Exercise prescription for weight management

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Whilst short-term weight loss is readily achievable, acceptable treatment regimens for long-term maintenance are less commonplace. The limited success in long-term weight-loss maintenance may be due to the unidimensional approach to treatment. Obesity is often considered as merely an issue of energy imbalance. It may be better viewed as the endproduct of chronic adaptation in factors responsible for energy metabolism. Two critical factors are total energy expenditure in general, and the thermic effect of physical activity in particular.

Whilst excessive energy intake, metabolic aberrations, and genotype are all influential in the predisposition to body fat accumulation (James, 1995; Prentice & Jebb, 1995; Saltsman & Roberts, 1995), the increasing prevalence of overweight and obesity cannot be explained by dietary or genetic changes of the population, or by unpredictable decreases in resting metabolic rate (RMR; Shah & Jeffery, 1991; Di Pietro, 1995; Prentice & Jebb, 1995; Bouchard, 1996). Thus, the only way to be successful in weight management is (in addition to sensible dietary modification) to increase energy expenditure by voluntary physical activity (Bouchard, 1996).

A significant challenge is to advise and encourage the ideal exercise or physical activity as part of an individual's daily lifestyle across the lifespan. Key features of exercise prescription should be to optimize energy expenditure, to maintain the more-metabolically-active tissues, and to prevent musculo-skeletal injuries. The purpose of the present paper is to review the current knowledge of the science and the art of exercise prescription, with specific reference to weight management.

The role of exercise in the aetiology of obesity

Obesity is a multi-factorial condition, with the obesity phenotype determined by genetic, metabolic, and socio-behavioural factors. The relative contributions that excessive energy intake, inactivity, or metabolic aberrations have on energy balance remain debatable (Shah & Jeffery, 1991; Stefanick, 1993; Di Pietro, 1995).

There is epidemiological evidence that an inverse relationship exists between physical activity and body weight, and that body fat is more favourably distributed in individuals who are physically active (Andersson *et al.* 1991; Wing *et al.* 1991; Di Pietro, 1995). Further, recent research into the relationship between body fatness and the different components of energy expenditure has shown that adiposity is inversely related to 'non-basal' energy expenditure (Schultz & Schoeller, 1994). From such evidence it has been suggested that level of physical inactivity is a predisposing factor to obesity (Rising *et al.* 1994; Powers & Howley, 1997). However, the associations between physical activity, energy expenditure and body composition are complex, and beyond the scope of the present review. Readers are referred to the following comprehensive epidemiological, clinical, and review papers on these aspects (Oscai, 1973; Epstein & Wing, 1980; Ravussin *et al.* 1988; Tremblay *et al.* 1990; Ballor & Keesey, 1991; Shah & Jeffery, 1991; Stefanick, 1993; Williamson *et al.* 1993; Di Pietro, 1995; Foreyt *et al.* 1995).

Rationale for the use of exercise in weight management

Assessing exercise effectiveness by changes in total body weight can underestimate the effect on desirable body composition changes (Van Zant, 1992). Further, shorter-term studies are unable to assess exercise interventions that require a number of months to be effective. Studies of longer duration have shown that regular endurance exercise is effective in altering body composition of obese individuals even in the absence of dietary restriction (Bouchard *et al.* 1990; Frey-Hewitt *et al.* 1990; Lee *et al.* 1994). However, exercise is not necessary to achieve weight loss.

In accordance with the first law of thermodynamics, weight loss occurs as a function of an energy deficit, the size of which can be controlled (to a degree) by dietary restriction (Hill *et al.* 1993). Obesity management using dietary restriction is based on the assumption that obesity is a consequence of hyperphagia, or some metabolic aberration resulting in lower energy requirements. As both RMR and energy intake per unit body weight are comparable with those of normal-weight subjects (Wilmore & Costill, 1994; Jebb & Prentice, 1995) neither assumption holds in

Abbreviations: EPOC, excess post-exercise O_2 consumption; FFM, fat-free mass; MET, metabolic equivalent; NEFA, non-esterified fatty acids; RMR, resting metabolic rate; SNS, sympathetic nervous system; V_{O_2}, O_2 uptake; V_{O_2max}, maximum O_2 uptake.

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https://doi.org/10.1079/PNS19980015 Published online by Cambridge University Press

most cases. Dietary restriction alone results in compensatory metabolic adaptations designed to preserve body mass (Ballor *et al.* 1990; de Groot *et al.* 1990; Saltzman & Roberts, 1995). In contrast, exercise has been widely identified as being central to the long-term successful management of overweight and obesity (Pate, 1995; National Health & Medical Research Council, 1997).

Exercise is a critical variable in optimizing body composition changes with weight loss, and in preventing weight regain (Hills & Wahlqvist, 1994). More important, however, is the recent recognition of the role that exercise plays in the management of metabolic disorders often associated with excessive body fat levels. Consequently, the role that exercise plays in treating the overweight or obese condition can be categorized into two distinct but related areas: (1) exercise for body composition management, a subcomponent of physical fitness; (2) exercise for metabolic fitness (Bouchard, 1994).

Metabolic *v.* physiological fitness

Physical activity plays a pivotal role in gaining and maintaining physical fitness through improvements in functional capacity, muscular strength and endurance, flexibility, and body composition (Pollock *et al.* 1995). Further, recognizing the strong inverse relationship between regular aerobic exercise and degenerative disease development, physical activity is recommended as an effective primary and secondary prevention modality (Pollock & Wilmore, 1990; American College of Sports Medicine, 1991; Fletcher *et al.* 1995). As body composition is a component of both physical fitness (physiological) and metabolic fitness, body weight will be influenced by exercise programmes designed for each purpose. The American College of Sports Medicine, along with other health-related agencies, has been instrumental in systematically recommending exercise prescriptions based on the most current scientific evidence.

A summary of recommendations outlined in Table 1 (adapted from Pollock *et al.* 1995) reflects the changing nature of research conducted to determine minimal and optimal levels of exercise needed to induce fitness-related adaptations in the cardiovascular–respiratory and musculoskeletal systems. Whilst the recommendations are generally accepted, Pollock *et al.* (1995) recognize that the guidelines lack precision and that more research is needed in the following areas: intensity prescription by heart rate for the elderly; resistance training; exercise adherence; training progression. One could add exercise prescription for weight management to this list.

Cross-sectional studies indicate that physically-active individuals have a reduced likelihood of developing hypertension and CHD (Paffenbarger *et al.* 1983; Sandvik *et al.* 1993). Exercise, with or without weight loss, significantly improves the plasma lipoprotein status by altering the content and composition of the major lipoprotein groups, and increasing HDL levels in particular (Despres, 1994). Reductions in visceral and total body fat have been demonstrated without alteration in maximum O_2 uptake (V_{O_2max}) in obese women who underwent a 14-month endurance training programme. The reduced visceral adipose-tissue levels were accompanied by improved cardiovascular risk of reduced plasma cholesterol and LDL–cholesterol, and increased HDL_2–cholesterol (Schwartz *et al.* 1991; Despres & Lamarche, 1994). Whilst the central adipocytes have a greater capacity to accumulate fatty acids rapidly, during periods of increased physical activity there is a more pronounced utilization of fatty acids from the visceral adipocytes and, thus, a reduced chance of developing the metabolic syndrome of non-insulin-dependent diabetes, hypertension and dyslipidaemia (Despres *et al.* 1991). Given that men display a preferential accumulation of body fat centrally, this is a possible reason for the suggestion that men respond better than women to the weight-loss effects of exercise (Ballor & Keesey, 1991). Recent research on exercise prescription for metabolic disorders has identified both resistance-based and endur-

Table 1. Standards, guidelines, and position statements regarding physical activity for adults

	Frequency	Intensity	Duration	Mode	Weight training
ACSM (1978) position statement	3–5 d/week	60–90 % HR_{max} or 50–85 % V_{O_2max} or HR_{max} reserve	15–60 min continuous	Traditional aerobic activities	Not stressed
ACSM (1990) position stand	3–5 d/week	60–90 % HR_{max} or 50–85 % V_{O_2max} or HR_{max} reserve	20–60 min continuous	Aerobic activities	One set eight to twelve reps; major muscle groups; 2 d/week
ACSM (1995) guidelines	3–5 d/week	50–90 or 60–90 % HR_{max} or 40–85 or 50–85 % V_{O_2max} or HR_{max} reserve	20–60 min continuous	Aerobic activities (expanded)	One set eight to twelve reps; major muscle groups; 2 d/week
1995 AHA exercise standards*	Minimum 3 d/week	50–60 % V_{O_2max} or HR_{max} reserve	Minimum 30 min	Health promotion activities	One set ten to fifteen reps; eight to ten exercises; 2–3 d/week
1995 CDC and ACSM public health statement†	Daily	Moderate	Accumulate 30 min/d	Health promotion activities	Addressed, not specific

ACSM, American College of Sports Medicine; AHA, American Heart Association; CDC, Centers for Disease Control and Prevention; V_{O_2max}, maximum O_2 consumption; HR_{max}, maximum heart rate; rep, repetitions.

* See Fletcher *et al.* (1995).

† See Pate *et al.* (1995).

ance exercise training to be beneficial in improving blood lipid profiles, increasing left ventricular wall contractility, decreasing resting blood pressure, improving insulin sensitivity and glucose tolerance (Soukup & Kovaleski, 1993; Dwyer *et al.* 1994; Katz & Lowenthal, 1994).

Some controversy surrounds the relative associations between endurance training-induced changes in metabolic variables considered risk factors for conditions such as CHD and non-insulin-dependent diabetes mellitus, and the magnitude of improvements in cardio-respiratory fitness (Despres & Lamarche, 1994). The American College of Sports Medicine (1990) position stand emphasized that the guidelines provided were based on scientific data relating the dose of endurance exercise to aerobic capacity and body composition outcomes. As outlined by Haskell (1994), there is an important distinction made between physical activity (and exercise in particular) as it relates to health *v.* fitness. The quantity and quality of exercise needed to obtain health-related benefits possibly differs from that recommended for fitness benefits. Prolonged endurance exercise of low intensity (approximately 50 % V_{O_2max}, performed on an almost daily basis appears to significantly improve metabolic variables through mechanisms that are likely to be independent of the training-related changes in cardio-respiratory fitness. Despres (1994) has suggested that for the purpose of treating and/or preventing metabolic disorders associated with excess adiposity, emphasis should not be placed on increasing V_{O_2max} reflecting 'physiological fitness', but rather on 'metabolic fitness' via enhanced weight (or fat) loss, and related improvements in carbohydrate and lipid metabolism, through a substantial increase in daily energy expenditure. Whether it is more advantageous to lose weight through a negative energy balance or a negative fat balance, is somewhat debatable.

Benefits of a negative energy balance *v.* a negative fat balance

Negative energy balance

Second only to resting metabolism, the thermic effect of physical activity has the greatest potential to influence the amount of energy expended by an individual. Consequently, it is also the most variable component of energy expenditure, ranging between 5 and 30 % of individual daily energy expenditure (Poehlman, 1989; Calles-Escandon & Horton, 1992). Whilst the amount of energy required to achieve any given task is greater for a person of greater mass, the inter-individual variance in the total daily thermic effect of exercise is primarily a function of the volume of intentional physical activity undertaken. The amount of energy expended during exercise is related both to the characteristics of the activity (intensity, mode and duration) and the body size and fitness status of the individual (Hill *et al.* 1995).

Exercise provides the additional energetic benefits of elevated energy expenditure in the post-exercise period as shown by 'excess post-exercise O_2 consumption' (EPOC; Bahr & Maehlum, 1986; Goldberg *et al.* 1990), and a possible reversal of the diet-induced suppression of basal metabolism (Tremblay *et al.* 1990). The quantitative significance of EPOC for weight loss has been questioned, as it may average only 38–125 kJ for low to moderate exercise of durations less than 80 min (Poehlman *et al.* 1991). However, the reversal of dietary-induced metabolic suppression by exercise is well founded (Thompson *et al.* 1996). Potential reasons for the dietary-induced reduction include decreases in triiodothyronine concentration, sympathetic nervous system (SNS) activity as indicated by noradrenaline kinetics, and fat-free mass (FFM; Ravussin & Tataranni, 1996; Saris, 1996). A meta-analysis of the effects of diet and diet-plus-exercise interventions on RMR concluded that moderate-intensity exercise (51–70 % V_{O_2max}) performed 31–60 min/d, 4–5 d per week, is sufficient to reverse some of the decreases in RMR resulting from dietary restriction (Thompson *et al.* 1996). Further, there is evidence that in obese individuals the adaptive responsiveness of the SNS to changing energy status is blunted (Ravussin & Tataranni, 1996; Saris, 1996). Hence, as the altered substrate demands during exercise require increased activation of SNS, which in turn results in increases in RMR and lipid oxidation, exercise may play an important role in overcoming the impaired lipid oxidation in muscle of obese individuals (Saris, 1996).

Negative fat balance

As a consequence of endurance exercise training, there are a number of biochemical adaptations which favour maintenance of homeostasis and improve the muscle's capacity to produce energy aerobically (Powers & Howley, 1997). Such adaptations include increased mitochondrial number, increased capillary density, and changes in mitochondrial oxidative enzymes (Holloszy & Coyle, 1983; Wibom *et al.* 1992). These biochemical changes result in an increased utilization of fat (fatty acid oxidation) in preference to carbohydrate during submaximal exercise (Henriksson, 1977) via the following mechanisms: an increased adrenaline-stimulated hydrolysis from subcutaneous adipose tissue (Crampes *et al.* 1989; Riviere *et al.* 1989); an increase in the capacity of the trained muscle to oxidize lipids (Bjorntorp, 1990); increased hydrolysis of triacylglycerols within the trained muscle (Hurley *et al.* 1986); increased hydrolysis of circulating triacylglycerols through lipoprotein lipase (*EC* 3.1.1.34) activity (Haskell, 1984); increased insulin concentrations, a primary inhibiting factor to lipid mobilization (Bjorntorp, 1990).

With the onset of dynamic large muscle mass exercise, the increase in skeletal muscle uptake of non-esterified fatty acids (NEFA) exceeds the slower-to-increase rate of lipolysis, resulting in a decreased plasma NEFA concentration during the initial 10–15 min of work (Friedberg *et al.* 1960; Havel *et al.* 1967). The work of Wolfe *et al.* (1990) indicated that the subsequent increased rate of lipolysis results in the proportion of energy that is derived from NEFA gradually increasing with longer duration of the exercise at a fixed submaximal work rate. After 15–20 min of exercise at 40 % V_{O_2max}, plasma NEFA turnover is three to four times the resting rate, and increases progressively to approximately six times resting rate after 4 h at this intensity (Zierler, 1976). For exercise at intensities below 40 % V_{O_2max}, the turnover rate of plasma NEFA is such that

https://doi.org/10.1079/PNS19980015 Published online by Cambridge University Press

the substrate requirements of skeletal muscle can be met entirely from this source (Martin, 1996). These findings indicate that exercise bouts of long duration may be more beneficial in terms of fatty acid consumption than the same amount of exercise accumulated through several bouts of short duration.

Low-intensity activities are professed by some to be advantageous for their 'fat burning' capacity. However, research on endurance-trained athletes shows that whilst at low intensities (e.g. 25 % V_{O_2max}) plasma-borne NEFA do provide nearly all the substrate required for exercise, NEFA provide 40–60 % of the total fuel required for exercise at 65 % V_{O_2max} (Romijn *et al.* 1993). In absolute terms, for the energy required to exercise at 65 % V_{O_2max}, the rate of fat oxidation is approximately 40 % higher than at 25 % V_{O_2max}. Hence, while more energy is being expended, the absolute amount of NEFA being used is equivalent. Tremblay *et al.* (1994) demonstrated that a training programme incorporating intermittent high-intensity exercise (approximately 85 % V_{O_2max}) resulted in a greater reduction in skinfold thicknesses than a similar duration of exercise at a lower target heart rate range. These findings are supported by a meta-analysis of the factors affecting changes in body weight and body composition. Ballor & Keesey (1991) concluded that the total energy expended in exercise is directly related, in a dose–response relationship, to the effectiveness of exercise.

The science of exercise prescription for weight management

American College of Sports Medicine guidelines

Weight-loss guidelines promoted by the American College of Sports Medicine (1995) support a combined mild energy restriction with regular endurance exercise. A desirable weight-loss programme should balance exercise intensity and duration to promote a high total energy expenditure, approximately 1250–2090 kJ per session and 4180–8360 kJ per week for adults. Given that obese individuals are at an increased risk for musculo-skeletal injury, it is recommended that the intensity of exercise be maintained at or below the intensity identified for improvement of cardio-respiratory endurance. Additionally, non-weight-bearing activities and/or rotation of exercise modalities, as well as frequent modification to the exercise frequency and duration, may also be required (American College of Sports Medicine, 1995).

Thus, the current guidelines for exercise prescription for weight management are somewhat general in nature, and consequently there is much room for interpretation. Given the relative paucity of scientifically-controlled research on exercise prescription for weight management, many studies suggest the need for further research to identify more specifically the amount, type, and intensity of exercise required to produce weight loss or maintain ideal body weight, while maximizing other desirable physiological and metabolic adaptations (Stefanick, 1993; Haskell, 1994; Zelasko, 1995; Thompson *et al.* 1996).

Dose–response

The exercise dose is characterized by the intensity, frequency, duration, and type or modality of exercise: modality (resistance weight training, cardiovascular endurance training); frequency (number of d per week, number of sessions per d); duration (period (min) of exercise, total energy expended (kJ), total energy (kJ)/kg body weight); intensity (% V_{O_2max}, % maximum heart rate, % heart rate reserve, rating of perceived exertion, lactate threshold, metabolic equivalent (MET)).

Exercise modalities for weight loss

All exercise modalities, if undertaken regularly at an appropriate energy expending threshold, will result in significant reductions in body mass and body fatness (McArdle *et al.* 1996). From an energy expenditure perspective, there is no selective effect of training mode on body composition changes if total work output is equivalent (Pollock *et al.* 1977). However, there are differences in the suitability of exercises for the overweight, and the obese in particular. Optimal exercise modalities minimize the cardiac effort whilst maximizing conditioning (DeVries & Housh, 1994).

Walking. Walking is the most effective modality for any individual initiating an exercise programme (Porcari *et al.* 1989*a*; Buskirk, 1993). The advantages of walking over other modalities include: avoidance of musculo-skeletal problems associated with running; the traffic hazards associated with cycling; inconvenience of finding a swimming pool; requiring no skill acquisition; suitable for most places and times; the ability to produce a training effect (Buskirk, 1993). Compared with running, the ground reaction forces are 3·6 times less for walking (Voloshin, 1988), resulting in less risk of injury.

When body weight is accounted for, the most important determinant of the energetic cost of walking is walking speed (Blessey *et al.* 1976). While the relationship between energy cost and walking speed is linear for speeds between 4 and 6 km/h, and curvilinear between 6 and 8 km/h, at any given speed the relationship between energy cost and grade is linear (Ebbeling *et al.* 1988). These relationships allow for the prediction of energy expenditure using regression equations (Porcari *et al.* 1989*a*). In order to achieve an aerobic training threshold of 70 % maximum heart rate, Porcari *et al.* (1987) recommend that depending on initial level of fitness, women and men need to walk between 5·6 and 6·4 km/h, and 6·4 and 7·2 km/h respectively. Jette (1975) developed the following equation (r 0·86) to estimate the walking speed (min/mile) that would achieve a target energy expenditure: speed $= 44{\cdot}7 - (0{\cdot}45 \times \text{target}) - (12{\cdot}3 \times \text{height}) + (0{\cdot}015 \times \text{weight})$ where target is the target energy expenditure (ml/kg per min) and height and weight are expressed in m and kg respectively. To assist in cardiac rehabilitation, Cornish (1983) outlined a walking programme that enables exercise to be prescribed to an accuracy of 1 m/min or two pulse beats/min. The basic principle involves individuals walking or jogging around a marked circular course, completing one circuit per min.

The radius of the circle increases marginally as the individual's fitness improves, and a timing device is employed to ensure a uniform pace is maintained by each participant.

Research has demonstrated that the energy cost and intensity of walking can be increased by adding weight to the head, hands, wrists, ankles or torso (Keren *et al.* 1981; Graves *et al.* 1987, 1988; Porcari *et al.* 1989*a*). Predominantly, loads of 0·45–2·2 kg have been employed (Graves *et al.* 1988), but much heavier weights have been utilized when carried on the torso (Robertson *et al.* 1982; Walcott *et al.* 1986). Whilst hand weights held by the side without arm movement do not increase V_{O_2max} significantly (Francis & Hoobler, 1986), a pumping action of the arms does (Makalous *et al.* 1988). Graves *et al.* (1988) noted a twelve beats per min increase in heart rate and a 1 MET increase in energy cost when 1·36 kg hand weights were employed. Although ankle weights elicit a lower increase in energy expenditure than hand weights for the same load (Graves *et al.* 1988), they have produced beneficial training effects for individuals with low levels of cardio-respiratory fitness (Pandolf & Goldman, 1975; Burse *et al.* 1979). External loads carried on the torso must be 'substantial' to increase energy expenditure significantly (Porcari *et al.* 1989*b*). Energy expenditure increases were noted when loads representing 15 % but not 7·5 % of total body mass were worn at the waist (Robertson *et al.* 1982). However, Walcott *et al.* (1986) noted that compared with the unweighted condition, carrying a weight vest containing 40 % of body mass at 5·6 km/h increased energy expenditure by only 7·5 kJ/min for women and 9·2 kJ/min for men. Despite the potential to increase energy expenditure when walking, carrying weights may be contra-indicated for individuals with high blood pressure or an exaggerated blood pressure response to exercise, and for individuals with orthopaedic problems.

Aqua. Due to the buoyancy effect, exercise performed in water has the benefit of reduced loading on joints and, thus, permits the obese individual to progress more rapidly in terms of volume of exercise (frequency, duration, intensity) with less risk of injury (Sheldahl, 1985). Further, the greater specific heat and thermoconductivity of water compared with air increases the capacity to remove body heat in cool water (Bullard & Rapp, 1970). Thus, exercise in cool water can reduce thermoregulation problems exaggerated for the obese in the heat, and increase the comfort of movement (Bar-Or *et al.* 1969; Vroman *et al.* 1983). In contrast, exercising in cold water is tolerated better by individuals who display a greater insulating layer of subcutaneous adipose tissue (Sheldahl *et al.* 1982). Research to assess the efficacy of exercising individuals on a cycle ergometer immersed to their shoulders in water revealed that higher work intensities could be tolerated by the obese individuals, particularly in cold (20°) water (O'Hara *et al.* 1977, 1979; Sheldahl *et al.* 1982; Avellini *et al.* 1983).

Provided the individual is adequately skilled, swimming also has the advantages of reduced weight-bearing stress, reduced heat stress in cold water, and the ability to exercise at an aerobic threshold (Sheldahl, 1985). Other water-based activities include kicking with a board or holding the side of the pool, aqua-aerobics (pool-based exercises to music), walking or running in either deep or shallow water, and strength exercises using water resistance. It must be recognized that upright exercises in the water exert a hydrostatic pressure gradient on the body surface, which increases the venous return from the lower extremities (Arborelius *et al.* 1972; Begin *et al.* 1976). Consequently, there is an increase in central blood volume and venous pressure, and increases in cardiac output and stroke volume of 25 % or more.

The effectiveness of deep-water running on maintenance of aerobic performance has been demonstrated by a number of studies. No significant differences in body composition, cardio-respiratory performance, or blood metabolites (glucose, lactate, noradrenaline) were noted between 6 weeks of land and water-based running in trained athletes (Wilber *et al.* 1996). While V_{O_2max} was the most important predictor of perceived exertion during deep-water running (Brown *et al.* 1996*a*), ratings of perceived exertion were significantly higher in deep-water running than treadmill running at the same cadence (Brown *et al.* 1996*b*). Svedenhag & Seger (1992) noted that for a given V_{O_2}, heart rate was eight to eleven beats per min lower than treadmill running irrespective of exercise intensity. Further, during deep-water running both the V_{O_2max} and heart rate were lower, while perceived exertion, respiratory exchange ratio, and blood lactate were higher at submaximal efforts (Ritchie & Hopkins, 1991). The authors suggested that the exercise effects of deep-water running were more comparable with cycle ergometry responses, and that both the external load and an altered running technique add to an increased anaerobic metabolism during supported deep-water running. Butts *et al.* (1991) also noted the magnitude of physiological responses for deep-water running were comparable with cycle ergometry, thus not precluding deep-water running as a training technique. Such findings suggest that training intensities for water running would be better derived from cycle ergometry tests, or if from treadmill tests, a correction factor needs to be employed. These studies hold promise for the use of deep-water running in prescribing exercise for the obese.

Resistance weight training. There is overwhelming support for the use of resistance weight training in exercise prescription for people of all ages, and considerable scope for the overweight and obese (American College of Sports Medicine, 1990; Pollock *et al.* 1994; Feigenbaum & Pollock, 1997). Given the recognition that long-term weight management is dependent on the maintenance of metabolically-active tissue, resistance weight training is an obvious choice for inclusion in an exercise programme. Adding strength training to a programme of regular physical activity will help decrease the risk of 'chronic diseases' while improving quality of life and functionality, thereby allowing people of all ages to improve and maintain their health and independent lifestyle (Pollock & Vincent, 1996). The American College of Sports Medicine (1990, 1995), American Heart Association (Fletcher *et al.* 1995), and the Surgeon General's Report, *Physical Activity and Health* (US Department of Health and Human Services, 1996) have recommended resistance weight training, with gains achieved through performing one set of eight to twelve repetitions (persons under 50 years) or ten to fifteen repetitions (persons over 50 years) of eight to twelve exercises two to three times per week. In addition to gains or maintenance of FFM during weight loss, the average energy expenditure of circuit resistance weight training is approximately 38 kJ/min, and can produce a substantial energy output during a 30–60 min workout (Ballor *et al.* 1989).

Exercise frequency for weight loss

Pollock *et al.* (1975) researched the training frequency required to significantly change the body composition of individuals who walked or ran for between 30 and 47 min/d at 80–95 % maximum heart rate for 20 weeks. Whilst training twice weekly was not instrumental in changing body weight, skinfolds, or percentage body fat, exercising 3 and 4 d weekly was effective. Further, the 4 d weekly group lost significantly more weight and fat than the 3 d weekly group. Thus, while exercising 3 d weekly will produce changes, training more frequently will be more effective. For general health benefits, it has been recommended in the Surgeon General's Report (US Department of Health and Human Services, 1996) that all people should aim to accumulate 30 min of moderate-intensity physical activity on most, and preferably all, days of the week.

Exercise duration for weight loss

A study by Milesis *et al.* (1976) investigated the influence of exercise duration on weight loss in a group of previously sedentary men. The subjects were divided into four groups, a control group who did not exercise, and three exercise groups: 15, 30, or 45 min per session. Whilst the three exercise groups decreased in body fat and waist girth significantly more than the control group, 45 min elicited significantly greater changes than 15 or 30 min of exercise. Despres (1994) has suggested that walking for at least 1 h on most days represents the best exercise prescription for most obese individuals. However, the most definitive suggestion to date, is that the duration of exercise should be long enough to have reached a threshold of 1250 kJ (Pollock & Jackson, 1977).

Exercise intensity for weight loss

For weight loss, maximizing energy expenditure may be superior to a regimen designed to maximize the use of fat during the exercise bout. Of the 1366 women and 1257 men recruited for the 1981 Canada Fitness Survey, Tremblay *et al.* (1994) found that individuals practising vigorous activities on a regular basis had lower subcutaneous skinfold thicknesses and waist : hip ratios than those not involved in such activities. These differences were reported to remain statistically significant after covariance analyses to remove the effect of estimated total energy expenditure of leisure-time activities, and appear to indicate that exercise undertaken at a higher intensity is more advantageous in preventing body fat gain. In contrast, more recent intervention-based research has shown no effect of exercise intensity on body composition changes, either with or without dietary restriction, when total energy expended weekly is comparable (Grediagin *et al.* 1995; Leutholtz *et al.* 1995).

Leutholtz *et al.* (1995) found that while on a supplemented 1760 kJ/d fast, exercise at 40 and 60 % of the heart rate reserve affected body composition of obese men and women to a similar extent when total training volume was held constant at 3760 kJ/week. The study involved 12 weeks of training, three sessions weekly, with subjects randomized into groups that exercised at target heart rates corresponding to 40 and 60 % of the heart rate reserve at the beginning of the programme. In both groups, decreases in body weight (15·3 (SD 6·7) kg) and body fat (14·9 (SD 5·0) kg) were significant, while lean mass remained unchanged. Grediagin *et al.* (1995) randomly assigned untrained, moderately-overfat, weight-stable women to either high-intensity (80 % V_{O_2max}) or low-intensity (50 % V_{O_2max}) exercise groups for four sessions weekly for 12 weeks, with each session of a duration sufficient to expend 1250 kJ. During the study, the subjects were instructed to maintain their normal diet and activity patterns. While there were no significant differences between groups for change in weight, percentage body fat, fat mass, FFM, sum of skinfold measurements, or sum of circumferences, the high-intensity group tended to have a greater increase in FFM. Grediagin *et al.* (1995) concluded that fat loss is a function of energy expended rather than exercise intensity. Thus, if fat loss is the goal and time is limited, persons should exercise at as high an intensity as tolerable to expend as much energy as possible during the time available. However, as previously alluded to, in addition to the substrate and energy utilization consideration, there are other issues including cardiovascular and musculoskeletal risk, metabolic *v.* cardiovascular fitness, and adherence issues to consider when prescribing the exercise intensity.

The art of exercise prescription for weight management

Intensity prescription

Arguably the most difficult aspect of exercise prescription lies in defining the exercise intensity for an individual, and in monitoring this intensity once an appropriate level has been prescribed (Pollock *et al.* 1995). Although the relative intensity of exercise can be addressed through prescription based on a percentage of the maximal values, these values may not be the most appropriate measure of endurance capacity, as they are not measures of a level of intensity able to be maintained for prolonged periods of time. It may be more appropriate to measure a submaximal marker of intensity that is related to a level of exercise intensity at which adaptations may occur, and which is able to reflect any changes in exercise capacity. As outlined in Table 2, research has delineated the association between these variables.

Implementing these variables requires either direct measurement of the maximal values, a prediction of the maximal values from a submaximal test, or the estimation from a predictive equation. Whilst the direct measurement

https://doi.org/10.1079/PNS19980015 Published online by Cambridge University Press

Table 2. Classification of exercise intensity based on 30–60 min of endurance training (Adapted from Pollock & Wilmore, 1990)

Relative intensity (%)			
HR_{max}	V_{O_2max} or HR_{max} reserve	Rating of perceived exertion*	Classification of intensity
< 35	< 30	< 10	Very light
35–59	30–49	10–11	Light
60–79	50–74	12–13	Moderate (somewhat hard)
80–89	75–84	14–16	Heavy
≥ 90	≥ 85	> 16	Very heavy

HR_{max}, maximum heart rate; V_{O_2max}, maximum O_2 consumption.
* Based on Borg 6–20 scale (Noble *et al.* 1983; Borg, 1985).

of maximal values is the most accurate method of assessment, it may be considered inappropriate for 'at risk' populations, and can result in reinforcement of the negative association with exercise, reducing the likelihood of adherence to subsequent prescription. Further, tests conducted on sedentary individuals more commonly reflect measurement of peak, rather than maximal values (Brooks *et al.* 1996). Additionally, the expense of the equipment required and the time needed for maximal testing can make it impractical for use in many exercise settings (Porcari *et al.* 1989*a*). In contrast, extrapolations of training thresholds from submaximal tests, or predictions from generalized equations are associated with greater error.

Heart rate. Heart-rate monitoring is a convenient method to assess exercise intensity. One shortcoming in this area, but not in the accuracy of monitoring, is in the methods used to determine an appropriate training level. Heart rate is closely associated with exercise intensity, with the relationship between heart rate and V_{O_2} being linear with increasing intensity. There are a number of approaches for calculating an appropriate target heart rate range. The best approach involves a plot of the relationship between exercise heart rate and aerobic capacity (V_{O_2}) or lactate concentration at given work levels during a maximal exercise test, from which the range of heart rates associated with given percentages of functional capacity can be determined. More commonly, predictive approaches, which use the percentage of heart rate reserve (difference between the maximum and resting heart rates), or a fixed percentage of the maximum heart rate, are employed. However, the variation in the most-commonly-utilized prediction equation for maximum heart rate (220 − age), has been calculated as ± ten beats per min in normal subjects (American College of Sports Medicine, 1995). Research by Miller *et al.* (1993) suggests that for obese individuals the equation 200 − (0·5 age) is more accurate.

Lactate threshold. Although beyond the scope of the present paper, the use of blood lactate concentration to assess relative intensity of exercise effort is well supported (Belman & Gaesser, 1990; Aellen *et al.* 1993; Casaburi *et al.* 1995), and readers are referred to an excellent review by Weltman (1995). In short, the lactate threshold is highly correlated with endurance performance, independent of V_{O_2max} and gender (Tanaka *et al.* 1990; Evans *et al.* 1995). Further, the lactate threshold, as well as representing a level at which training adaptations are most significant, is itself a trainable physiological variable in both untrained and highly-trained individuals (Belman & Gaesser, 1990; Casaburi *et al.* 1995; Weltman, 1995). The lactate threshold, therefore, is able to provide a submaximal marker of exercise intensity that is relative to the training status of the individual. It is possible that the lactate threshold may also represent a level of maximum energy expenditure at a tolerable workload. One disadvantage of the lactate threshold for the prescription of exercise intensity is the invasive nature of its direct measurement. As yet, there are no means by which the lactate threshold can be indirectly measured or estimated accurately. Our recent work suggests that there may be merit in the use of predictive equations to define training thresholds based on heart rate and age and the relationship with blood lactate at given workloads (Hills & Byrne, unpublished results).

Perceived exertion. Perceived exertion is a psychophysical measure of an individual's perception of a level of exercise or work intensity. This measure may be expressed using a variety of scales such as the Borg 6-20, and the Borg 0–10 (category-ratio) scales (Noble *et al.* 1983; Borg, 1985). As it has been proposed that both perceived exertion and heart rate increase with the intensity of exercise either one may be predicted from the measurement of the other, as well as being used as an estimate of exercise intensity. However, perceived exertion, being composed of a multitude of psychological and physiological factors, therefore, may be a more accurate indicator of intensity than any one of these factors (Williams & Eston, 1989). Psychological variables which may affect perceived rate of exertion include personality traits, previous exercise experience and distraction, each of which can lead to a decrease in reported values of perceived exertion (Williams & Eston, 1989).

Physiological variables such as blood lactate accumulation, carbohydrate depletion, respiration rate, hydration state and aerobic capacity as well as heart rate can also influence perceived exertion (Barr *et al.* 1991; Burgess *et al.* 1991; Hetzler *et al.* 1991; Seip *et al.* 1991). Blood lactate, in particular, is closely related to perceived exertion at specific workloads, regardless of training state or training modality (Hetzler *et al.* 1991; Seip *et al.* 1991). The lactate threshold corresponds to perceived exertion values of 11·0 (SD 2·0), and fixed blood lactate concentrations of 2·0, 2·5, and 4·0 mmol/l correspond with ratings of 13·7 (SD 2·1), 14·5 (SD 1·8) and 16·5 (SD 2·3) respectively for males (Glass *et al.* 1991; Seip *et al.* 1991).

It may be concluded from recent work assessing the efficacy of perceived exertion ratings of athletic, sedentary, overweight, or cardiac rehabilitation patients, that scales of ratings of perceived exertion do have a valid role to play in the monitoring of exercise intensity. However, there are many factors to be taken into consideration, including the need for appropriate education, before scales of ratings of perceived exertion can be used effectively (Glass *et al.* 1991; Dishman, 1994; Dunbar *et al.* 1994, 1996*a,b*; Jakicic *et al.* 1995; Dunbar & Bursztyn, 1996; Eston & Connolly, 1996).

Summary

The debate surrounding the level of intensity of exercise that is best for health improvement has potentially clouded the issue of optimal exercise prescription for weight management. Low-intensity activity is potentially superior to moderate to high intensity for improving metabolic risk factors, and accumulated small bouts of physical activity are as effective to this end as single longer bouts, as long as the overall volume of energy expenditure is equivalent. What should not be forgotten however, is that for weight-loss, it is the total volume of energy expended that will dictate the size of the energy deficit imposed, not the composition of the exercise per se.

Exercise prescription for weight management is a conundrum. Whilst it is the total volume of energy expended that will dictate the magnitude of weight lost, not the composition of the exercise per se, it is the nature of the exercise prescription that will dictate the long-term success of an exercise programme. It is how well the exercise prescription is individualized that influences tolerance of and interest in the programme and, thus, the adherence to it in the long term.

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