

Exercise as a Management Strategy for the Overweight and Obese: Where Does Resistance Exercise Fit in?

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SUMMARY

EXCESS BODYWEIGHT, SPECIFICALLY EXCESS FAT WEIGHT, INCREASES THE RISK OF CHRONIC DISEASE AND PREMATURE DEATH. INCREASED PHYSICAL ACTIVITY/EXERCISE IS A RECOMMENDED STRATEGY FOR THOSE SEEKING TO EFFECTIVELY REDUCE AND MANAGE BODYWEIGHT. TRADITIONALLY, WEIGHT MANAGEMENT EXERCISE RECOMMENDATIONS HAVE FOCUSED ON AEROBIC-TYPE ACTIVITIES, SUCH AS WALKING, BIKING, SWIMMING, AND THE LIKE, WHICH TEND TO RESULT IN A SIGNIFICANT CALORIC EXPENDITURE DURING THE EXERCISE SESSION. STUDIES SUGGEST THAT RESISTANCE EXERCISE CAN ALSO PLAY AN IMPORTANT ROLE IN A LONG-TERM WEIGHT MANAGEMENT PROGRAM, ALBEIT THROUGH DIFFERENT MECHANISMS. THIS ARTICLE EXPLORES CURRENT ACTIVITY/EXERCISE RECOMMENDATIONS FOR WEIGHT LOSS/MANAGEMENT AND DISCUSSES THE POTENTIAL ROLE OF RESISTANCE EXERCISE.

INCIDENCE AND IMPACT OF BEING OVERWEIGHT AND OBESE

Currently, in the United States, 69% of adults are overweight (body mass index [BMI] ≥ 25 kg/m²), whereas 36% meet the criteria for obesity (BMI ≥ 30 kg/m²) (13). After several decades of rapid increase, recent data suggest that we may be seeing at least a temporary plateau in obesity rates (13). Although this plateau is encouraging, efforts to reduce the current rates of the overweight and obese must remain a top public health priority. A nationwide plan focused on health promotion and disease prevention, Healthy People 2020, has established several objectives related to the reduction of the overweight and obese (21).

According to the Healthy People 2020 document, the overweight and obese are associated with an increased risk of chronic disease and premature death (21). Chronic conditions associated with being overweight and obese include, but are not limited to, hypertension, type 2 diabetes, hyperlipidemia, heart disease, stroke, various types of cancer, osteoarthritis, respiratory problems, and gallbladder disease (2,12,21). The precise relationship between excess bodyweight and all-cause mortality is

somewhat controversial. Although some studies have reported that adult all-cause mortality rates increase in concert with the increasing levels of the overweight and obese (1,5), Flegal et al. (14,15) reported no excess mortality associated with being overweight (BMI of 25–29.9 kg/m²). These studies are in agreement with the elevated mortality risk associated with obesity (BMI ≥ 30 kg/m²). Moreover, this excess mortality risk is exacerbated with increasing levels of obesity.

As further evidence of the seriousness of this issue, poor nutrition and a lack of physical activity (PA), often precursors of obesity, have been cited as the second leading “actual cause of death” in the United States, right behind tobacco usage, mainly cigarette smoking and exposure to second-hand smoke (28). The economic impact of being overweight and obese in the United States is staggering, estimated at more than \$215 billion annually, with \$147 billion in direct medical cost (18).

KEY WORDS:

obesity; weight management; aerobic exercise; resistance exercise; excess postexercise oxygen consumption

MANAGEMENT OF THE OVERWEIGHT AND OBESE

Clearly, there are a significant number of Americans who are currently above the recommended BMI range of 18.5–24.9 kg/m² (13). Although a considerable number of adult's report that they are trying to lose weight, few are making the necessary lifestyle changes required to promote weight loss (3). Furthermore, among those individuals who have lost at least 10% of their bodyweight, 8 of 10 are unable to maintain the weight loss for 1 year (40). The current clinical recommendations suggest an initial weight loss goal of 10% of bodyweight over the course of 6 months and define successful weight maintenance as “a weight regain of <3 kg in 2 years and a sustained reduction in waist circumference of at least 4 cm” (7).

When considering lifestyle approaches to weight loss and weight management, the American College of Sports Medicine (ACSM), the National Heart, Lung, and Blood Institute in cooperation with the National Institute of Diabetes and Digestive and Kidney Diseases, and the Obesity Society all recommend that attention be directed toward the following 3 component areas (7,24):

1. Diet—a reduction in daily caloric intake. Specifically, a reduction in foods and beverages that tend to be high in fat or simple sugars but are often lacking in essential nutrients. Examples include snack foods items like chips, sodas, candy, desserts and, of course, the ever-convenient “fast-food” fare.
2. Physical activity/exercise—To compound the problem of excess caloric intake through the overconsumption of high-fat/high-calorie foods, most Americans expend too few calories through PA. Less than 45% of adults are currently meeting minimal PA recommendations, with 36% reporting no leisure-time PA at all (21).
3. Behavior modification—This component area has to do with identifying behaviors associated with or contributing to poor dietary choices and

a sedentary lifestyle and then implementing strategies that lead to favorable changes in these behaviors. Environmental challenges that make PA more difficult (decreasing emphasis on physical education in the schools, lack of safe areas to walk/bike, poor air quality, etc.) and poor nutritional choices (abundance of fast-food restaurants, high-calorie “convenience” snacks and drinks, lack of fresh fruits and vegetables in many intercity neighborhoods etc.) must be overcome for the successful long-term management of bodyweight.

This comprehensive lifestyle approach to weight loss/weight management affords individuals with the best opportunity for successful long-term weight loss success.

While recognizing the essential importance of diet and behavior modification, the focus of this article is to examine the role of PA/exercise in assisting with weight loss/weight management. Specifically, we will review the current recommendations concerning traditional aerobic-type PA (walking, biking, swimming, etc.) for the purpose of weight loss/weight management and then examine the potential role of resistance exercise (RE) as part of a comprehensive weight management strategy.

PHYSICAL ACTIVITY AND HEALTH

In 1995, the Centers for Disease Control and the ACSM jointly released their landmark recommendations on PA and health, encouraging “30 minutes or more of moderately intense PA on most, preferably all, days of the week” (31). This recommendation was later endorsed in the 1996 release of Physical Activity and Health: A Report of the Surgeon General and the 2000 release of Healthy People 2010 (36,37). The health benefits associated with regular PA include reduced risk of coronary heart disease, hypertension, weight gain, type 2 diabetes, osteoporosis, colon and breast cancer, anxiety and depression, and overall mortality (6,33,37). In addition, regular PA can

enhance both physical and cognitive function in older adults (33).

In 2007, the ACSM and the American Heart Association issued an update and clarification of the original 1995 recommendations (19). Any confusion as to the recommended minimal frequency of weekly bouts of PA was clarified in the updated release. The goal is to “accumulate” a minimum of 30 minutes of moderate-intensity (3–6 metabolic equivalents) PA throughout the course of the day, at least 5 d/wk, for a weekly total of at least 150 minutes. The fact that 30 minutes can be “accumulated” (bouts of 10 minutes or more) over the course of the day truly makes it a realistic and achievable goal for most adults. Additionally, those capable of safely engaging in vigorous (>6 metabolic equivalents) PA may derive similar health benefits with fewer and shorter sessions (19). The focus of both the original and updated recommendation is on the quantity and quality of mainly aerobic-type PA/exercise, associated with improved health and reduced risk of chronic disease. Individuals who exceed the minimal goals are likely to experience even greater improvements in health, indicating a dose-response relationship (19). Similar recommendations on PA and health were subsequently presented in the 2008 Physical Activity Guidelines for Americans (32), Healthy People 2020 (21), and the 2011 ACSM position stand on exercise for “apparently healthy adults” (16). In addition, recent initiatives such as “Let’s Move” (27) and “NFL Play 60” (29) have sought to promote health and prevent obesity in children by encouraging 60 minutes of moderate-to-vigorous PA each day. Table 1 provides the summary of key documents on PA and health.

PHYSICAL ACTIVITY FOR WEIGHT MANAGEMENT

In 2001, ACSM released its position stand titled Appropriate Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults (24). An updated version of this position stand was released in 2009 (10). Although

Table 1
Key documents on PA and health for adults

Year released and title	Issuing organization	Aerobic activity recommendations/conclusions	Resistance exercise recommendations/conclusions
1995: Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine (31)	ACSM and Centers for Disease Control	≥30 minutes of “accumulated” moderate-intensity PA performed most, preferably all, days of the week	Acknowledged as being beneficial but no specific recommendations presented
1996: Physical Activity and Health: A Report of the Surgeon General (36)	US Department of Health and Human Services	Aerobic PA goals consistent with the 1995 ACSM/Centers for Disease Control recommendation	≥2 d/wk
		Increased intensity or duration will likely result in greater health benefits	
2000: Healthy People 2010 (37)	US Department of Health and Human Services	Aerobic PA goals consistent with the 1995 ACSM/Centers for Disease Control recommendation	≥2 d/wk
		Additional goals for vigorous activity: ≥3 d/wk, ≥20 min/d	
2007: Physical activity and public health updated recommendations for adults from the American College of Sports Medicine and the American Heart Association (17)	ACSM and American Heart Association	≥30 minutes of “accumulated” (bouts of 10 min or more) moderate-intensity PA 5 d/wk	≥2 nonconsecutive days each week, 8–10 exercises addressing the major muscle groups, 8–12 repetitions to a point of volitional fatigue
		OR	
		Vigorous activity 20 min/d 3 d/wk	
		OR	
		Various combinations of moderate- and vigorous-intensity PAs	
Exceeding the above levels will provide even greater health benefits			

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Table 1
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2008: 2008 Physical Activity Guidelines for Americans (32)	US Department of Health and Human Services	≥150 minutes of moderate-intensity PA/wk (accumulated in bouts of 10 minutes or more)	≥2 d/wk, exercises addressing the major muscle groups, 8–12 repetitions, moderate to high intensity
		OR	
		≥75 min of vigorous activity	
		OR	
		Various combinations of moderate- and vigorous-intensity PAs	
		Exceeding the above levels will provide even greater health benefits	
2010: Healthy People 2020 (21)	US Department of Health and Human Services	Aerobic PA goals consistent with the 2008 Physical Activity Guidelines for Americans	Resistance exercise goals consistent with the 2008 Physical Activity Guidelines for Americans
2011: Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise (16)	ACSM	Moderate-intensity aerobic activity (3–5.9 metabolic equivalents) for ≥30 min/d on ≥5 d/wk for a total of ≥150 min/wk	2–3 d/wk addressing each of the major muscle groups. Also included were recommendations for inclusion of exercises to improve flexibility, agility, balance, and coordination on ≥2 d/wk
		OR	
		Vigorous aerobic activity (≥6 METs) for ≥20 min/d on ≥3 d/wk (~75 min/wk)	
		OR	
		Various combinations of moderate- and vigorous-intensity PAs	

ACSM = American College of Sports Medicine; PA = physical activity.

consistent with the original position stand the recent update provides clear and concise PA recommendations based on the particular weight management goal (prevention of weight gain, weight loss, or maintenance of weight loss). These recommendations are summarized below:

- 150–250 min/wk of moderate-intensity PA will help protect against initial weight gain.
- >250 min/wk of moderate-intensity PA can result in a “clinically significant” weight loss.
- For improved maintenance of weight loss, 250–300 min/wk of moderate-intensity PA is recommended (“approximately 2,000 kcal/wk”).

This position stand article clearly indicates that although the public health recommendation of 150 min/wk of moderately intense PA may provide important health benefits and assist in weight control, a greater amount of PA is necessary for weight loss and successful long-term weight management. In 2002, the Institute of Medicine recommended the accumulation of 60 min/d of moderately intense PA to optimize weight management (23). This level of PA is consistent with that reported by the National Weight Control Registry whose members have successfully maintained a weight loss of at least 30 pounds, for more than 5 years (40). In a recent study, Lee et al. (26) reported that over a 13-year follow-up period of 34,000 women, those who were most successful in preventing weight gain were averaging 60 minutes of moderate-intense PA per day. In their systematic review, Curioni and Lourenco (8) concluded that the combination of exercise and diet results in greater weight loss and better success with weight loss maintenance than diet alone. However, the difficulty of maintaining weight-loss is evident in the finding that both diet plus exercise and diet alone groups regain approximately half of their weight in 1 year (8).

In preparation for the release of the 2008 Physical Activity Guidelines for Americans (32), the Physical Activity Guidelines Advisory Committee Report,

2008, was released (33). This comprehensive document examined the evidence-based health benefits of PA, including the role that PA plays in weight management. Based on an extensive review of the literature, the Advisory Committee Report concluded that 150 min/wk of moderate-intensity activity (“walking at a 4 mile/h pace”) or 75 minutes of more intense PA (“jogging at a 6 mile/h pace”) will help prevent initial weight gain, and when coupled with dietary modification, it can assist with weight loss. To prevent weight regain in individuals who have previously lost weight, the PA requirement is significantly greater. The suggested volume of exercise to prevent weight regain ranged from 26 minutes per day when jogging at a 6 mile per hour pace to 80 minutes per day when walking at a 3 mile per hour pace (33).

These intensity-dependent duration goals seek to assure similar weight management benefits, despite variations in exercise intensity. This is in keeping with the previously mentioned recommendations for PA and health (19), although the volume of PA required for optimizing weight management success is clearly greater than that necessary for improving health. Table 2 provides the summary of key documents on PA and weight management.

RESISTANCE EXERCISE FOR WEIGHT MANAGEMENT

RE is typically performed for the purpose of increasing strength or muscle mass or both (20). In addition to improvements in strength and muscle mass, RE also leads to favorable changes in the areas of body composition, muscular endurance, bone density, cardiac risk factors, psychosocial well-being, and metabolism (4,7,20,35–37,39). In their extensive review article, Strasser and Schobersberger concluded that RE results in favorable changes in body composition (decreased fat mass and increased lean body mass [LBM]), can help “maintain reduced fat mass in obese patients after exercise training or energy intake restriction,” and is effective in

reducing abdominal obesity (35). Common modes of RE include the use of barbells/dumbbells, resistive bands/tubing, strength training machines, and various bodyweight exercises. Public health recommendations on PA and health encourage the inclusion of regular strength training activities (7,16,19,21,33).

Despite the significant health and functional benefits that RE can provide, it is not an effective sole strategy for reducing excess bodyweight. Furthermore, the combination of RE and a reduced calorie diet does not provide additional weight loss benefits beyond that seen with diet alone (10). This should by no means discourage the use of RE as part of a weight loss/weight management plan. Although the inclusion of RE might not enhance short-term weight loss, it does result in healthy changes in body composition (decreased fat mass and increased LBM) and may play an important role in successful long-term weight management.

A notable study by Kirk et al. (25) illustrated the potential weight management value of brief but intense RE sessions. In this 6-month study, young overweight adults engaged in 3 RE sessions per week completing 1 set of 9 different exercises using loads equivalent to 85–90% of the 1 repetition maximum. The heavy loading limited the number of completed repetitions to 3–6 for each exercise. The average amount of time required to complete each workout session was approximately 11 minutes. Upper-body and lower-body strength in the resistance-trained group increased by approximately 50% and fat-free mass (FFM) increased by 2.7%. The resistance-trained subjects experienced a significant increase in both resting metabolic rate (RMR) and sleep metabolic rate (SMR) when compared with control subjects. Additionally, there was an encouraging increase in 24-hour energy expenditure (EE) and a decrease in the resting and sleep respiratory quotient (RQ) values in the resistance-trained group. This decrease in RQ suggests a greater reliance on fat as a fuel source. The changes seen in RMR, SMR,

Table 2
Key documents on PA and weight management for adults

Year released and title	Issuing organization	Aerobic activity recommendations/conclusions	RE recommendations/conclusions
1998: Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults – The Evidence Report (7)	National Heart, Lung, and Blood Institute, in cooperation with the National Institute of Diabetes and Digestive and Kidney Diseases	An initial goal of 30–45 minutes of moderate-intensity PA 3–5 d/wk, with a long-term goal of ≥ 30 min/d on most, preferably all days of the week	None
	Also adopted by the North American Association for the Study of Obesity now known as The Obesity Society		
2001: ACSM position stand Appropriate Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults (24)	ACSM	Overweight and obese adults should progress toward an initial goal of at least 150 min/wk and should eventually progress to 200–300 min/wk or $> 2,000$ kcal/wk of leisure time PA	No specific recommendations based on the lack of evidence that the addition of RE provides any additional weight loss benefit over and above that of diet alone or combined diet and aerobic activity
			The strength enhancing and functional benefits of RE were acknowledged
2008: Physical Activity Guidelines Advisory Committee Report (33)	US Department of Health and Human Services	Conclusions were based on the particular weight management goal and the intensity of the activity:	No specific recommendations related to weight management
		<ul style="list-style-type: none"> To prevent initial weight gain: walking at a 4 mile per hour pace (moderate) for 150 min/ wk or jogging at a 6 mile per hour pace (vigorous) for 75 min/wk 	
		<ul style="list-style-type: none"> To promote weight loss: 150–300 min/wk To prevent weight regain: walking 80 min/d at a 3 mile per hour pace OR 54 min/d at a 4 mile per hour pace OR jogging 26 min/d at a 6 mile per hour pace 	
			Based on its review of the literature the committee report concluded that RE did not have a significant impact on weight loss or fat loss, although it could contribute to favorable changes in body composition via increases in fat-free mass

**Table 2
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2009: ACSM position stand Appropriate Physical Activity Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults (10)	ACSM	Moderate-intensity PA: 150–250 min/wk to help prevent initial weight gain	No specific recommendations based on the lack of evidence that the addition of RE provides any additional weight loss benefit over and above that of diet alone or combined diet and aerobic activity
		> 250 min/wk for weight loss	RE increases fat-free mass both when used alone and in combination with a diet- induced weight loss program
		250–300 min/wk for weight loss maintenance ("approximately 2,000 kcal/wk")	RE in combination with aerobic exercise can facilitate the loss of fat mass beyond that seen with RE alone
ACSM = American College of Sports Medicine; PA = physical activity; RE = resistance exercise.			

and 24-hour EE were based on oxygen consumption values obtained 72 hours after exercise using a room calorimeter and appeared to be a function of the increase in FFM. Although the aim of this study was not to induce weight loss, the findings offer compelling support for the inclusion of RE as part of a weight management strategy. Specifically, the potential role of high intensity, low volume RE as part of a comprehensive weight management program. Although Kirk et al. (25) did not examine the impact of exercise-induced excess post-exercise oxygen consumption (EPOC) in their study, Schuenke et al. (34) have demonstrated that high-intensity RE results in EPOC for periods of up to 38 hours after exercise, whereas Heden et al. (22) have reported elevations in EPOC and EE (approximately 100 kcal/24 h) for up to 72 hours. Thus, a RE-induced EPOC could further augment EE to levels beyond that which are solely attributable to increased FFM for a period of up to 3 days and therefore assist in weight management.

Encouraging reports on the value of RE when combined with a reduced calorie diet have also been reported in the literature (4,11,17). Of significant importance was the finding that during periods of reduced caloric intake, RE could attenuate (11,17) or even prevent (4) the loss of FFM. Subjects in these studies who were on the same low-calorie diets and performing aerobic exercise experienced a significant loss of FFM (4,17). Because the primary goal of most weight loss programs is to reduce unhealthy body fat, those programs that better target the loss of fat while minimizing the loss of healthy and functional lean tissue are preferable.

While results have been mixed, another conceivable weight management benefit of RE is its potential to preserve RMR during periods of weight loss. Maintaining a higher RMR would conceivably result in greater success with weight loss maintenance and long-term weight management. Wang et al. (38) have reported that the EE associated with 1 kg of muscle tissue is approximately 13 kcal/d, whereas 1 kg of fat tissue requires

approximately 4.5 kcal/d. Therefore, RE to protect against the loss of muscle tissue and thus better preserve RMR would appear to be an important strategy for long-term weight management.

Bryner et al. (4) reported that in a 12-week study, RMR was preserved in subjects who consumed a very low-calorie diet (VLCD) and engaged in a 3 d/wk RE program (10 exercises, 2–4 sets, 8–15 repetitions). This preservation of RMR was not seen in subjects who consumed a VLCD in combination with 4 d/wk of aerobic exercise (20–60 minutes of walking biking, or stair climbing) (4). However, in an 8-week study, Geliebter et al. (17) reported similar decreases in RMR in subjects on a reduced calorie diet and performing RE (8 exercises, 3 sets, 6–8 repetitions) versus those on a reduced calorie diet and performing aerobic exercise. The shorter study duration and lower training volume may help explain the failure of RE to preserve RMR in the RE group in this study compared with the findings of Bryner et al. (4). The ability of RE to protect against declines in RMR during weight loss requires further investigation.

The adaptive responses commonly observed with aerobic exercise (increased $\dot{V}O_{2\max}$ and decreased fat mass) and those typical of RE (increased LBM, increased strength, and increased RMR) have been reported in exercise studies that combined these 2 modes of exercise (9,30). When compared with aerobic only (9, 30) or resistance only (9), the combined training was superior in terms of its effects on percent body fat (9) and the reduction of fat mass (9,30). These studies suggest that perhaps the best exercise program for both health and weight management is one that combines these 2 modes of exercise.

Although further studies are necessary, there is credible evidence to suggest that RE can play an important role in a comprehensive weight management program. The potential for RE to reduce, or perhaps even prevent the decreases in RMR and FFM that often accompany weight loss programs that are

based solely on diet or diet plus aerobic exercise, is intriguing and merits further investigation. Studies using various levels of caloric restriction and incorporating a variety of combined aerobic and RE protocols might yield further insight as to the “optimal” exercise approach to weight loss/weight management.

CONCLUSIONS

1. More than two-thirds of American adults are overweight or obese and are at an increased risk for chronic disease and premature death. In addition to the human toll, the overweight and obese represent a huge economic burden to society.
2. Aerobic-type PA is associated with a wide variety of health benefits and is recognized as a critical component of a comprehensive weight loss/weight management program.
3. For the purpose of optimizing weight management, adults should be encouraged to work toward a goal of 60 min/d of moderate-intensity PA that is mainly aerobic in nature. Individuals who can safely engage in more vigorous PA can derive similar weight management benefits in less than 60 min/d.
4. RE promotes improvements in muscle mass and strength in addition to providing other valuable health benefits. Current recommendations on PA and health encourage the inclusion of RE.
5. Programs that include both aerobic and RE can provide all the healthful benefits of each of these very different types of exercise and may be superior in terms of producing favorable changes in body composition.
6. A weight management strategy that combines a reduced calorie diet, aerobic exercise, and RE may be the best combination for reducing unhealthy body fat while attenuating the losses in LBM and RMR that commonly occur during periods of weight loss. Further study is required to determine how best to incorporate RE into

a comprehensive weight loss/weight management program.



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REFERENCES

1. Adams KF, Schatzkin A, Harris TB, Kipnis V, Mouw T, Ballard-Barbash R, Hollenbeck A, and Leitzmann MF. Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. *N Engl J Med* 355: 763–778, 2006.
2. Aronne LJ. Classification of obesity and assessment of obesity-related health risks. *Obes Res* 10: 105S–115S, 2002.
3. Bish CL, Blanck H, Serdula MK, Marcus M, Kohl HW III, and Khan LK. Diet and physical activity behaviors among Americans trying to lose weight: 2000 Behavioral Risk Factor Surveillance System. *Obes Res* 13: 596–607, 2005.
4. Bryner RW, Ullrich IH, Sauers J, Donley D, Hornsby G, Kolar M, and Yeater R. Effects of resistance vs. aerobic training combined with an 800 calorie liquid diet on lean body mass and resting metabolic rate. *J Am Coll Nutr* 18: 115–121, 1999.
5. Calle EE, Thun MJ, Petrelli JM, Rodriguez C, and Heath CW Jr. Body-mass index and mortality in a prospective cohort of U.S. adults. *N Engl J Med* 341: 1097–1105, 1999.
6. Colberg SR, Albright AL, Blissmer BJ, Braun B, Chasan-Taber L, Ferhall B, Regensteiner JG, Rubin RR, and Sigal RJ. American College of Sports Medicine and American Heart Association joint position statement. Exercise and type 2 diabetes. *Med Sci Sports Exerc* 42: 2282–2303, 2010.
7. *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report (98-4083)*. Washington, DC: US Dept. of Health and Human Services, 1998.
8. Curioni CC and Lourenço PM. Long-term weight loss after diet and exercise: A systematic review. *Int J Obes* 29: 1168–1174, 2005.

9. Dolezal BA and Potteiger JA. Concurrent resistance and endurance training influence basal metabolic rate in nondieting individuals. *J Appl Physiol* 85: 695–700, 1998.
10. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, and Smith BK. American College of Sports Medicine position stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc* 41: 459–471, 2009.
11. Donnelly JE, Jakicic JM, Pronk NP, Smith BK, Kirk EP, Jacobsen DJ, and Washburn R. Is resistance exercise effective for weight management? *Evid Based Prev Med* 1: 21–29, 2003.
12. Field AE, Coakley EH, Must A, Spadano JL, Laird N, Dietz WH, Rimm E, and Colditz GA. Impact of overweight on the risk of developing common chronic diseases during a 10-year period. *Arch Intern Med* 161: 1581–1586, 2001.
13. Flegal KM, Carroll MD, Kit BK, and Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. *JAMA* 307: 491–497, 2012.
14. Flegal KM, Graubard BI, Williamson DF, and Gail MH. Cause-specific excess deaths associated with underweight, overweight, and obesity. *JAMA* 298: 2028–2037, 2007.
15. Flegal KM, Graubard BI, Williamson DF, and Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA* 293: 1861–1867, 2005.
16. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, and Swain DP. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc* 43: 1334–1359, 2011.
17. Geliebter A, Maher MM, Gerace L, Gutin B, Heymsfield SB, and Hashim SA. Effects of strength or aerobic training on body composition, resting metabolic rate, and peak oxygen consumption in obese dieting subjects. *Am J Clin Nutr* 66: 557–563, 1997.
18. Hammond RA and Levine R. The economic impact of obesity in the United States. *Diabetes Metab Syndr Obes* 3: 285–295, 2010. Available at: <http://www.dovepress.com/the-economic-impact-of-obesity-in-the-united-states-peer-reviewed-article-DMSOTT>. Accessed: May 13, 2011.
19. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, and Bauman A. Physical activity and public health updated recommendations for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* 39: 1423–1434, 2007.
20. Hass CJ, Feigenbaum MS, and Franklin BA. Prescription of resistance training for healthy populations. *Sports Med* 31: 953–964, 2001.
21. Healthy People 2020. Available at: www.healthypeople.gov. Accessed: April 15, 2011.
22. Heden T, Lox C, Rose P, Reid S, and Kirk EP. One set resistance training elevates energy expenditure for 72 h similar to three sets. *Eur J Appl Physiol* 111: 477–484, 2011.
23. Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids. Available at: <http://www.nap.edu/openbook.php?isbn=0309085373>. Accessed: April 13, 2010.
24. Jakicic JM, Clark K, Coleman E, Donnelly JE, Foreyt J, Melanson E, Volek J, and Volpe SL. American College of Sports Medicine position stand. Appropriate intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc* 33: 2145–2156, 2001.
25. Kirk EP, Donnelly JE, Smith BK, Honas J, Lecheminant JD, Bailey BW, Jacobsen DJ, and Washburn RA. Minimal resistance training improves daily energy expenditure and fat oxidation. *Med Sci Sports Exerc* 41: 1122–1129, 2009.
26. Lee IM, Djousse L, Sesso HD, Wang L, and Buring JE. Physical activity and weight gain prevention. *JAMA* 303: 1173–1179, 2010.
27. Let's Move. Available at: www.letsmove.gov/. Accessed: May 24, 2012.
28. Mokdad AH, Marks JS, Stroup DF, and Gerberding JL. Actual causes of death in the United States, 2000 [published correction appears in *JAMA* 293:298, 2005]. *JAMA* 291: 1238–1245, 2004.
29. NFL Play 60. Available at: www.nfl.com/play60. Accessed: May 24, 2012.
30. Park SK, Park JH, Kwon YC, Kim HS, Yoon MS, and Park HT. The effect of combined aerobic and resistance exercise training on abdominal fat in obese middle-aged women. *J Physiol Anthropol Appl Human Sci* 22: 129–135, 2003.
31. Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, Buchner D, Ettinger W, Heath GW, King AC, Kriska A, Leon AS, Marcus BH, Morris J, Paffenbarger RS, Patrick K, Pollock ML, Rippe JM, Sallis J, and Wilmore JH. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 273: 402–407, 1995.
32. 2008 Physical Activity Guidelines for Americans. Available at: <http://www.health.gov/paguidelines/pdf/paguide.pdf>. Accessed: March 4, 2011.
33. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008*. Washington, DC: U.S. Department of Health and Human Services, 2008. Available at: <http://www.health.gov/paguidelines/Report/pdf/CommitteeReport.pdf>. Accessed: May 28, 2010.
34. Schuenke MD, Mikat RP, and McBride JM. Effect of an acute period of resistance exercise on excess post-exercise oxygen consumption: Implications for body mass management. *Eur J Appl Physiol* 86: 411–417, 2002.
35. Strasser B and Schoberberger W. Evidence for resistance training as a treatment therapy in obesity. *J Obes* 9, 2011. doi:10.1155/2011/482564. Available at: <http://www.hindawi.com/journals/jobes/2011/482564/>. Accessed: May 21, 2012.
36. U.S. Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Control and Prevention, 1996.
37. U.S. Department of Health and Human Services. *Healthy People 2010*. Washington, DC: US Dept. of Health and Human Services, 2000. Conference Edition, In Two Volumes.
38. Wang Z, Ying Z, Bosy-Westphal A, Zhang J, Heller M, Later W, Heymsfield SB, and Muller MJ. Evaluation of specific metabolic rates of major organs and tissues: Comparison between men and women. *Am J Hum Biol* 23: 333–338, 2011.
39. Williams MA, Haskell WL, Ades PA, Amsterdam EA, Bittner V, Franklin BA, Gulanick M, Laing ST, and Stewart KJ. Resistance exercise in individuals with and without cardiovascular disease: 2007 update: A scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation* 116: 572–584, 2007.
40. Wing RR and Phelan S. Long-term weight loss maintenance. *Am J Clin Nutr* 82: 222S–225S, 2005.