1.4% vs. 12.8%, $P < 0.001$). The “other cardiovascular machine” listed in the Paffenbarger coding category included elliptical machines, glider type machines (i.e., cardioglide, aeroglider), and spinning bicycles. There were also differences over time in the percentage of women reporting other activities with higher numbers of recent entrants reporting running (8.1% vs. 14.8%, $P < 0.001$), treadmill walking and unspecified treadmill use (9.8% vs. 18.2%, $P < 0.001$), and floor conditioning (8.5% vs. 15.6%, $P < 0.001$) and fewer recent entrants reporting aerobics (22.5% vs. 16.6%, $P = 0.002$), and cycling (20.6% vs. 14.9%, $P = 0.002$). It is important to note that spinning, a relatively recently developed form of group indoor cycling, was coded in the Paffenbarger scoring system as an “Other Cardio” activity though it could also have been considered a form of cycling. Over time, there was a lower percentage of women reporting walking as their only form of activity (17.9% vs. 12.5%, $P < 0.001$), while the percentage reporting other activities only and walking plus other activities was nonsignificantly higher. No significant differences were noted in activity breakdown in men.

DISCUSSION

On average, NWCR entrants continue to greatly exceed the minimum entry criteria for weight loss maintenance. Participants entering the registry between 1993 and 2004 report (at the time of enrollment), an average weight loss of 32.3 kg and maintaining this weight loss for an average of 5.8 years. Current NWCR entrants are ~4.7 kg heavier compared to entrants a decade ago, and report that they were ~7.9 kg heavier prior to weight loss. These changes appear to mirror the gradual weight gain seen in most of the population over the past decade (17,18). In men, weekly activity was ~500 kcal/week higher in initial registry entrants compared to recent entrants, however, there was no significant difference in activity level over time in female entrants. Thus, it is possible that a decrease in amount of physical activity over time was responsible for the higher body weight on registry entry in men; however, this could not be the case for women as reported physical activity level on registry entry did not change over time in women.

Our analyses have shown that physical activity level on registry entry is related not only to body weight on registry entry but also to amount of weight loss maintained. Interestingly, despite reporting the same amount of activity on registry entry over time, female NWCR entrants in 2001–2004 report maintaining an ~3.5 kg greater weight loss on registry entry than those in 1993–1996. In men, while activity reported on registry entry has decreased significantly over time, average amount of weight loss maintained on registry entry is unchanged. Thus, it appears likely that the higher pre-weight loss body weight reported by more recent NWCR entrants (rather than a change in amount of activity or amount of weight loss maintained) is the main factor driving the higher body weight on registry entry in more recent entrants. It will be important to follow NWCR entrants over time and see if the trends for both increasing pre weight loss body weight and increasing body weight on registry entry continue. In addition, it would be interesting to determine whether the trend for decreasing levels of physical activity reported on NWCR entry in men continues, and becomes significant in women as well.

While the overall characteristics of NWCR participants have remained relatively constant since 1993, there were some slight shifts in the demographics of NWCR entrants over time. For example, while it is still predominantly female, there were increases over time in the proportion of men who joined the NWCR. Increasing participation by men may be the result of differences in recruitment sources (e.g., more articles in men's magazines) or it may be that more men are addressing their weight now than in the early 1990s. The registry is still predominately white; this probably represents difficulties in recruitment of minorities rather than the fact that minorities are not successful at weight loss maintenance. The low numbers of minorities in the NWCR is a limitation of this study and may affect the ability to generalize these results to minority populations.

Data from the earlier report of physical activity in the NWCR (5) were instrumental in justifying higher physical activity recommendations for weight loss maintenance for the general public (9,10,12). As the number of NWCR participants has grown from 784 to 3,683, the average amount of physical activity has declined only slightly and remains higher than the majority of the US population. The average weekly amount of physical activity reported

by NWCR participants ($2,621 \pm 2,252$ kcal/week) translates to ~60–75 min (5–6.5 kcal/min) of moderate intensity activity such as brisk walking per day or ~35–45 min (8–10 kcal/min) of vigorous activity such as jogging per day. However, it is important to note that the standard deviation of the average weekly kilocalories of physical activity reported by NWCR members is quite high suggesting a wide range in the amount of activity NWCR entrants are performing.

Activity patterns of NWCR participants have also shifted slightly over the past decade. While walking remains a favored activity, women appear to be walking less distance outdoors than before and using treadmills more. Over time, the percentage of women reporting walking as their only form of activity has decreased. This may be related to environmental changes that have occurred over the past decade that discourage outdoor walking. A relatively high percentage of both men and women in the registry report some form of resistance training, and the most striking change over time in the type of physical activities reported by registry members is the increase in resistance training observed in both men and women. It is most likely that the changes over time in activities most frequently reported in the NWCR, including resistance training, reflect shifts in activity trends and preferences of the population as a whole over the past decade.

A recent review by Donnelly *et al.* (19) of resistance exercise interventions concluded that when used independently of reductions in energy intake, resistance exercise did not produce significant weight loss, although beneficial changes in body composition are generally observed. Further, when used in combination with dietary energy restriction, resistance exercise showed no clear weight loss advantage when compared with other forms of exercise. However, resistance training may theoretically be beneficial for weight loss maintenance (6). While the energy expenditure of resistance training is generally lower than that of aerobic exercise, resistance training may increase total energy expenditure by promoting an increase in muscle mass, which would lead to an increase in energy expenditure throughout the day (19–21).

Thus, while the energy expenditure of resistance training is relatively low, the accumulated increase in energy expenditure across 24 h may be substantial enough to aid in prevention of weight regain after weight loss. While a high percentage (29%) of individuals in the NWCR report resistance training, the majority of individuals who have been successful at weight loss maintenance based on the NWCR criteria did not report resistance exercise. Thus, it is important to note that participation in resistance exercise is not required to be successful at weight loss maintenance. In addition, most (91.9%) of the individuals who report resistance training report engaging in other activities as well.

The current public health recommendations for physical activity from the Centers for Disease Control and Prevention and the Surgeon General, of 30 min of moderate intensity activity on most days of the week (22,23) corresponds to ~10 MET-h/week, or ~700 kcal/week for a 70-kg male (as the Paffenbarger activity kilocalories per week are standardized to a 68-kg (150 lb) male. We have calculated approximate calorie per week conversions for public health activity recommendations using a body weight value of 70 kg). Approximately 85% of NWCR members report expending >500 kcal/week in leisure time physical activity

and ~75% of NWCR members report expending >1,000 kcal/week. In contrast, recent data from the 2001 Behavioral Risk Factor Surveillance Survey suggests less than half (45%) of US adults are active at these recommended levels during nonworking hours (24). This public health recommendation for physical activity in adults was developed with a primary focus on the chronic disease risk reduction and fitness enhancement effects. More recently, exercise guidelines have been revised to recommend more physical activity for weight loss maintenance. In 2001 the American College of Sports Medicine Position Stand recommended overweight and obese individuals should progress to >2,000 kcal/week of leisure time physical activity for long-term maintenance of weight loss (10). In 2002 the Institute of Medicine recommended a minimum of 60 min/day of moderate intensity exercise (~28 MET/h/week or ~2,000 kcal/week) to control body weight (25). About half of NWCR participants would meet or exceed these recommendations: 54% report >2,000 kcal/week. In 2003 the International Association for the Study of Obesity published recommendations that formerly obese individuals may require 60–90 min of moderate intensity activity on most days to prevent weight regain (9). Similarly, the 2005 Dietary Guidelines for Americans recommended that weight-reduced adults need 60–90 min/day of moderate intensity physical activity to maintain weight loss (12). Only about a third (34%) of NWCR participants meet or exceed 3,000 kcal/week of activity, roughly the equivalent of 90 min/day of moderate intensity activity. In addition, it is interesting to note that 25% of NWCR entrants report <1,000 kcal/week in activity and 15% report <500 kcal/week.

There appears to be a significant relationship between the level of physical activity reported on registry entry and the amount of weight loss maintained with subjects in the highest quartile of activity, who maintain a ~9 lb greater weight loss than those in the lowest quartile of activity, even after adjustment for age and gender. This suggests there may be a dose–response relationship between physical activity and weight loss maintenance. Future research could be designed to evaluate whether there is a relationship between self-reported physical activity level and weight regain over time within the NWCR.

Thus, while high levels of physical activity appear to be related to long-term weight loss maintenance (3,11,26–29), the variability in the amount of activity reported by NWCR entrants highlights the difficulty in developing a single recommendation for the optimum amount of physical activity for weight loss maintenance. As about half of the NWCR participants meet or exceed 60 min/day of moderate intensity physical activity and only about one-third meet or exceed 90 min/day of physical activity, 60 min/day may be a better recommendation to the public. However, it should be noted that there might be exceptions to any recommendation. There is a subgroup of NWCR participants who appear to be able to maintain a significant weight loss with relatively low levels of physical activity while others report extremely high levels of activity. Individual-specific factors such as dietary caloric intake, amount of weight lost, age, gender and genetic factors may significantly impact the amount of activity needed for weight loss maintenance. In addition, two major limitations of this study relate to the accurate quantification of physical activity: (i) the reliance on self-reported physical activity data and (ii) the fact that the Paffenbarger questionnaire does not incorporate or account for subject body weight. An analysis of total daily activity energy expenditure, in subjects from the NWCR, using techniques such as accelerometry or doubly

labeled water would be important to objectively quantify the amount and variability of physical activity in this population.

It may also be useful to examine recommendations for exercise intensity for weight loss maintenance. In both men and women, kilocalories derived from heavy intensity activities are the most significant component of weekly reported activity kilocalories (34% of total reported kilocalories per week) suggesting that high intensity activities comprise a significant component of caloric expenditure of NWCR members in exercise. This is also supported by the types of activities most frequently reported by NWCR members, which, with the exception of walking, tend to be relatively high intensity activities (resistance training, cycling, using cardiovascular exercise machines, running, and aerobics). Although walking is the most commonly reported activity, the majority of NWCR members report participating in activities other than or in addition to walking. Studies in the weight loss literature suggest that it is the total energy expenditure of the activity rather than the intensity of activity that appears to be important for weight loss/maintenance (30). Thus, these results that demonstrate that high intensity activities comprise a significant component of caloric expenditure for NWCR members, may suggest that higher intensity activities could be preferred by many individuals to achieve the caloric expenditure required for weight loss maintenance; this could be because the time required to attain the same caloric expenditure would be less for higher intensity activities.

In summary, those who are most successful at weight loss in the NWCR are extremely physically active, and these findings provide further evidence that high levels of physical activity are important for long-term maintenance of weight loss. However, there is a wide variation in the amount of activity reported by NWCR members and it is difficult to develop a single recommendation for the optimum amount of physical activity for weight loss maintenance. A better understanding of individual-specific determinants of how much activity is required for weight loss maintenance ought to become a high research priority.

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Table 1

Baseline characteristics for NWCR entrants 1993–2004

	1993–2004			P value
	M (n = 887)	F (n = 2,796)	All (n = 3,683)	
Age	51.6 ± 12.7	45.4 ± 12.0	46.9 ± 12.4	<0.001
Education (%)				<0.001
Junior high school	0.1	0.2	0.2	
High school	5.5	11.4	10.0	
Vocational training	4.2	6.4	5.9	
Some college	18.1	24.9	23.3	
College degree	30.2	26.8	27.6	
Graduate/professional	41.9	30.3	33.1	
Marital status (%)				0.014
Never married	14.4	14.8	14.7	
Married	68.8	63.0	64.4	
Cohabitation	2.8	3.7	3.5	
Separated	1.4	1.8	1.7	
Divorced	8.6	12.7	11.7	
Widowed	3.4	3.2	3.2	
Other	0.7	0.9	0.9	
Ethnicity (%)				0.268
White	96.3	95.2	95.5	
African American	1.1	2.3	2.0	
Asian	0.2	0.3	0.3	
Hispanic	1.2	1.3	1.3	
Other	1.1	0.9	1.0	
Current weight (kg)	84.1 ± 16.5	67.4 ± 13.3	71.5 ± 15.9	<0.001
Current BMI (kg/m ²)	26.1 ± 4.5	24.6 ± 4.6	25.0 ± 4.6	<0.001
Maximum weight (kg)	117.7 ± 28.8	99.3 ± 23.2	103.8 ± 25.9	<0.001
Maximum BMI (kg/m ²)	36.5 ± 8.3	36.3 ± 8.1	36.3 ± 8.1	0.637
Weight change (kg)	33.4 ± 18.5	32.0 ± 16.1	32.3 ± 16.7	0.017
Weight maintenance duration (months)	71.8 ± 97.3	67.2 ± 84.9	68.3 ± 88.1	0.181

Data reported as mean ± s.d. Excluding weight-loss surgery, ineligible, withdrew.

Table 2

Frequency distribution of NWCR entrants reporting various levels of physical activity: 1993–2004

Activity level (kcal/week)	1993–2004		
	M (%)	F (%)	All (%)
<500	12.7	16.0	15.2
500–999	10.0	10.2	10.1
1,000–1,499	10.3	11.0	10.8
1,500–1,999	8.6	10.4	10.0
2,000–2,499	9.3	10.0	9.9
2,500–2,999	8.4	9.4	9.1
3,000–3,499	9.8	7.2	7.9
3,500–3,999	5.6	6.2	6.0
4,000–4,499	6.0	4.6	4.9
4,500–4,999	4.1	3.6	3.7
>5,000	15.1	11.5	12.3

Excluding eight participants with Paffenbarger total kcal/week >23,000, kcal/week stairs >10,000, blocks >7,000, light activity >10,000, medium activity >15,000 or heavy activity >20,000.

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Table 3

Physical activity characteristics of NWCR entrants: 1993–2004

	1993–2004			<i>P</i> value
	M	F	All	
Total kilocalories per week	2,903 ± 2,509	2,532 ± 2,156	2,621 ± 2,252	<0.001
Stairs	184 ± 204	171 ± 211	174 ± 209	0.097
Blocks	763 ± 968	755 ± 918	757 ± 930	0.829
Light	155 ± 537	168 ± 544	165 ± 542	0.522
Medium	692 ± 1,296	613 ± 1,000	632 ± 1,079	0.059
Heavy	1,114 ± 1,648	822 ± 1,439***	892 ± 1,479	<0.001

Data reported as mean ± s.d. Total kilocalories and component kilocalories excluding eight participants with Paffenbarger total kcal/week >23,000, kcal/week stairs >10,000, blocks >7,000, light activity >10,000, medium activity >15,000 or heavy activity >20,000.

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Table 4

Types of activities reported by NWCR entrants: 1993–2004

	1993–2004			P value
	M (n = 887)	F (n = 2,796)	All (n = 3,683)	
Walking (%) ^a	82.6	80.9	81.4	0.257
Walking (%) ^b	71.0	72.5	72.1	0.395
Walking (%) ^c	48.6	53.4	52.2	0.013
Outdoors 1 block	80.5	77.5	78.2	0.067
Outdoors 3 blocks	67.0	67.1	67.1	0.976
Outdoors 1 mile	40.9	43.2	42.7	0.228
Outdoors 3 miles	12.6	12.8	12.8	0.890
Treadmill	11.6	14.5	13.8	0.033
Walking	3.2	3.9	3.7	0.331
Unspecified	8.5	10.6	10.1	0.066
Resistance training (%)	31.3	28.5	29.2	0.105
Cycling (%)	23.7	16.6	18.3	<0.001
Aerobics (%)	4.5	19.2	15.7	<0.001
Running (%)	22.3	11.3	14.0	<0.001
Cardio machines (%)	12.7	15.2	14.6	0.067
Stairmaster/lifestep	6.0	6.6	6.4	0.546
Nordic track	3.7	2.8	3.0	0.158
Other cardio	4.5	7.4	6.7	0.003
Floor conditioning (%)	9.0	10.6	10.2	0.189
Floor exercises	6.1	4.5	4.9	0.057
Yoga	1.4	3.7	3.1	0.001
Pilates, stretching	2.0	3.1	2.8	0.101
Swimming (%)	5.4	5.3	5.4	0.924

Excluding weight-loss surgery, ineligible, withdrew.

^aWhere walking is defined as 1 block outside, treadmill walking, treadmill unspecified, power walking.

^bWhere walking is defined as 3 blocks outside, treadmill walking, treadmill unspecified, power walking.

^cWhere walking is defined as 12 blocks (1 mile) outside, treadmill walking, treadmill unspecified, power walking.

Table 5
 Relationship between physical activity level at registry entry and subject characteristics (1993–2004)

	Total calories per week at enrollment				P value for linear trend ^b
	<1,000 (n = 910)	1,000 to <2,250 (n = 934)	2,250 to <3,500 (n = 779)	3,500+ (n = 968)	
Age ^a	49.39 ± 13.02	47.94 ± 12.74	45.51 ± 11.97	44.35 ± 11.26	<0.0001
Gender					
Female	78.4%	78.5%	73.9%	72.4%	0.002 ^c
Male	21.6%	21.5%	26.1%	27.6%	
Ethnicity					0.751 ^d
White	95.6%	95.6%	96.1%	94.7%	
African American	2.3%	2.3%	1.7%	1.8%	
Asian	0.1%	0.2%	0.4%	0.4%	
Hispanic	1.1%	1.1%	1.2%	1.8%	
Other	0.9%	0.9%	0.6%	1.3%	
Marital status					<0.0001 ^d
Married					
Separated	66.5%	64.7%	65.7%	61.1%	
Divorced	1.2%	2.4%	1.8%	1.4%	
Widowed	12.0%	12.4%	10.4%	11.1%	
Never married	5.2%	3.5%	2.1%	2.0%	
Not married (living with significant other)	12.0%	13.0%	15.6%	18.5%	
	2.7%	3.4%	3.6%	4.2%	
Other	0.4%	0.5%	0.9%	1.7%	
Education level					<0.0001 ^d
Grade school	0.0%	0.0%	0.0%	0.0%	
Junior high school	0.2%	0.2%	0.3%	0.0%	
High school	15.3	10.3%	7.2%	6.5%	
Vocational training	7.9%	5.6%	4.2%	5.3%	
Some college (<4 years)	27.2%	22.8%	21.2%	22.2%	
College/university degree	23.9%	26.1%	29.6%	30.7%	
Graduate or professional	25.4%	35.0%	37.5%	35.3%	

	Total kcalories per week at enrollment					P value for linear trend ^b
	<1,000 (n = 910)	1,000 to <2,250 (n = 934)	2,250 to <3,500 (n = 779)	3,500+ (n = 968)		
Enrollment weight (kg) ^e	73.47 ± 0.48	71.93 ± 0.47	70.98 ± 0.52	70.12 ± 0.46		<0.0001
Enrollment BMI (kg/m ²) ^e	25.77 ± 0.15	25.20 ± 0.15	24.68 ± 0.17	24.51 ± 0.15		<0.0001
Maximum pre-enrollment weight (kg) ^e	104.33 ± 0.83	103.75 ± 0.81	103.51 ± 0.89	105.14 ± 0.80		0.553
Maximum pre-enrollment BMI (kg/m ²) ^e	36.69 ± 0.27	36.36 ± 0.27	36.05 ± 0.29	36.76 ± 0.27		0.940
Weight change (maximum-enrollment, kg) ^e	30.86 ± 0.55	31.82 ± 0.54	32.07 ± 0.60	35.02 ± 0.54		<0.0001
Weight maintenance duration (months) ^e	67.26 ± 2.90	65.96 ± 2.85	68.95 ± 3.14	70.22 ± 2.82		0.359

^aData reported as mean ± s.d.

^bP-values calculated from a general linear model with polynomial contrasts unless otherwise specified.

^cP-values calculated from logistic regression model with polynomial contrasts.

^dPearson's chi-square P value.

^eData reported as mean ± standard error, adjusted to the sample mean age and proportion male.

Table 6

Physical activity characteristics of NWCER entrants: 1993–1996 vs. 2001–2004

	1993–1996			2001–2004			P value ^d		
	M (n = 237)	F (n = 954)	All (n = 1,191)	M (n = 330)	F (n = 819)	All (n = 1,149)	M	F	All
Total kilocalories per week	3,215 ± 2,765	2,635 ± 2,344	2,749 ± 2,443	2,682 ± 2,198	2,526 ± 2,029	2,571 ± 2,080	0.012	0.308	0.063
Stairs	183 ± 177	180 ± 204	180 ± 199	163 ± 197	167 ± 233	165 ± 223	0.203	0.206	0.087
Blocks	841 ± 1,074	818 ± 1,012	823 ± 1,024	707 ± 869	673 ± 814	683 ± 830	0.106	0.001	<0.001
Light	223 ± 750	186 ± 642	193 ± 664	134 ± 485	169 ± 469	159 ± 474	0.088	0.527	0.150
Medium	720 ± 1,477	585 ± 982	612 ± 1,099	668 ± 1,095	677 ± 1,051	674 ± 1,064	0.625	0.058	0.165
Heavy	1,245 ± 1,866	868 ± 1,585	943 ± 1,651	1,026 ± 1,440	836 ± 1,352	891 ± 1,380	0.115	0.654	0.408

Data reported as mean ± s.d. Excluding weight-loss surgery, ineligible, withdrew.

^a Significance level for difference over time.