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Comparing exercise prescribed with exercise completed: effects of gender and exercise mode

Running Head: Exercise and compliance

Key Words: gender, exercise, mode

Abstract

The purpose of this study was to compare the amount of exercise prescribed with the amount completed between two different modes of training intervention and gender. Thirty-two men (mean age=39.1yr; BMI=32.9kg/m^2) and women (mean age=39.6yr; BMI=32.1kg/m^2) were prescribed traditional resistance training (RT) or light-resistance circuit training (CT) for 16 weeks. Measurements of lean mass (LM) and fat mass (FM) were determined by Dual Energy X-ray Absorptiometry at weeks 1 and 16. A completion index was calculated to provide a measure of the extent to which participants completed exercise training relative to the amount of exercise prescribed. The absolute amount of exercise completed by the CT group was significantly greater than the amount prescribed ($P<0.0001$). The RT group consistently under-completed relative to the amount prescribed, but the difference was not significant. The completion index for the CT group (26%±21.7) was significantly different compared with the completion index for the RT group (-7.4%±3.0). The completion index was not significantly different between men and women in either group. These data suggest that overweight and obese individuals participating in light-resistance circuit training completed more exercise than prescribed. Men and women do not differ in the extent to which they over- or under-complete prescribed exercise.

Introduction

The most effective mode, duration and intensity of exercise for successful body weight control are continually debated (Dudley and Djamil, 1985*;* Walberg, 1989; Nelson *et al*, 1990*;* McCarthy *et al*, 1995*;* Hunter *et al*, 1998; Hills and Byrne, 1998; Bell *et al*, 2000*;* Jakicic and Gallagher, 2003; Donnelly *et al*, 2003; Donnelly *et al*, 2004). It has been suggested that exercise produces modest reductions in body weight (Garrow and Summerbell, 1995*;* Miller *et al*, 1997), and is a fruitless method of weight loss for women (Gleim, 1993). A failure of exercise to produce significant reductions in body weight is assumed to be a lack of effectiveness of the exercise treatment *per se*. However, the validity of some studies evaluating the effectiveness of exercise need to be questioned – especially since the exercise intervention tends not to be monitored. In most exercise interventions, conclusions about the efficacy of exercise are based on the volume of exercise prescribed rather than the exercise completed. However, reduced compliance could undermine the capacity of exercise to promote successful weight loss.

A similar phenomenon is observed with nutrition and pharmaceutical interventions in which their efficacy is confounded by a reduction in compliance to the prescription (Manninen *et al*, 1998; Laurance *et al*, 2003). In a lipid-lowering drug trial effectiveness was markedly reduced in patients who complied with less than 70% of the prescribed dose (Cramer, 2002). The rationale for prescribing medication is that it is easier for the patient than altering their dietary or exercise behaviours (Cramer, 1989). However, even in the case of relatively simple once-daily medications, patients fail to comply (Cramer, 2002). Although there is large variability, in general patients take approximately 75% of medication as prescribed (Cramer, 1989; Cramer, 1998). Wallace *et al*, (1995) showed that on average, approximately 50% of the exercise prescription is completed. Given that it is unlikely that 100% compliance to exercise prescriptions occur - even when the exercise monitored in the laboratory (King *et al*, 2008) or free-living (Colley *et al*, 2008) - the evaluation of the effectiveness of the intervention should be based on the volume of exercise actually completed, not the exercise prescribed. Even in highly motivated elite swimmers (Stewart and Hopkins, 1997) and endurance runners (Hewson and Hopkins, 1995) the intensity of training completed was lower than the intensity prescribed. Therefore, sedentary, overweight and obese individuals unfamiliar to exercising are likely to complete less than the amount of exercise prescribed.

Gender is also believed to be a strong moderator of the effects of exercise on weight loss. There is a commonly held belief that females experience less weight loss benefits from exercise training than males. Doucet *et al* (1999) noted a difference in fat mass losses between males and females when participants were prescribed a combination of moderate dietary restriction and exercise program, and reported that the effect could be entirely explained by the difference in the net energy cost of the exercise. As reported in other training studies (e.g., Tremblay *et al*, 1994), the authors suggested that this sex difference was attributable to the exercise intensity actually achieved, reporting that despite the same exercise intensity being prescribed, females exercised on average at an intensity 19% lower than the males.

Therefore, gender differences in compliance to prescribed exercise could potentially undermine the true efficacy of exercise to promote weight and fat loss. However, the problem of determining gender differences in compliance and efficacy is compromised by a lack of studies reporting compliance and/or expressing the outcomes by gender (Gibson, et al, 2005). There is a need for more studies to include data on gender differences in compliance and its association with the efficacy of exercise to promote weight and fat mass loss.

Most studies use traditional aerobic exercise or resistance training (i.e. strength) interventions, however, more novel interventions such as circuit training could provide a more effective and appropriate exercise modality. Circuit training usually consists of discontinuous exercise involving exercising for a fixed number of repetitions using a series of stations involving light resistance training. Each station usually involves an equal exercise:rest ratio lasting between 60-120 sec. In essence, circuit training is similar to a combination of aerobic and resistance exercise (Walberg, 1989; Nelson et al, 1990; McCarthy et al, 1995; Kaikkonen et al, 2000; Kaikkonen et al, 2000; Maiorana et al, 2002; Park et al, 2003; Takeshima et al, 2004).

The present study compared the compliance and efficacy of this novel type of circuit training with traditional resistance training by using the tonnage lifted to compare the amounts of prescribed and completed exercise. The aim of this study was to compare the amount of prescribed exercise with completed exercise, and to determine if this is moderated by gender or mode of exercise.

Method

Participants

Forty-two sedentary, overweight or obese men and women were recruited to take part in a training study, but only 32 completed the study. Table 1 represents data from 32 participants who completed the study. All participants were healthy, non-smokers, and not taking any medication known to affect heart rate or body composition. Sedentary was defined as no regular physical activity (less than 30 mins per week) in the past twelve months, including work-related physical activity. Using a between subjects design, the participants were randomly assigned to one of two training groups; traditional resistance training (RT) and light-resistance circuit training (CT). Thirty-two participants (RT n=16; CT n=16) completed the study and met the 92% adherence criterion. There were equal numbers of males and females in each training group. There was no significant difference in age and BMI between the two training groups. Participants visited the laboratory to exercise on three occasions per week for a period of 16 weeks. Written and informed consent was obtained from each participant and ethical approval from the University ethics committee.

Table 1 about here

Training Programmes

All training sessions were supervised by a qualified exercise physiologist. Each exercise session for both training groups started with a 5 min light, aerobic warm-up. The frequency (3 times per week) and duration (16 weeks) of the training regimes were fixed for both groups. There was a 1-2 day rest interval between each exercise day. The criterion for adherence was greater than 92% attendance (>44 sessions) which was recorded by the experimenter. Participants self-recorded the weight lifted, repetitions, and sets completed for each exercise. Tonnage was calculated using the following equation:

Tonnage (kg) = [Weight lifted (kg) x repetitions] x sets

The tonnage lifted per session was determined by addition of the tonnage for each individual exercise. Similarly, the total tonnage lifted is the sum of tonnage every session across the 16-week program.

1-Repetition Maximum (RM) strength testing

1-RM strength was determined for leg press, bench press and shoulder press exercises. All participants were initially naive to 1-RM testing and completed a familiarisation session before testing. During the familiarisation period, participants became acquainted with the exercise equipment, and exercise techniques. Grip width for both the bench press and shoulder press was self-selected (approximately shoulder width) and measured for each participant to provide a repeatable starting point for the lift. Feet were positioned at approximately shoulder width apart for the seated leg press. Following extensive explanation and demonstration of correct technique, participants first performed each lift at a low intensity, with emphasis being placed on correct breathing and body mechanics. Over the course of the familiarisation period, participants progressed to multiple repetitions and sets of low-to-moderate intensity. Immediately before testing, participants performed two warm-up sets of 2–5 repetitions at approximately 50 and 80% of perceived 1-RM separated by a 1 min rest interval. With verbal encouragement by the experimenter, each participant made 3 to 4 attempts until a 1-RM was attained and each was separated by at least 3 min rest intervals. The same experimenter assessed all successful 1-RM attempts.

Resistance training (RT)

Resistance training was performed in a gym environment using pneumatic resistance machines (Ab HUR Oy, Finland). Each training session consisted of fifteen heavy resistance exercises: chest press, body extension, biceps curl, triceps extension, leg press, lat curl, abdominal curl/back extension, pull-down/shoulder press, leg extension/leg curl, seated row, abduction/adduction. The intensity of the training session increased progressively across the weeks, from one set of 8-10 repetitions at 65% 1-RM in week one to 3 sets of 8-10 repetitions at 80% 1-RM in week 16. The concentric/eccentric phase of the contraction was set at 1-0-1 sec. A 1-RM was completed on each of the 15 exercises the week prior to the beginning of the programme, and at weeks 6 and 11 to account for any strength adaptations over the course of the 16-week training period.

Circuit training (CT)

The circuit training was performed using the pneumatic resistance machines (Ab HUR Oy, Finland). Each training session consisted of fifteen light-resistance exercises: chest press, body extension, biceps curl, triceps extension, leg press, rear deltoid fly, abdominals, back extension, lat pull-down, shoulder press, leg extension, leg curl, seated row, leg abduction, leg adduction. The resistance equipment is designed such that some pieces combined two exercises; usually antagonistic muscle groups (e.g., for example biceps/triceps, abduction/adduction). One circuit of 10 exercises was completed and in the case of a second circuit the antagonistic muscle group (to that exercised in the first circuit) was exercised. Participants exercised for 30 sec followed by a 30 sec rest period. A total of 20 repetitions were prescribed during each 30 sec exercise period. During the 30 sec rest period participants moved to the next station and prepared themselves for the next exercise period. A digital timed audio signal was used to indicate the start/end of the 30 sec exercise or rest session. Training over the duration of the programme was at 50% 1-RM and participants progressed in time and circuit number from one circuit (12 min) in week one to 5 circuits (60 min) in week 16. A 1-RM was completed on each of the 15 exercises the week prior to the beginning of the programme, and weeks 6, and 11 to account for any strength adaptations over the course of the 16-week training period.

Test Procedure

Body weight and composition measurements were assessed at baseline and immediately after the 16-week intervention. Participants reported to the University laboratory a minimum of four hours after their last food or fluid intake, wearing light-weight, comfortable clothing, having abstained from strenuous exercise and consumption of alcohol or salty foods in the previous 12 hours, and having voided a maximum of 10 minutes prior.

Body Composition Assessment

Anthropometry

Measurements of body height (stretch stature) to the nearest 0.1 cm using a Harpenden stadiometer, waist circumference to the nearest 0.2 cm with a tape (Futaba, Japan) and body weight to the nearest 5 g recorded on a digital scale (Tanita), were taken when participants were in a fasted state and immediately after they voided.

Dual Energy X-ray Absorptiometry (*DXA).* Whole-body and regional (trunk, arm, and leg) lean and fat tissue were determined by DXA (DPX-L; Lunar Radiation Corp, Madison, WI) and scans analysed using ADULT software, version 3.6. Using specific anatomic landmarks, the legs and arms are isolated on the skeletal X-ray planogram (anterior view). The arm encompasses all soft tissue extending from the centre of the arm socket to the tips of the phalanges, and contact with the ribs, pelvis, or greater trochanter is avoided. The leg consists of all soft tissue extending from an angled line drawn through the femoral neck to the tips of the phalanges. The system software provides the total mass, ratio of soft tissue attenuations, and bone mineral mass for the isolated regions. The ratio of soft tissue attenuation for each region was used to divide bone mineral–free tissue of the extremities into fat and lean components. Limb fat and lean tissue were calculated from the sum of arm and leg fat and lean tissues, respectively.

Data treatment and statistical analysis

The absolute amount of exercise prescribed was quantified by calculating the total amount of weight (tonnage expressed in kg) that was prescribed based on participants' 1-RM values. The absolute amount of exercise actually completed was measured by calculating the accumulative tonnage lifted. A completion index was also calculated using the following formula:

$$\frac{(\text{tonnage completed} - \text{tonnage prescribed}) \times 100}{(\text{tonnage prescribed})}$$

To the best of our knowledge the completion index has not been used previously in this context. Therefore, the formula used to derive the completion index provides a novel measure of the extent to which participants over- or under-completed exercise relative to the amount of exercise prescribed. A negative completion index indicated that the amount of exercise completed was lower than the amount prescribed, whereas a positive completion index indicated the amount of exercise completed was greater than the amount prescribed. The greater the completion index (+ve or -ve), the greater the differential between the amounts of exercise prescribed and completed; a completion index of zero indicated that the amount of exercise completed was equal to the prescription. To assess the changes in body fat and composition induced by the 16-week training programmes the differences between baseline and 16 weeks were calculated. Comparisons between the training groups were performed for each of the dependent variables using a 3-way mixed ANOVA, with gender and training group (CT and RT) as the between subject factor, and tonnage (prescribed, completed) as the repeated factor. Differences between pairs of training groups were assessed using Bonferroni corrections. Statistical analyses were undertaken using SPSS (version 14) with significance for all analyses set at $P < 0.05$.

Results

Prescribed versus Completed exercise

The absolute amount of exercise completed (i.e., tonnage lifted) by the CT group was significantly greater than the amount prescribed (*P=0.002*). While the RT group consistently lifted less than the amount prescribed, the difference was not statistically significant. Men were prescribed and lifted significantly more tonnage than women (*P=0.016*). Figure 1 shows the absolute amounts of exercise prescribed and completed for men and women in the RT and CT groups.

Completion index

The mean (± SD) completion indices for the CT and RT groups were +26% (±21.7) and -7% (±3.0) respectively. Therefore, there was a larger individual variability in the CT group and a higher than prescribed completion compared with the RT group. The difference in completion index between the two groups was significant (*P<0.0001*). There was no significant difference between genders in the completion index for either group (see Table 2).

Figure 1 and Table 2 about here

Body weight and composition

The mean (±SD) fat mass loss in the CT (-3.40 ±2.13kg) group was significantly greater than the RT (-1.66 ±1.89kg) group (*P=0.022*). Table 2 shows that the difference in the mean change in fat mass between females in the CT group (4.07 ±2.56kg) and RT group (0.96 ±0.91kg) contributed markedly to the difference between the training groups. However, the interaction between training group and gender just failed to reach significance (*P=0.054*). There was no significant difference between men (2.48 ±1.90kg) and women (2.52 ±2.46kg) in changes in fat mass when data from the two training groups were pooled.

Discussion

This study demonstrates two important phenomena regarding the relationship between the amounts of exercise prescribed and completed. Firstly, two different modes of training exerted different effects on the amount of exercise completed relative to the amount prescribed. Secondly, men and women did not differ in the extent to which they over- or under-completed their prescribed exercise target. The identification of under- and over-completers of prescribed exercise provides strong rationale for monitoring the amount of exercise completed in exercise intervention studies. The effectiveness of an intervention depends on compliance (Manninen *et al*, 1998; Laurance *et al*, 2003) – these data confirm that compliance, and the amount of exercise completed will influence the effectiveness of exercise to promote weight and fat loss.

The marked differential between prescribed and completed exercise in the CT group in the current study suggests that there is more opportunity to increase the work load with a light resistance circuit training intervention compared with traditional resistance training; therefore there is greater capacity to over complete in the CT sessions. On one hand this is not surprising given the differences in maximum repetitions possible for each of the CT (50%1RM) and RT (80%1RM) prescriptions. It is commonly reported that at 50%1RM, 19-20 repetitions are theoretically possible prior to fatigue, whereas at 80%1RM the range is 8-12 repetitions. However, there is considerably more between-individual variability in the number of repetitions which can be completed before fatigue at 50%1RM, ranging up to 50 repetitions in endurance trained wrestlers (Zatsiorsky and Kraemer, 2006). The implication is that the predicted training load for CT had a greater chance of being over completed if participants were lifting to fatigue on each set. However, this was not the case as the current CT program had a time restriction of 30 sec per set. Therefore, even for an individual with high muscular endurance who may be able to complete well in excess of 20 repetitions at 50%1RM, there is still a limit to the number of repetitions which can be completed with correct form in 30 seconds. Therefore for CT, the number of repetitions completed was both a function of fatigability and time.

With the exception of two participants, the CT group consistently over-completed relative to the prescribed amount. Although, this has been reported previously in studies using athletes (Hewson and Hopkins, 1995; Stewart and Hopkins, 1997), as far as we know this phenomenon has not been reported in overweight or obese sedentary individuals. Without exception, all participants in the RT group under-completed. The lack of over-completion in the RT group is not surprising. The nature of resistance training inherently restricts the opportunity to over-complete the amount of training prescribed; there is a ceiling work load due to the inherent design of the tonnage prescription being based on 1-RM.

With respect to effectiveness, the results of our study suggest that a novel form of light-resistance circuit training produces marked reduction in body fat predominantly in females. This is in contrast to some evidence which suggests that the exercise-induced reductions in body weight and fat mass are more pronounced in males compared with females (Ballor and Keesey, 1991; Westerterp *et al*, 1992; Gleim, 1993; Donnelly *et al*, 2003). However, in these studies, the interventions typically involved aerobic exercise, and in most cases, not the same level of monitoring and supervision as in our study. Therefore, this gender- and training-specific effect could be due to a combination of the novel modality of exercise and the level of supervision. The improved reduction in body fat observed in females in the CT group was unlikely to be due to an increase in the amount of work completed. In fact, by design, the absolute amount of tonnage lifted by the women was significantly less compared with the men. There is some evidence that CT, when compared with aerobic training, elicits greater perturbations in cariorespiratory factors during the exercise, and is associated with greater energy expenditure and a higher respiratory exchange ratio (RER) during the exercise session and in the first five minutes of recovery (Braun et al 2005). Therefore, it is possible that a greater excess post-exercise oxygen consumption (EPOC) associated with the CT partly contributed to the increase in fat mass. However, this effect has also been demonstrated in males (Burleson et al, 1998), so it is not certain why in our study the increase in fat mass loss was more marked in females.

The lack of a significant difference in compliance index between men and women confirms that the women did not over-complete more than the men in the CT group. Wallace *et al* (1995) also showed that there is no difference between men and women in the proportion who met the prescribed target of exercise intensity.

Therefore, our data provide further support that circuit training is more beneficial than traditional resistance training at promoting fat loss (Mosher *et al*, 1998; Dolezal and Potteiger, 1998; Maiorana *et al*, 2002; Park *et al*, 2003; Takeshima *et al*, 2004; Balducci *et al*, 2004; Chtara *et al*, 2005). This has important implications for exercise adherence because it demonstrates the ability of overweight and obese individuals to tolerate and benefit from resistance training and light-resistance circuit training. We did not collect any measures of perceived tolerance or difficulty of exercise training such as rating of perceived exertion. Therefore, we acknowledge that we can only assume that the obese tolerated both modes of exercise training since they completed this study. Evidence which provides information about tolerance and perceived difficulty of exercise in obese individuals is required.

Another key feature of this study is the ability of exercise to improve body composition despite a lack of loss in body weight. Therefore, without the body composition measurements, this effect would have been overlooked. There is a need to include body composition data, and other markers of health, rather than assessing the effectiveness of exercise based exclusively on body weight (King et al, 2009).

The light-resistance training provides support for introducing more novel and alternative methods of activity-induced weight control for obese individuals (Mosher *et al*, 1998; Kaikkonen *et al*, 2000). With the exception of extreme levels of obesity (e.g., > 45 kg/m^2) there is no reason why obese individuals do not have the capacity to participate in exercise – in particular high-intensity exercise (King *et al*, 2005). High-intensity exercise has been promoted as a useful method of weight loss (Tremblay *et al*, 1994; Hunter *et al*, 1998), whereas others propose that moderate activity is more effective at increasing daily energy expenditure (e.g., Westerterp, 2001).

The main strength and novelty of the current study are the opportunity to report the comparison of exercise prescribed with exercise completed. Although the participants self-recorded the amount of weight lifted and number of repetitions, the sessions were supervised. We accept that participants could have misreported, however, this is unlikely given the level of control exerted and supervision provided. Therefore, an important feature of this intervention study – which differs from most others – is that the exercise was supervised and controlled. Typically, other studies have made assumptions about work completed, or relied on self-report data from home-based interventions. There is evidence that obese and overweight individuals over-report their physical activity which is associated with poorer weight loss (Lichtman *et al*, 1992; Jakicic *et al*, 1998;*;* Norman *et al*, 2001; Walsh *et al*, 2004).

However, a systematic bias in misreporting in the CT group only would have had to occur for this to be the case; which is unlikely. It is also worth noting, that despite the over-completion of exercise prescribed to the CT group, there were no reports of musculoskeletal injuries by participants.

In conclusion, these data reveal differences in the amounts of exercise prescribed and completed between two different types of exercise training. Men and women over-complete to the same extent when prescribed a novel type of low-resistance training compared with traditional resistance training. This mode of training has important implications for exercise compliance and provides an alternative type of training. Females appear to be more responsive to light-resistance training compared with males. Collectively, these data provide further justification of measuring the actual exercise completed when evaluating the effectiveness of exercise interventions.

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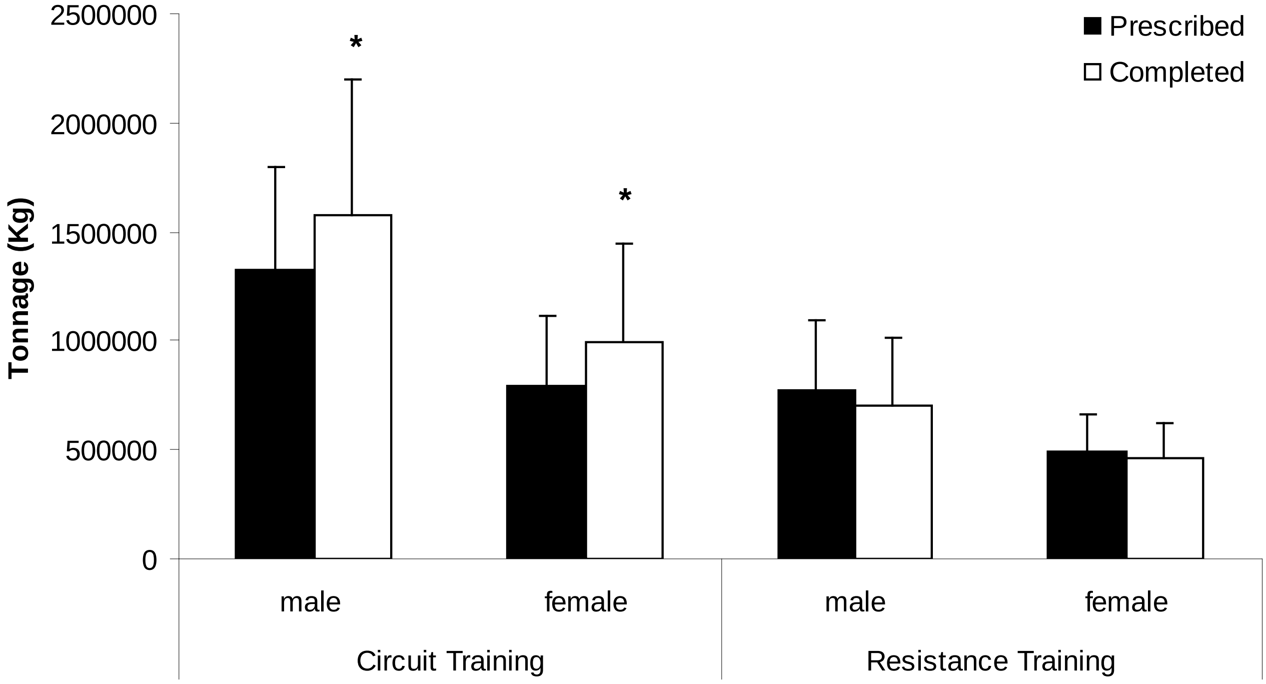
Table 1. Mean (±SD) subject characteristics at baseline by gender and training group for participants (n=32) who completed the study.

	CT Male (n=8)	CT Female (n=8)	RT Male (n=8)	RT Female (n=8)
Age (yr)	38.2 (±4.8)	40.5 (±5.0)	39.9 (±4.5)	38.8 (±4.8)
Height (m)	1.80 (±0.06)	1.64 (±0.04)	1.80 (±0.07)	1.67 (±0.03)
Weight (kg)	105.4 (±19.4)	90.1 (±14.7)	107.6 (±14.5)	86.4 (±4.9)
BMI kg/m^2	32.7 (±5.4)	33.4 (±4.6)	33.1 (±3.3)	30.8 (±2.1)

Table 2. Mean (±SD) changes in body weight and composition after 16 weeks of training for 32 participants. The completion index (%) indicates the degree of over- and under-completion of exercise relative to the amount prescribed.

	CT Male (n=8)	CT Female (n=8)	RT Male (n=8)	RT Female (n=8)
Change in FM (kg)	-2.64 (±1.28)	-4.07 (±2.56)	-2.35 (±2.40)	-0.96 (±0.91)
Change in LBM (kg)	-0.47 (±2.50)	1.46 (±1.45)	2.21 (±2.82)	1.09 (±0.76)
Change in body weight (kg)	-3.08 (±2.22)	-2.62 (±2.87)	-0.14 (±3.40)	0.13 (±1.60)
Completion index (%)	23.8 (±14.9)	28.2 (±27.8)	-8.0 (±2.5)	-6.9 (±3.4)

Figure 1. Mean (±SD) absolute amount of exercise (tonnage) prescribed and completed. Data from 32 participants who completed the study. 8 males and 8 females in each training group.



* Completed tonnage significantly different from prescribed (p<0.001)