THE ACUTE PHYSIOLOGICAL RESPONSES TO A UNIVERSITY STEP AEROBICS SESSION

submitted by

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ABSTRACT

The Sport and Recreation Service of Glasgow University has introduced a step aerobics class called "Uni-Step" to its range of exercise classes. It has been suggested that step aerobics is a suitable exercise modality for developing cardiovascular fitness and for promoting weight loss in healthy adults. These assumptions are based on the specific step heights and choreography utilised in previous studies. Exercise intensity is commonly estimated using heart rate (HR) or Ratings of Perceived Exertion (RPE); however, neither may accurately predict intensity during step aerobic exercise. The aim of this study was to provide cardiovascular and metabolic data for Uni-Step at three different step heights, and to evaluate the use of heart rate (%HR $_{max}$), %Heart Rate Reserve (%HRR) and RPE for the estimation of exercise intensity during this mode.

Ten healthy females (22 ± 2.2 years) (mean ± S.D.), who were regular participants in step aerobics, performed a 40 minute Uni-Step routine as demonstrated on a TV monitor, on a 6" (15.2 cm), 8" (20.3 cm) and 10" (25.4 cm) step (STEP6, STEP8 and STEP10) on separate occasions. The order of testing was randomised. Oxygen uptake ($\dot{V}O_2$), HR and RPE were recorded throughout each test. Expired air was collected continuously in Douglas bags (12 samples). Heart rate was recorded every 15 s using a Polar 4000 portable heart rate monitor. RPE was measured 30 s before the end of each sample of expired air using the Borg 6 - 20 scale. Total energy expenditure was estimated using the Weir formula (Weir, 1949). Maximum oxygen uptake and maximum heart rate were determined using a continuous treadmill protocol. All four tests took place within a three week period.

Repeated measures analysis of variance showed a significant increase ($P < 0.001$) in mean $\dot{V}O_2$, mean HR, mean RPE and total energy expenditure with each increase in step height. These results are summarised in Table 1. Correlations indicated a strong positive relationship between $\%\dot{V}O_{2\,max}$ and HR ($r = 0.90$ at STEP6, 0.94 at STEP8 and 0.96 at STEP10 for both $\%HR_{max}$ and %HRR) and a less good relationship between $\%\dot{V}O_{2\,max}$ and RPE ($r = 0.61$ at STEP6, 0.66 at STEP8 and 0.79 at STEP10) (r values are median correlation coefficients for all ten subjects).

Table 1. Oxygen uptake ($\dot{V}O_2$), heart rate (HR), ratings of perceived exertion (RPE) and total energy expenditure (means and standard deviations) at each step height.

	STEP6	STEP8	STEP10
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	21.5 ± 2.1	23.4 ± 2.1	26.4 ± 1.9
$\%\dot{V}O_{2\,max}$	45.6 ± 6.6	51.6 ± 3.9	56.2 ± 7.3
HR ($beats \cdot min^{-1}$)	140 ± 17	150 ± 10	158 ± 13
%HRR	57.2 ± 8.5	63.6 ± 6.0	70.1 ± 7.7
$\%HR_{max}$	70.2 ± 7.5	75.0 ± 4.7	79.3 ± 5.5
RPE (Borg 6-20 Scale)	12.3 ± 1.0	12.9 ± 1.1	13.4 ± 1.0
Total Energy Expenditure (kcal.)	209.7 ± 35.0	226.9 ± 31.8	255.1±34.2

According to the American College of Sports Medicine recommendations (A.C.S.M., 1990), Uni-Step, when performed on STEP8 and STEP10, is of a sufficient relative intensity to maintain or improve cardiovascular fitness. STEP6 could perhaps be of value to participants of a low fitness level. Heart rate exhibited a strong positive correlation with $\dot{V}O_2$, however, the mean heart rate responses suggested an overestimation of the actual metabolic cost of exercise at all three step heights during this mode (McArdle et al, 1994), and therefore caution would be advised if used as a predictor of intensity. The low correlations between $\%\dot{V}O_{2\,max}$ and RPE at STEP6 and STEP8 indicate that the use of RPE to prescribe intensity may have limitations. Uni-Step meets well recognised guidelines (A.C.S.M., 1990; Haskell, 1985; Haskell et al, 1985) for promoting changes in body composition when performed at STEP8 and STEP10.

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INTRODUCTION

Regular exercise is encouraged in the general population as it is widely believed that both health and fitness benefits may be gained (Haskell, 1994). A wide range of activities including walking, swimming and cycling have been suggested, along with guidelines for the optimal quantity of exercise for the improvement of aerobic fitness (A.C.S.M., 1990). It is important to establish that exercise is performed at an appropriate level for benefits to be achieved, however, exercise should also be comfortable and enjoyable in order to promote adherence.

The Sport and Recreation Service at the University of Glasgow has acknowledged the importance of providing a variety of activities to promote the health and fitness of the University population, and a step aerobics session called "Uni-Step" has recently been added to the wide range of group exercise sessions which are currently offered to students and staff.
Step aerobics was originally developed in the late 1980's by Reebok as a training initiative for the injured. It was adapted from bench stepping, which is a low impact activity, and it can be performed in time to rhythmic music. This exercise mode consists of choreographed lower body movements while stepping onto and off a bench or "step". The energy cost of step aerobics can be altered in a number of different ways. Step height, step rate and choreography can be varied, and arm movements can be incorporated.

Since its introduction in 1992, Uni-Step has become a popular class with an estimated attendance of 100 participants per week. Previous studies (Davidson, 1995; Grant et al, 1992; Grant et al, 1993; Sutherland et al, 1993) have investigated the physiological responses of a range of Glasgow University fitness sessions, however, to date, no physiological evaluation of Uni-Step has been carried out.

Uni-Step has individual characteristics; for example, in comparison to the other Glasgow University exercise sessions, it is performed very much in a limited space on and around the step, whereas other sessions involve some amount of walking or jogging around the gymnasium. The literature suggests that step aerobics is an acceptable mode for the development of aerobic fitness, however, each step session includes distinctive choreography, and therefore, specific evaluation of the Uni-Step session as an aerobic training mode is required, and has been requested by the staff of the Sport and Recreation Service at Glasgow University.

AEROBIC TRAINING

The aim of physical training is to bring about adaptations in the body which will cause it to function more effectively, and thereby improve performance in the activity for which the individual is training. In order for adaptation to take place, the body must be subjected to an overload, that is, a greater stress than is encountered on an everyday basis. Adaptations are specific to the physiologic and metabolic systems which are overloaded during the training activity. Aerobic activities, those which can be prolonged for more than a few minutes, stimulate improvements in those functions which are involved in the transport and use of oxygen, since the energy for muscular contraction during this type of activity is derived almost exclusively from aerobic metabolic reactions. Local changes occur in the specifically trained muscles, increasing their efficiency in the production of fuel for contraction. In addition, adaptations occur in the cardiovascular system which improve its ability to transport oxygen to the working muscles, and to carry away the waste products of metabolism. The local changes contribute to increased performance only during exercise modes in which the trained muscles are activated, whereas the cardiovascular improvements can, to a large extent, be carried over into other aerobic activities (McArdle et al, 1994).

TEST OF AEROBIC FITNESS

An individual's level of cardiovascular, or aerobic, fitness is generally determined by their maximum oxygen uptake ($\dot{V}O_{2max}$). This is a measure of the amount of oxygen which can be taken up by the cells of the body in a minute during maximum exercise, and reflects the body's capacity for aerobic metabolism. $\dot{V}O_{2\,max}$ is commonly measured by a continuous treadmill or cycle ergometer test during which the subject walks / runs or cycles at a steadily increasing workload until exhaustion (Shephard, 1984). Oxygen uptake and heart rate can be measured throughout the test and maximal values recorded. Several criteria have been established (B.A.S.S., 1988) in order to determine whether the maximum values recorded are actually representative of a true maximum effort. These are a decline or plateau in $\dot{V}O_2$ with an increase in workload such that there is a difference in $\dot{V}O_2$ of less than or equal to 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$, a blood lactate concentration of greater than or equal to 8 $mmol \cdot l^{-1}$, a respiratory exchange ratio of greater than or equal to 1.15 or attainment of a heart rate within 10 $beats \cdot min^{-1}$ of the age predicted maximum heart rate.

IMPROVEMENT OF $\dot{V}O_{2\,max}$

An increase in $\dot{V}O_{2\,max}$ can be brought about with training, however, the magnitude of the increase can vary widely among individuals depending on the initial fitness level of the individual, the duration of the training programme and the training load (A.C.S.M., 1990).

The range of improvement in $\dot{V}O_{2\,max}$ in studies of 6 - 12 months in duration has been 5% - 30% $\dot{V}O_{2\,max}$. Larger changes in $\dot{V}O_{2\,max}$ have been reported for special populations, including subjects with very low initial fitness levels (A.C.S.M., 1990). Improvements in aerobic fitness tend to be inversely related to initial fitness level (Sharkey, 1970), and are directly related to the intensity, duration and frequency of training (A.C.S.M., 1990). The training load should be individualised according to current fitness level. Participants of low fitness can benefit from a lower training load than those with a higher level of fitness (Devries, 1971; Wenger & Bell, 1986). In fact, an unfit individual would be unable to sustain the same training load as that of an athlete. For example, a marathon runner can maintain an intensity of 80% $\dot{V}O_{2\,max}$ for over 2 hours in a race, whereas a sedentary person would become fatigued within minutes while exercising at this level (A.C.S.M., 1986). As training progresses, performance will normally improve so that the training load should be increased in order for further adaptation to occur.

RECOMMENDATIONS FOR AEROBIC TRAINING LOAD

The American College of Sports Medicine has produced recommendations for the quality and quantity of exercise, or training load, required for the maintenance or improvement of cardiorespiratory fitness in healthy adults (A.C.S.M., 1990). These recommendations are based upon evidence from previous research into the effects of aerobic training, and they encompass the mode, intensity, duration and frequency of training which can be modified to influence the magnitude of fitness improvements.

Mode

The types of activities suggested as most useful for the development of aerobic power are those which employ the large muscle groups of the body in continuous, rhythmic movement which can be sustained for a prolonged period (A.C.S.M., 1990). According to the A.C.S.M. (1986), endurance activities can be classified into two groups. Firstly, those in which the intensity of exercise

can be easily maintained at a steady level with little variation in heart rate response. This group includes running, cycling, swimming and other activities consisting of a repetitive movement pattern. The second group consists of activities such as dancing, figure skating and a variety of games and sports. Although not specifically mentioned by the A.C.S.M., step aerobics, a relatively new form of cardiovascular training, could belong to this category as it is similar in style to aerobic dance. Exercise intensity during aerobic dance is dependent on the particular manoeuvre being performed at a given time (Abernethy & Batman, 1994). The manoeuvres in step aerobics, which include a variety of choreographed steps on to and off a bench or step, coordinated with arm movements, are only performed for several repetitions before they are replaced by another combination. Thus, the ever changing nature of the movements would be unlikely to elicit a steady heart rate response.
Certain activities, such as running or jumping, are considered to be of a high impact nature and are more likely to produce injury than low impact and non weight bearing activities (A.C.S.M., 1990).

Intensity

There appears to be a minimum threshold level of intensity below which no adaptation to training occurs. The A.C.S.M. (1990) recommends a minimum intensity of 50% $\dot{V}O_{2max}$ for an improvement in aerobic fitness. However, they also accept that individuals with a low fitness level can benefit from a lower training stimulus and indicate a training intensity of 40% - 50% $\dot{V}O_{2\,max}$ for those individuals. From a review of the literature, McArdle et al (1994) suggest that 50% - 55% $\dot{V}O_{2max}$ is the minimum intensity which will provide a training effect. Other studies have suggested minimum training thresholds of 45% $\dot{V}O_2$

$_{max}$ (Badenhop et al, 1983) and as low as 20% $\dot{V}O_{2\,max}$ for a completely sedentary individual (Pollock, 1992). Haskell (1994) pointed out that exercising at a lower intensity than stated by the A.C.S.M. (1990) as a minimum guideline has been shown to produce improvement in aerobic capacity or performance in sedentary or elderly subjects. In general, a greater improvement in $\dot{V}O_{2\,max}$ can be expected with a higher intensity of training (Wenger & Bell, 1986).

Exercise intensity can be measured or prescribed using a percentage of $\dot{V}O_{2\,max}$ or maximum heart rate. The A.C.S.M. (1990) recommend an average training intensity of between 50% and 85% of $\dot{V}O_{2\,max}$ or maximum heart rate reserve (HRR) for the duration of an exercise session. Heart rate reserve (Karvonen et al, 1957) is the difference between maximum heart rate and resting heart rate. The heart rate training zone can be calculated as 50% - 85% of heart rate reserve plus resting heart rate. Davis & Convertino (1975) have shown that there is a good relationship between %HRR and the corresponding $\%\dot{V}O_{2\,max}$.
Training intensity can also be prescribed as 60% to 90% of maximum heart rate (HR_{max}). It should be noted that oxygen uptake is a direct measure of exercise intensity, whereas heart rate is simply an estimation, however, the use of heart rate may be of greater practical value in the general population since the measurement of oxygen uptake is not widely available. The estimation of exercise intensity by heart rate will be reviewed in a later section.

It is important to be able to monitor the intensity of exercise to ensure that it is kept within the training zone. A consistently low intensity would be unlikely to produce any improvement in aerobic fitness, whereas too high an intensity may involve an increased risk of muscular and skeletal injury, cardiac risk for certain individuals and reduced adherence (A.C.S.M., 1990).

Duration

Exercise duration for developing aerobic fitness should be 20 - 60 minutes per session (A.C.S.M., 1990). Exercise intensity and duration are interdependent. Similar improvements in aerobic fitness can be expected for both low intensity longer duration activity and high intensity shorter duration activity, as long as the minimum intensity threshold is reached and the total energy cost of both activities are equal (Burke & Franks, 1975; Sharkey, 1970; Wenger & Bell, 1986). Training durations of less than 20 minutes have yielded a training response (A.C.S.M., 1986), however, intensity was close to maximum, and therefore would not be recommended for the general population.

Frequency

The A.C.S.M. (1990) recommend a frequency of exercise of 3 - 5 times per week. Frequencies of 2 days per week can result in the development of aerobic power in less fit participants, however, Wenger & Bell (1986) suggest that fitter individuals with a $\dot{V}O_{2\,max}$ of greater than 50 $ml \cdot kg^{-1} \cdot min^{-1}$ require a frequency of at least 3 times per week for improvement to occur. Studies have shown that improvements in $\dot{V}O_{2\,max}$ tend to plateau as frequency is raised above 3 days per week (Crews & Roberts, 1976; Pollock & Wilmore, 1990) and that little added improvement is seen at a frequency of greater than 5 days per week (Pollock, 1973).

Exercise prescription for Sedentary Individuals

Wenger & Bell (1986) suggest that although maximal gains in aerobic power are elicited with intensities of 90% - 100% $\dot{V}O_{2\,max}$, durations of 35 - 45 minutes and frequencies of 4 times per week, they note that high intensity or frequency of exercise can lead to distress, muscle soreness, muscle strain injury and unnecessary fatigue. They state that lower intensities of exercise still produce effective changes in aerobic power and reduce the risk of injury in the sedentary population. Milesis et al (1976) have shown that the incidence of injury is much greater in beginners who exercise for durations longer than 30 minutes.

The A.C.S.M. (1986) suggest that sedentary individuals should begin exercising at a moderate intensity of 40% - 60% of $\dot{V}O_{2\,max}$ with the duration set at a comfortable level for the first few weeks of exercise. Thereafter, both intensity and duration can be increased based on the individual's physiological response. The average conditioning intensity for healthy adults is usually between 60% - 70% of $\dot{V}O_{2\,max}$ with a duration of 20 - 30 minutes. They advise that at the beginning of a training programme for a sedentary person, excessive stress to bones and joints unused to exercise may occur, and therefore exercise sessions should be alternated with rest days until some adaptation to exercise has been achieved (A.C.S.M., 1986).

STEP TRAINING

Step aerobics is generally a low impact activity, which by definition means that at least one foot remains on the floor or on the step at all times, although high impact movements requiring hopping or jumping can be incorporated. There appears to be a decreased incidence and severity of lower extremity injury for low impact aerobics when compared to high impact aerobics as measured by self report following an eight week period of training at the same intensity, duration and frequency for each mode (Harnischfeger et al, 1988), however, there is limited information on injury rates for step aerobics.

Both Requa & Garrick (1993) and Crisp (1994) have suggested that the injury rate for step aerobics is approximately the same as that for traditional or high impact aerobics. Requa & Garrick (1993) recorded self reported injury rates for various types of aerobic dance, including step aerobics, in 986 exercisers over more than 13000 hours of participation. Crisp (1994) reported only the findings of his study. Another recent study (Byrnes et al, 1993) compared the incidence and severity of self reported injury among running, race walking and step aerobics performed at the same intensity, duration and frequency over a 28 week training period. They suggested that the severity of injury during both race walking and step training was lower compared to running training.

METHODS OF ALTERING THE INTENSITY OF STEP AEROBICS

Despite its low impact status, step aerobics can be performed at a wide range of intensities. The main approaches to altering intensity during step aerobics include the adjustment of one or more of the following factors: step height, step rate, choreography and the use of hand held weights.

Step Height

The height of the step is typically adjustable in increments of 2", and the most commonly studied heights range from 4" to 12". However, Crisp (1994) has indicated that raising the step too high may infringe upon the safety of this mode of exercise due to increased muscular strain and a subsequently higher potential for injury, although this claim has not actually been investigated. Crisp (1994) has suggested that step heights of 10" or above should not be used.

Several studies (Olson et al, 1991; Stanforth & Stanforth, 1993; Thomas & Long, 1991; Whitney et al, 1993; Woodby-Brown et al, 1993) have documented a significant increase in $\dot{V}O_2$ with an increase in step height. A summary of the relevant findings can be found in Table 1. Some of these studies have, to date, been published only in abstract form, and therefore, information is limited and results have been reported in differing formats. The step rate utilised in all studies corresponded to a cadence of 120 beats·min^{-1}, which allowed 30 cycles of stepping onto and off the step each minute, unless otherwise stated. Both Olson et al (1991) and Woodby-Brown et al (1993) reported $\dot{V}O_2$ during step aerobics at a range of step heights, and it is clear that the intensity of this exercise mode can be increased by increasing the height of the step.

It should be pointed out that although similar observations have been made in several studies involving step aerobics, they are specific to the particular choreography, step heights and step rates utilised in those investigations, and therefore results may not be directly comparable, and generalisations about

TABLE 1. SUMMARY OF RESULTS OF PREVIOUS STUDIES RELATING TO STEP HEIGHT AND OXYGEN COST

Study	Subjects	Results				
Olson et al (1991)	10 active females mean age = 30.4 ± 8.2 yr.	Significant increase in $\dot{V}O_2$ with increase in step height.				
		Step height	6"	8"	10"	12"
		$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	28.4	31.3	33.8	37.3
Woodby-Brown et al (1993)	10 females experienced in step aerobics. mean age = 29.0 ± 4.5 yr.	Significant increase in $\dot{V}O_2$ with increase in step height.				
		Step height	4"	8"	10"	
		$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	19.8	25.3	28.6	

TABLE 1. SUMMARY OF RESULTS OF PREVIOUS STUDIES RELATING TO STEP HEIGHT AND OXYGEN COST (Continued)

Study	Subjects	Results
Stanforth & Stanforth (1993) (Abstract)	26 females (mean age not reported)	Significant increase in $\dot{V}O_2$ with each increase in step height of 2" between 6" and 10".
Thomas & Long (1991) (Abstract)	10 experienced female step instructors (mean age not reported)	Significant increase in $\dot{V}O_2$ with increase in step height at step rates of 120 and 140 steps·min^{-1} (20% increase from 6" - 12").
Whitney et al (1993) (Abstract)	18 females aged 20 - 30 yr. (mean age not reported)	Significant increase in $\dot{V}O_2$ with increase in step height for each of four arm patterns (40% increase in $\dot{V}O_2$ from 4"-8", 90% increase from 4" - 12").

the physiological effects of this mode of exercise may be difficult to make.

Step Rate

A step routine is normally performed at a fairly constant cadence throughout, and the length of an individual's leg may affect his or her ability to maintain the cadence. Crisp (1994) suggested that the most efficient frequency of stepping is inversely proportional to leg length, and that participants with short legs may find faster rates of stepping easier to perform than participants with long legs, although this claim was not substantiated. United Kingdom guidelines recommend stepping rates according to music speeds from 118 to 122 beats·min^{-1} (Crisp, 1994).

Goss et al (1989) reported a direct relationship between $\dot{V}O_2$ and step rate in a study in which male subjects performed basic step without simultaneous upper body movement at two different step rates on a 13.5" step. "Basic step" is the repetitive pattern of stepping up onto the step with the leading foot, bringing the other foot onto the step, stepping back off with the leading foot and bringing the trailing foot back onto the floor. $\dot{V}O_2$ rose from 26.1 ml·kg^{-1}·min^{-1} at a cadence of 80 beats·min^{-1} to 38.9 ml·kg^{-1}·min^{-1} at 120 beats·min^{-1}, an increase in intensity of 33%. Thomas & Long (1991) showed that an increase in the cadence of a step routine from 120 beats·min^{-1} to 140 beats·min^{-1} resulted in a 6% - 7% increase in oxygen uptake.

Choreography

Crisp (1994) suggested that variations in choreography may increase intensity during stepping by up to 50%, although no results were presented to verify this statement. In a study by Hayakawa et al (1994) using an 8" step, basic step elicited an intensity of 63.2% $\dot{V}O_{2\ max}$ while “lunge step”, a movement pattern in which propulsion is required, elicited an intensity of 81.0% $\dot{V}O_{2\ max}$.

From comparison of the $\dot{V}O_2$ values for step aerobics on 8" and 10" steps reported by Olson et al (1991) and Woodby-Brown et al (1993) (see Table 1), it is apparent that the intensity of exercise was lower in the latter study. Woodby-Brown et al (1993) suggested that this may be due to minimal travelling movements and high intensity movements such as lunges incorporated into their step routine whereas the routine in the study by Olson et al (1991) included plyometric lunges.

Arm movements can be manipulated to produce a higher or lower energy cost. Crisp (1994) estimated that adding arm movements to a step routine may increase intensity by 12%, although again no evidence was presented to support this assertion. Whitney et al (1993) studied the differences in $\dot{V}O_2$ when stepping was accompanied by four common arm movement patterns. These were arms at sides, pulling action with arms low, pulling action with arms front and pulling action with arms overhead. There was no significant difference in $\dot{V}O_2$ between arms low and in front, but $\dot{V}O_2$ was significantly higher when the arms were overhead and was significantly lower when the arms were held at the sides.

Use of Hand Held Weights

The effect of using hand held weights on the energy cost of step aerobics on an 8" step has been studied (Olson et al, 1991; Wang et al, 1993). Both studies found no significant increase in energy cost with 0.45 kg. hand held weights. Olson et al (1991) reported a modest increase in $\dot{V}O_2$ from 29.7 $ml \cdot kg^{-1} \cdot min^{-1}$ to 31.8 $ml \cdot kg^{-1} \cdot min^{-1}$ with 0.91 kg. hand held weights. The authors noted that subjects complained of acute muscular pain and soreness, particularly in the medial deltoid region, during all trials with hand held weights.

Goss et al (1989) reported a significant increase in $\dot{V}O_2$ from 26.1 $ml \cdot kg^{-1} \cdot min^{-1}$ to 30.5 $ml \cdot kg^{-1} \cdot min^{-1}$ when 0.91 kg. hand weights were pumped rhythmically during basic step at a cadence of 80 $beats \cdot min^{-1}$ and an increase from 38.9 $ml \cdot kg^{-1} \cdot min^{-1}$ to 45.0 $ml \cdot kg^{-1} \cdot min^{-1}$ at 120 $beats \cdot min^{-1}$. There was a further increase in $\dot{V}O_2$ with 1.82 kg. weights, however, it was not significant. Stanforth & Stanforth (1993) utilised a weight belt with an increasing amount of weight over the duration of a step routine and found that 2.5 kg of weight must be added to equal the increase in $\dot{V}O_2$ brought about by increasing the bench height by only 1 cm.

In summary, an increase in step height has been shown to significantly increase exercise intensity. A substantial advantage of an adjustable step height is that participants of a wide range of fitness levels can perform the same routine by choosing the appropriate height for their level.
Step rate should be kept within a narrow range for participants' comfort and

safety, and therefore offers little scope for varying intensity.

Variations in choreography are thought to produce up to 50% differences in intensity. It has been shown that movements which require propulsion, or high impact moves, can increase intensity by 22% (Hayakawa et al, 1994) and variations in arm patterns can increase intensity by 12% (Whitney et al, 1993). The use of hand held weights results in a small increase in intensity (7% - 14%) however, it can involve accompanying muscular discomfort.

Therefore, it appears that the most effective means of increasing intensity in step aerobics would be to vary the choreography and for the participant to vary the step height according to his or her ability.

RELATIVE EXERCISE INTENSITY DURING STEP AEROBICS

Recent studies have suggested that step aerobics meets the A.C.S.M. requirements for exercise intensity (Forte et al, 1995; Olson et al, 1991; Petersen et al, 1993; Woodby-Brown et al, 1993) when it is performed on step heights between 6" and 12". A summary of the results of these studies can be found in Table 2.

Woodby-Brown et al (1993) recorded a mean relative intensity of 45% $\dot{V}O_{2max}$ on a 4" step. This may be useful for a previously sedentary beginner as the A.C.S.M. (1990) indicate that individuals with a low fitness level could achieve an improvement with a training intensity as low as 40% - 50% of $\dot{V}O_{2max}$.

In addition, two studies reported the relative intensity of basic stepping. Goss et al (1989) measured an intensity of 47.1% $\dot{V}O_{2max}$ at a cadence of 80 beats·min^{-1} and 70.2% $\dot{V}O_{2max}$ at 120 beats·min^{-1} on a 13.5" step ($\dot{V}O_{2max}$ =

55.4 $ml \cdot kg^{-1} \cdot min^{-1}$). Hayakawa et al (1994), using an 8" step, noted an intensity of 63.2% $\dot{V}O_{2\,max}$ for basic step and 81.0% $\dot{V}O_{2\,max}$ for lunge step ($\dot{V}O_{2\,max}$ = 43.4 $ml \cdot kg^{-1} \cdot min^{-1}$). Therefore, it appears that the relative intensity of step aerobics can be very different dependent on the specific movement pattern.

Thus, on the basis of the A.C.S.M. (1990) guidelines for prescription of exercise intensity, step aerobics appears to be a suitable exercise modality for maintaining or developing the cardiorespiratory fitness of healthy adults of a wide range of fitness levels when performed at step heights between 6" and 12".

TABLE 2. RELATIVE EXERCISE INTENSITY DURING STEP AEROBICS

Study	Subjects	$\dot{V}O_{2max}$ (mean (S.D.)) ($ml \cdot kg^{-1} \cdot min^{-1}$)	Step Height	Relative Intensity ($\%\dot{V}O_{2max}$)	
Forte et al (1996)	4 males, 6 females	34.1 (5.3) (predicted)	Unspecified	58.3	
	mean age = 58.7 yr.				
Olson et al (1991)	10 active females	47.5 (5.2)	6"	59.8	
	mean age = 30.4 yr.		8"	65.9	
			10"	71.2	
			12"	78.5	
Petersen et al (1993)	10 healthy females	48.4 (8)*	10"	58.4	
	mean age = 27 yr.				
Woodby-Brown et al	10 females	43.6 (6.9)	4"	45*	(* decimal
(1993)	aged 19 - 34 yr.		8"	56*	places
	Experienced in Step Aerobics		10"	66*	not reported)

METHODS OF MONITORING EXERCISE INTENSITY

Exercise intensity is a vital part of the exercise prescription. The general practice for establishing aerobic training intensity is to prescribe a training range relative to maximum oxygen uptake.

As noted previously, oxygen uptake ($\dot{V}O_2$) is a direct measurement of exercise intensity, however, it requires expensive technical equipment and trained personnel to measure. It would be impractical to prescribe and monitor exercise intensity in this way in the general population, and therefore, it would be advantageous to be able to estimate exercise intensity rather than to measure it directly. The most popular methods of estimation are the use of target heart rates and the use of ratings of perceived exertion. Both methods will be described below.

TARGET HEART RATE

A linear relationship between heart rate (HR) and oxygen uptake has been demonstrated for running and cycling (Franklin et al, 1980), and since heart rate is fairly simple to measure by the exerciser, by palpation of the carotid or radial arteries, it is widely used to prescribe and monitor exercise intensity on the basis of this relationship (Birk & Birk, 1987).

When an individual begins to exercise, there is an increase in demand for oxygen from the working muscles. To cater for this demand, there is an increase in cardiac output, that is, the amount of blood pumped by the heart per minute. This extra blood provides the additional oxygen required.

Throughout the majority of the work range from rest to maximum exercise, there is a close linkage between cardiac output and $\dot{V}O_2$. Cardiac output is the product of the stroke volume of the heart, the amount of blood pumped per beat, and the heart rate. At low levels of exercise, the increase in cardiac output is brought about by an increase in both stroke volume and heart rate. Therefore, cardiac output and $\dot{V}O_2$ do not increase proportionally with heart rate at this level of intensity. Maximum stroke volume is reached at an intensity of about 40% - 50% $\dot{V}O_{2\,max}$ (McArdle et al, 1994), and the relationship between heart rate and $\dot{V}O_2$ becomes linear at this point since further increases in cardiac output are due solely to increased heart rate. At very high intensities, above 95% $\dot{V}O_{2\,max}$ (Franklin et al, 1980), $\dot{V}O_2$ increases relatively more than heart rate does, the relation becoming curvilinear. This is due to an increase in the arterio-venous oxygen difference.

It therefore appears that, within the linear portion of the relationship, which includes the training range recommended by the A.C.S.M., the heart rate response to exercise could be used to predict $\dot{V}O_2$.

Methods of Determining Target Heart Rate

There are two main methods of computing the training heart rate (A.C.S.M., 1986) without the direct determination of the relationship between submaximal heart rate and $\dot{V}O_2$. For either to be effective, measurement or prediction of HR_{max} and substantiation of the submaximal HR-$\dot{V}O_2$ relationship for the population are required.

The first of these is the heart rate reserve method of Karvonen et al (1957). As stated previously, heart rate reserve is the difference between maximum heart rate and resting heart rate. The heart rate training zone can be calculated as 50% - 85% of heart rate reserve plus resting heart rate.

This method requires both the measurement of resting heart rate and the measurement or estimation of maximum heart rate. Resting heart rates are often difficult to establish accurately since they can be influenced by several non metabolic factors such as emotion, posture and time of day (Astrand & Rodahl, 1986), however, Davis & Convertino (1975) suggest that variation in the resting heart rate has little or no effect on the heart rate reserve. Maximum heart rate can be estimated by the equation HR_{max} ($beats{\cdot}min^{-1}$) = 220 - age (yr.), although there is a standard deviation of plus or minus 10 $beats{\cdot}min^{-1}$ within any age group (Astrand & Rodahl, 1986).

Davis & Convertino (1975) have indicated that $\%\dot{V}O_{2\,max}$ and %HRR are interchangeable between 50% and 85% $\dot{V}O_{2\,max}$, however, a more recent study by Wier & Jackson (1992) has suggested that $\%\dot{V}O_{2\,max}$ and %HRR are not equivalent indices of exercise intensity. It was shown that 70% $\dot{V}O_{2\,max}$ was equivalent to 70% HRR_{max} for both male and female subjects during a maximal treadmill test. However, above this level, %HRR overestimated $\%\dot{V}O_2$, with the error becoming progressively larger as intensity increased, and below this level, %HRR underestimated $\%\dot{V}O_2$, with the error becoming progressively larger as intensity decreased.

A similar method for establishing training heart rate is to prescribe it as a percentage of estimated maximum heart rate, with the A.C.S.M. recommending a training zone of 60% - 90% of HR_{max}. According to Pollock & Wilmore (1990), 50% - 74% $\dot{V}O_{2\,max}$ is equivalent to 60% - 79% HR_{max} and 75% - 84% $\dot{V}O_{2\,max}$ is equivalent to 80% - 89% HR_{max}.

A disadvantage of methods which do not directly establish the individual HR-$\dot{V}O_2$ relationship is inter-individual variation. The relationship tends to be linear regardless of age or sex, however, the rate of change of heart rate with respect to $\dot{V}O_2$ may differ from person to person. Therefore, the same heart rate does not necessarily correspond to the same $\dot{V}O_2$ as that of another individual. Standard practice is to use HR-$\dot{V}O_2$ regression equations which have been calculated using data from males and apply them to individuals of both sexes. Franklin et al (1980) found no sex related difference in the relationship between %$\dot{V}O_{2\,max}$ and %HR_{max}. This conclusion was based on the results of a number of studies on both men and women utilising different modes of exercise, and subjects with differing physical and physiological attributes. In contrast, Matheny & Swain (1991) showed from regression analysis of data from a maximal treadmill test that the relationship differed between males and females. They postulated that this was due to a greater reliance on heart rate to achieve a given $\dot{V}O_2$ in females. However, the meaning of this statement is unclear. It is assumed that the greater reliance on heart rate in females is due to a lower stroke volume. However, stroke volume reaches maximum at approximately 40% - 50% $\dot{V}O_{2\,max}$ (McArdle et al, 1994), and therefore, at greater intensities than this, both sexes would rely on heart rate in order to increase cardiac output.

Swain et al (1994) recently assessed the target heart rates recommended by the A.C.S.M. (1990) for both males and females during treadmill exercise. They found a significantly greater %HR_{max} at each tested level of %$\dot{V}O_{2\,max}$ between 40% and 85% $\dot{V}O_{2\,max}$ than expected from the A.C.S.M. (1990) values.

Thus, although the above two methods for establishing training heart rates are in common use, there is contradictory evidence for their efficacy.

It was noted earlier that the use of target heart rate methods which do not use direct measurement of the HR-$\dot{V}O_2$ relationship require that the relationship is substantiated for the population in question. It may also be necessary to validate the HR-$\dot{V}O_2$ relationship for the specific mode of exercise.
The linear relationship between $\dot{V}O_2$ and HR has been well established for running and cycling (Franklin et al, 1980), however, it has been suggested (Parker et al, 1989) that this relationship is disproportional during aerobic dance type exercise, in which there is typically a large upper body component, compared with lower body dominant activities (Parker et al, 1989).
The applicability of using heart rate to estimate $\dot{V}O_2$ during this mode of activity has therefore been questioned, and it has been suggested that the differences in the HR-$\dot{V}O_2$ relationship for this exercise mode should be taken into account in the development of an exercise prescription.

The HR-VO_2 Relationship in Arm versus Leg Exercise

A disproportionate relationship between heart rate and $\dot{V}O_2$ has been reported in other activities involving arm work. Several studies have shown that upper body exercise elicits a higher heart rate compared to leg exercise or combined arm and leg exercise at the same $\dot{V}O_2$ (Astrand et al, 1968; Bevegard et al, 1966; Stenberg et al, 1967; Toner et al, 1990; Vokac et al, 1975). These studies are summarised in Table 3.

TABLE 3. SUMMARY OF PREVIOUS STUDIES OF HEART RATE RESPONSE TO UPPER BODY EXERCISE

Study	Subjects	Results
Astrand et al (1968)	11 healthy, skilled carpenters, mean age = 27 yr. (range 20 - 36 yr.)	Higher heart rate (HR) and blood pressure (BP) were reported during nailing work above head and at head level than during nailing at bench level, which in turn produced a higher HR than cycling at the same $\dot{V}O_2$. This was mainly attributed to a higher sympathetic tone during arm exercise. In addition, nailing at or above head level introduced a static component which probably contributed to the higher HR and BP.
Bevegard et al (1966)	6 healthy males, mean age = 24 ± 1.3 yr.	Higher HR and lower stroke volume (SV) were reported in arm exercise than in leg exercise or combined exercise at a given submaximal $\dot{V}O_2$. It was suggested that the higher HR could be due to an increased sympathetic outflow in arm exercise.

TABLE 3. SUMMARY OF PREVIOUS STUDIES OF HEART RATE RESPONSE TO UPPER BODY EXERCISE

(Continued)

Study	Subjects	Results
Stenberg et al (1967)	4 healthy females aged 21 - 22 yr. 6 healthy males aged 20 - 39 yr.	A higher HR was reported in arm exercise than in leg exercise or combined exercise at a given submaximal $\dot{V}O_2$, except at lower workloads. A difference of 10 beats·min^{-1} in HR was found between arm and leg exercise at 30% $\dot{V}O_{2\,max}$ and a difference of 35 beats·min^{-1} was found at 60% $\dot{V}O_{2\,max}$. The higher HR at a given $\dot{V}O_2$ reflected a lower SV in arm exercise which was thought to be due to a decreased venous return. Also observed were a higher BP and total peripheral resistance in arm exercise.

TABLE 3. SUMMARY OF PREVIOUS STUDIES OF HEART RATE RESPONSE TO UPPER BODY EXERCISE

(Continued)

Study	Subjects	Results
Toner et al (1990)	6 males, mean age = 22.7 ± 4.2 yr.	A higher HR and lower SV were reported for arm only exercise compared to arm exercise combined with varying amounts of leg activity (25%,50%, 75% and 100% leg involvement) at three intensities. The suggested cause was decreased venous return due to decreased muscle pump activity.
Vokac et al (1975)	7 healthy males aged 22 - 25 yr.	HR was significantly higher in arm exercise than in leg exercise at a $\dot{V}O_2$ of 1.9 $l \cdot min^{-1}$. There was no significant difference in HR at a $\dot{V}O_2$ of 1.0 $l \cdot min^{-1}$. The higher HR in arm exercise reflected higher total peripheral resistance and mean arterial blood pressure.

A possible explanation for the higher heart rates observed during exercise involving the arms has been suggested (Astrand et al, 1968; Bevegard et al, 1966).

There is an increase in activity of sympathetic nerves in exercise which normally causes an increase in heart rate. The increase in sympathetic activity during leg exercise is directly related to intensity. Exercise with smaller muscle groups than the legs, such as the arms, appears to evoke a similar, and sometimes even greater, rise in sympathetic tone than that reported for leg exercise (Astrand et al, 1968), which would imply a greater rise in heart rate.

Several studies have reported higher catecholamine levels during arm exercise compared to leg exercise at the same $\dot{V}O_2$ (Davies et al, 1974; Hooker et al, 1990; Lewis et al, 1983), which may support the suggestion of a higher sympathetic tone during arm exercise, although Astrand & Rodahl (1986) have noted that plasma norepinephrine concentration is a relatively poor indicator of sympathetic activity due to its effective reuptake. When arm and leg exercise are performed at similar levels of $\dot{V}O_2$, the amount of work per unit cross sectional area of muscle is higher for arm exercise. This may be a contributing factor to the higher sympathetic tone (Astrand et al, 1968).

Although the supply of blood to exercising muscles is primarily controlled by local vasodilation in response to increased metabolic activity, the increased activity in sympathetic nerves also causes vascular dilation in the heart and active skeletal muscles, and vasoconstriction in other vascular beds (McArdle et al, 1994). The net outcome of these effects is the redistribution of the cardiac output to the exercising muscles, where the increased blood flow is most needed.

In arm exercise, where the total working muscle mass is smaller, the local vasodilation will overcome a smaller fraction of the increased sympathetic tone. Therefore, there will be an increased total peripheral resistance resulting in a higher mean arterial blood pressure in exercise involving a smaller muscle mass. A higher blood pressure at a given cardiac output will result in greater cardiovascular strain. Since the cardiac output at a given submaximal $\dot{V}O_2$ is similar in arm and leg exercise, at any submaximal level of work, there will be greater cardiovascular strain in arm exercise (McArdle et al, 1994).

Three of the five studies summarised in Table 3 reported higher blood pressure and total peripheral resistance in conjunction with higher heart rates during arm compared to leg exercise (Bevegard et al, 1966; Stenberg et al, 1967; Vokac et al, 1975) while Astrand et al (1968) reported a higher blood pressure.

Astrand et al (1968) showed that the position of the arms during arm exercise can have an effect on the heart rate. When arm exercise was performed above shoulder height, heart rate was higher in comparison to arm exercise with the arms below shoulder height. It was suggested that this response could be due to the introduction of a static component in holding the arms up. Static exercise has been shown to increase heart rate above the value expected from the observed level of $\dot{V}O_2$, and also to increase blood pressure (McArdle et al, 1994). This suggestion was supported by the finding of a large increase in heart rate and blood pressure when subjects stood with arms elevated without performing any exercise (Astrand et al, 1968).

The higher heart rate at a given $\dot{V}O_2$ reflected a lower stroke volume in arm work, as there was no difference in cardiac output between arm exercise and leg exercise or combined exercise (Bevegard, 1966; Stenberg, 1967; Toner, 1990).

Toner et al (1990) suggested that the lower stroke volume was caused by a decreased venous return due to less muscle pump activity during arm only exercise. It was found that by incorporating a small amount of lower body exercise (25% of total power output), stroke volume was maintained at all three levels of intensity studied, and the heart rate was not disproportionately increased.

In summary, it appears that the increased heart rate reported in arm exercise may be due to an increased sympathetic tone in exercise utilising smaller muscle groups or including a static component, and / or a decreased stroke volume in arm exercise due to decreased venous return as a consequence of less muscle pump activity in the lower body.

McArdle et al (1994) state that a greater metabolic and physiological strain accompanies arm exercise, and therefore, exercise prescriptions based on running or cycling cannot be applied to arm exercise.

Studies on Aerobic Dance Exercise

Several studies have investigated the HR-$\dot{V}O_2$ relationship during aerobic dance exercise, and although this exercise mode combines both arm and leg exercise, a disproportionately elevated heart rate response with respect to $\dot{V}O_2$ has been reported.

Parker et al (1989) compared the HR-$\dot{V}O_2$ relationships for treadmill exercise and aerobic dance exercise, and found a higher heart rate response in aerobic dance compared to jogging at the same $\dot{V}O_2$. They suggested that this finding could be due, at least in part, to increased sympathetic activity from the extensive use of overhead arm movements.

The results of several other studies are in agreement with those of Parker et al (1989). Data from a study by Hornsby et al (1991) showed that the metabolic cost of several dance exercise routines varied despite the fact that they were all performed at the same mean heart rate (70% HRR). It was suggested that these differences may be related to the total muscle mass involved in the different routines. A study by Williford et al (1989) showed a similar result in that two different styles of aerobic dance, low impact and high impact, were performed at the same heart rate, however, the $\dot{V}O_2$ measured for each was significantly different. It was suggested that the lower oxygen cost at the same heart rate for the low impact routine may have been due to less activity of the large leg muscles in combination with vigorous arm movements.
Stanforth et al (1988) reported that during low impact aerobic dance movements, heart rate was higher at a given $\dot{V}O_2$ when there was minimal lower limb involvement as opposed to significant lower limb involvement. They suggested that the accepted HR-$\dot{V}O_2$ relationship was invalid during low impact aerobic movements with minimal lower body involvement, whereas it was valid when there was significant lower body involvement.

Thus, the validity of the HR-$\dot{V}O_2$ relationship during aerobic dance type exercise may depend upon the relative contributions of the upper and lower body to total power output. Toner et al (1983) suggested that a contribution from the arms of greater than 60% of total $\dot{V}O_2$ during combined arm and leg exercise on a specially designed arm-leg ergometer would cause a disproportionate increase in heart rate. Goss et al (1989) reported no disproportionate increase in heart rate during bench stepping while pumping hand weights where the arms contributed only 17.5% of total body $\dot{V}O_2$.

In contrast to the findings of Parker et al (1989), a study by Berry et al (1992) compared the heart rate responses to aerobic dance with arm movements above or below the head, and running at the same $\dot{V}O_2$, and found no significant difference in the heart rate responses to all three exercise modes. The authors suggested that these conflicting findings were possibly due to the lower relative intensity of exercise which was utilised in this study in comparison to that used by Parker et al (1989).

It has been shown previously that when leg exercise is compared to combined arm and leg exercise, the heart rate response is essentially the same at low intensity. At higher intensity, the heart rate tends to be higher in combined arm and leg exercise than leg exercise alone (Toner et al, 1983).

Stenberg et al (1967) showed that heart rate was higher at a given $\dot{V}O_2$ in arm exercise compared to leg exercise, except at lower workloads (see Table 3). Vokac et al (1975) found that there was no significant difference in the heart rate response between arm and leg exercise at the lowest workload where $\dot{V}O_2$ was 1 $l \cdot min^{-1}$.

These studies support the results of Berry et al (1992) who concluded that heart rate may be an appropriate monitor of exercise intensity during aerobic dance at low intensity (50% $\dot{V}O_{2max}$), as long as the arm movements are of a dynamic nature with little or no static component.

The findings of Reeves & Darby (1991) and Stanforth et al (1988) also conflict with those of Parker et al (1989). Reeves & Darby (1991) found no significant difference between the regression slopes of heart rate and $\dot{V}O_2$ for incremental dance exercise and treadmill exercise. Stanforth et al (1988) showed that the use of the arms in low impact aerobic dance did not affect the HR-$\dot{V}O_2$ relationship, and similar to the study by Berry et al (1992), the relative intensity of exercise was quite low (58.0% $\dot{V}O_{2max}$ for aerobic dance without arms and

57.6% $\dot{V}O_{2\,max}$ with arm involvement).

In summary, although there is some conflicting evidence, it appears that the HR-$\dot{V}O_2$ relationship during aerobic dance exercise may be disproportional in comparison to the relationship established for lower body dominant activities. It may be influenced by the relative contributions of the upper and lower body to total power output, whether the muscular contractions are static or dynamic, and by the relative intensity of exercise.

These contradictory findings bring into question the applicability of the use of heart rate monitoring to assess exercise intensity during this mode.

The Use of Target Heart Rate during Step Aerobics

Several studies have reported oxygen uptake and heart rate during step aerobics.

Goss et al (1989) reported a significantly higher $\dot{V}O_2$ for bench stepping with no arm movements, compared with stepping at a lower step rate combined with arm movements, when performed at similar heart rates. This finding suggests that if the $\dot{V}O_2$ were held constant, the heart rate may be elevated in the trial which included arm movements.

Olson et al (1991) measured $\dot{V}O_2$ and heart rate during 20 minutes of step aerobic exercise on 6", 8", 10" and 12" steps. They reported a significant increase in $\dot{V}O_2$ from 10" to 12", although there was no significant difference in the heart rate response between these heights. Since the relative intensity was in excess of 90% $\dot{V}O_{2\,max}$ at 12", they suggested that the discrepancy may have been due to more conservative arm movements at the higher step height. This would allow a greater relative blood flow to the lower body resulting in a higher stroke volume and consequently a lower heart rate. However, it is possible that this finding may have been due to a plateau in heart rate as it approached maximum. The heart rate responses at 10" and 12" were reported as 88.5% and 88.8% HR_{max} respectively.

Petersen et al (1993) suggested that heart rate may not accurately reflect oxygen uptake as displayed by the HR-$\dot{V}O_2$ relationship during a 30 minute step routine on a 10" step. They recorded a mean heart rate response of 76.4% HR_{max} at a relative intensity of 58.4% $\dot{V}O_{2\,max}$. These studies support the findings of Parker et al (1989).

In a study by Thomas and Long (1991), correlational analysis showed no significant relationship between oxygen uptake and heart rate during a step routine performed on two different step heights (6" and 12") and at two step rates (120 beats$\cdot$min^{-1} and 140 beats$\cdot$min^{-1}), however there was no indication whether heart rate overestimated $\dot{V}O_2$.

Roach et al (1993) directly compared the HR-$\dot{V}O_2$ relationship between treadmill running and three types of aerobic dance including step aerobics. It was found that for each type of aerobic dance, the relationship was significantly different from that of treadmill running such that heart rate underpredicted $\dot{V}O_2$ by as much as 10%. This result is contradictory to that of Parker et al (1989) where it was reported that heart rate tends to overestimate $\dot{V}O_2$ during exercise in which there is considerable use of the arms.

Forte et al (1995) investigated the relationship between step aerobics and treadmill walking in middle aged subjects of both sexes (four males and six females). In contrast to Parker et al (1989), regression equations indicated no difference in the HR-$\dot{V}O_2$ relationships between exercise modes.

Many of the above studies have, to date, been published in abstract form (Forte et al, 1995; Petersen et al, 1993; Roach et al, 1993; Thomas & Long, 1991) and thus, there is limited information on which to base an opinion. However, although there is no firm consensus, there is evidence to suggest that heart rate overestimates $\dot{V}O_2$ during step aerobic exercise, and therefore may not be an accurate predictor of exercise intensity for this exercise mode. It has been suggested that this could be due to the inclusion of arm movements as a substantial part of the choreography.

RATINGS OF PERCEIVED EXERTION

The A.C.S.M. (1990) advocates another method of estimating intensity during exercise, which is the use of ratings of perceived exertion (RPE). Perceived exertion is a description of effort during exercise. It involves the integration of physiological signals from the working muscles and joints, from the cardiorespiratory system and from the central nervous system (Birk & Birk, 1987). Psychological factors also contribute to feelings of exertion during exercise. Morgan (1973) reported that as much as 33% of the variance in perceived exertion was dependent on measurable psychological components. Ratings of perceived exertion can also provide an indication of the level of comfort of the participant during an exercise session.

Much of the research into perceived exertion has focused on the relative contributions of local and central physiological factors to the overall perception of effort. Local factors are those which arise in the exercising muscles or joints, such as accumulation of blood lactate. Central factors are associated with sensations from the cardiorespiratory system, such as heart rate or respiratory rate. It is generally acknowledged that local factors dominate the perception of exertion, although it has been suggested that central factors may dominate at higher work intensities (Watt & Grove, 1993). However, the literature regarding this issue is inconclusive.

Psychological factors include dissociation strategies whereby the exerciser can work at a higher intensity with a lower RPE, thus possibly having beneficial effects on exercise adherence. Activities such as aerobics may facilitate these strategies as music seems to lower the level of perceived exertion for exercise of the same physiological cost (Watt & Grove, 1993). Two recent studies reported a lower RPE than expected from the metabolic cost of aerobic dance exercise. It was suggested that this was possibly due to the music distracting from the physiological effort cues (Grant et al, 1993; Sutherland et al, 1993). Another psychological element which may be of importance to the use of RPE within a group exercise setting, such as an aerobics class, is social influence. A study by Hardy et al (1986) found that the presence of another exerciser lowered RPE scores in males at low to moderate intensities. There was no modification of RPE at high intensity although another study (Boutcher et al, 1988) showed that males reported lower RPE scores at high intensity when the experimenter was female. Therefore, it appears that psychological factors can influence RPE at a range of intensities, however, it is difficult to interpret the findings of studies with a psychological element since the RPE reported by subjects may not be the RPE actually perceived.

Borg (1970) introduced a 15 point category scale for rating perceived exertion. This scale consists of the numbers from 6 to 20 with verbal descriptions of effort corresponding to the odd numbers. The descriptions range from "very, very light" at 7 to "very, very hard" at 19. A copy of this scale can be found in Table 4. The exerciser uses the numbers and verbal descriptions to estimate the intensity of his or her effort in terms of overall body sensations.

The scale has been shown to display a high degree of validity and reliability in the estimation of physical strain during several lower body dominant activities (Stamford, 1976; Watt & Grove, 1993), and has been widely used. The use of instructions (Morgan, 1981) and perceptual anchoring may improve the accuracy of ratings (Dunbar, 1993).

The scale was developed to increase linearly with workload, and therefore physiological variables which also increase linearly with workload would tend to match the perceived exertion (Birk & Birk, 1987). RPE has been found to correlate highly with several physiological parameters of exercise stress including heart rate and oxygen uptake (A.C.S.M., 1986).

Borg originally reported a correlation of 0.85 between heart rate and RPE, however, these two variables may not be causally related. Davies & Sargeant (1979) showed that the HR-RPE relationship could be easily upset by beta blockade. A study by Squires et al (1982) showed that cardiac patients taking beta-adrenergic blockers, which depress the heart rate response, could still use RPE to accurately estimate exercise intensity. Both variables appear to be dependent on exercise strain and would therefore tend to parallel one another with changes in exercise intensity.

Pollock & Wilmore (1990) have stated that an RPE of 12 - 13 is equivalent to 50% - 74% $\dot{V}O_{2\,max}$ and an RPE of 14 - 16 is equivalent to 75% - 84% $\dot{V}O_{2\,max}$. It has been suggested (A.C.S.M., 1986) that this range should provide an adequate training intensity for most people. These ratings correspond to the range of "somewhat hard" to "hard". Birk & Birk (1987) suggest that an RPE of

TABLE 4. RATING OF PERCEIVED EXERTION SCALE

6	
7	VERY, VERY LIGHT
8	
9	VERY LIGHT
10	
11	FAIRLY LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD
16	
17	VERY HARD
18	
19	VERY, VERY HARD
20	

12 - 15 corresponds to 58 - 89% $\dot{V}O_{2\,max}$.

A possible dissociation between RPE and $\%\dot{V}O_{2\,max}$ has been reported by Davidson (1995), Grant et al (1993) and Sutherland et al (1993). All three studies reported a rise in RPE over a 20 minute aerobic dance routine although $\dot{V}O_2$ was relatively stable, and it was hypothesised that the effect of fatigue may decrease the validity of RPE during sustained activity. Carton & Rhodes (1985) noted previously that despite a stabilisation of physiological variables in steady state exercise, RPE continues to rise.

The A.C.S.M. (1986) state that RPE can replace heart rate as a means of prescribing exercise intensity once the individual relationship between the two variables has been established. At the beginning of a training programme, an individual can use target heart rates to monitor his or her exercise. At the same time, the RPE response to that level of exercise can be monitored. Once the individual has become familiar with his or her RPE responses in relation to heart rate, the monitoring of heart rate can gradually be discontinued. Changes in RPE at a given submaximal load can then be used to modify the exercise prescription.

Morgan (1981) suggested that 90% of adults can learn to rate the intensity of exercise with RPE, however, no results were reported to corroborate this statement.

Williams & Eston (1989) have suggested that for RPE to be a practical option for monitoring exercise intensity, its validity would have to be established for different exercise modes, at a range of intensities and among different populations. Pandolf (1983) has stated that different types of exercise will produce a different mixture of local and central signals, thus influencing the perception of effort. RPE tends to be higher in arm exercise compared to leg exercise at the same submaximal $\dot{V}O_2$ (McArdle et al, 1994), possibly caused by greater local effort sensations due to a smaller working muscle mass at a given submaximal workload.

<u>The Use of Ratings of Perceived Exertion during Step Aerobics</u>

Several studies have shown a significant increase in RPE with an increase in step height (Olson et al, 1991; Stanforth & Stanforth, 1993; Thomas & Long, 1991).

In the study by Olson et al (1991), $\dot{V}O_2$, HR and RPE were measured at step heights of 6", 8", 10" and 12". Mean $\dot{V}O_2$ was significantly higher with each increase in step height. Both Mean HR and mean RPE increased significantly between 6" and 8"and between 8" and 10", however, there was no significant difference in either HR or RPE between 10" and 12". As indicated previously, the authors suggested that this could be due to less relative contribution of the arms at the higher step height. Thus, the smaller proportion of arm work could have altered the relative contribution of local and central signals to decrease the RPE with respect to the metabolic load.

Roach et al (1993) reported that RPE was possibly a better monitor of intensity than heart rate during step aerobics. The RPE-$\dot{V}O_2$ regression lines were the same for step aerobics and treadmill running, whereas, the HR-$\dot{V}O_2$ relationship was significantly different for the two types of exercise.

In contrast, Thomas & Long (1991) found no significant correlation between any combination of $\dot{V}O_2$, HR or RPE during step aerobics.

Hayakawa et al (1994) showed that the energy cost of bench stepping was higher than that of cycling at the same level of RPE, suggesting that at the same $\%\dot{V}O_{2\,max}$, RPE would be lower for bench stepping and that the $\dot{V}O_2$-RPE relationship was different for these two modes.

The viability of RPE as a method of estimating intensity during step aerobics is dependent upon the relationship between $\dot{V}O_2$ and RPE for this mode of exercise. The use of RPE could be advantageous since the validity of target heart rate for this mode is unclear. Also, the use of RPE would alleviate the difficulty of measuring heart rate by palpation which often involves substantial error. Finally, the participant could monitor his or her intensity without interrupting exercise to take a measure of heart rate. There is some debate about the ability of post exercise heart rates to give an accurate indication of intensity during exercise. Bell & Bassey (1996) suggest that heart rates measured immediately following aerobic dance exercise do not accurately represent the heart rate during exercise in individuals.
However, there is no consensus from the limited evidence to suggest that RPE could be used to monitor intensity during step aerobic training.

THE ENERGY COST OF STEP AEROBICS

The goal of many participants in exercise programmes is that of weight loss. Body weight is gained when caloric intake is higher than caloric expenditure. This is termed positive energy balance. In contrast, weight is lost when there is a negative energy balance, that is, caloric intake is less than expenditure.

There are three ways of promoting a negative energy balance. These are decreasing energy intake by dietary restriction, increasing energy expenditure by increasing physical activity or a combination of both.

The A.C.S.M. (1983) recommend a combination of both decreased food intake and increased exercise, and they suggest that the negative energy balance should be not more than 500 - 1000 kcal. per day. When weight is lost solely due to dietary restriction, there tends to be a loss of both fat and fat free mass. However, the inclusion of exercise in a weight loss regime diminishes the loss of lean tissue so that there is an increase in resting metabolic rate, thus aiding further weight loss (McArdle et al, 1994).

Aerobic activities can be useful for the control of body composition. The total energy expenditure of an exercise session is the most important factor in an exercise programme in which the aim is weight control (McArdle et al, 1994).

In their guidelines for the quantity and quality of exercise required for a weight loss programme, the A.C.S.M. (1990) recommend a minimum duration of 20 minutes at an intensity high enough to achieve an energy expenditure of 300 kcal. per session if the frequency of exercise is 3 times per week, or 200 kcal. per session if the frequency is 4 times per week. The A.C.S.M. have also recognised the suggestion of Haskell (1985) and Haskell et al (1985) that body weight should be taken into account when calculating energy expenditure such that an individual should expend a minimum of 4 $kcal \cdot kg^{-1}$ of body weight per day.

To date there have been no studies carried out which have measured changes in body composition following a period of step aerobics, although several studies have investigated the acute energy cost of this activity.

Olson et al (1991) found that the energy cost of a 20 minute step routine ranged from 150 kcal. at a height of 6" to 210 kcal. at 12". By extrapolating their results, it was predicted that a duration of approximately 40 minutes would be required for the expenditure of 300 kcal. on a 6" step, whereas slightly under 30 minutes would be required when the routine was performed on a 12" step. It was concluded that if weight loss was desired, the activity would need to be prescribed for greater than 20 minutes in order to reach the level recommended by the A.C.S.M..

Petersen et al (1993) reported an energy expenditure of 243 kcal. for a 30 minute step routine performed on a 10" step. This corresponded to a mean expenditure of 8.1 $kcal \cdot min^{-1}$, whereas in the study by Olson et al (1991), the mean expenditure at 10" was 9.5 $kcal \cdot min^{-1}$. Wang et al (1993) found a mean energy cost of 8.7 $kcal \cdot min^{-1}$ at a step height of 10". Both Olson et al (1991) and Wang et al (1993) reported a significant 1 $kcal \cdot min^{-1}$ increase in energy cost with each 2" increment in step height. However, comparing results from different studies is difficult due to a variety of factors influencing energy cost such as choreography, step height, step rate and subjects' fitness levels.

As noted previously, the effect of using hand held weights on the energy cost of step aerobics has been studied (Olson et al, 1991; Wang et al, 1993). Both studies found no significant increase in energy cost with 0.45 kg. hand held weights. Olson et al (1991) reported an increase in energy cost with the use of 0.91 kg. hand held weights, however, this increase would approximate to only 20 kcal. accumulated over a 20 minute exercise bout. Stanforth & Stanforth (1993) found that the energy cost of step aerobics could be increased by 3 kcal. for every 1 kg. of external weight added to a belt worn round the subject's waist.

It would appear that the duration or frequency of a step aerobics session, when performed at step heights of 6", 8" or 10", would need to be increased above 20 minutes or 3 times per week in order to enhance the potential of this exercise mode for promoting weight loss. However, while the A.C.S.M. (1990) provide threshold levels of energy expenditure for the promotion of weight loss, it should be recognised that any increase in energy expenditure has the potential to increase weight loss. The A.C.S.M. (1983) state that if the main purpose of a training programme is weight loss, a greater frequency and duration of training, coupled with a low to moderate intensity are recommended. Thus, step aerobics would appear to be a practical mode of exercise for this objective.

PURPOSE OF THE STUDY

The purpose of this study is to measure the acute cardiovascular and metabolic responses of subjects to a Uni-Step class. Although similar observations have been made in other studies involving step aerobics, they have been specific to the particular choreography, step heights and step rates utilised in those investigations. In addition, relatively small sample sizes have been used. These factors make it difficult to generalise conclusions.

The results of this study will add to the growing body of information about this quickly developing exercise mode since the step heights, step rates and movements used in this study are fairly universal. However, the choreography utilised in Uni-Step is distinctive, and therefore, the results will also provide specific information for the evaluation of Uni-Step classes, which will be of benefit to both teachers and participants.

The specific aims of the study are as follows:

1. to investigate the effect of step height on $\dot{V}O_2$, HR, RPE and total energy expenditure.

2. to measure the relative intensity of Uni-Step at three step heights and to assess its potential for the development of cardiovascular fitness.

3. to examine the relationship between $\dot{V}O_2$ and HR during Uni-Step exercise at three step heights and to subjectively evaluate the use of HR for estimating exercise intensity.

4. to examine the relationship between $\dot{V}O_2$ and RPE during Uni-Step exercise at three step heights and to subjectively evaluate the use of RPE for estimating exercise intensity.

5. to estimate the energy cost of Uni-Step at three step heights and to assess

its utility for promoting weight loss.

These aims are embodied in the following null hypotheses:

1. the null hypothesis is that an increase in step height does not cause an increase in $\dot{V}O_2$, HR, RPE and total energy expenditure.

2. the null hypothesis is that the relative intensity of Uni-Step at three step heights is not sufficiently high for the maintenance or improvement of cardiovascular fitness.

3. to examine the relationships between $\dot{V}O_2$ and HR and $\dot{V}O_2$ and RPE during Uni-Step exercise at three step heights and to subjectively evaluate the use of HR and RPE for estimating exercise intensity.

4. the null hypothesis is that the energy cost of Uni-Step at three step heights is not sufficiently high to promote weight loss.

METHODS

SUBJECTS

Ten healthy female subjects took part in the study. Characteristics of the subjects are shown in Table 7. Twenty four people volunteered for the study, however fourteen were excluded. Six people were excluded for medical reasons as specified below, four withdrew before testing began, two were injured at the time of testing, one was above the upper age limit required for ethical approval and one was male.

Seven of the subjects were regular participants in Uni-Step classes at Glasgow University, attending between one and three times per week. The remaining subjects had recently participated in step aerobics, and therefore all subjects were familiar with the type of exercise which they would be asked to perform in the testing sessions.
All subjects had exercised regularly at least three times per week during the two month period prior to testing, and it was therefore assumed that they would have a sufficient level of fitness to complete the test routines.

Prior to recruitment, all potential participants in the study were required to complete a general health questionnaire (see Appendix B). Exclusion criteria were diabetes, anaemia, epilepsy, heart disease, chest pain, palpitations, dizzy spells and other ailments which could affect endurance capability. In addition, any person currently taking medication was excluded.

Ethical approval was granted for this study and informed consent was obtained from all participants prior to testing. (A copy of the informed consent form can be found in Appendix B).

The General Practitioner of each subject was informed by letter that she had volunteered to take part in a research study, and a one week period from this notification was allowed before testing began.

PROCEDURES

PILOT STUDY

A pilot study was conducted to evaluate the test procedures and their reproducibility. This study is described in Appendix A.

MAIN STUDY

Format of Main Study

Each subject visited the laboratory on four occasions. On the first three visits, a standard Uni-Step routine was performed on a different step height at each visit. The fourth test was a continuous treadmill protocol for the determination of maximum oxygen uptake and maximum heart rate.

All four visits to the laboratory took place within a three week period (range: 5 - 21 days) to minimise the effects of changes in training status. Tests for each subject were performed on non-consecutive days to allow for a recovery period. An exception was made for the final subject, who, due to other commitments, had to complete all four tests within a five day period.

The three step routines took place at the same time of day to control for the effect of diurnal variation in heart rate (Astrand & Rodahl, 1986).

General Instructions to Subjects

Subjects were asked to refrain from eating during the three hours prior to all tests to minimise the thermic effect of food on metabolism (McArdle et al, 1994). They were also asked to avoid caffeinated drinks during this period due to the ergogenic effect of caffeine (McArdle et al, 1994). None of the subjects in this study were smokers.

Subjects were also asked not to engage in any strenuous exercise on the day before a test or on the test day itself.

Physical Measurement of Subjects

On the first visit to the laboratory, the subject's height was measured.

Percentage body fat was estimated using the skinfold technique of Durnin and Womersley (1974).

Leg length was measured from the anterior superior iliac crest to the medial malleolus on the right side of the body using a tape measure (Ellis, 1983).

Resting heart rate was determined prior to the third test using a Polar 4000 portable heart rate monitor (Polar Electric). The subject was seated for 10 minutes and heart rate was noted at 9.5 minutes, 9.75 minutes and 10 minutes. Resting heart rate was recorded as the lowest value measured.

Body mass was measured prior to every test.

LABORATORY SIMULATION OF A UNI-STEP SESSION

The subject followed a videotaped Uni-Step routine on three different step heights.

Step Heights Utilised in Main Study

Prior to the start of testing, the step heights to be used in the main study were decided by attending two regular Uni-Step sessions to determine which heights were most popular with participants. The proportions of participants using each step height are shown in Table 5.

Table 5. Step Heights used by Uni-Step Participants

	Step Height	Number of Participants	% Total Participants
SESSION 1	4"	0	0
Attendance = 21	6"	2	9.5
	8"	16	76.2
	10"	3	14.3
SESSION 2	4"	0	0
Attendance = 18	6"	6	33.3
	8"	12	66.7
	10"	0	0

Therefore, it was decided that 6" (15.2 cm), 8" (20.3 cm) and 10" (25.4 cm) steps (STEP6, STEP8 and STEP10) would be appropriate for taking measurements which would be of most benefit to both teachers and participants.

The order of use of the different step heights for each subject was randomised using a Latin Square design to control for familiarisation effects.

Description of Uni-Step Session

A Uni-Step session lasts for approximately 40 minutes, and consists of three sections; 30 minutes of aerobic exercise, 5 minutes of muscle conditioning and 5 minutes of flexibility exercises. The aerobic section is similar to other step classes in that it involves choreographed movements of both the arms and legs while stepping on to and off a step. The muscle conditioning includes exercises such as sit ups, tricep dips and half squats. The flexibility exercises consist of stretching of the major muscle groups of the body.

The specific Uni-Step routine used in this study had a total duration of 38 minutes 40 seconds. The aerobic section lasted 30 minutes 30 seconds and was followed by 4 minutes 45 seconds of muscle conditioning and 3 minutes 25 seconds of flexibility. The rates of stepping during the aerobic section corresponded to cadences of 125 - 132 steps$\cdot$min^{-1}.

The routine used in this study was choreographed and presented by an experienced Uni-Step teacher and it was typical of routines taught in regular Uni-Step sessions. Full details of the movements and their timing are described in Appendix C. Subjects were asked to replicate the speed and range of movement used in the videotape as closely as possible.

Measurement of Oxygen Uptake

The routine was performed while linked to gas collection equipment and the subject was familiarised with the equipment before the first test. Expired air was collected in Douglas bags. The subject wore a nose clip and a rubber mouthpiece which was securely taped to a two way high velocity low resistance breathing valve (Hans Rudolph No. 2600). The breathing valve was supported by a lightweight head-support (model 2726 head-support for Rudolph valves) and was connected to the Douglas bag by a length of flexible tubing. The tubing was taped to the head-support at the right hand side of the subject's head and the tube was extended down the subject's back over her right shoulder. In this way, the Douglas bag could be supported by the investigator such that the equipment caused minimal disruption to the subject's arm movements. In addition, the presence of the investigator was made less distracting by her location behind the subject's back.

Samples of expired air were collected continuously throughout the routine. The sample durations were as follows:

Aerobic section	0:03 - 3:00
	3:03 - 6:00
	6:03 - 9:00
	9:03 - 12:00
	12:03 - 15:00
	15:03 - 18:00
	18:03 - 21:00
	21:03 - 24:00
	24:03 - 27:00

Aerobic section (cont.)	27:03 - 30:30
Muscle Conditioning	30:33 - 35:15
Flexibility	35:18 - 38:40

A 3 second pause in the collection of expired air was allowed at the start of each sample for the exchange of Douglas bags since the use of a T-piece is impractical during this type of exercise. This resulted in a total loss of 1.6 % of expired air from the whole routine.

Expired air was analysed immediately following each test using a Servomex 570A oxygen analyser and a P.K. Morgan 801D carbon dioxide analyser. These were calibrated prior to each test with standard reference gases of known composition. The Douglas bag was evacuated through a Parkinson-Cowan dry gas meter containing a temperature probe to determine the volume of the expired air which was corrected to S.T.P.D..
From these data, the mean $\dot{V}O_2$ of each sample was calculated using standard equations (McArdle et al, 1994).
The energy cost of each sample was calculated using the Weir formula (Weir, 1949).

Measurement of Heart Rate

Heart rate was recorded at 15 second intervals throughout the routine using a Polar 4000 portable heart rate monitor with a memory mode (Polar Electric). The validity and reliability of this heart rate monitor has been documented (Leger & Thirierge, 1988). The mean heart rate during each expired air sample was recorded. The subject was asked not to look at the monitor display so that she would not use the information to adjust her exercise intensity (further details are given in Appendix A).

Measurement of Ratings of Perceived Exertion

Ratings of perceived exertion (RPE) were recorded throughout the routine. The subject was asked for an RPE 30 seconds before the end of each sample of expired air. This ensured that there was enough time to record the correct rating before the bag changeover.

Prior to each test, the subject was shown a copy of the Borg 6 - 20 scale (Borg, 1982) (see Table 4) and was asked to read instructions on how to use the scale. These instructions were adapted from Morgan (1981) and Dunbar (1993) and can be found in Appendix D. A large copy of the Borg scale was displayed in front of the subject throughout the test and she was asked to provide a rating of perceived exertion by signalling the relevant number with her fingers. The experimenter then repeated the number and the subject indicated with a thumbs up signal if this was correct. If not, the subject was asked to signal again until the experimenter stated the correct rating.

TEST OF MAXIMUM OXYGEN UPTAKE

On completion of the three Uni-Step tests, each subject performed a continuous graded treadmill test for the measurement of maximum oxygen uptake and maximum heart rate.

Prior to the test, the subject was informed of the test procedures and it was stressed that she should continue to maximum effort.

Familiarisation and Warm Up

The subject was given an initial familiarisation period on the treadmill (Shephard, 1984). The subject was allowed to walk on the treadmill (Powerjog EG30) holding on to the sides until she felt comfortable to walk unaided. She was then allowed to walk or jog for one minute at each of the test velocities (a copy of the test protocol can be found in Table 6). The subject was also given the opportunity to experience the range of test gradients while walking at 4.8 k.p.h. for 30 seconds at each gradient up to 10%. This familiarisation served as a warm up and the test itself commenced after a brief rest period during which the subject was linked to the gas collection equipment.

Test Protocol

The test was continuous with progressive increments in work rate each minute (see Table 6). The subject was given the choice of 8.8 k.p.h. or 9.6 k.p.h. as the final test velocity according to comfort. Eight of the ten subjects chose 8.8 k.p.h. as their final velocity. In these cases, the subjects spent minutes four and

TABLE 6. MAXIMUM TEST PROTOCOL

Time (min.)	Speed (k.p.h.)	Gradient (% incline)
0-1	4.8	0
1-2	6.4	0
2-3	8.0	0
3-4	8.8	0
4-5	9.6	0
5-6	9.6	2
6-7	9.6	4
7-8	9.6	6
8-9	9.6	8
9-10	9.6	10
10-11	9.6	12
11-12	9.6	14

five of the test at a velocity of 8.8 k.p.h. and a gradient of 0%, whereas the subjects who had chosen the faster velocity spent minute four at a velocity of 8.8 k.p.h. and minute five at a velocity of 9.6 k.p.h., both at a zero gradient.
The main aim of the protocol was to give rise to a test duration of 8 - 12 minutes (Buchfuhrer et al, 1983). A similar protocol was successfully used in two previous studies with similar subject populations (Grant et al, 1993; Sutherland et al, 1993).

Measurement of Oxygen Uptake

Expired air was collected with the apparatus described for the Uni-Step tests. Samples of one minute in duration were collected from the point the subject's heart rate reached 170 beats$\cdot$min^{-1} until the end of the test. The subject was instructed to provide a signal when she felt that she could only continue for a further minute. At this point a separate one minute sample was collected irrespective of the duration of the previous sample.
The test was discontinued after this period. The subject then walked on the treadmill until the heart rate had dropped below 130 beats$\cdot$min^{-1}.

Analysis of expired air was carried out as described for the Uni-Step tests. $\dot{V}O_{2\ max}$ was recorded as the highest measurement from all samples.

Measurement of Heart Rate

Heart rate was monitored throughout the familiarisation period, the test itself and during recovery using a three lead Hewlett-Packard E.C.G. type 43200A. The heart rate was recorded in the final 15 seconds of each expired air sample. Maximum heart rate was recorded as the highest heart rate measured during the test.

Measurement of Ratings of Perceived Exertion

Immediately upon cessation of the test, the subject was asked to provide a rating of perceived exertion for the final minute of the test by pointing to the relevant level on the Borg 6 - 20 scale which was displayed in front of the subject throughout the test.

STATISTICAL ANALYSIS

In order to achieve the aims of the study, the following statistical analyses were carried out.

To investigate the effect of step height on $\dot{V}O_2$, $\%\dot{V}O_{2\,max}$, %HRR, $\%HR_{max}$, RPE and total energy expenditure, repeated measures analysis of variance was carried out for all six dependent variables.

The heart rate responses to Uni-Step were reported and analysed in terms of both %HRR and $\%HR_{max}$, since both variables are used in the prescription of exercise intensity.

In order to investigate the relationships between $\dot{V}O_2$ and heart rate and between $\dot{V}O_2$ and RPE, individual Pearson product moment correlations were carried out for each subject at each step height for the following combinations of variables: $\%\dot{V}O_{2\,max}$ and %HRR, $\%\dot{V}O_{2\,max}$ and $\%HR_{max}$, $\%\dot{V}O_{2\,max}$ and RPE. In addition, the relationship between heart rate and RPE was examined by correlating RPE and %HRR and RPE and $\%HR_{max}$.

The median correlation coefficients for the group at each step height were reported, as the mean may not have been representative of the typical values since the data were skewed.

RESULTS

SUBJECT CHARACTERISTICS

Mean subject characteristics are displayed in Table 7. The subjects in this study were very fit with a mean $\dot{V}O_{2\,max}$ of 47.7 $ml \cdot kg^{-1} \cdot min^{-1}$, however, there was quite a large range of scores (41.7 - 63.9 $ml \cdot kg^{-1} \cdot min^{-1}$).

The criteria generally used to determine whether a true maximum effort has been achieved were considered (B.A.S.S., 1988). Four subjects demonstrated a decline or plateau in oxygen consumption (defined as a change in $\dot{V}O_2$ of less than 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$ with an increase in workload). A respiratory quotient greater than 1.15 was recorded for five subjects (mean $\pm$ standard deviation = 1.13 $\pm$ 0.1). Nine subjects attained a maximum heart rate within 10 $beats \cdot min^{-1}$ of their age predicted maximum heart rate. The subject who did not was an endurance athlete and she had a measured maximum of 12 $beats \cdot min^{-1}$ lower than predicted. Eight subjects met at least two of the three criteria.

TABLE 7. SUBJECT CHARACTERISTICS

Subject Characteristic	Mean	Standard Deviation
Age (yr.)	22.0	2.2
Height (cm.)	163.7	4.5
Body mass (kg.)	58.6	6.9
Estimated percentage body fat (%)	24.9	4.2
Leg length (cm.)	87.4	4.2
Resting heart rate (beats$\cdot$min^{-1})	61.1	9.8
Maximum heart rate (beats$\cdot$min^{-1})	198.9	9.4
Maximum oxygen uptake (ml$\cdot$kg$^{-1}\cdot$min^{-1})	47.7	6.8
RER at maximum	1.1	0.1
RPE at maximum	18.6	1.0

THE EFFECT OF STEP HEIGHT ON ALL DEPENDENT VARIABLES

ANALYSIS OF DATA

The Uni-Step routine consisted of the following components. The first six minutes of the routine (samples 1 and 2) was the warm up period. The remainder of the aerobic section of the routine lasted from minute 6 to minute 30.5 (samples 3 -10). The muscle conditioning section (sample 11) and the flexibility section (sample 12) lasted from this point until the end of the routine at 38.67 minutes.

The analysis of results for the dependent variables $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), $\%\dot{V}O_{2\,max}$, %HRR, $\%HR_{max}$ and RPE was limited to between 6 minutes and 30.5 minutes of the duration of the Uni-Step routine.
The first six minutes of the routine (samples 1 and 2) consisted of a warm up during which the subject performed marching on the spot, marching and tapping the step with the free foot and marching and lifting the knee. There were no movements which involved actually stepping onto the step and transferring the body weight, with the exception of ten cycles of basic stepping at the end of sample 2. Therefore, little difference would be expected in the dependent variables among the three different step heights during this warm up period since almost identical movements were being performed.
The inclusion of data from the first six minutes of the routine could possibly contaminate the overall findings, since it may lessen the ability of later statistical analysis to detect differences in dependent variables among the step heights for the remainder of the routine where differences would be expected.

Repeated measures analysis of variance was carried out to determine whether there was in fact any difference in any of the dependent variables $\dot{V}O_2$, $\%\dot{V}O_{2\ max}$, %HRR, $\%HR_{max}$ and RPE) during the first six minutes of exercise among the three step heights. It was found that there were no differences among step heights for the variables $\dot{V}O_2$, $\%\dot{V}O_{2max}$ and RPE during the first six minutes of sampling. Significant differences were found in %HRR and $\%HR_{max}$ ($P = 0.05$), however, they were small and not meaningful in physiological terms. The differences in mean heart rates between the three step heights were no more than 5 beats·min^{-1} for both samples recorded during the first six minutes of exercise.

Therefore, it was decided that the data recorded during the first six minutes of the routine should be eliminated from the statistical analysis, since the only significant difference was found in heart rate response, which is susceptible to environmental influence, and therefore, the differences were probably not attributable to the change in step height.

Similarly, data from the muscle conditioning and flexibility sections of the routine were omitted from the analysis since movements were identical for all three step heights. Again, repeated measures analysis of variance was carried out for each dependent variable ($\dot{V}O_2$, $\%\dot{V}O_{2\ max}$, %HRR, $\%HR_{max}$ and RPE) to determine whether there were any differences across step heights during these sections of the routine. There was a significant increase in heart rate (%HRR and $\%HR_{max}$) with each increase in step height ($P < 0.001$), however, again, the lack of a significant difference in $\dot{V}O_2$ would suggest that the heart rate may have been influenced by non metabolic factors.

The analysis of results for the dependent variable, total energy expenditure (EE), included measurements from all 12 samples.

Repeated measures analysis of variance was carried out for all dependent variables firstly, to determine whether there was any difference in the pattern of response for each variable over time at each step height, and secondly, to determine whether there was any significant difference in the magnitude of each dependent variable across step heights. Details of these analyses can be found in Appendix E.

This analysis took into account any effect caused by the order of testing of the three step heights. It was found that the order of testing affected only $\dot{V}O_2$ and $\%\dot{V}O_{2max}$ ($P < 0.05$) such that the oxygen uptake response was higher in the first test and became lower in later tests. This may have been due to increased familiarity with the routine and a subsequent increase in the efficiency of movement with practice. A similar effect was noted in the pilot study (see Appendix A). The randomised order of testing should prevent contamination of the results of the study.

THE EFFECT OF STEP HEIGHT ON OXYGEN UPTAKE

Unfortunately, there were only eight sets of oxygen uptake data for STEP8. Subject three was unable to take part in the STEP8 test due to other commitments, and thus there were also no heart rate or RPE scores for this subject at STEP8. The oxygen uptake results for the STEP8 test completed by subject four were discarded since, due to equipment failure, these samples of expired air were unable to be analysed immediately. However, the heart rate and RPE values for this test were included in the analysis.

Figure 1 shows the mean oxygen cost for the duration of the Uni-Step routine at all three step heights. It indicates that the oxygen cost at each height varied throughout the routine, most likely due to variations in the movements. The highest oxygen cost was recorded for sample 10 (minutes 27 - 30.5) during which the subjects performed variations on a straddle step (see Appendix C). The lowest oxygen cost in the aerobic section was recorded during the first sample of the warm up (minutes 0 - 3). During this time, the subjects were marching or stepping and tapping the step with their free foot.
The pattern of response at each height looked similar, with a rise in $\dot{V}O_2$ over the first six minutes of exercise followed by a steeper rise in $\dot{V}O_2$ at minute 9 at the two higher step heights. $\dot{V}O_2$ continued to rise until minute 12 and then remained fairly stable between minutes 12 and 18 at both STEP8 and STEP10 with a slight dip at minute 15. At both of these heights, $\dot{V}O_2$ declined from minute 18 until minute 27. At STEP6, $\dot{V}O_2$ began to decline from minute 12, with a plateau over the samples from minutes 15 and 18, followed by a decline until minute 27. Finally, for all three step heights there was a steep rise in the last sample of the aerobic section. The oxygen uptake was much lower during the muscle conditioning and flexibility sections than during the aerobic section,

as expected.

Repeated measures analysis of variance revealed no significant difference in the pattern of oxygen uptake response among the three step heights.

It is apparent from the graph that there was very little difference in the oxygen uptake response to this exercise at different step heights during the warm up period (the first six minutes) and during the muscle conditioning and flexibility sections, and repeated measures analysis of variance confirmed that there were no significant differences. However, during the remainder of the aerobic section following the warm up, there was a clear difference in $\dot{V}O_2$ at each time point among the three step heights. Repeated measures analysis of variance showed that there was a significantly higher oxygen uptake at each greater step height ($P < 0.001$). The estimated differences between all three step heights are displayed in Table 8. The mean $\dot{V}O_2$ values for the aerobic section can be found in Table 9.

Figure 2 shows the oxygen uptake results expressed as mean relative intensity ($\%\dot{V}O_{2max}$) over the duration of the Uni-Step routine for all three step heights. Again, it can be seen from the graph that the pattern of response throughout the routine was very similar at all three heights and in fact, repeated measures analysis of variance revealed no significant difference in $\%\dot{V}O_{2max}$ among the three step heights.

The mean relative exercise intensity was below 40% $\dot{V}O_{2max}$ during the warm up period for all three step heights. Like the absolute $\dot{V}O_2$ results above, the inspection of Figure 2 revealed that the relative intensity appeared to be at a similar level for each step height during the warm up period and during the

TABLE 8. ESTIMATES OF DIFFERENCES BETWEEN STEP HEIGHTS FOR ALL DEPENDENT VARIABLES

	10" - 6"	10" - 8"	8" - 6"
$\dot{V}O_2$ (ml·kg^{-1}·min^{-1})	6.1 (5.3, 6.9)	3.4 (2.6, 4.2)	2.7 (1.9, 3.5)
%$\dot{V}O_2$ max	13.1 (11.5, 14.7)	7.2 (5.6, 8.8)	5.9 (4.3, 7.5)
%HRR	15.3 (13.3, 17.3)	9.3 (7.3, 11.3)	6.0 (4.0, 8.0)
%HR max	10.9 (9.3, 12.5)	6.6 (5.0, 8.2)	4.3 (2.7, 5.9)
RPE (Borg Scale)	1.5 (1.1, 1.9)	0.8 (0.4, 1.2)	0.7 (0.3, 1.1)
Total Energy Expenditure (kcal.)	45.4 (35.0, 55.8)	24.4 (14.0, 34.8)	20.9 (10.5, 31.3)

estimate

(95% confidence interval *)

* set of simultaneous 95% interval estimates for each variable.

TABLE 9. MEAN VALUES AND STANDARD DEVIATIONS FOR ALL DEPENDENT VARIABLES

	Step Height		
	6"	8"	10"
$\dot{V}O_2$ (ml·kg^{-1}·min^{-1})	21.5 ± 2.1	23.4 ± 2.1	26.4 ± 1.9
%$\dot{V}O_{2\,max}$	45.6 ± 6.6	51.6 ± 3.9	56.2 ± 7.3
Heart Rate (beats·min^{-1})	139.7 ± 16.7	150.3 ± 9.8	157.8 ± 12.5
%HRR	57.2 ± 8.5	63.6 ± 6.0	70.1 ± 7.7
%HR_{max}	70.2 ± 7.5	75.0 ± 4.7	79.3 ± 5.5
RPE (Borg Scale)	12.3 ± 1.0	12.9 ± 1.1	13.4 ± 1.0
Energy Cost (kcal·min^{-1})	6.1 ± 1.0	6.7 ± 0.9	7.6 ± 1.0
Energy Cost (kcal·kg^{-1})	3.6 ± 0.3	3.9 ± 0.2	4.3 ± 0.3
Total Energy Expenditure (kcal.)	209.7 ± 35.0	226.9 ± 31.8	255.1 ± 34.2

All values are mean ± standard deviation of the aerobic section of the Uni-Step routine, with the exception of Total Energy Expenditure which are means of the whole routine.

muscle conditioning and flexibility sections of the routine and repeated measures analysis of variance again confirmed no significant differences. Throughout the aerobic section of the routine, the mean relative intensity was again clearly higher as step height was increased. Repeated measures analysis of variance showed that there was a highly significant increase ($P < 0.001$) in $\%\dot{V}O_{2\,max}$ with each increase in step height. The estimated magnitude of increase between step heights is shown in Table 8.

During the aerobic section, excluding the warm up, the mean relative intensity ranged between 41.1$\%\dot{V}O_{2\,max}$ and 55.4 $\%\dot{V}O_{2\,max}$ at STEP6. It remained below the 50% minimum threshold for 12 minutes of this time. At STEP8, the range was 46.1 $\%\dot{V}O_{2\,max}$ to 61.8 $\%\dot{V}O_{2\,max}$, only dipping below 50% during one three minute sample. The highest relative intensity reached during STEP10 was 68.1 $\%\dot{V}O_{2\,max}$ and the lowest was 51.0 $\%\dot{V}O_{2\,max}$, thus remaining above the threshold for the entire duration of the aerobic section.

THE EFFECT OF STEP HEIGHT ON HEART RATE RESPONSE

Figures 3 and 4 show the mean heart rate response (expressed as %HRR and $\%HR_{max}$ respectively) across each step height. Inspection of the graphs reveals a pattern similar to that of the oxygen uptake response. For all three step heights, there was an initial rise in heart rate over the first six minutes of exercise followed by a steeper rise in the next sample. It then continued to rise more gradually until minute 18 with a slight dip at minute 15 for STEP6 only. This was followed by a decline until minute 27 and finally a steep rise in the last sample of the aerobic section.

Repeated measures analysis of variance showed that the pattern of heart rate response over time did not differ among the three step heights for both %HRR and %HR $_{max}$.

From inspection of figures 3 and 4, there appeared to be a clear difference in the mean heart rate response at each step height throughout the aerobic section of the routine. However, in contrast to the oxygen uptake response, the heart rates during the muscle conditioning and flexibility sections also appeared to be higher as step height increased. In addition, during the warm up, the response appeared to be highest at STEP10 and lowest at STEP8. Repeated measures analysis of variance showed significant differences across all three step heights for both of these sections of the routine ($P = 0.05$ for the warm up and $P < 0.001$ for muscle conditioning and flexibility). Mean heart rate responses for these sections of the routine are shown in Table 10.

There was a significant increase ($P < 0.001$) in the heart rate response measured by both %HRR and %HR $_{max}$ with an increase in step height during the aerobic section (excluding the warm up). Estimated differences between step heights can be found in Table 8. Mean values for both variables at each step height can be found in Table 9.

The A.C.S.M. (1990) guidelines recommend a training zone of 50% - 85% HRR or 60% - 90% HR $_{max}$. It is clear from figures 3 and 4 that the heart rate response was within these zones for the entire duration of the aerobic section, excluding the warm up period, of the Uni-Step routine.

TABLE 10. MEAN HEART RATE RESPONSES AT THREE STEP HEIGHTS DURING THE WARM UP, MUSCLE CONDITIONING AND FLEXIBILITY SECTIONS OF THE UNI-STEP ROUTINE

	Step Height		
	6"	8"	10"
%HRR			
Warm Up (sample 1)	39.5	39.9	42.9
Warm Up (sample 2)	43.8	42.5	46.2
Muscle Conditioning	44.6	48.6	56.1
Flexibility	36.9	40.6	46.4
%HR $_{max}$			
Warm Up (sample 1)	58.1	58.8	60.7
Warm Up (sample 2)	61.0	60.5	62.9
Muscle Conditioning	61.5	64.7	69.7
Flexibility	56.1	59.2	62.9

THE EFFECT OF STEP HEIGHT ON RPE

Figure 5 shows the mean RPE response at each step height throughout the Uni-Step routine. It can be seen that the mean response was lower during the warm up than during the remainder of the aerobic section of the routine, and thereafter increased steadily until the end of the aerobic section, dropping only once at all three step heights after 24 minutes. The pattern of response at each step height appeared to be similar throughout the aerobic section, and in fact, repeated measures analysis of variance confirmed this. RPE was again lower at the end of the routine during the muscle conditioning and flexibility sections. It appeared from Figure 5 that there was little difference in the RPE responses among the different step heights during the muscle conditioning, flexibility and the warm up sections, as would be expected since the step was not utilised during these periods.

Repeated measures analysis of variance of the aerobic section (minus the warm up) revealed a significant increase ($P < 0.001$) in RPE at each step height (see Table 8). Mean values for the entire aerobic section at each step height can be found in Table 9.

THE EFFECT OF STEP HEIGHT ON TOTAL ENERGY EXPENDITURE

Table 11 shows the mean total energy expenditure, the standard deviation and the range for all ten subjects at each step height. The figures for energy expenditure are for the full duration of the Uni-Step routine. It should be noted that all values of energy expenditure for the Uni-Step routine are slightly underestimated due to the small percentage of expired air which was not collected during bag changeover. The total loss of expired air was 36 seconds out of a total duration of 38 minutes 40 seconds, or 1.6%.

Table 11. Total Energy Expenditure (mean ± standard deviation) for the Uni-Step Routine at each Step Height

Step Height	Mean Energy Expenditure (kcal.)	Standard Deviation	Range (kcal.)
6"	209.7	35.0	165.3 - 271.8
8"	226.9	31.8	188.0 - 295.0
10"	255.1	34.2	204.7 - 308.9

Figure 6 shows the energy expenditure across the different step heights for all ten subjects. Visual inspection of the graph suggests that there was a greater energy expenditure as the step height increased. A repeated measures analysis of variance test revealed a significant difference ($P < 0.001$) in mean energy expenditure across the three step heights. The estimated differences between step heights are shown in Table 8.

Only one subject, performing the routine on STEP10, reached the minimum A.C.S.M. (1990) recommendation of 300 kcal. per session. Four subjects at STEP6 reached a total expenditure of 200 kcal., although another three subjects were within 5 kcal. of this target. Seven subjects out of eight at STEP8 and all ten subjects at STEP10 also reached 200 kcal. per session.

As stated previously, Haskell (1985) and Haskell et al (1985) recommend a minimum energy expenditure of 4 $kcal \cdot kg^{-1}$ of body mass per exercise session. Table 12 shows the total energy expenditure for each subject at each of the three step heights studied, along with the minimum energy expenditure recommended by the above authors for each subject according to her body mass. It can be seen that this minimum threshold was reached by nine of the ten subjects at STEP10, two out of eight subjects at STEP8 (although another four were within 8.0 kcal. of their target) and only one out of ten subjects at STEP6. The mean energy costs per kilogramme of body mass for each step height are displayed in Table 9.

TABLE 12. COMPARISON OF ACTUAL ENERGY EXPENDITURE OF UNI-STEP ROUTINE AND THAT RECOMMENDED BY HASKELL (1985) AND HASKELL ET AL (1985)

Subject	Body Mass (kg.)	Recommended Energy Expenditure (kcal.)	Actual Energy Expenditure (kcal.)		
			Step Height (inches)		
			6	8	10
1	54.5	218.0	165.3	215.4	**226.4**
2	56.6	226.4	189.4	218.4	**241.5**
3	55.1	220.4	195.8	*	**239.4**
4	61.2	244.8	**259.6**	*	**294.6**
5	73.0	292.0	271.8	**295.0**	**308.9**
6	48.3	193.2	173.1	188.0	**204.7**
7	52.3	209.2	194.9	208.9	**233.5**
8	61.5	246.0	223.7	227.9	**280.4**
9	62.9	251.6	199.4	217.3	236.9
10	61.1	244.4	224.3	**244.4**	**284.4**

* Missing Data.

The figures in bold type are those which reach the threshold recommended by Haskell (1985) and Haskell et al (1985).

CORRELATION OF DEPENDENT VARIABLES

For each pair of dependent variables which were studied (%$\dot{V}O_{2\,max}$ / %HRR, %$\dot{V}O_{2\,max}$ / %HR $_{max}$, RPE / %$\dot{V}O_{2\,max}$, RPE / %HRR and RPE / %HR $_{max}$), individual correlations were carried out for each subject at each step height. Again, the analysis omitted data from samples measured during the warm up, muscle conditioning and flexibility sections of the routine (samples 1, 2, 11 and 12). The median value of the correlation coefficient at each step height was then recorded. Table 13 displays the median correlation coefficients and the range of scores of the group for each pair of variables. The individual data are detailed in Appendix E.

CORRELATION OF OXYGEN UPTAKE AND HEART RATE RESPONSE

The comparison of Figure 2, which shows mean %$\dot{V}O_{2\,max}$ over time at each step height, with both Figures 3 and 4, which show the heart rate response over time (as %HRR and %HR $_{max}$ respectively), revealed that the pattern of response of these variables appeared to be similar throughout the aerobic section of the routine.

From visual examination of the graphs, there was little noticeable difference in pattern except during the muscle conditioning and flexibility sections, in which the heart rate response was different at each step height, whereas the oxygen uptake response appeared to be very similar at all heights during this part of the routine.

Closer inspection revealed that whereas the oxygen uptake values in the

TABLE 13. SUMMARY STATISTICS FOR CORRELATION ANALYSIS

Variables	Step Height	Median Correlation Coefficient	Range
$\%\dot{V}O_{2\,max}$ and HR	6"	0.90	0.45 - 0.97
(Both %HRR and $\%HR_{max}$)	8"	0.94	0.80 - 0.97
	10"	0.96	0.89 - 0.99
$\%\dot{V}O_{2\,max}$ and RPE	6"	0.61	0.27 - 0.91
	8"	0.66	0.52 - 0.92
	10"	0.79	0.76 - 0.93
RPE and HR	6"	0.80	0.65 - 0.93
(Both %HRR and $\%HR_{max}$)	8"	0.83	0.74 - 0.96
	10"	0.92	0.74 - 0.97

aerobic section (excluding the warm up) ranged between approximately 40% $\dot{V}O_{2\,max}$ and 70% $\dot{V}O_{2\,max}$, the heart rates ranged between approximately 55 %HRR and 85 %HRR and between approximately 70%HR $_{max}$ and 90% HR $_{max}$.

Figures 7 and 8 illustrate the correlation for each subject at each step height for %$\dot{V}O_{2\,max}$ against %HRR and %$\dot{V}O_{2\,max}$ against %HR $_{max}$ respectively. There was a very high positive correlation between %$\dot{V}O_{2\,max}$ and heart rate with all r values above 0.8 with the exception of the values for subject seven at STEP6 and STEP8, subject one at STEP6 and subject nine at STEP6.
The median correlation coefficients for %$\dot{V}O_{2\,max}$ against heart rate (both %HRR and %HR $_{max}$) were 0.90 at STEP6, 0.94 at STEP8 and 0.96 at STEP10.

CORRELATION OF OXYGEN UPTAKE AND RPE

Figure 9 shows both %$\dot{V}O_{2\,max}$ and RPE over the duration of the Uni-Step routine at each of the three step heights. Visual examination of the two graphs showed that the mean pattern of response of RPE at each step height did not appear to mirror %$\dot{V}O_{2\,max}$ throughout the whole routine. This was especially clear between minutes 21 and 30.5 as emphasised on the graphs. The pattern of response for both RPE and %$\dot{V}O_{2\,max}$ were similar during the warm up, muscle conditioning and flexibility sections, but not during the remainder of the aerobic section. RPE gradually climbed throughout the aerobic section of the routine with a small decline at minute 24 for all three step heights. The general pattern of the $\dot{V}O_2$ response at all step heights was an increase to minute 18 followed by a decline from that point until minute 27. The substantial rise in $\dot{V}O_2$ seen at the end of the aerobic section (30.5 minutes) at all three step heights was not accompanied by a similar rise in RPE.

Figure 10 shows correlation of the two variables for each subject at each step height. It can be seen that there was more individual variation in correlation coefficients at the lower step heights, especially at STEP6 where the range was from 0.27 to 0.91. Only one subject (subject five) showed extremely good correlation at all three step heights.

There was an overall poor positive correlation at STEP6 and STEP8, although it appeared to be higher at STEP10. The median correlation coefficients ranged from 0.61 at STEP6 to 0.66 at STEP8 to 0.79 at STEP10.

CORRELATION OF HEART RATE RESPONSE AND RPE

Figures 11 and 12 show the correlation for each subject at each step height for RPE against %HRR and RPE against $\%HR_{max}$ respectively. There was a reasonably good positive correlation between RPE and heart rate. Individual variation in correlation coefficients seemed to be less at greater step heights and the median correlation appeared to be higher at STEP10.

Median correlation coefficients were 0.80 at STEP6, 0.83 at STEP8 and 0.92 at STEP10.

Figure 1. Mean Oxygen Uptake against Time at Three Step Heights

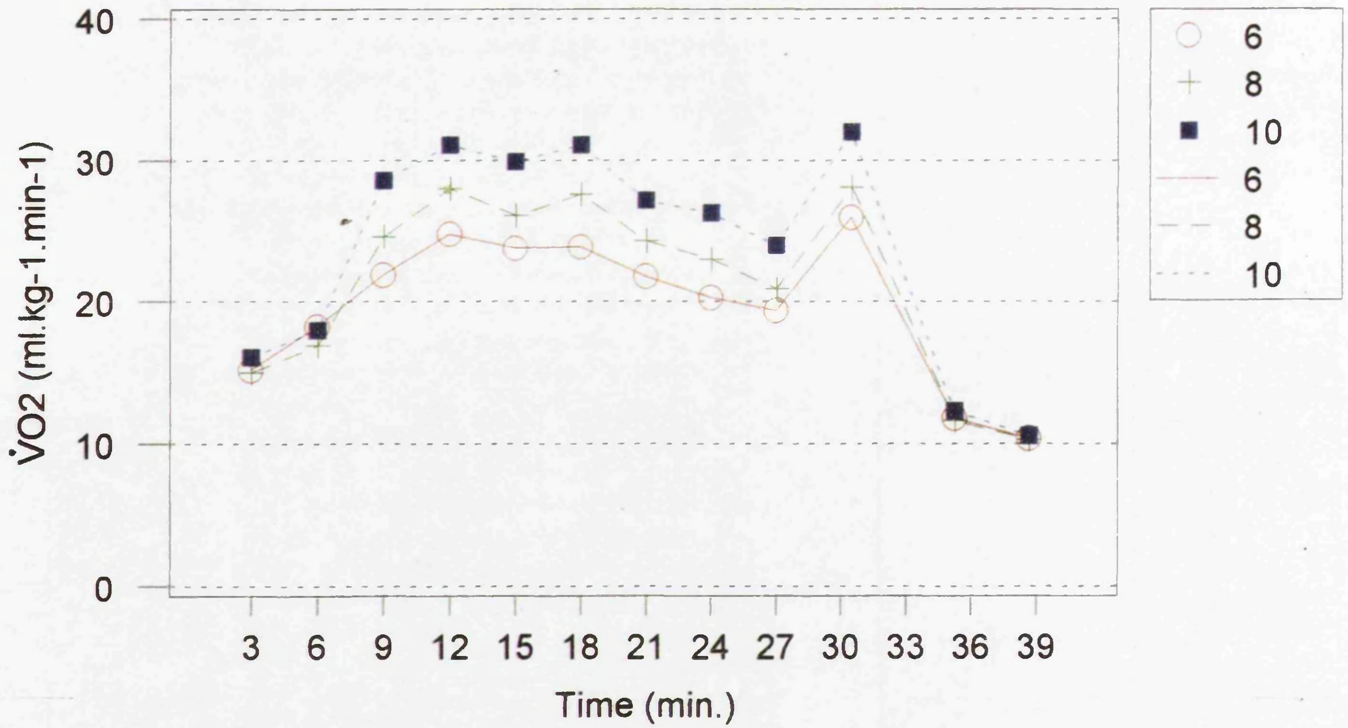


Figure 2. Mean %$\dot{V}O_2$ max against Time at Three Step Heights

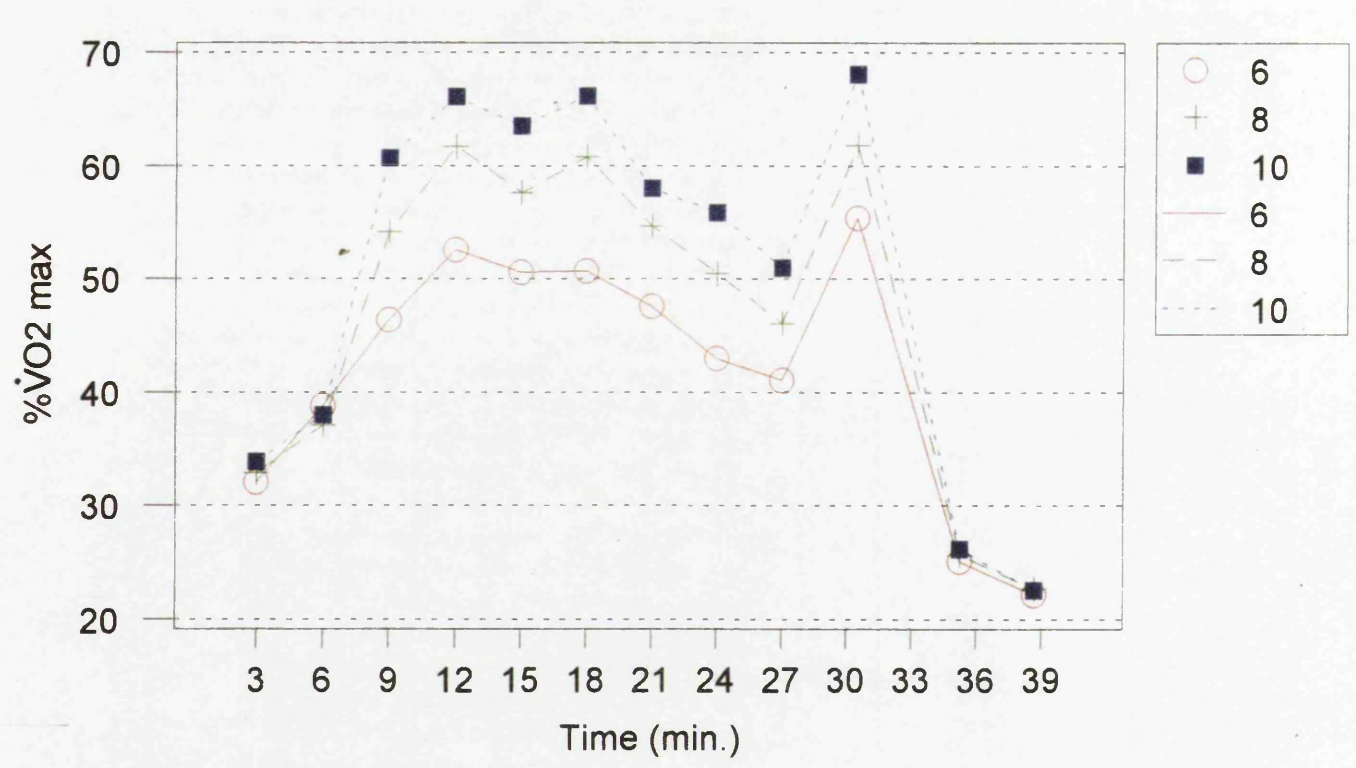


Figure 3. Mean %HRR against Time at Three Step Heights

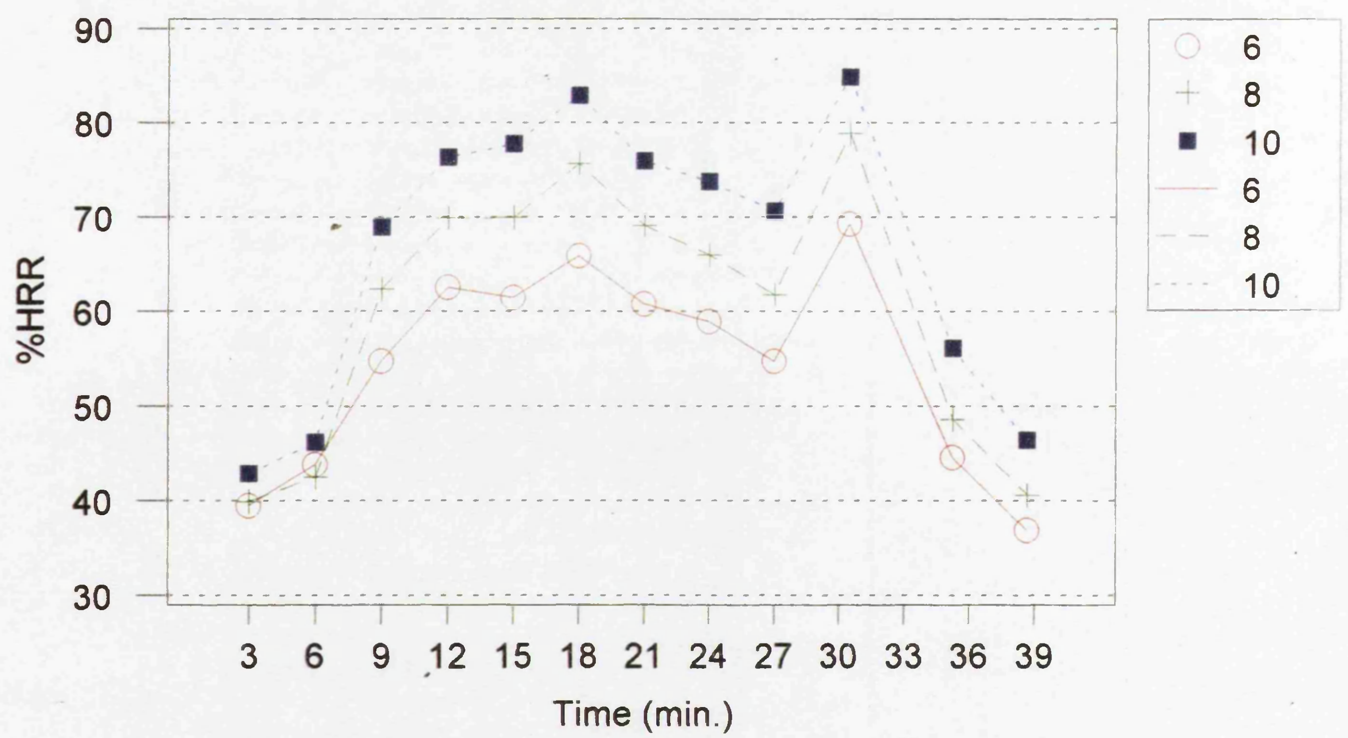


Figure 4. Mean %HR max against Time at Three Step Heights

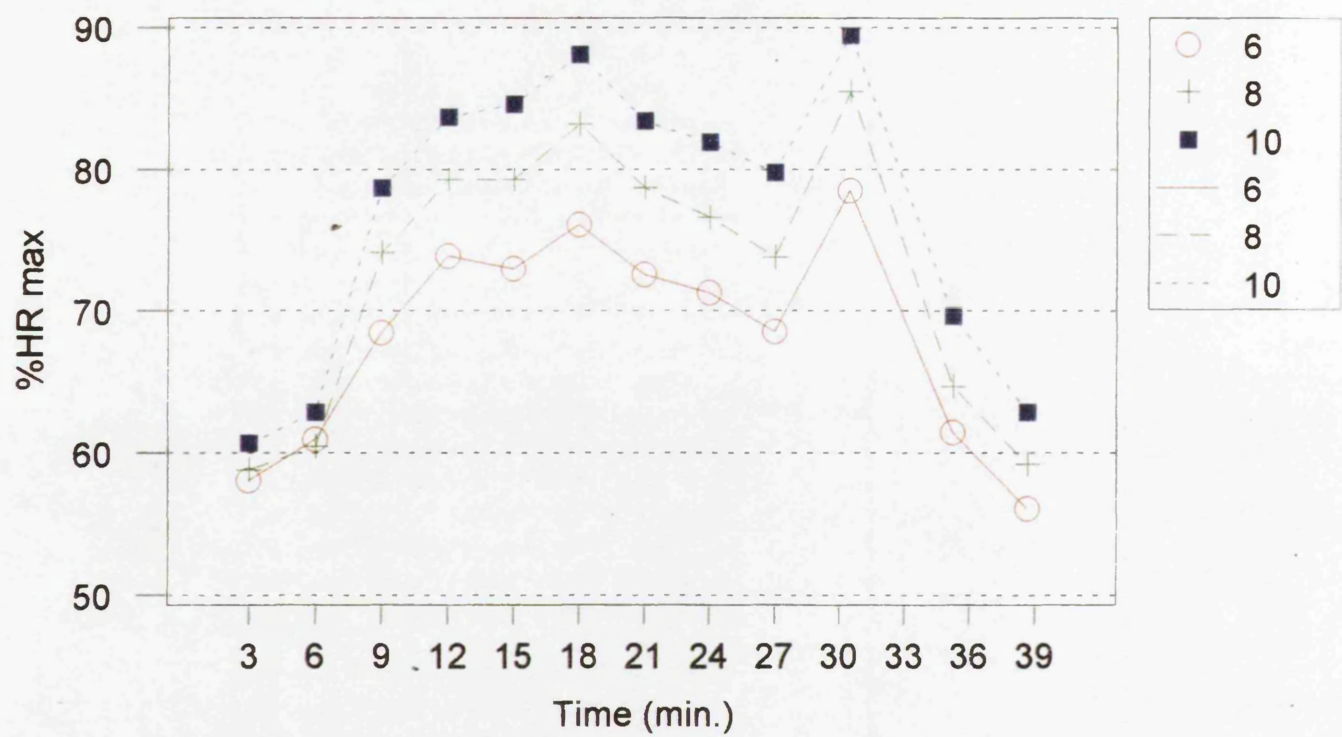


Figure 5. Mean RPE against Time at Three Step Heights

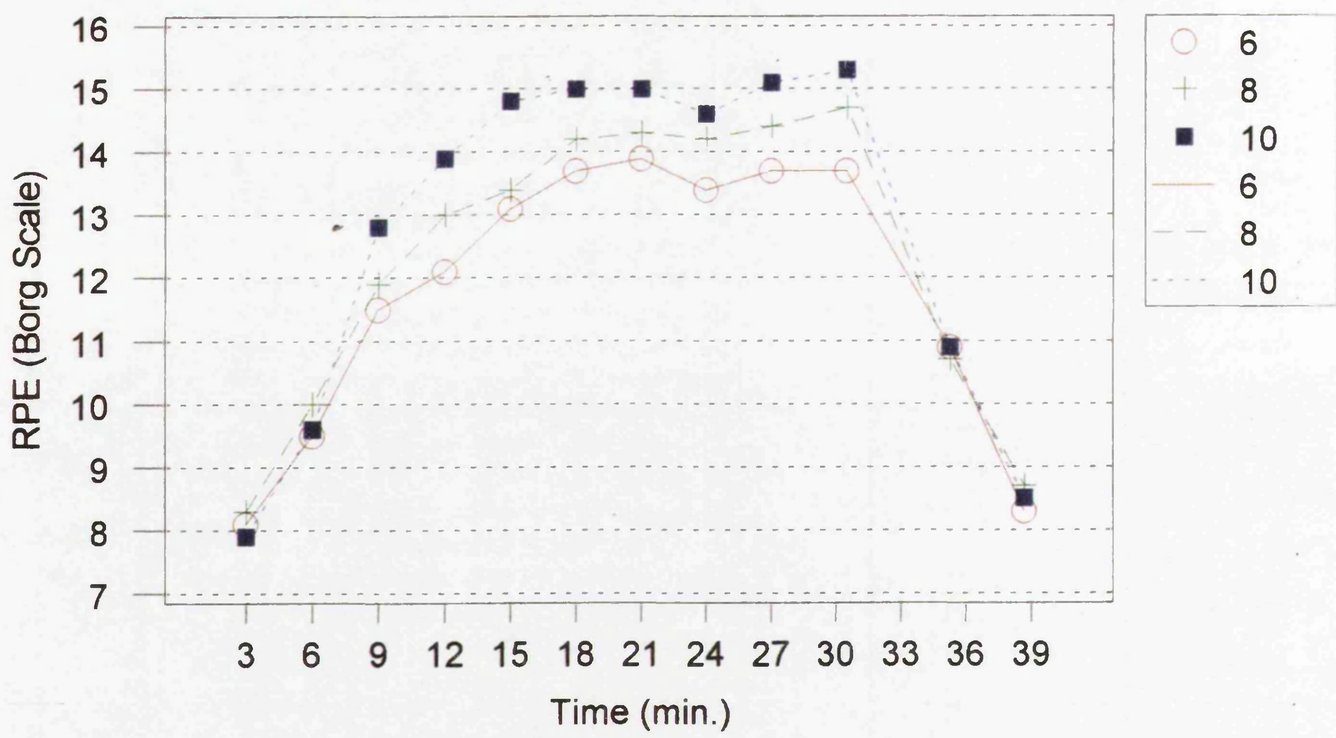
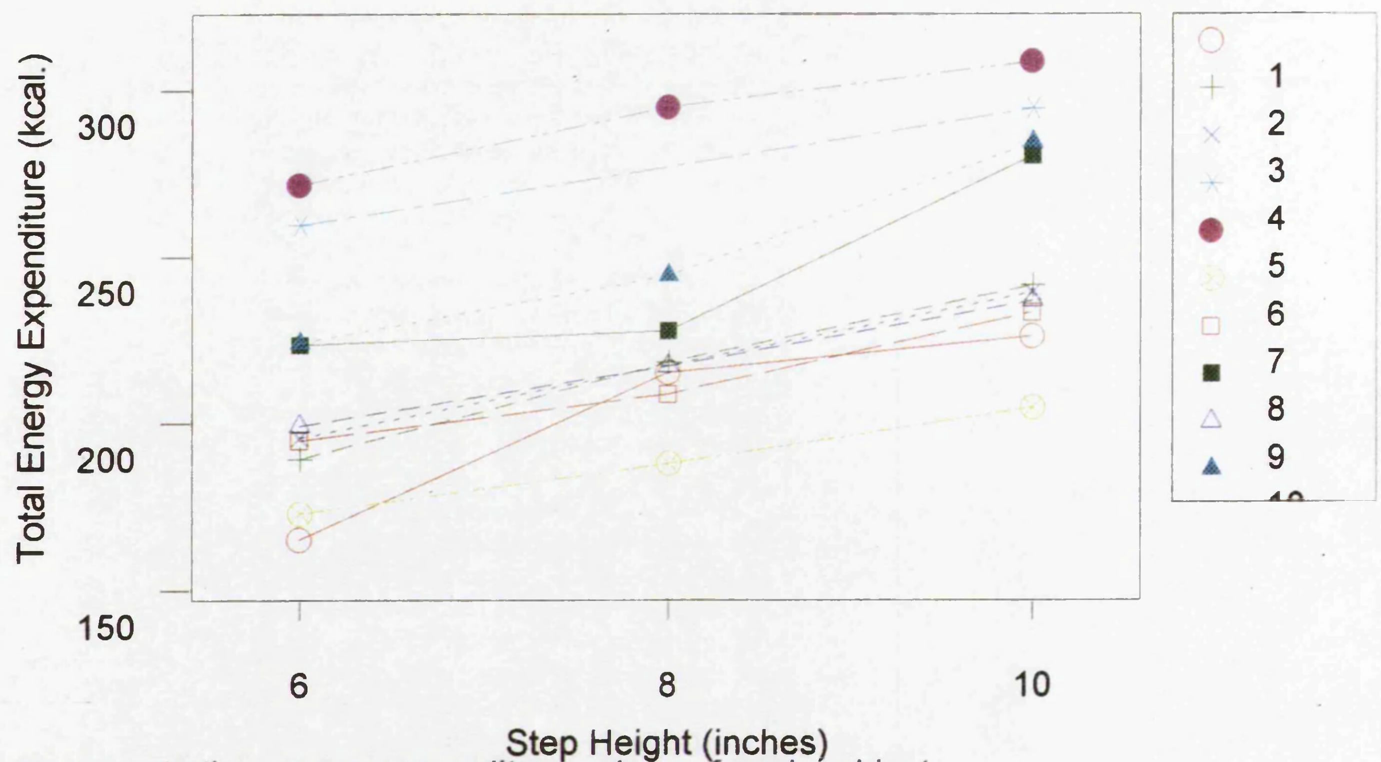


Figure 6. Total Energy Expenditure across Three Step Heights



Each line connects the energy expenditure values of each subject.

FIGURE 7. SAMPLE CORRELATIONS OF INDIVIDUALS BY STEP HEIGHT - %$VO_{2\,max}$ against %HRR

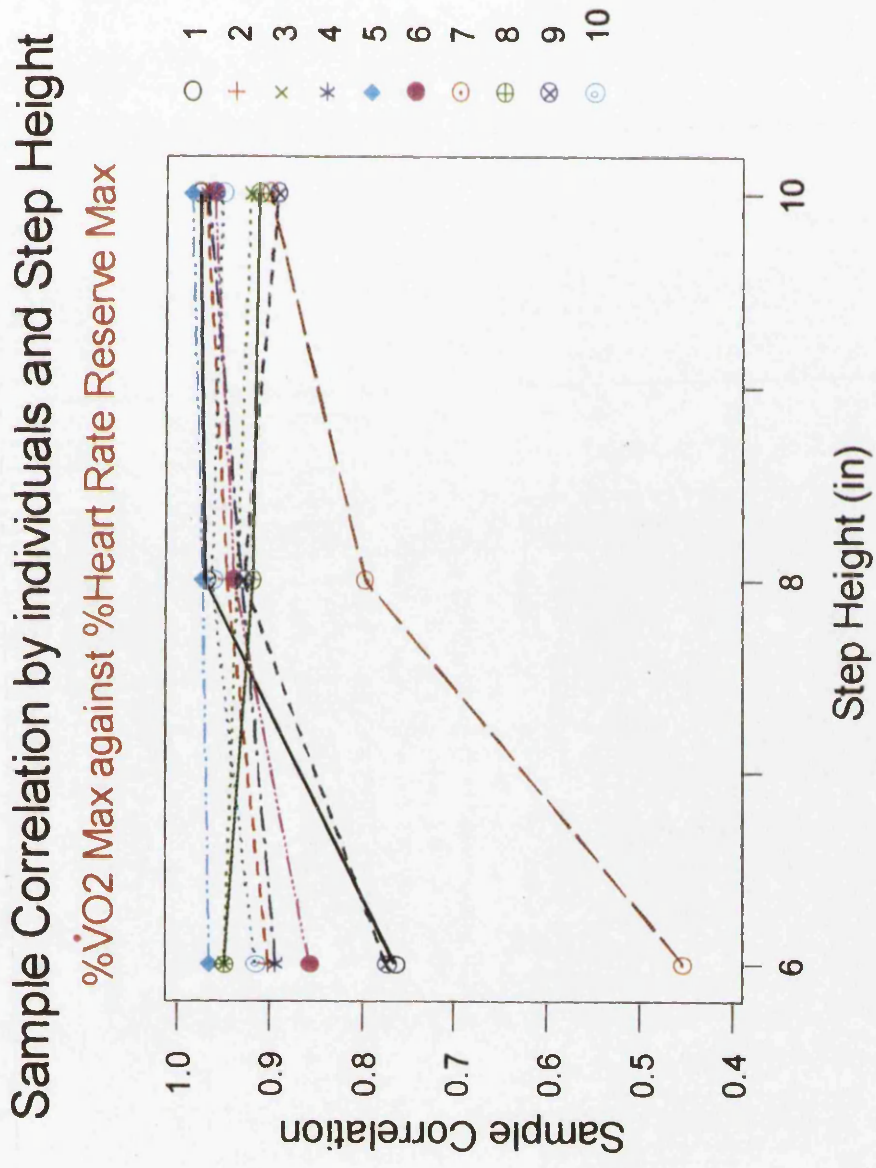


FIGURE 8. SAMPLE CORRELATIONS OF INDIVIDUALS BY STEP HEIGHT - $\%VO_{2\ max}$ against $\%HR_{max}$

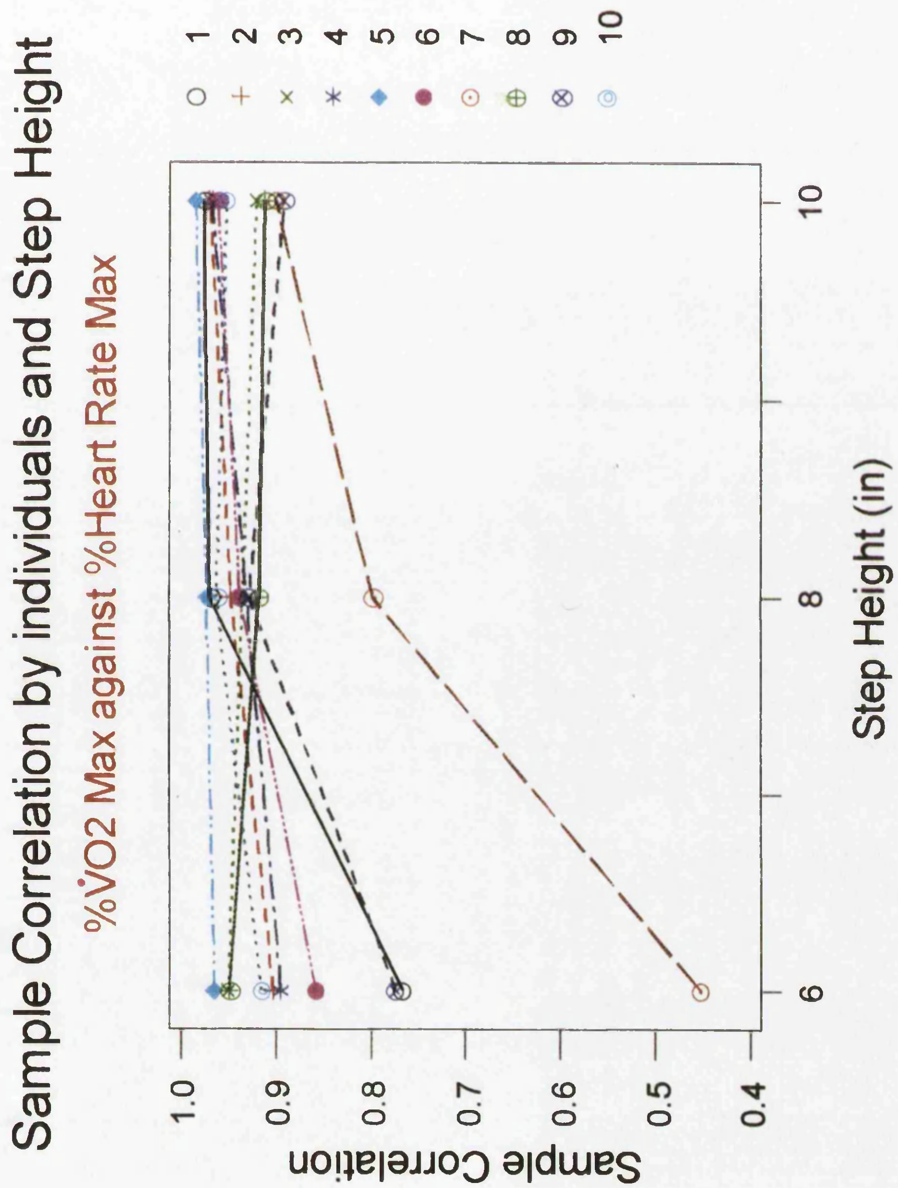
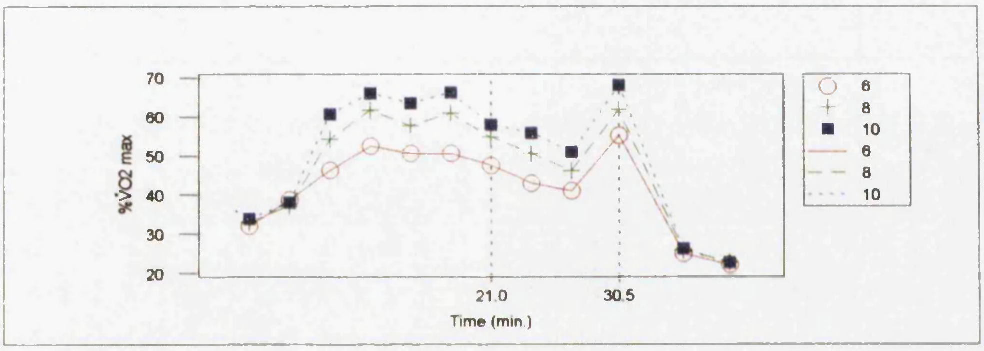


Figure 9. RPE against Time and %V̇O2 max against Time at Three Step Heights



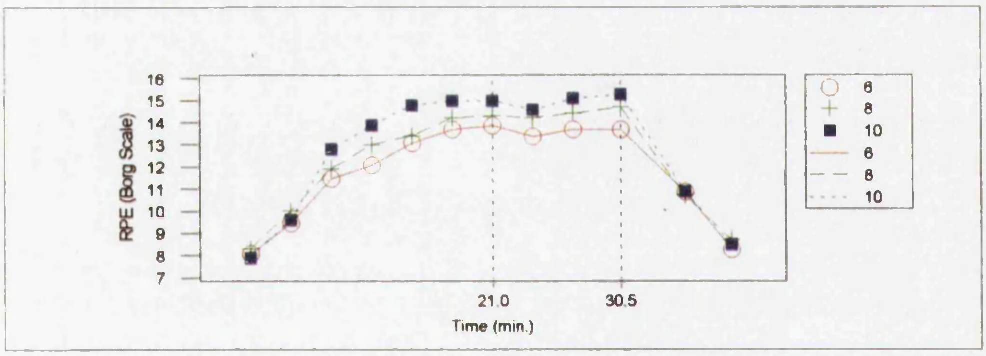


FIGURE 10. SAMPLE CORRELATIONS OF INDIVIDUALS BY STEP HEIGHT - RPE against %VO_2 max

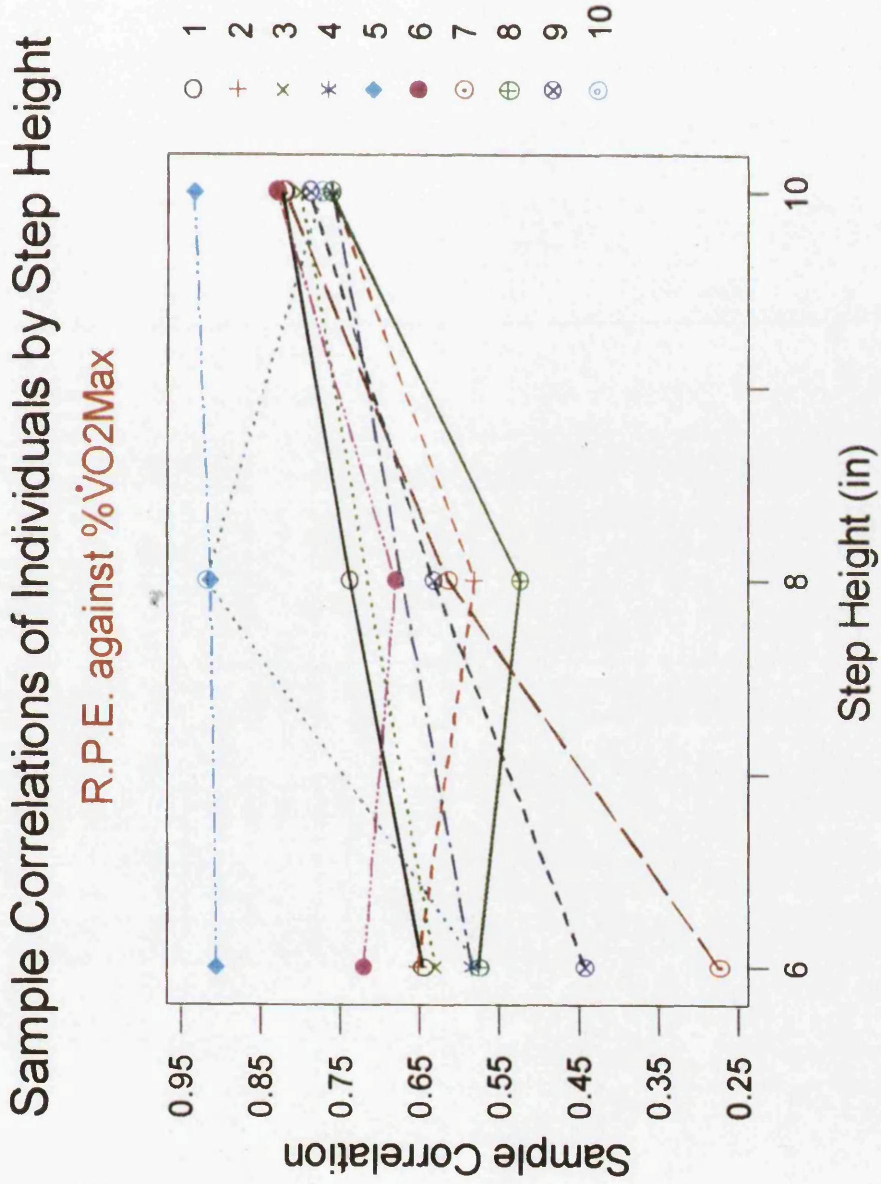


FIGURE 11. SAMPLE CORRELATIONS OF INDIVIDUALS BY STEP HEIGHT - RPE against %HRR

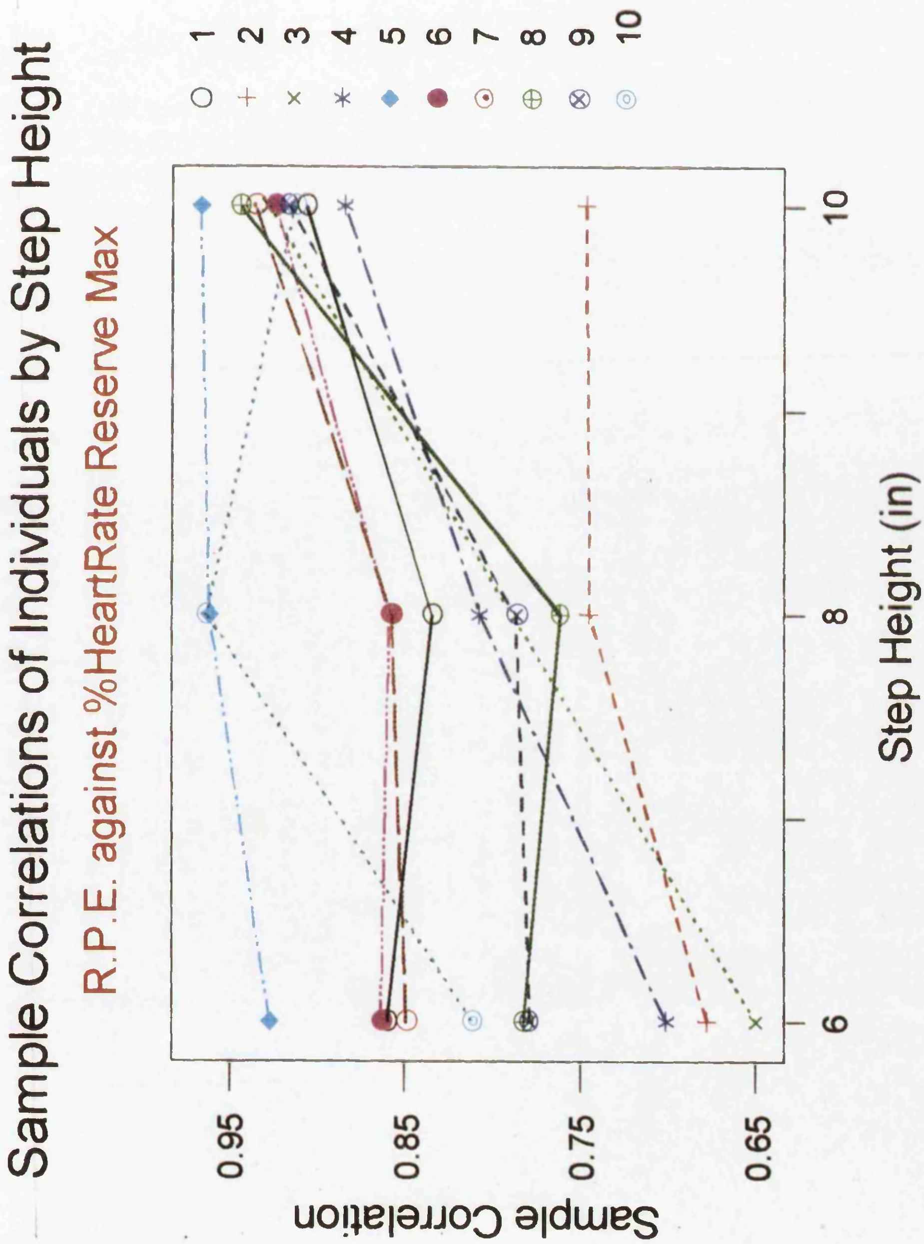
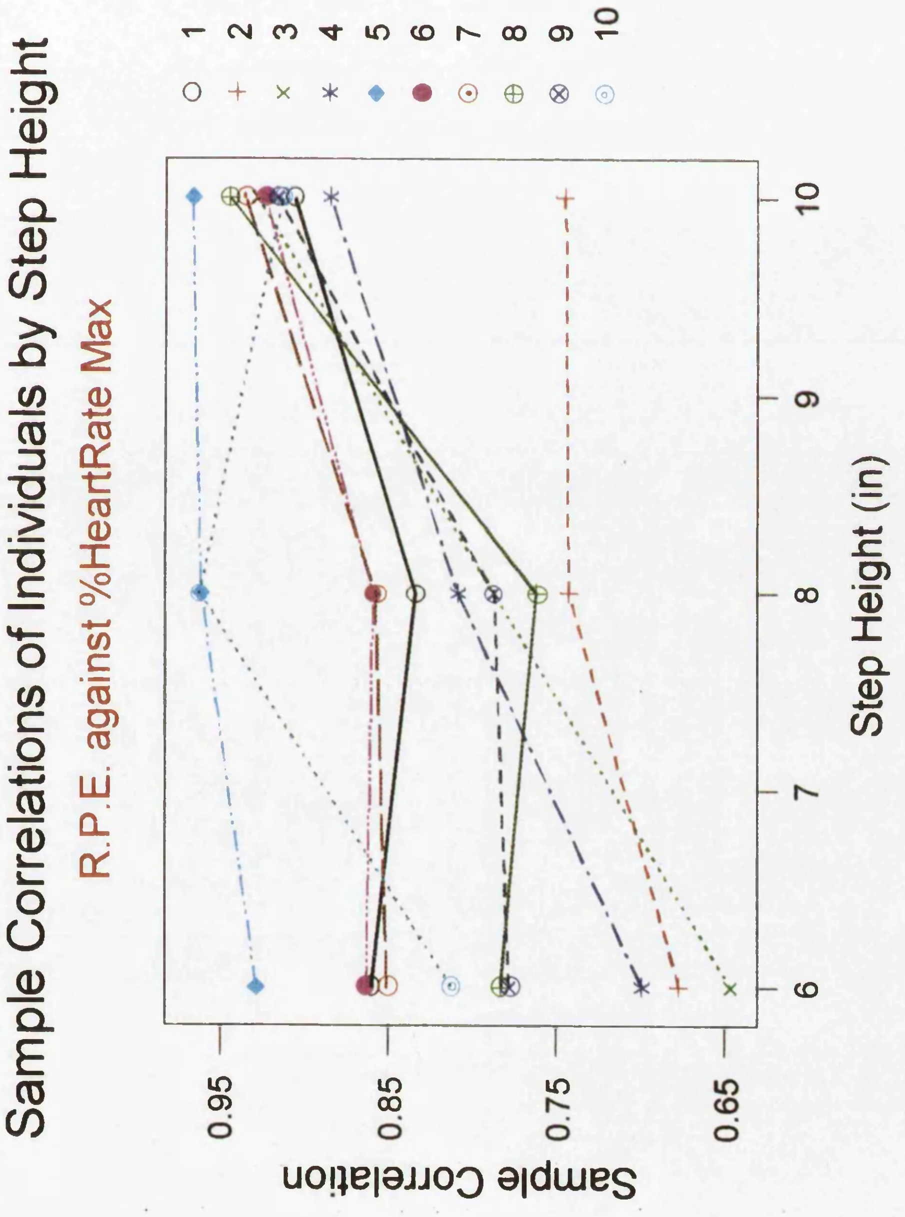


FIGURE 12. SAMPLE CORRELATIONS OF INDIVIDUALS BY STEP HEIGHT - RPE against %HR $_{max}$



DISCUSSION

THE OXYGEN COST OF UNI-STEP EXERCISE

The results of this study are consistent with those of previous step studies (Olson et al, 1991; Stanforth & Stanforth, 1993; Thomas & Long, 1991; Whitney et al, 1993; Woodby-Brown et al, 1993) which reported a significant increase in $\dot{V}O_2$ with an increase in step height (see Table 1).

However, the mean oxygen cost of Uni-Step was lower at all three step heights than that recorded in previous step studies (Olson et al, 1991; Petersen et al, 1993; Woodby-Brown et al, 1993) which reported the following range of scores: 28.4 $ml \cdot kg^{-1} \cdot min^{-1}$ at a step height of 6", 25.3 - 31.3 $ml \cdot kg^{-1} \cdot min^{-1}$ at a step height of 8" and 27.9 - 33.8 $ml \cdot kg^{-1} \cdot min^{-1}$ at a step height of 10" respectively. The mean oxygen costs measured during Uni-Step were 21.5 $ml \cdot kg^{-1} \cdot min^{-1}$ at a step height of 6", 23.4 $ml \cdot kg^{-1} \cdot min^{-1}$ at 8" and 26.4 $ml \cdot kg^{-1} \cdot min^{-1}$ at 10" (see Table 9).

The lower oxygen cost in this study may be attributed to differences in choreography among the step routines studied. Abernethy & Batman (1994) have suggested that the exercise intensity during aerobic dance exercise is dependent on the particular movements being performed at the time of measurement. For example, the routine in the study by Olson et al (1991) included travelling movements and high intensity lunges. Hayakawa et al (1994) showed that lunge step elicited a relative intensity of 81.0% $\dot{V}O_{2\,max}$, while basic step performed at the same step height elicited a lower relative intensity of 63.2% $\dot{V}O_{2\ max}$. The routine used by Woodby-Brown et al (1993) and the Uni-Step routine incorporated a minimum amount of these types of movements, and the oxygen cost in both of these studies was lower at each step height than that reported by Olson et al (1991). The mean $\dot{V}O_2$ of 25.3 $ml \cdot kg^{-1} \cdot min^{-1}$ reported by Woodby-Brown et al (1993) at a step height of 8" was similar to the mean $\dot{V}O_2$ of 25.8 $ml \cdot kg^{-1} \cdot min^{-1}$ and 24.6 $ml \cdot kg^{-1} \cdot min^{-1}$ measured during the pilot tests carried out prior to the present study, also performed at a step height of 8".

The step rate corresponding to a cadence of 120 $beats \cdot min^{-1}$ in the studies by Olson et al (1991) and Woodby-Brown et al (1993) was similar to that used in the Uni-Step routine where the cadence ranged from 125 to 132 $beats \cdot min^{-1}$ during the aerobic section of the routine. Therefore, it is likely that this factor did not contribute significantly to differences in oxygen cost .

The study by Petersen et al (1993) was published in abstract form and did not specify step rate or the types of movements performed during the routine. Therefore, the greater oxygen cost in comparison to Uni-Step performed at the same step height, in this case may have been due to a higher step rate, more strenuous choreography, or a combination of both.

Another factor which may have been partly responsible for differences in oxygen cost is familiarity of subjects with the exercise mode. It was found that the mean $\dot{V}O_2$ measured during the Uni-Step pilot study was approximately 5% greater than that measured during the main study. It is possible that subjects in the main study had more experience of Uni-Step than those in the pilot study and were therefore able to perform the movements more efficiently. Prior to acceptance into either study, subjects were asked to specify the number of times per week which they currently attended Uni-Step sessions. Mean attendance at Uni-Step for subjects in the pilot study was 1.0 times per week, whereas mean attendance for subjects in the main study was 1.4 times per week.

The relative intensity of Uni-Step was calculated at three different step heights to determine whether this mode of exercise could be effective in the maintenance or development of cardiovascular fitness. The A.C.S.M. (1990) recommend a mean minimum exercise intensity of 50% $\dot{V}O_{2max}$ for a duration of at least 20 minutes per session for this purpose.

The results of this study would suggest that Uni-Step exercise is of a sufficient relative intensity to promote improvements in the cardiovascular fitness of the subjects in this study when performed at step heights of 8" and 10", but not at a step height of 6", however, these results were recorded in individuals with a mean $\dot{V}O_{2max}$ of 47.7 $ml \cdot kg^{-1} \cdot min^{-1}$. It is possible that Uni-Step performed on a 6" step could be of a sufficiently high intensity for individuals of lower fitness levels than the subjects in this study. The mean $\dot{V}O_2$ for Uni-Step at STEP6 was 21.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Individuals with a $\dot{V}O_{2max}$ of 43 $ml \cdot kg^{-1} \cdot min^{-1}$ or below would be exercising at or above a mean intensity of 50% $\dot{V}O_{2max}$ during Uni-Step performed on a 6" step.

According to the mean absolute oxygen costs recorded for Uni-Step at the three different step heights, this mode of exercise could be a suitable cardiovascular stimulus for individuals with a maximum oxygen uptake of between 25.3 $ml \cdot kg^{-1} \cdot min^{-1}$ and 52.8 $ml \cdot kg^{-1} \cdot min^{-1}$ when performed on step heights of 6", 8" or 10". All such individuals could exercise between 50% and

85% of their maximum oxygen uptake as recommended by the A.C.S.M. (1990).

Participants in Uni-Step classes are encouraged to choose a step height appropriate to their level of fitness. However, due to inexperience, it is possible that there may be a tendency for individuals to choose the same height as the teacher, or others in the class, regardless of fitness level. However, if an individual's maximum oxygen uptake has been measured, then a suitable step height could be recommended on the basis of mean absolute oxygen cost data reported in this study, prior to that individual taking part in a Uni-Step class. The University of Glasgow Sport and Recreation Service offers estimation of maximum oxygen uptake to all users of the facilities, however, a recent study (Grant et al, 1995) using male subjects found that the predictive methods currently used at Glasgow University tended to underestimate $\dot{V}O_{2\,max}$. Perhaps choice of step height could be based upon an individual's heart rate response to the first step class attended.

For participants wishing to exercise at a higher relative intensity, consideration should be given to the increased risk of injury with the use of a higher step. Crisp (1994) suggested that if step height is raised above one quarter of the leg length of the participant, there may be increased muscular strain and a higher potential for injury, although this has not yet been investigated. The leg lengths of the subjects in this study ranged from 79.0 cm. (31.1 in.) to 93.0 cm. (36.6 in.), thus according to Crisp, the maximum advisable step height for these subjects would be between 7.8 in. and 9.2 in..

An upper limit on step height would have implications for participants with a high level of aerobic fitness. Due to the design of the step used in Uni-Step sessions, the step height can only be increased in increments of 2". Therefore, the maximum height for the subjects in the present study, in light of Crisp's recommendation (1994), would be 8". The mean relative intensity at a step height of 8" in this study was 51.6% $\dot{V}O_{2\,max}$. Although it is recommended (A.C.S.M., 1990) that 50% $\dot{V}O_{2\,max}$ is the minimum threshold for the maintenance or improvement of cardiovascular fitness, it has been noted that the average conditioning intensity for healthy adults is usually between 60% - 70% of $\dot{V}O_{2\,max}$ (A.C.S.M., 1986). The subjects in this study were of a relatively high fitness level and therefore, the level of intensity recorded for Uni-Step at this step height may not actually provide a substantial increase in fitness. In addition, Hickson et al (1985) reported that training intensity is important for the maintenance of aerobic fitness since subjects exhibited a detraining effect on $\dot{V}O_{2\,max}$ with a reduction in training intensity. Thus, participants with a high fitness level may experience a decline in aerobic fitness by using Uni-Step as their sole training mode. A training study would be required to effectively answer this point.

The intensity of step aerobics can also be increased by an increase in step rate, or the use of more strenuous choreography. Crisp (1994) also recommends that a limitation be placed upon the rate of stepping, since participants with longer legs may find it difficult to keep up at higher rates.

Olson et al (1991) used a routine which included more strenuous choreography than the Uni-Step routine, and recorded a mean relative intensity of 65.9% $\dot{V}O_{2\,max}$ at a step height of 8". Therefore, perhaps a Uni-Step session containing more strenuous choreography would be more suitable for participants of a higher level of aerobic fitness.

THE "EXTENDED" DURATION OF THE UNI-STEP ROUTINE

The aerobic section of a Uni-Step routine is 30 minutes in length. In addition, there are 10 minutes of muscle conditioning and flexibility exercises, and therefore, the full duration of a session is 40 minutes. This is in contrast to the more common 20 minute duration of many aerobic exercise sessions. Other exercise sessions run by the Sport and Recreation Service at Glasgow University are 30 minutes in length, having a 20 minute aerobic section.
The reason for the extended duration of the Uni-Step aerobic section is that when the class was being designed, it was proposed that the relative intensity of the warm up would be low. The warm up period, which lasts for approximately 6 minutes, is incorporated into the aerobic section of the routine. If the aerobic section was only 20 minutes in length, the low intensity of the warm up period may lower the mean relative intensity of the aerobic section below the minimum threshold of 50% $\dot{V}O_{2\,max}$ recommended by the A.C.S.M. (1990). The recommendation specifies that the mean intensity should be at or above this level for a duration of at least 20 minutes. The duration of the aerobic section was extended to 30 minutes as it was hoped that the mean intensity of at least 20 minutes of that time would be sufficiently high to meet the A.C.S.M. (1990) recommendation.

Some individuals may feel that they cannot afford the time to structure a 40 minute exercise session into their daily schedule, and therefore, the duration of the session may be a possible deterrent to participants. It would be helpful to ascertain whether the extra 10 minutes of aerobic exercise are actually necessary for participants to maintain or improve their aerobic fitness levels. In order to determine this, the mean relative intensity data from the aerobic section of the routine were examined.

First of all, it was noted that the mean relative intensity of the warm up period was low, as expected. It was below 40% $\dot{V}O_{2\,max}$ at all three step heights.

The mean relative intensity of samples 1 to 7 were averaged, giving an aerobic duration of 21 minutes. These samples consisted of a 6 minute warm up period plus a further 15 minutes of aerobic exercise. Unfortunately, due to the methods employed in collecting the samples, it was not possible to study the mean relative intensity of exactly 20 minutes of aerobic exercise.

The mean relative intensity of samples 1 to 7 was 45.2% $\dot{V}O_{2\,max}$ at STEP6, 51.1 % $\dot{V}O_{2\,max}$ at STEP8 and 55.2% $\dot{V}O_{2\,max}$ at STEP10. These values were only slightly lower than those reported for the full 30 minute aerobic section (see Table 9), however, the %$\dot{V}O_{2\,max}$ at STEP8 and STEP10 was still above the threshold required for a training effect.

Therefore, these findings suggest that despite the low intensity during the warm up period, the duration of the aerobic section of the Uni-Step routine could be decreased to 21 minutes without the mean intensity dropping below the minimum threshold required for maintaining or improving aerobic fitness.

However, it should be noted that a reduction in the total duration of the session would cause a decrease in total energy expenditure and thus would have implications for those participants who were exercising in order to lose body weight.

Samples 1 to 7 plus the muscle conditioning and flexibility sections could constitute a Uni-Step routine with an aerobic section of 21 minutes duration. The mean total energy expenditure for this "routine" was calculated as 151.1 kcal. at STEP6, 162.4 kcal. at STEP8 and 181.1 kcal. at STEP10. The energy cost relative to body mass was 2.6 $kcal \cdot kg^{-1}$ at STEP6, 2.8 $kcal \cdot kg^{-1}$ at STEP8 and 3.1 kcal·kg^{-1} at STEP10. Therefore, although the duration of the aerobic section could be decreased with little change to the mean intensity, the total energy expenditure of the routine would not be high enough to promote weight loss according to the recommendations of the A.C.S.M. (1990) or Haskell (1985) and Haskell et al (1985).

THE HEART RATE RESPONSE DURING UNI-STEP

Mean heart rate increased significantly with each increase in step height between 6" and 10" during Uni-Step. This finding is in agreement with those of previous step studies (Olson et al, 1991; Stanforth & Stanforth, 1993).

From examination of individual heart rate responses during Uni-Step, it was seen that several subjects had mean heart rates in excess of 90% HR_{max} during the last sample of the aerobic section at STEP10. However, the corresponding $\%\dot{V}O_{2\,max}$ values recorded during these samples showed that the subjects were not, in fact, exercising at a near maximal intensity. Williford et al (1989) similarly reported heart rates close to maximum during aerobic dance exercise although the oxygen uptake response was well within aerobic capacity. The authors suggested that the high heart rate response may have been due to several possible factors including additional stress from attempting to follow the instructor or keep up with other class members, or by the use of vigorous and overhead arm movements. These possibilities, with the exception of trying to keep up with other class members, could be associated with the high heart rates found in this study. The possibility of vigorous and overhead arm movements causing an increased heart rate will be examined in more detail in a later section.

There was a tendency for the heart rate response to be lower for STEP8 in comparison to both STEP6 and STEP10 during the warm up period of the Uni-Step routine (samples 1 and 2). This may be a chance finding or may be attributed to familiarity with this step height. Eight out of the ten subjects used this height during their regular attendance at step sessions. Heart rate may be affected by apprehension during exercise of a low to moderate intensity (Astrand & Rodahl, 1986) and it is possible that the heart rate response during the warm up stages of exercise at unfamiliar step heights may have been increased in this way.

The heart rate was higher at STEP10 during the warm up period, compared to the two lower step heights, despite the subject performing virtually the same movements at each step height. This may have been due to a disproportionately larger anticipatory rise in heart rate at the highest step height. It has been shown that heart rate rises in anticipation of exercise. It has also been shown that the rise tends to be higher preceding sprint events of a shorter duration, which would be at a higher intensity, than a longer duration sprint (McArdle et al, 1994).

None of the subjects in this study had previously performed Uni-Step on a 10" step, therefore, the anticipatory rise in heart rate may have been disproportionately higher at this step height due to overexpectation of the intensity level required. It is also possible that heart rate may have been increased further by apprehension (Astrand & Rodahl, 1986).

There may have been a further anticipatory rise in heart rate during sample two. During this period, the subjects began to perform the movement of marching and tapping the step with their free foot. This movement pattern is commonly used during the warm up period of Uni-Step to introduce the participants to the height of their step, so that they can become accustomed to it shortly before beginning to step onto it. It is conceivable that, during this sample, there may have been a further anticipatory rise stimulated by the knowledge of impending activity at a greater intensity.

The mean heart rate response increased with increasing step height during the muscle conditioning and flexibility sections of the Uni-Step routine. During these sections, the subject should have performed the same movements at all three step heights and this appeared to be confirmed by the lack of difference in $\dot{V}O_2$ responses among step heights. Thus, if the heart rate response was linked to the oxygen uptake response, no differences would be expected in heart rate among the three step heights during these sections. It is possible that these differences may have been due to a longer heart rate recovery period as the step height increased. During the sample immediately before the muscle conditioning section, the heart rate was significantly higher as step height increased due to the greater metabolic cost of exercise. Therefore, the heart rate would have further to fall at the greater step heights and would presumably take longer. However, this does not explain the differences during the flexibility section.

THE APPLICABILITY OF HEART RATE AS A PREDICTOR OF EXERCISE INTENSITY DURING UNI-STEP

The strong correlation between HR and $\dot{V}O_2$ at each step height confirmed that there was a linear relationship between the two variables as expected. The linear relationship between HR and $\dot{V}O_2$ has been extensively used for the estimation of exercise intensity during aerobic activity. The exercise prescriptions of the A.C.S.M. (1990) are based upon the HR-$\dot{V}O_2$ relationship established for treadmill running and described by Pollock & Wilmore (1990) as follows; $\%\dot{V}O_{2\,max}$ and %HRR are interchangeable between 50% and 85% and 60% - 90% HR_{max} is equivalent to 50% - 85% $\dot{V}O_{2\,max}$.

Davis & Convertino (1975) have suggested that heart rate is equivalent to $\dot{V}O_2$ during treadmill running. However, as noted from the review of the literature, some authors indicate that this relationship holds for alternate modes of exercise and others dispute this. Therefore, it is necessary to be cautious in the interpretation of the findings of the present study.

The results of the present study showed that the heart rate response (both %HRR and $\%HR_{max}$) to Uni-Step exercise at all three step heights was unrepresentatively high with respect to $\dot{V}O_2$ in comparison to the established relationship between HR and $\dot{V}O_2$.

It is possible, therefore, that the relationship for Uni-Step may be disproportional with respect to the relationship established for treadmill running and recommended by the A.C.S.M. (1990) as the basis for exercise prescription. However, it is only possible to make a limited evaluation without a direct comparison of the HR-$\dot{V}O_2$ relationship between Uni-Step and treadmill running. It was not possible to carry out this comparison in the present study due to lack of time.

FINDINGS OF PREVIOUS STUDIES

Some previous studies have reported a significant difference in the HR-$\dot{V}O_2$ relationship between aerobic dance and treadmill exercise (Parker et al, 1989; Stanforth et al, 1988) whereas some have reported no significant difference (Berry et al, 1992; Reeves & Darby, 1991).

Other studies did not directly compare the HR-$\dot{V}O_2$ relationship of aerobic dance with that of treadmill exercise, but, similar to the present study, simply measured $\dot{V}O_2$ and HR responses during aerobic dance. Some of these studies reported an elevated heart rate with respect to $\dot{V}O_2$ in comparison to the heart rate response expected from the HR-$\dot{V}O_2$ relationship established by the A.C.S.M. (1990) (Davidson, 1995; Hornsby et al,1991; Williford et al, 1989). Others reported no elevation in the expected heart rate response (Davidson, 1995; Grant et al, 1993; Sutherland et al, 1993).

Several studies have specifically examined step aerobics, rather than aerobic dance. Forte et al (1995) reported no significant difference between the HR-$\dot{V}O_2$ relationship during step aerobic exercise and treadmill walking. Petersen et al (1993) found no disproportionate elevation in heart rate with respect to the $\dot{V}O_2$ response when compared to the established HR-$\dot{V}O_2$ relationship.

In contrast, Olson et al (1991) did find an elevated heart rate response in comparison to the established HR-$\dot{V}O_2$ relationship during step aerobics at step heights of 6", 8" and 10", although not at 12". The results of the present study are in agreement with these findings.

Thus, there does not appear to be any overall agreement in the literature. It is difficult to generalise the results of previous research since aerobic dance and step aerobics are not standardised modes of exercise like treadmill exercise or cycle ergometry where a standard workload can be compared between studies. Movements during these exercise modes are specific to each routine and may be very different between routines. Some routines incorporate lower body movements such as hopping and jumping, whereas others are low impact routines during which one foot is kept on the floor at all times. Arm movements can be vigorous and overhead, or gentle and low at the front or the sides of the body. Therefore, no two studies may actually be measuring the same "type" of exercise and a comparison is perhaps inappropriate.

EXPLANATION OF ELEVATED HEART RATE RESPONSE

A suggested explanation for the disproportionately elevated heart rate response in aerobic dance exercise is an increased sympathetic tone due to the large amount of arm movements in this mode, especially at or above shoulder level. This was first suggested by Astrand et al (1968), and more recently by Parker et al (1989) and Olson et al (1991).

In the study on step aerobics by Olson et al (1991), heart rate and $\dot{V}O_2$ were measured at a range of step heights. There was a significant difference in $\dot{V}O_2$ between the 10" and 12" heights, although there was no significant difference in the heart rate response. The authors postulated that this finding may be due to subjects using a smaller range of arm movements at 12", since the relative intensity at this step height was in excess of 90% $\dot{V}O_{2\,max}$. If so, this finding would support the hypothesis that vigorous arm movements may be the cause of the elevated heart rate during this exercise mode.

It is unclear if the elevated heart rate response found in the present study was caused by an increased sympathetic tone, since no appropriate measurements were made. An increase in sympathetic tone would be accompanied by an increase in blood norepinephrine concentration, however, it has been noted (Astrand & Rodahl, 1986) that plasma norepinephrine concentration is a relatively poor indicator of sympathetic activity. Further study would be required to clearly determine the cause of the elevated heart rate.

Berry et al (1992) specifically examined the effect of arm movements on the HR-$\dot{V}O_2$ relationship during aerobic dance. They reported no difference in the HR-$\dot{V}O_2$ relationship between aerobic dance performed with the arms above head level and with the arms below shoulder level. There was also no difference between this relationship and that of treadmill running. They suggested that the lack of an elevated heart rate response may be due to the low relative intensity of exercise in their study. Subjects exercised at approximately 50% $\dot{V}O_{2max}$ in all three exercise modes.

The data from the present study contradict the suggestion that heart rate is not elevated at a low relative intensity of exercise. Although Uni-Step was performed at a similar low relative exercise intensity (45.6% $\dot{V}O_{2max}$ at STEP6 - 56.2% $\dot{V}O_{2max}$ at STEP10), it appeared that there was an elevated heart rate response based on the established HR-$\dot{V}O_2$ relationship. The $\dot{V}O_{2\,max}$ of subjects in both studies was very similar (47.3 $ml \cdot kg^{-1} \cdot min^{-1}$ in Berry et al (1992) compared to 47.7 $ml \cdot kg^{-1} \cdot min^{-1}$ in the present study) and therefore, the absolute intensity of exercise in both studies was also very similar.

ALTERNATIVE EXPLANATION OF ELEVATED HEART RATE RESPONSE

A recent study (Davidson, 1995) may point to an alternative explanation for an elevated heart rate response. Heart rate and $\dot{V}O_2$ responses were measured during low impact and high impact aerobic dance sessions. Although both sessions utilised the same arm movements, an elevated heart rate was found in the low impact session only. This finding would suggest that another factor, other than arm movements, may be responsible for the elevated heart rate in this study.

An alternative explanation for an elevated heart rate response in exercise may be a lowered stroke volume due to decreased venous return. Bevegard et al (1966), Stenberg et al (1967) and Toner et al (1990) reported a lower stroke volume associated with an elevated heart rate during arm exercise compared to leg exercise or combined arm and leg exercise. Decreased venous return is a feature in arm exercise due to lack of activity of muscle pumps in the lower limbs which assist blood flow back to the heart. However, in light of Toner's suggestion that stroke volume is maintained with 25% of total power output from the legs (Toner, 1990), it is difficult to support the postulation that the smaller lower body component in low impact aerobic dance could be responsible for less activity in the muscle pumps of the lower body and thus a decreased venous return.

Several studies have examined low impact aerobic dance during which one foot is kept on the floor at all times. There are no hopping or jumping movements as there are in traditional (or high impact) aerobic dance, and therefore the lower body movements are less vigorous. Step aerobics tends to be a low impact exercise mode although high impact elements can be incorporated. The Uni-Step routine used in this study was of a low impact nature.

Low impact and step studies have tended to show an elevated heart rate response (Davidson, 1995; Hornsby et al, 1991; Olson et al, 1991; Williford et al, 1989) and high impact studies have tended to show no elevated heart rate response (Berry et al, 1992; Davidson, 1995; Grant et al, 1993; Sutherland et al, 1993).

There are exceptions to this where an elevated heart rate response was found in high impact aerobic dance (Parker et al, 1989) and heart rate was not elevated in low impact or step studies (Forte et al, 1995; Petersen et al, 1993; Stanforth et al, 1988). Again, there appears to be no consensus in this area. Some low impact routines may have a greater lower body component than others making comparisons among studies difficult to make. Of course, the elevated heart rate in many of these studies may have been due to increased sympathetic influence since the effects of arm movements were not directly examined. Further study would be required to clearly determine the cause of any elevated heart rate response in each individual study.

Toner et al (1990) reported that as little as 25% of leg activity was enough to maintain stroke volume in combined cycling and arm cranking exercise. In light of this result, it is difficult to imagine that Uni-Step, or any other aerobic dance activity, low or high impact, would not have enough leg involvement to maintain venous return. A study by Goss et al (1989) reported that during basic stepping on a 34.6 cm (13.4") step while pumping arms, the arms contributed only 17.5% of total $\dot{V}O_2$. Even taking into consideration the lower step height in the present study, which would indicate a smaller amount of total work done by the lower body, and the more vigorous arm movements, it would seem extremely unlikely that the proportion of leg work would be less than 25% of the total energy cost of the activity (Toner et al, 1990).

Stroke volume was not measured in the present study and therefore, it is not possible to determine if this was a factor involved in the elevated heart rate found in Uni-Step exercise.

Static muscular contractions, such as those utilised in resistance training, have previously been shown to cause an elevated heart rate (Hurley et al, 1984), however, the arm movements in Uni-Step exercise were largely of a dynamic nature and therefore, it is unlikely that static contractions were the cause of the higher heart rates during Uni-Step. However, without further study, it is only possible to speculate on the reasons for the elevated heart rate found in Uni-Step exercise.

IMPLICATIONS OF THESE FINDINGS

The results of the present study have implications for the use of heart rate monitoring in Uni-Step classes. Participants in these classes are encouraged to use heart rate (%HR $_{max}$) to monitor the intensity of their exercise. There is a short break in the exercise during which the teacher leads a 15 second pulse count.

The heart rate response during Uni-Step appeared to overestimate the actual metabolic cost of exercise at all three step heights, perhaps due to the large amount of arm movements during this type of exercise. This may be misleading to participants and they may not benefit as much as expected in terms of aerobic fitness by regular participation if this discrepancy is not taken into consideration.

It appears that the HR-$\dot{V}O_2$ relationship for Uni-Step exercise may be disproportional in comparison to the relationship for treadmill running. Since exercise prescriptions are based upon the HR-$\dot{V}O_2$ relationship found for treadmill running, the use of heart rate to estimate intensity during Uni-Step may have limitations. Therefore, on the basis of the present results, it is concluded that heart rate may be inappropriate as a predictor of exercise intensity during Uni-Step and caution would be advised in its use.

THE RPE RESPONSE DURING UNI-STEP

Only one previous study (Olson et al, 1991) has measured RPE at a range of step heights. A significant increase in RPE with each increase in step height between 6" and 10" was reported. The results of the present study are in agreement with this finding.

The mean RPE responses during Uni-Step at step heights of 6", 8" and 10" were higher than those reported in the Olson study. The mean values found in the present study were 12.3, 12.9 and 13.4 for 6", 8" and 10" respectively. Olson et al (1991) found lower RPE responses of 10.6, 11.9 and 13.1 for the same step heights even though the mean relative intensity of exercise was higher in their study (59.8%, 65.9% and 71.2% $\dot{V}O_{2\,max}$ for 6", 8" and 10" respectively, in contrast to 45.6%, 51.6% and 56.2% $\dot{V}O_{2\,max}$ in the present study).

Another study measured RPE at a single step height. Petersen et al (1993) reported a mean RPE response of 13 with a mean relative intensity of 58.4% $\dot{V}O_{2\,max}$ for step aerobics at a height of 10". A slightly higher RPE response was found in the present study at a similar mean relative intensity. The mean $\dot{V}O_{2\,max}$ of subjects in all three studies was very similar (47.5 $ml \cdot kg^{-1} \cdot min^{-1}$ in Olson et al (1991), 48.4 $ml \cdot kg^{-1} \cdot min^{-1}$ in Petersen et al (1993) and 47.7 $ml \cdot kg^{-1} \cdot min^{-1}$ in the present study).

The reason for the higher RPE values in this study is unknown since many factors influence the perception of exertion (Watt & Grove, 1993). It is possible that the different choreography involved in the different routines could have

been at least partly responsible for the differences noted in the RPE responses. Pandolf (1983) has stated that different types of exercise will produce a different mixture of local and central signals, thus influencing the perception of effort. RPE tends to be higher in arm exercise compared to leg exercise at the same submaximal $\dot{V}O_2$ (McArdle et al, 1994), possibly caused by greater local effort sensations due to a smaller working muscle mass at a given submaximal workload. Olson et al (1991) found no significant difference in RPE response during step aerobics performed on a 10" and 12" step and postulated that this was due to a smaller proportion of arm work at the higher step height which could have altered the relative contribution of local and central signals to decrease the RPE with respect to the metabolic load. Perhaps the amount of arm work included in their routine was lower in comparison to Uni-Step thus producing lower RPE responses, however it is not possible to speculate further without a detailed analysis of the movements used in both studies.
Eston & Williams (1988) showed that the magnitude of correlations between perceived exertion and $\%\dot{V}O_{2\ max}$ increased across three exercise trials, conducted on separate days, suggesting that the ability to estimate exercise intensity using RPE may increase with practice. Thus, subjects with more experience of the RPE scale may be able to more accurately estimate exercise intensity in this way, and this may contribute to differences in RPE responses across studies. However, experience with the use of RPE was not reported in any of the above cited studies.

If participants perceive an exercise session to be too strenuous, then adherence may decrease. On the other hand, if they feel that it is too easy, they may not believe that they are gaining the benefits which they are seeking, and therefore, this again may decrease their motivation to attend the session.

Mean RPE responses during the aerobic section of the Uni-Step routine (excluding the warm up period) were mainly between 11 ("fairly light") and 15 ("hard") on the Borg 6 - 20 scale, although some individuals registered responses as high as 17 ("very hard") during the more strenuous samples at STEP10. The overall mean responses at each step height for the aerobic section of the routine were 12.3 at STEP6, 12.9 at STEP8 and 13.4 at STEP10 which correspond reasonably well with the rating "somewhat hard". It has been suggested (A.C.S.M., 1986) that a range of 12 - 16 should provide an adequate training intensity for most people. It appears then that the level of exertion perceived by the subjects in this study may, in general, have been high enough to suggest benefits and low enough to avoid discomfort, although clearly, for some subjects, there was discomfort at certain points during Uni-Step at STEP10.

THE APPLICABILITY OF RPE AS A PREDICTOR OF EXERCISE INTENSITY DURING UNI-STEP

RPE has been recommended as a substitute for regulating exercise intensity (A.C.S.M., 1990). In order to examine the relationship between RPE and $\dot{V}O_2$, and to evaluate the applicability of using RPE to estimate intensity during Uni-Step, correlation of $\%\dot{V}O_{2\,max}$ against RPE was carried out.

The RPE-$\dot{V}O_2$ correlation appeared to be higher at STEP10 ($r = 0.79$) than at STEP6 ($r = 0.61$) or STEP8 ($r = 0.66$). This may have been due to less distraction from physiological cues at a higher intensity. It has been suggested

that it may be possible to disassociate from physiological feedback to reduce ratings of perceived exertion at low to moderate intensities of exercise, however, at higher intensities, physiological cues become stronger and harder to ignore (Watt & Grove, 1993). This hypothesis has been contradicted (Boutcher et al, 1988), however, the findings of studies involving psychological factors can be complicated since it is unknown whether the RPE reported by subjects is the RPE which is actually perceived.
It is possible that the subjects in this study may have been distracted from physiological effort cues to some extent, perhaps due to the music accompanying the exercise. Previous studies (Grant et al, 1993; Sutherland et al, 1993) have suggested a distraction effect from music accompanying an exercise session.

The reasonably low correlations between RPE and $\dot{V}O_2$ were not unexpected since the mean RPE response pattern did not reflect the pattern of the mean oxygen uptake response. Mean RPE tended to increase steadily throughout the aerobic section of the Uni-Step routine at each step height, whereas the mean oxygen uptake response increased for the first 12 minutes of the routine and then tended to decrease until the end of the aerobic section when there was a sharp increase in the last sample. This finding suggests that other factors apart from $\dot{V}O_2$ may have been responsible for the subjects' perceptions of exertion. It has already been noted that the perception of exertion is based upon many factors, both physiological (such as $\dot{V}O_2$, heart rate, respiratory rate and blood lactate) and psychological (Birk & Birk, 1987; Morgan, 1973).

Previous aerobic dance studies carried out at Glasgow University have reported a similar steadily increasing RPE throughout a 20 minute session while $\dot{V}O_2$ remained fairly stable or increased to a peak and then declined again (Davidson, 1995; Grant et al, 1993; Sutherland et al, 1993). It was postulated that the steady increase in RPE may have been due to the effect of fatigue. It is possible that this may have been a factor in the steadily increasing RPE reported in the present study.

Some studies (Eston & Williams, 1988; Smutok et al, 1980) have used only short periods of exercise (less than 10 minutes) to assess the ability of RPE to predict exercise intensity. If, in fact, fatigue does influence the perception of effort, then further study would be required to validate the use of RPE during longer durations of exercise.

RPE RESPONSES HIGHER THAN THOSE CITED IN LITERATURE

The RPE responses in the present study appeared to be marginally higher than those cited in the literature. Pollock & Wilmore (1990) stated that an RPE of 12 - 13 was equivalent to 50 - 74 $\%\dot{V}O_{2\,max}$ and an RPE of 14 - 16 was equivalent to 75 - 84 $\%\dot{V}O_{2\,max}$. Birk & Birk (1987) suggested that an RPE range of 12 - 15 was equivalent to 58 - 89 $\%\dot{V}O_{2\,max}$.

McArdle et al (1994) have noted that the perception of effort is generally higher in exercise in which the arms are used. The above guidelines were generated from lower body exercise, and therefore, this may be partly responsible for the discrepancy between these guidelines and the results of the present study in which the RPE responses to exercise involving the arms were examined.

The RPE responses in this study may have been elevated due to the fact that although subjects were asked to report an overall sensation of effort during the Uni-Step tests, it is possible that the large amount of stepping involved in this exercise mode may have caused a large input from local sensations from the muscles of the thighs. This input may have had an overbearing effect on the overall perception of effort.

However, the ability to precisely target relative intensity using RPE within an exercise setting appears problematic. For example, it is suggested by Pollock & Wilmore (1990) that the range 50 - 74 %$\dot{V}O_{2\,max}$, which is 25% of the total range of %$\dot{V}O_{2\,max}$, can be targeted by an increase of just one RPE unit. Therefore, it is difficult to come to a clear conclusion concerning the results of the present study.

CORRELATION OF HEART RATE AND RPE

Some individuals find it difficult to measure their own heart rate and the A.C.S.M. (1990) have suggested that RPE can be substituted for heart rate once the individual relationship between the two variables has been learnt by the participant. The good correlation found between HR and RPE for Uni-Step would agree with this suggestion. However, the findings of this study have already shown that it may be inappropriate to use heart rate to estimate intensity during Uni-Step.

INDIVIDUAL VARIABILITY IN RPE RESPONSE

There were quite marked individual variations in the RPE response to Uni-Step exercise. For example, the raw data were examined for instances of a subject having the same mean $\dot{V}O_2$ response for more than one sample in a test. Sixteen instances occurred, from nine of the subjects, and in fourteen of these there was a difference in RPE response of between 1 and 3 units. There were also individual variations found between tests for the same subject. Twenty eight occurrences of the same mean $\dot{V}O_2$ response from all three step tests were found. In eighteen of these, there was a difference in RPE response of between 1 and 5 units. Thus, the same individual may perceive a given submaximal exercise intensity differently in different exercise situations and it would seem questionable that an RPE value could be equated with a given level of $\dot{V}O_2$ in this exercise mode. This finding highlights the difficulties involved in simply prescribing an exercise intensity of 12 - 16 as recommended by the A.C.S.M. (1990). Some participants may be able to use RPE to quite accurately predict $\dot{V}O_2$. For example, one subject in this study showed extremely good correlation between RPE and $\dot{V}O_2$ at all three step heights. However, the spread of correlation coefficients was wide, with most subjects recording r values below 0.7 at the two lower step heights indicating a low ability to accurately predict exercise intensity using RPE.

LIMITATION OF MEASUREMENT OF RPE

Due to the measuring system employed for $\dot{V}O_2$, continuous measurement was not possible and a mean response was recorded for each 3 minute sample period. The decision to measure the RPE response 30 seconds prior to the end of each sample was an arbitrary one. Thus, the movements being performed at the time of response to the RPE scale may not have been representative of the rest of the sample, and so, for example, if subjects were asked to give an RPE response while performing a particularly strenuous movement, they might be expected to overestimate their exertion in relation to their mean level of exertion throughout the sample period.

The choreography of the Uni-Step routine (see Appendix C) was examined to determine whether the actual movements performed at the time of each RPE response were, in fact, representative of the movements performed throughout the whole of each sample. It was found that in eight of the ten samples measured during the aerobic section of the routine, the movement pattern at the time the subject was asked to respond to the RPE scale appeared to be reasonably representative of the movements performed throughout the rest of the sample. In the remainder of the aerobic section, the movements at the time of the RPE response appeared to be less vigorous than during the rest of the sample (samples 2 and 10).

This may have been a limitation of this study and correlation of $\dot{V}O_2$ and RPE when measured in this way is perhaps inappropriate. This problem could be solved by the use of equipment which continuously measures $\dot{V}O_2$, rather than calculating mean $\dot{V}O_2$ over a short period of time.

IMPLICATIONS OF THESE FINDINGS

The low correlation between $\%\dot{V}O_{2max}$ and RPE for the majority of subjects at STEP6 and STEP8, and the considerable individual variation in responses at all three step heights suggest that the use of RPE may have limited applicability for the estimation of exercise intensity during Uni-Step.

In view of these results, caution would be recommended for the use of RPE to estimate intensity during Uni-Step. However, the fact that RPE was slightly higher in this study than expected from values cited in the literature would provide a useful safety measure; that is, if participants followed the RPE exercise prescription recommended by the A.C.S.M. (1990), they may be exercising at an actual intensity lower than the recommendation. Therefore, there would be little chance of exercising at an intensity high enough to be associated with an increased risk of injury. High intensity exercise has been associated with both an increased risk of injury and a decreased adherence (A.C.S.M., 1990). The subjects in this study did not rate RPE too highly in general, and therefore, it would appear that they did not tend to find it uncomfortably strenuous, thus promoting good adherence to this exercise mode.

THE ENERGY COST OF UNI-STEP EXERCISE

The energy cost of Uni-Step exercise was lower at all three step heights in comparison to previous studies on step aerobics (Olson et al, 1991; Petersen et al, 1993; Wang et al, 1993; Woodby-Brown et al, 1993) which reported energy costs ranging from 6.7 - 7.5 $kcal \cdot min^{-1}$ at 6", 7.7 - 8.5 $kcal \cdot min^{-1}$ at 8" and 8.1 - 9.5 $kcal \cdot min^{-1}$ at 10". The corresponding values recorded for Uni-Step were 6.1 $kcal \cdot min^{-1}$, 6.7 $kcal \cdot min^{-1}$ and 7.6 $kcal \cdot min^{-1}$. All studies calculated the energy cost of exercise from the product of the oxygen cost and the caloric equivalent of the respiratory exchange ratio (RER) or a constant value of 5 $kcal \cdot l^{-1}$. It is likely that these differences were due to variations in oxygen cost since the results of the studies mentioned, including the present one, which reported both $\dot{V}O_2$ and energy cost (Olson et al, 1991; Petersen et al, 1993; Woodby-Brown et al, 1993) were such that the study which reported the highest $\dot{V}O_2$ at each step height also reported the highest energy cost and the study which reported the lowest $\dot{V}O_2$ at each step height also reported the lowest energy cost.

The mean body mass of the subjects in the studies by Olson et al (1991) and Woodby-Brown et al (1993) were 55.4 kg. and 63.6 kg. respectively. Mean body mass for the subjects in the present study was 58.6 kg.. Body mass was not reported for the other two studies which have, to date, only been published in abstract form. These values are not largely different and therefore, body mass is unlikely to have been a factor in the differing energy costs.

It was the aim of this study to estimate the energy cost of Uni-Step exercise at three different step heights and, from these data, to determine the utility of this mode of exercise for promoting weight loss. The A.C.S.M. (1990) suggest that an exercise session with a total energy expenditure of at least 300 kcal. performed three times per week could aid weight loss. The A.C.S.M. (1990) also recognise the suggestion of Haskell (1985) and Haskell et al (1985) of a mean energy cost of 4 kcal$\cdot$kg^{-1} of body mass per session.

The mean total energy expenditure during Uni-Step at each step height was below this minimum recommendation. Only one subject reached an expenditure of 300 kcal. (subject 5 expended 308.9 kcal. at STEP10), although three others were within 20 kcal. of this value, also at STEP10. However, an expenditure of 200 kcal. per session has also been shown to be useful (Sidney et al, 1977). The A.C.S.M. (1990) recommend a frequency of four times per week at this level of energy expenditure. The mean total energy expenditure of the Uni-Step routine was above 200 kcal. for all three step heights studied, although at STEP6, six subjects expended less than 200 kcal. (although four of these subjects were within 10.6 kcal. of a total expenditure of 200 kcal.). At STEP8, only one subject who had the lowest body mass, expended less than 200 kcal..

Uni-Step is a weight bearing activity, and therefore the energy cost would be expected to be higher for individuals with a greater body mass. When the energy cost of the aerobic section of Uni-Step was related to body mass, a mean energy cost of 4 kcal$\cdot$kg^{-1} recommended by Haskell (1985) and Haskell et al (1985) was only met during STEP10. The mean energy cost at STEP8 was slightly below the recommended level at 3.9 kcal$\cdot$kg^{-1}, although half of the subjects at this step height (four of eight) reached the recommended level and another two subjects reached a total expenditure within 8.0 kcal. of their target (see Table 12).

In order to determine if Uni-Step is a suitable mode of exercise for promoting loss of body mass, a training study would be required in which total daily energy intakes and expenditures are controlled and measured. Unfortunately, this was outwith the scope of the present study. However, the results of this study have been examined in relation to well recognised guidelines for energy expenditure.

The total energy expenditure of Uni-Step when performed at STEP8 or STEP10 with a frequency of four times per week meets the A.C.S.M. (1990) recommendation for the promotion of weight loss. In addition, the total energy expenditure at STEP6 could be suitable for some participants. It also appears that Uni-Step when performed at STEP10, and at STEP8 for some participants, is of a sufficient energy cost related to body mass to be useful for weight loss. Therefore, it is concluded that Uni-Step performed at STEP8 and STEP10 could be useful for weight loss in the majority of individuals.

However, it is recognised that a threshold of energy expenditure for an exercise session may not be appropriate since any increase in energy expenditure would be useful for weight loss.

SUMMARY OF FINDINGS

1. A significant increase in oxygen uptake, heart rate, RPE and total energy expenditure was found during Uni-Step with each increase in step height of 2" between 6" and 10", thus the null hypothesis that an increase in step height does not cause an increase in $\dot{V}O_2$, HR, RPE and total energy expenditure can be rejected. These findings are in agreement with previous studies on step aerobics.

2. The results of this study indicate that Uni-Step meets the A.C.S.M. (1990) recommendations for the intensity of exercise for the maintenance or improvement of cardiovascular fitness when performed at step heights of 8" and 10", but not at 6". Therefore, the null hypothesis that the relative intensity of Uni-Step at three step heights is not sufficiently high for the maintenance or improvement of cardiovascular fitness can be rejected in the case of step heights of 8" and 10", but not in the case of a 6" step height.
These findings suggest that this mode of exercise may be of a sufficiently high intensity to promote improvements in the cardiovascular fitness of the subjects in this study when performed at step heights of 8" and 10", but not at a step height of 6", however, these results were recorded in individuals with a relatively high level of aerobic fitness. It is possible that Uni-Step performed on a 6" step could be of a sufficiently high intensity for individuals of lower fitness levels than the subjects in this study.
The levels of intensity recorded at step heights of 8" and 10" were at the lower end of the recommended range, and therefore, may not provide a substantial increase in aerobic fitness for those participants with a high level of fitness.

Perhaps a Uni-Step session containing more strenuous choreography would be more suitable for such participants since a limitation on step height and step rate have been suggested for reasons of safety.

3. The third aim was to examine the relationships between $\dot{V}O_2$ and HR and between $\dot{V}O_2$ and RPE during Uni-Step exercise at three step heights, and to evaluate the use of HR and RPE for estimating exercise intensity.

The results of the present study have implications for the use of heart rate monitoring in Uni-Step classes since the heart rate responses during this exercise mode appeared to overestimate the actual metabolic cost of exercise at all three step heights. It has been suggested that this may be due to the inclusion of a large amount of arm movements as a substantial part of the choreography during this type of exercise, although further study would be required to clearly determine the cause of the elevated heart rate. This apparent elevation of heart rate may be misleading, and individuals may experience less improvement in aerobic fitness than expected from regular participation if it is not taken into consideration. Caution would be advised for the use of heart rate monitoring in this exercise mode.

The value of RPE for exercise prescription during Uni-Step may also be limited as low correlation was found between $\%\dot{V}O_{2\,max}$ and RPE and there was a great deal of individual variation in RPE response at a given level of oxygen uptake. In addition, RPE was slightly higher for a given relative intensity ($\%\dot{V}O_{2\,max}$) than the values cited in the literature (A.C.S.M., 1990).

Mean RPE responses at each step height suggested that, in general, subjects did not find Uni-Step uncomfortably strenuous, thus potentially promoting good adherence to this exercise mode.

4. The null hypothesis that the energy cost of Uni-Step at three step heights is not sufficiently high to promote weight loss can be rejected in the case of step heights of 8" and 10", but not in the case of a step height of 6".
In order to clearly determine the utility of Uni-Step for promoting changes in body composition, measurements would need to be made over a period of training. Unfortunately, due to lack of time, this was not one of the aims of the present study. In the absence of such data, it is possible to make a limited evaluation on the basis of well recognised guidelines, and it appears that Uni-Step performed at step heights of 8" or 10" may be useful for promoting changes in body composition in the majority of individuals. However, it is recognised that smaller amounts of energy expenditure may also be useful.

Therefore, in conclusion, it appears that Uni-Step may be a useful mode of exercise for promoting changes in both aerobic power and body composition when performed at step heights of 8" and 10", and may be a suitable cardiovascular stimulus for participants of a lower fitness level when performed at a step height of 6".
The use of both heart rate and RPE to monitor the intensity of exercise during this mode appear to limited.

FURTHER RESEARCH

Possibilities for further study in order to better assess the potential of Uni-Step for the development of cardiovascular fitness include the investigation of changes in $\dot{V}O_{2max}$ following a period of training using this mode of exercise. In addition, measurement of changes in body composition over this period could more precisely demonstrate the potential of Uni-Step to promote weight loss. Other variables which could be examined are possible differences in the development of aerobic power due to changing the duration of the aerobic section of the routine. Although it appears that the mean intensity of the aerobic section would not change greatly if the duration of this section was decreased to 21 minutes, thus making the session more "user friendly", the decrease in duration would cause a decrease in the overall training load. It would be useful to examine whether this decrease in duration would significantly alter the magnitude of expected improvement in aerobic fitness. In addition, the decreased total duration of the session would be expected to have an effect on the potential of this exercise session for promoting weight loss, and so, measurements for this variable would also be useful.

Further study is also required to directly compare the HR-$\dot{V}O_2$ relationships between Uni-Step exercise and treadmill running since the present results suggest that the relationship for Uni-Step may be disproportional with respect to that of treadmill running. Since exercise prescriptions are based upon the HR-$\dot{V}O_2$ relationship established for treadmill running, the use of heart rate to estimate intensity during Uni-Step may have limitations. This point could be clarified with the direct comparison of this relationship between the two modes of exercise.

APPENDIX A. PILOT STUDY

INTRODUCTION

A pilot study was undertaken, firstly to determine whether data collection was possible without interfering with the performance of the Uni-Step routine. Due to the dynamic nature of step aerobic exercise, it was conceivable that the gas collection equipment may restrict the subjects' range of movement, especially their arm movements. Data collection during this mode of exercise has been achieved successfully in previous studies (Olson et al, 1991; Petersen et al, 1993), however, due to widely varying choreography among step routines, it was considered appropriate to carry out an initial step test to determine the extent of interference from the equipment, if any, during the specific step routine to be utilised in this study.

A second aim of the pilot study was to examine the reproducibility of measurements between tests, to eliminate any technical difficulties prior to the start of the main study, and to evaluate test procedures and ensure that instructions to subjects were clear and easy to follow.

METHODS

Part 1 - Practicality of Data Collection during Uni-Step

An initial step test was carried out to determine whether the use of gas collection equipment would interfere with the performance of the exercise. Procedures were as described in the main study, with several minor alterations which will be fully described below. In addition, the subject chose to perform the routine on a 4 inch step.

An experienced Uni-Step teacher acted as the subject in this test as her familiarity with the routine would provide a good foundation for judgement of the potential interference of the equipment.

Part 2 - Reproducibility of Measurement

The remainder of the tests in the pilot study were designed to evaluate the reproducibility of the measuring procedures and to refine test procedures and instructions to subjects if necessary.

Subjects

Six healthy female subjects took part in the pilot study. Eleven people volunteered to participate, however, two were excluded for medical reasons and a further three withdrew prior to the start of testing. Inclusion criteria from the main study were applied and all subjects completed a health questionnaire and gave informed consent prior to taking part. (A copy of the informed consent form for the pilot study can be found in Appendix B).

The General Practitioner of each subject was informed by letter that she had volunteered to take part in a research study, and a one week period from this notification was allowed before testing began.

Four subjects were regular participants in Uni-Step classes at Glasgow University, attending between once and twice per week, while the other two subjects had recent regular experience of step aerobics outwith the University. All subjects had exercised regularly at least three times per week during the two month period prior to testing, and it was assumed that they would have a sufficient level of fitness to complete the test routines.

Procedures

Each subject attended the laboratory on two occasions within a two week period (range: 2 - 14 days) to perform a standard videotaped Uni-Step routine. Tests for each subject were not performed on consecutive days in order to allow for sufficient recovery time.

On both occasions the routine was performed on an 8 inch step. This height was selected because it appeared to be the most popular with Uni-Step participants (see main study for details).

Both tests for each subject took place at the same time of day to control for the effect of diurnal variation in heart rate (Astrand & Rodahl, 1986).

Measurement of $\dot{V}O_2$, heart rate and RPE was carried out as described in the main study, with the exception of several minor alterations, as detailed below, which were made prior to the start of the main study due to the occurrence of technical problems.

The subjects' height, body mass, estimated percentage body fat, leg length and resting heart rate were measured as described in the main study.

In order to evaluate test procedures in terms of subject comfort, and to determine the effectiveness of the instructions given to subjects regarding the performance of the routine and the use of the RPE scale, each subject was asked to comment on whether they found any difficulty in performing the exercise while linked to the measuring equipment, and whether they understood the instructions. These comments were requested following each subject's first test.

Statistical Analysis

Repeated measures analysis of variance was carried out for each dependent variable, $\dot{V}O_2$, heart rate and RPE, to determine whether there was any significant difference between test 1 and test 2. This analysis was limited to between 6 minutes and 30.5 minutes of the aerobic section of the Uni-Step routine (see main study for details).

RESULTS

Part 1 - Practicality of Data Collection during Uni-Step

The subject reported that the gas collection equipment did not interfere with her performance of the Uni-Step routine. Therefore, it was assumed that the necessary physiological measurements could be made without disturbing the performance of the exercise.

Part 2 - Reproducibility of Measurement

Characteristics of the subjects are given in Table A1.

Table A1. Pilot Study Subject Characteristics

Subject Characteristic	Mean	Standard Deviation
Age (yr.)	22.5	3.0
Height (cm.)	164.2	4.2
Body mass (kg.)	57.7	2.4
Estimated body fat (%)	22.3	2.2
Leg length (cm.)	88.8	3.0
Resting heart rate (beats$\cdot$min^{-1})	68.5	7.2

Means and standard deviations of all dependent variables can be found in Table A2.

Repeated measures analysis of variance showed that there was a significant systematic bias for all three dependent variables, $\dot{V}O_2$, HR and RPE, with test 1, on average, higher than test 2 as shown in Table A3.

The values of $\dot{V}O_2$ tended to be approximately 5% lower in test 2 compared to test 1. Heart rates tended to be approximately 4% lower in test 2 and RPE values tended to be approximately 3% lower in test 2.

Technical Difficulties

Several samples of expired air were lost due to technical difficulties. There were four types of problem as follows.

Two samples were lost due to an ill fitting seal between the tube and the Douglas bag valve (subject 2: sample 2, test 2; subject 4: sample 11, test 2).

In the first case, no air escape was noticed during collection and the sample was analysed. However, the results of gas analysis showed a 37.9% decrease in $\dot{V}O_2$ between test 1 and test 2. This magnitude of difference was considered too large to be physiological, and therefore was attributed to technical error. The raw data showed that there was a large decrease in the volume of expired air from test 1 to test 2 with no change in FeO_2 or $FeCO_2$. On examination of the gas collection system, it was thought probable that the air escape occurred between the tube and the valve. The results from this sample were excluded from the statistical analysis.

In the second case, the experimenter became aware of air escape from the junction point of the tube and the Douglas bag valve while the sample was

TABLE A2. MEAN VALUES AND STANDARD DEVIATIONS FOR ALL DEPENDENT VARIABLES IN PILOT STUDY

	Test 1	Test 2
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	25.8 ± 5.2	24.6 ± 4.8
HR ($beats \cdot min^{-1}$)	141 ± 16	137 ± 14
RPE (Borg Scale)	11.6 ± 2.1	11.2 ± 2.1

All values are mean ± standard deviation of the aerobic section of the Uni-Step routine.

TABLE A3. RESULTS OF STATISTICAL ANALYSIS OF PILOT STUDY

Variable	Bias*	P value	Mean value
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	1.28 (0.24)	< 0.001	27.2
HR ($beats \cdot min^{-1}$)	5.23 (0.76)	< 0.001	145
RPE (Borg Scale)	0.42 (0.20)	0.05	12.3

* Test 1 - Test 2. Standard error is shown in brackets.

being collected, and therefore the gases were not analysed.
This problem was eliminated by winding tape around the valve. Thus, in effect, the circumference of the valve was increased so that a tight fit between tube and valve was achieved. Following the first occurrence of this problem, the seal between all valves and the tube were checked. However, due to other laboratory users having access to the same equipment, this complication arose a second time. Therefore, the standard practice of checking each seal before each test was introduced to prevent further occurrence of this problem.

Two samples were lost due to a loose closure mechanism on one of the Douglas bag valves (subject 2: sample 6, test 2; subject 3: sample 7, test 1). The valve was accidentally opened before the bags were analysed. After the first time this happened, more care was taken with this valve. However, the problem recurred and so the valve was discarded.

One sample was lost during bag changeover (subject 5: sample 1, test 1). After closure of the valve, it was accidentally pulled from the Douglas bag while attempting to pull the tube from the valve. More care was taken in subsequent tests to ensure that this did not occur again.

Two samples were not analysed following the discovery of a leak in the Douglas bags (subject 5: sample 1, test 2; subject 6: sample 1, test 1). These bags were subsequently discarded.

Estimation of Energy Expenditure

The energy expenditure of the lost samples was estimated so that an approximate value for the energy expenditure of the Uni-Step routine could be produced. This was done by substituting the energy expenditure of the sample which had the most similar heart rate response during that test. In all cases, there was no more than plus or minus 7 beats·min^{-1} of a difference in the heart rates.

All values of energy expenditure for the Uni-Step routine were slightly underestimated due to the small percentage of expired air which was not collected during bag changeover. The mean loss of expired air was 2.3% of the total duration of the routine. However, a limitation of the pilot study was that the bag changeover time was not of a constant duration for each sample throughout each test or between tests. This was due to a lack of experience with the equipment. Therefore, the loss of expired air as a percentage of the total duration of the routine was not the same for each test.

Evaluation of Test Procedures

In the first two tests of the reproducibility series, both of which involved subject one, the subject was asked to start the heart rate monitor recording at the beginning of exercise so that the experimenter could switch on the stopwatch and open the Douglas bag valve at the same time. However, in the second of these tests, the heart rate monitor failed to record any information. The display of the heart rate monitor was concealed with tape to prevent the subject from using this information to adjust her exercise intensity, and so the fact that no information was being recorded went undetected during the test. The display was not concealed in following tests so that the experimenter could check that the recorder was functioning normally throughout each test. In addition, the experimenter switched on both the stopwatch and heart rate monitor at the start of exercise, and there was a 3 second delay before the Douglas bag valve was opened. Thus, the risk of recording no heart rate information was minimised. In addition, the introduction of a pause in the collection of expired air at the start of the first sample allowed for the standardisation of the loss of expired air throughout all samples. Previously, there had been a pause at the beginning of each sample with the exception of the first one in each test.

In the first three pilot tests, the subject's RPE was ascertained by holding the scale up in front of the subject so that she could point to the relevant level. However, it was suggested by the next subject, who was an experienced Uni-Step teacher, that it might be easier for both subject and experimenter if the scale was on display throughout the test. Therefore, the RPE scale was displayed below the television screen and a system of hand signals was developed so that the subject could communicate her RPE without having to point to the scale (for full details, see methods section in main study). This method was found to be less cumbersome by the experimenter and subsequent subjects found it easy to understand and use. Therefore it replaced the original procedure.

All subjects observed no significant difficulties in performing the exercise while linked to the gas collection apparatus. Two subjects had been involved in previous research and were familiar with the equipment prior to their first test. The remaining four subjects remarked that it had taken less time than expected to become used to the equipment.
All six subjects stated that all instructions had been clear and easy to follow.

DISCUSSION

The initial pilot test established that the gas collection equipment did not restrict the subjects' movements and that physiological measurements could therefore be made during a Uni-Step routine without interfering with the performance of the exercise. This finding provided the basis to conduct the main study.

Examination of the reproducibility data revealed a tendency for oxygen uptake, heart rate and RPE to decrease from test 1 to test 2. These findings suggest a familiarisation effect, however, the order of testing for the three step heights in the main study was randomised to avoid contamination of the results due to this bias.

The pilot study was a learning experience in the practicalities of data collection during the Uni-Step routine. For example, at certain bag changeovers, it was found that the position of the subject, or the particular movement pattern she was engaged in required the experimenter to adopt a specific position in relation to the subject in order to avoid pulling on the tube attached to the breathing valve, as this might cause discomfort to the subject or jeopardise the closed gas collection system.

Several technical difficulties were overcome prior to the start of the main study, and minor alterations were made to procedures in order to make the data collection process more efficient, and to minimise the possibility of losing data. In addition, all instructions to subjects were found to be easily understood.

From experience gained during the pilot study, it was found that the time required for the changeover of Douglas bags could be standardised at 3 seconds, thus, the percentage loss of expired air would be a consistent factor in the main study.

In conclusion, the pilot study provided the basis for conducting the main study. It allowed refinement of the methodology for the main study, thus minimising the risk of error in data collection.

APPENDIX B. HEALTH QUESTIONNAIRE

UNIVERSITY OF GLASGOW

DEPARTMENT OF PHYSICAL EDUCATION AND SPORTS SCIENCE

INFORMATION REQUIRED FOR FITNESS ASSESSMENTS

Name: ______________________ Date: ______________

1. Exercise Lifestyle

a) What kind of exercise have you been doing in the past month?

(circle answer)

			Number of times per week				
		Walking	1	2	3	4	5
		Jogging	1	2	3	4	5
		Cycling	1	2	3	4	5
		Swimming	1	2	3	4	5
	:	(Early morning Tune-up)	1	2	3	4	5
	:	(Low-key Tune-up)	1	2	3	4	5
University	:	(Low-key Popmobility)	1	2	3	4	5
Sessions	:	(Popmobility)	1	2	3	4	5
	:	(Sweat Session)	1	2	3	4	5
	:	(Conditioning for Sportsmen/women)	1	2	3	4	5
	:	(Uni-Step)	1	2	3	4	5
		Other *(please specify)*	1	2	3	4	5

____

b) How many minutes have you spent exercising per week in the last month?

0	10	20	30	40	50	60	70	80	90	100
110	120	130	140	150	160	170	180	190	200	

more than 200

c) How long have you been exercising at least twice per week for 20-30 minutes each session?________________________________

d) Have you ever had a fitness assessment in the Department of Physical Education and Sports Science before? YES/NO

2. <u>Smoking Habits</u>

Please circle the appropriate number.

Never smoke	0	Do you have, or have you had any symptoms such as:	
Gave up in the last 6 months	1		
Gave up more than 6 months ago	2		
Smoke 1-9 cigarettes per day	3	Chest pain	YES/NO
Smoke 10-19 cigarettes per day	4	Palpitations	YES/NO
Smoke 20-39 cigarettes per day	5	Dizzy turns	YES/NO
Smoke 40+ cigarettes per day	6		

Do you get breathless when walking at a normal pace? YES/NO

Do you have, or have you had any other symptoms or complaints relating to your health? YES/NO

If YES, state ______________________________

3. <u>Have you ever had</u>:

Diabetes	YES/NO
Anaemia	YES/NO
Epilepsy	YES/NO
Heart disease	YES/NO
Any other illnesses which could affect endurance capability	YES/NO

4. Are you taking any medication at the present time? YES/NO

Please specify ______________________________

APPENDIX B. ETHICAL FORM

GREATER GLASGOW HEALTH BOARD

THE WEST ETHICAL COMMITTEE

FORM OF CONSENT FOR PATIENTS / VOLUNTEERS IN CLINICAL RESEARCH PROJECT

Brief Title of Project

"THE ACUTE PHYSIOLOGICAL EFFECTS OF STEP AEROBICS"

Patient's summary (Purpose of study, nature of procedure, discomfort and possible risks in terms which the patient or volunteer can understand.)

We would like to invite you to take part in a study to determine the exercise intensity and energy cost of the warm up and aerobic sections of a university step class. We also wish to evaluate the use of target heart rate monitoring in these classes.

If you wish to take part, we will ask you to participate in the following tests, each on a separate occasion.

1. Test of maximal oxygen uptake. This test will involve walking / jogging on a treadmill until exhaustion. This procedure usually takes 10-12 minutes. Expired air will be collected and heart rate will be monitored throughout the test. It should be noted that maximal effort is required for this test which produces some discomfort and requires a high degree of motivation. This test involves a risk to your health. There is a risk of cardiac complications during the test, i.e. the test could trigger abnormalities of heart rhythm which are potentially fatal if not treated adequately. A medically qualified physician will however be available on immediate call during testing and the laboratory technician has received cardiopulmonary training, therefore, if necessary, he can initiate resuscitation. There is also a defibrillator in the laboratory.

2. We will measure heart rate with a portable heart rate monitor and collect expired air during three Uni-Step sessions which will be performed in the laboratory. We will ask you to perform the Uni-Step routine on varying bench heights.

It should be noted that your participation in this study may not be of direct benefit to you.

You may, if you wish, withdraw from the study at any time.

If you wish to take part in this study, your General Practitioner will be advised of your participation.

If you are, or are likely to become, pregnant, you should not participate in this study.

I certify to the best of my knowledge and belief that I have no physical or mental illness or weakness that would increase the risk to me of participation in this investigation and agree to take part in the research project described to me. The researcher has fully explained the time commitments involved.

Consent

I,..of..

give my consent to the research procedures described above, the nature, purpose and possible consequences of which have been described to me by Rona Sutherland.

Signed.. Date..

Witness..

APPENDIX B. ETHICAL FORM FOR PILOT STUDY

GREATER GLASGOW HEALTH BOARD

THE WEST ETHICAL COMMITTEE

FORM OF CONSENT FOR PATIENTS / VOLUNTEERS IN CLINICAL RESEARCH PROJECT

Brief Title of Project

"THE ACUTE PHYSIOLOGICAL EFFECTS OF STEP AEROBICS"

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We would like to invite you to take part in a study to determine the exercise intensity and energy cost of the warm up and aerobic sections of a university step class. We also wish to evaluate the use of target heart rate monitoring in these classes.

If you wish to take part, we will ask you to participate in the following tests, each on a separate occasion.

1. We will measure heart rate with a portable heart rate monitor and collect expired air during a Uni-Step session which will be performed in the laboratory.

2. This test will be repeated within one week.

It should be noted that your participation in this study may not be of direct benefit to you.

You may, if you wish, withdraw from the study at any time.

If you wish to take part in this study, your General Practitioner will be advised of your participation.

If you are, or are likely to become, pregnant, you should not participate in this study.

Consent

I,...of..

give my consent to the research procedures described above, the nature, purpose and possible consequences of which have been described to me by

....

Signed... Date...

Witness..

APPENDIX B. SAMPLE DATA SHEET FOR UNI-STEP TESTS

STEP TESTS

Subject | Date | P_B (mmHg.)

Test number | Time | Lab temp. (deg. C)

Step height (inches) | Body mass (kg.)

SAMPLE	START	END
1	0:03	3:00
2	3:03	6:00
3	6:03	9:00
4	9:03	12:00
5	12:03	15:00
6	15:03	18:00
7	18:03	21:00
8	21:03	24:00
9	24:03	27:00
10	27:03	30:30
11	30:33	35:15
12	35:18	38:40

RPE TIME	RPE	HEART RATE
2:30		
5:30		
8:30		
11:30		
14:30		
17:30		
20:30		
23:30		
26:30		
30:00		
34:45		
38:10		

DATA ANALYSIS

SAMPLE	DURATION	INITIAL READING	FINAL READING	TEMP.	FeO2	FeCO2	Pv
1	2.95						
2	2.95						
3	2.95						
4	2.95						
5	2.95						
6	2.95						
7	2.95						
8	2.95						
9	2.95						
10	3.45						
11	4.70						
12	3.37						

APPENDIX B. SAMPLE DATA SHEET FOR MAXIMUM OXYGEN UPTAKE TESTS

MAXIMUM OXYGEN UPTAKE TESTS

Subject	Date	P_B (mmHg.)
Body mass (kg.)	Time	Lab temp. (deg. C)

PROTOCOL

Time (min.)	Speed (k.p.h.)	Gradient (% incline)
0-1	4.8	0
1-2	6.4	0
2-3	8.0	0
3-4	8.8	0
4-5	9.6	0
5-6	9.6	2
6-7	9.6	4
7-8	9.6	6
8-9	9.6	8
9-10	9.6	10
10-11	9.6	12
11-12	9.6	14

DATA ANALYSIS

DURATION	INITIAL READING	FINAL READING	TEMP.	FeO2	FeCO2	Pv	HEART RATE

RPE at maximum:

APPENDIX C. DETAILS OF UNI-STEP ROUTINE

The figures in brackets refer to the number of repetitions of each movement, unless otherwise specified.
[R] or [L] refers to the starting foot for the movement; i.e. right or left.

AEROBIC SECTION

TRACK 1 - WARM UP (132 steps / minute)

SAMPLE 1 (0 - 3 minutes)

(1)	March on spot, using arms	(24 s)	
(2)	Step 2, 3, tap foot on "step"	[R]	(12)
(3)	As (2), punch front then overhead	[L]	(9)
(4)	As (2), punch arms close together in front then overhead	[L]	(7)
(5)	March	(12 s)	
(6)	Step 2, 3, bring knee up, arms as (4)	[R]	(10)
(7)	As (6), bring arms overhead and then down to sides	[R]	(8)
(8)	March	(7 s)	
(9)	As (4)	[L]	(12)
	RPE response after 12 repetitions		
(10)	As (6)	[L]	(12)

TRACK 1 (continued)

(11)	As (7)	[L]	(5)

SAMPLE 2 (3 - 6 minutes)

(12)	As (11)	[R]	(3)
(13)	As (2)	[L]	(2)
(14)	As (2), swing arms in a curve in front of body at shoulder level	[L]	(14)
(15)	As (2), bring both arms overhead at one side of body and down in front	[L]	(3)
(16)	Four corner clap	[R]	(4)
(17)	As (2), arms as marching	[L]	(4)
(18)	As (2), bicep curls	[L]	(12)
(19)	As (6)	[L]	(6)
(20)	As (7)	[L]	(12)
(21)	As (14)	[L]	(10)

TRACK 2 (128 steps / minute)

(1)	March, using arms	(23 s)	
	RPE response after 11 seconds		
(2)	Basic step, arms as marching	[R]	(10)

SAMPLE 3 (6 - 9 minutes)

(3)	Basic step, arms as marching	[R]	(6)
(4)	Basic step, change leading foot with tap back	[R]	(1)
(5)	As (2)	[L]	(16)
(6)	As (2)	[R]	(8)
(7)	As (2)	[L]	(8)
(8)	As (2)	[R]	(4)
(9)	As (2)	[L]	(4)
(10)	As (2)	[R]	(4)
(11)	As (2)	[L]	(4)
(12)	As (2)	[R]	(2)
(13)	As (2)	[L]	(2)
(14)	Basic step, one on each side	[R]	(4)
(15)	As (14), turning on "step" so that body is side on to "step" when on floor, punch forward with both arms	[R]	(22)
	RPE response after 16 repetitions		
(16)	March	(14 s)	
(17)	Stand side on to "step", step up, lift knee, step down, arms as climbing a ladder	[L]	(3)

SAMPLE 4 (9 - 12 minutes)

(18)	As (17)	[R]	(17)
(19)	March	(8 s)	
(20)	As (17)	[R]	(21)
(21)	Basic step, hands on hips	[R]	(11)
(22)	As (21)	[L]	(16)
(23)	As (21), arms as marching	[R]	(8)
(24)	As (23)	[L]	(9)
	RPE response after 2 repetitions		
(25)	As (23)	[R]	(4)
(26)	As (23)	[L]	(4)

SAMPLE 5 (12 - 15 minutes)

(27)	As (17), arms as marching	[L]	(4)
(28)	As (17), punch arms in front at shoulder height	[L]	(2)
(29)	As (17), punch arms in front at head height	[L]	(1)
(30)	As (17), punch arms above head	[L]	(5)
(31)	As (30)	[R]	(5)

TRACK 3 (129 steps / minute)

(1)	March	(18 s)	
(2)	Stand side on to “step”, step up and over, bicep curls	[L]	(16)
(3)	As (2), arms upright rowing	[L]	(19)
(4)	Step up, tap on “step” with other foot, punch arms forward one at a time	[R]	(15)
(5)	As (4), punch arms overhead one at a time	[R]	(12)
	RPE response after 4 repetitions		
(6)	As (2)	[R]	(1)
(7)	As (2), punch arms out in front	[L]	(7)

SAMPLE 6 (15 - 18 minutes)

(8)	As (2), punch arms up then out in front	[L]	(8)
(9)	As (2), hands on hips	[L]	(20)
(10)	Step up, swing other leg out to side, step down, hands on hips	[L]	(17)
(11)	As (10), bring arms overhead at sides of body and down again	[L]	(15)
(12)	As (2), bicep curls one arm at a time	[L]	(9)
(13)	As (11)	[R]	(15)
	RPE response after 11 repetitions		
(14)	As (2), hands on hips	[R]	(5)
(15)	As (3)	[R]	(7)

TRACK 3 (continued)

SAMPLE 7 (18 - 21 minutes)

(16)	As (15)	[L]	(5)
(17)	As (2), arms open and close above head	[R]	(10)
(17)	March	(60 s)	

TRACK 4 (125 steps / minute)

(1)	V step	[R]	(4)
(2)	As (1), bring arms from one side of the body to the other in a curve at shoulder level	[R]	(3)
(3)	As (1), punch both arms out to one side, then the other side, then two punches downwards	[R]	(8)
(4)	As (1), arms as (3) except two punches upwards on last two beats	[R]	(1)
(5)	As (1), arms as (3) except alternating between two upward and two downward punches	[R]	(15)
(6)	March	(18 s)	
	RPE response after 3 seconds		
(7)	V step, arms as (5)	[L]	(8)

SAMPLE 8 (21 - 24 minutes)

(8)	As (7)	[L]	(16)
(9)	March	(16 s)	
(10)	Z step	[R]	(8)
(11)	As (10), arms swing from one side above head down in front and up to the other side above head	[R]	(8)
(12)	Basic step, hands on hips	[R]	(12)
(13)	V step, arms as (5)	[R]	(4)
(14)	Basic step, bicep curls one arm at a time	[R]	(4)
(15)	V step, arms as (5)	[R]	(4)

RPE response after 1 repetition

(16)	Basic step, hands on hips	[L]	(8)
(17)	V step, arms as (5)	[L]	(5)

SAMPLE 9 (24 - 27 minutes)

(18)	As (17)	[R]	(3)
(19)	Basic step, hands on hips	[L]	(9)

NO MUSIC

March while taking pulse	(47 s)

TRACK 5 (127 steps / minute)

(1)	March on the "step"	(26 s)	
(2)	Straddle the "step", step back on, bicep curls one arm at a time	[L]	(20)
(3)	Straddle the "step",step back on and lift trailing knee	[L]	(8)
(4)	As (3), punch forward on straddle, punch opposite arm above head when knee is coming up	[L]	(12)
	RPE response after 1 repetition		
(5)	Straddle the "step", Punch arms up then down at sides, step back on and lift trailing foot to touch inside foot with opposite hand	[L]	(5)

SAMPLE 10 (27 - 30.5 minutes)

(6)	As (5)	[R]	(10)
(7)	Straddle the "step", step back on and kick trailing foot in front, hands on hips	[L]	(11)
(8)	As (7), bicep curls	[L]	(9)
(9)	Straddle the "step", step back on and place trailing heel on the "step"	[L]	(4)
(10)	As (9), "pec dec" * arms	[L]	(9)

* "pec dec" - arms are out at sides at shoulder height with elbows bent at 90 degrees. Bring elbows and wrists together in front of the chest, then move back to starting position.

TRACK 5 (continued)

(11)	As (2), hands on hips	[R]	(4)
(12)	As (3), hands on hips	[R]	(4)
(13)	As (5), touch inside foot with opposite hand	[R]	(4)
(14)	As (7), hands on hips	[R]	(4)
(15)	As (10)	[R]	(7)
(16)	March on "step"	(8 s)	
(17)	As (11)	[R]	(12)
(18)	March	(4 s)	
(19)	Step 2, 3, tap foot on "step", arms open and close above head	[L]	(14)
	RPE response after 8 repetitions		
(20)	As (19), arms open and close into chest at shoulder level	[L]	(4)
(21)	As (19), bring arms from shoulder level down to sides of body	[L]	(5)

MUSCLE CONDITIONING

SAMPLE 11 (30.5 - 35.25 minutes)

March	(11 s)
Step to side	(25s)
Tricep dips using step	(50 s)
Triceps: punching hand behind head	(20 s)
"Pec dec"	(40 s)
Sit ups using step	(50 s)
Twisting sit ups using step	(40 s)
Half squats on both sides using step	(60 s)

RPE response after 13 seconds

FLEXIBILITY

SAMPLE 12 (35.25 - 38.67 minutes)

Side stretch	(35 s)
Tricep stretch behind head while standing	(35 s)
Hamstring stretch on floor, twisting ankle	(50 s)
Spine twist	(35 s)
Quadriceps stretch on floor	(40 s)

RPE response after 13 seconds

Upward stretch	(10 s)

APPENDIX D. RATINGS OF PERCEIVED EXERTION INSTRUCTIONS FOR SUBJECTS

When you are asked to rate the degree of perceived exertion that you feel, try to estimate how hard you feel the work is.

Think of perceived exertion as the total amount of exertion and physical fatigue, combining all sensations and feelings of physical stress, effort and fatigue.

When rating how the whole body is feeling while exercising, don't concern yourself with any one factor such as leg pain, shortness of breath or work intensity, simply try to concentrate on your total inner feeling of exertion.

Try to estimate as honestly and objectively as possible. Don't underestimate the degree of exertion you feel, but don't overestimate it either. Just try to estimate as accurately as possible.

An RPE of 6 is equivalent to quiet, seated rest and the most taxing physical effort that you can remember is equivalent to an RPE of about 19.

APPENDIX E. STATISTICAL ANALYSIS

General Linear Model

Factor	Levels	Values							
SUBJECT	10	1	2	3	4	5	6	7	8
9 10									
HEIGHT	3	6	8	10					
TEST	3	1	2	3					

Analysis of Variance for EE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SUBJECT	9	27487.2	27004.4	3000.5	36.76	0.000
HEIGHT	2	10294.9	10027.5	5013.8	61.42	0.000
TEST	2	147.7	147.7	73.9	0.90	0.427
Error	14	1142.8	1142.8	81.6		
Total	27	39072.7				

Unusual Observations for EE

Obs.	EE	Fit	Stdev. Fit	Residual	St. Resid
1	165.300	180.926	6.616	-15.626	-2.54R

R denotes an obs.with a large st. resid.

General Linear Model

Factor	Levels	Values							
SUBJECT	10	1	2	3	4	5	6	7	8
9 10									
HEIGHT	3	6	8	10					

Analysis of Variance for EE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SUBJECT	9	27487.2	27331.5	3036.8	37.65	0.000
HEIGHT	2	10294.9	10294.9	5147.5	63.82	0.000
Error	16	1290.5	1290.5	80.7		
Total	27	39072.7				

Term	Coeff	Stdev	t-value	P
Constant	231.817	1.739	133.29	0.000
SUBJECT				
1	-29.450	4.953	-5.95	0.000
2	-15.383	4.953	-3.11	0.007
3	-14.800	6.025	-2.46	0.026
4	44.700	6.025	7.42	0.000
5	60.083	4.953	12.13	0.000
6	-43.217	4.953	-8.73	0.000
7	-19.383	4.953	-3.91	0.001
8	12.183	4.953	2.46	0.026
9	-13.950	4.953	-2.82	0.012
HEIGHT				
6	-22.087	2.390	-9.24	0.000
8	-1.167	2.593	-0.45	0.659

Unusual Observations for EE

Obs.	EE	Fit	Stdev. Fit	Residual	St. Resid
1	165.300	180.280	5.710	-14.980	-2.16R
11	215.400	201.200	5.797	14.200	-2.18R
18	227.900	242.833	5.797	-14.933	-2.18R

R denotes an obs. with a large st. resid

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9 10									
TEST	3	1	2	3					

Analysis of Variance for $\dot{V}O_2$

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	1225.459	1233.302	176.186	65.63	0.000
HEIGHT	2	1464.374	1415.027	707.513	263.53	0.000
TIME*HEIGHT	14	27.342	26.228	1.873	0.70	0.775
SUBJECT	9	606.167	575.824	63.980	23.83	0.000
TEST	2	27.180	27.180	13.590	5.06	0.007
Error	186	499.357	499.357	2.685		
Total	220	3849.879				

Unusual Observations for $\dot{V}O_2$

Obs.	VO_2	Fit	Stdev. Fit	Residual	St. Resid
1	13.3000	20.4725	0.6515	-7.1725	-4.77R
7	26.2000	22.6845	0.6246	3.5155	2.32R
17	30.1000	26.4181	0.6761	3.6819	2.47R
20	22.8000	26.8556	0.6761	-4.0556	-2.72R
37	22.2000	25.5445	0.6246	-3.3445	-2.21R
61	18.8000	22.3525	0.6515	-3.5525	-2.36R
67	29.4000	24.5645	0.6246	4.8355	3.19R
227	23.6000	29.8806	0.6761	-6.2806	-4.21R

R denotes an obs.with a large st. resid.

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9 10									
TEST	3	1	2	3					

Analysis of Variance for $\dot{V}O_2$

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	1225.46	1244.76	177.82	67.67	0.000

HEIGHT	2	1464.37	1420.34	710.17	270.24	0.000
SUBJECT	9	607.36	577.52	64.17	24.42	0.000
TEST	2	27.10	27.10	13.55	5.16	0.007
Error	200	525.59	525.59	2.63		
Total	220	3849.88				

Term	Coeff	Stdev	t-value	P
Constant	25.6386	0.1143	224.32	0.000
TIME				
9	-0.5361	0.2869	-1.87	0.063
12	2.3496	0.2869	8.19	0.000
15	1.0139	0.2869	3.53	0.001
18	1.8781	0.2869	6.55	0.000
21	-1.2863	0.3021	-4.26	0.000
24	-2.4040	0.2869	-8.38	0.000
27	-4.1361	0.2869	-14.42	0.000
HEIGHT				
6	-2.9357	0.1624	-18.08	0.000
8	-0.2103	0.1766	-1.19	0.235
SUBJECT				
1	-1.5111	0.3241	-4.66	0.000
2	-0.4665	0.3232	-1.44	0.150
3	-1.0441	0.4074	-2.56	0.011
4	3.1116	0.3961	7.86	0.000
5	0.6822	0.3173	2.15	0.033
6	-0.6886	0.3173	-2.17	0.031
7	1.2572	0.3173	3.96	0.000
8	0.0572	0.3173	0.18	0.857
9	-3.0928	0.3173	-9.75	0.000
TEST				
1	0.4351	0.1542	2.82	0.005
2	0.0541	0.1627	0.33	0.740

Unusual Observations for $\dot{V}O_2$

Obs.	VO_2	Fit	Stdev. Fit	Residual	St. Resid
1	13.300	20.7098	0.5193	-7.4098	-4.83R
7	26.2000	22.9348	0.4835	3.2652	2.11R
17	30.1000	26.5844	0.4919	3.5156	2.28R
20	22.8000	27.0219	0.4919	-4.2219	-2.73R
37	22.2000	25.8205	0.4835	-3.6205	-2.34R
61	18.8000	22.2598	0.5193	-3.4598	-2.25R
67	29.4000	24.4848	0.4835	4.9152	3.18R
227	23.6000	30.2416	0.4919	-6.6416	-4.30R

R denotes an obs. with a large st. resid

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9	10								
TEST	3	1	2	3					

Analysis of Variance for %$\dot{V}O_2$ max

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	5663.39	5786.75	826.68	59.09	0.000
HEIGHT	2	6518.70	6548.75	3274.37	234.05	0.000
TIME*HEIGHT	14	153.64	123.14	8.80	0.63	0.839
SUBJECT	9	8206.94	8243.88	915.99	65.47	0.000
TEST	2	130.40	130.40	65.20	4.66	0.011
Error	186	2602.16	2602.16	13.99		
Total	220	23275.22				

Unusual Observations for %$\dot{V}O_2$ max

Obs.	%VO_2 max	Fit	Stdev. Fit	Residual	St. Resid
1	30.0000	46.0517	1.4873	-16.0517	-4.68R
7	57.8000	50.3820	1.4258	7.4180	2.15R
17	66.4000	58.4358	1.5433	7.9642	2.34R
20	49.2000	58.1108	1.5433	-8.9108	-2.62R
37	49.0000	56.5920	1.4258	-7.5920	-2.20R
61	42.3000	50.2117	1.4873	-7.9117	-2.31R
67	64.9000	54.5420	1.4258	10.3580	3.00R
227	52.1000	66.0358	1.5433	-13.9358	-4.09R

R denotes an obs.with a large st. resid.

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9	10								
TEST	3	1	2	3					

Analysis of Variance for %$\dot{V}O_2$ max

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	5663.4	5824.1	832.0	61.06	0.000

HEIGHT	2	6518.7	6569.8	3284.9	241.07	0.000
SUBJECT	9	8237.4	8272.0	919.1	67.45	0.000
TEST	2	130.4	130.4	65.2	4.78	0.009
Error	200	2725.3	2725.3	13.6		
Total	220	23275.2				

Term	Coeff	Stdev	t-value	P
Constant	54.4810	0.12603	209.33	0.000
TIME				
9	-1.2530	0.6533	-1.92	0.057
12	5.0434	0.6533	7.72	0.000
15	2.2256	0.6533	3.41	0.001
18	4.1148	0.6533	6.30	0.000
21	-2.7468	0.6880	-3.99	0.000
24	-5.2459	0.6533	-8.03	0.000
27	-8.8994	0.6533	-13.62	0.000
HEIGHT				
6	-6.3377	0.1624	-17.14	0.000
8	-0.4108	0.1766	-1.02	0.308
SUBJECT				
1	-0.1367	0.7381	-0.19	0.853
2	-8.2442	0.7359	-11.20	0.000
3	-16.2292	0.9276	-17.50	0.000
4	4.2629	0.9020	4.73	0.000
5	4.5398	0.7225	6.28	0.000
6	-0.2394	0.7225	-0.33	0.741
7	4.8815	0.7225	6.76	0.000
8	7.1523	0.7225	9.90	0.000
9	-0.5435	0.7225	-0.75	0.453
TEST				
1	0.0593	0.3511	3.02	0.003
2	-0.1955	0.3705	-0.53	0.598

Unusual Observations for %$\dot{V}O_2$ max

Obs.	%VO_2 max	Fit	Stdev. Fit	Residual	St. Resid
1	30.0000	46.5581	1.1826	-16.5581	-4.74R
7	66.4000	58.7580	1.1202	7.6420	2.17R
17	49.2000	58.4330	1.1202	-9.2330	-2.63R
20	49.0000	57.2043	1.1010	-8.2043	-2.33R
37	42.3000	50.0367	1.1826	-7.7367	-2.21R
61	64.9000	54.3865	1.1010	10.5135	2.98R
67	37.7000	30.1358	1.1069	7.5642	2.15R
227	52.1000	66.7723	1.1202	-14.6723	-4.17R

R denotes an obs. with a large st. resid

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9	10								
TEST	3	1	2	3					

Analysis of Variance for %HRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	6036.77	6058.88	865.55	28.21	0.000
HEIGHT	2	9424.99	9211.00	4605.50	150.08	0.000
TIME*HEIGHT	14	74.00	74.00	5.29	0.17	1.000
SUBJECT	9	10264.46	10295.86	1143.98	37.28	0.000
TEST	2	84.71	84.71	42.35	1.38	0.254
Error	197	6045.44	6045.44	30.69		
Total	231	31930.37				

Unusual Observations for %HRR

Obs.	%HRR	Fit	Stdev. Fit	Residual	St. Resid
20	53.000	64.393	2.195	-11.393	-2.24R
23	64.000	51.743	2.222	12.257	2.42R
29	62.900	76.526	2.126	-13.626	-2.66R
50	61.200	71.915	2.195	-10.715	-2.11R
53	69.900	59.083	2.222	10.817	2.13R
148	94.500	84.104	2.129	10.396	2.03R
178	94.500	81.864	2.129	12.636	2.47R
204	58.000	69.512	2.115	-11.512	-2.25R
208	92.500	78.794	2.129	13.706	2.68R
213	39.000	52.432	2.222	-13.432	-2.65R

R denotes an obs.with a large st. resid.

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9	10								
TEST	3	1	2	3					

Analysis of Variance for %HRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	6036.8	6036.8	862.4	29.74	0.000
HEIGHT	2	9425.0	9211.0	4605.5	158.80	0.000
SUBJECT	9	10264.5	10295.9	1144.0	39.44	0.000
TEST	2	84.7	84.7	42.4	1.46	0.234
Error	211	6119.4	6119.4	29.0		
Total	231	31930.4				

Term	Coeff	Stdev	t-value	P
Constant	68.2411	0.3585	190.36	0.000
TIME				
9	-6.8362	0.9354	-7.31	0.000
12	0.7224	0.9354	0.77	0.441
15	0.8086	0.9354	0.86	0.388
18	5.9086	0.9354	6.32	0.000
21	-0.2672	0.9354	-0.29	0.775
24	-2.6569	0.9354	-2.84	0.005
27	-6.4397	0.9354	-6.88	0.000
HEIGHT				
6	-7.0709	0.5136	-13.77	0.000
8	-1.1105	0.5281	-2.10	0.037
SUBJECT				
1	0.005	1.047	0.00	0.996
2	-7.145	1.047	-6.83	0.000
3	-17.568	1.307	-13.44	0.000
4	-1.499	1.047	-1.43	0.153
5	1.363	1.047	1.30	0.194
6	-1.520	1.047	-1.45	0.148
7	6.967	1.047	6.66	0.000
8	7.505	1.047	7.17	0.000
9	8.396	1.047	8.02	0.000
TEST				
1	0.5798	0.5001	1.16	0.248
2	0.3010	0.5136	0.59	0.558

Unusual Observations for %HRR

Obs.	%HRR	Fit	Stdev. Fit	Residual	St. Resid
20	53.000	64.371	1.615	-11.371	-2.21R
23	64.000	52.319	1.733	11.681	2.29R
29	62.900	77.102	1.615	-14.202	-2.76R
50	61.200	71.929	1.615	-10.729	-2.09R
159	78.200	67.490	1.601	10.710	2.08R
178	94.500	81.850	1.619	12.650	2.46R
182	57.000	46.705	1.592	10.295	2.00R
204	58.000	68.784	1.601	-10.784	-2.10R
208	92.500	78.067	1.619	14.433	2.81R
213	39.000	52.942	1.733	-13.942	-2.73R

R denotes an obs. with a large st. resid

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9	10								
TEST	3	1	2	3					

Analysis of Variance for %HR $_{max}$

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	2820.75	2831.21	404.46	25.80	0.000
HEIGHT	2	4777.01	4664.70	2332.35	148.77	0.000
TIME*HEIGHT	14	35.14	35.14	2.51	0.16	1.000
SUBJECT	9	6645.74	6656.14	739.57	47.17	0.000
TEST	2	54.08	54.08	27.04	1.72	0.181
Error	197	3088.43	3088.43	15.68		
Total	231	17421.15				

Unusual Observations for %HRR $_{max}$

Obs.	%HR $_{max}$	Fit	Stdev. Fit	Residual	St. Resid
20	68.300	76.023	1.569	-7.723	-2.12R
23	73.400	64.468	1.588	8.932	2.46R
29	77.000	85.595	1.520	-8.595	-2.35R
50	73.900	81.178	1.569	-7.278	-2.00R
53	77.700	69.448	1.588	8.252	2.28R
148	96.000	88.238	1.522	7.762	2.12R
178	96.000	86.708	1.522	9.292	2.54R
208	94.500	84.658	1.522	9.842	2.69R
213	54.900	64.698	1.588	-9.798	-2.70R

R denotes an obs.with a large st. resid.

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9	10								
TEST	3	1	2	3					

Analysis of Variance for %HR max

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	2820.75	2820.75	402.96	27.22	0.000
HEIGHT	2	4777.01	4664.70	2332.35	157.55	0.000
SUBJECT	9	6645.74	6656.14	739.57	49.96	0.000
TEST	2	54.08	54.08	27.04	1.83	0.164
Error	211	3123.57	3123.57	14.80		
Total	231	17421.15				

Term	Coeff	Stdev	t-value	P
Constant	77.8936	0.2561	304.13	0.000
TIME				
9	-4.6698	0.6683	-6.99	0.000
12	0.4888	0.6683	0.73	0.465
15	0.5371	0.6683	0.80	0.423
18	3.9957	0.6683	5.98	0.000
21	-0.2043	0.6683	-0.31	0.760
24	-1.8250	0.6683	-2.73	0.007
27	-4.3664	0.6683	-6.53	0.000
HEIGHT				
6	-5.0451	0.3669	-13.75	0.000
8	-0.7690	0.3773	-2.04	0.043
SUBJECT				
1	0.1227	0.7447	-0.16	0.870
2	-5.9977	0.7447	-8.02	0.000
3	-14.3579	0.9340	-15.37	0.000
4	2.5939	0.7447	3.47	0.001
5	0.2648	0.7447	0.35	0.724
6	-2.0186	0.7447	-2.70	0.008
7	4.6273	0.7447	6.19	0.000
8	4.3148	0.7447	5.77	0.000
9	7.6273	0.7447	10.20	0.000
TEST				
1	0.5109	0.3573	1.43	0.154
2	0.1737	0.3669	0.47	0.636

Unusual Observations for %HR max

Obs.	%HR max	Fit	Stdev. Fit	Residual	St. Resid
20	68.300	76.035	1.154	-7.735	-2.11R
23	73.400	64.854	1.238	8.546	2.35R
29	77.000	85.980	1.154	-8.980	-2.45R
53	77.700	70.012	1.238	7.688	2.11R
148	96.000	88.329	1.157	7.671	2.09R
178	96.000	86.708	1.157	9.292	2.53R
208	94.500	84.167	1.157	10.333	2.82R
213	54.900	65.046	1.238	-10.146	-2.79R

R denotes an obs. with a large st. resid

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9 10									
TEST	3	1	2	3					

Analysis of Variance for RPE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	153.172	153.529	21.933	29.70	0.000
HEIGHT	2	81.484	82.207	41.104	55.66	0.000
TIME*HEIGHT	14	4.603	4.603	0.329	0.45	0.958
SUBJECT	9	230.219	230.177	25.575	34.63	0.000
TEST	2	2.134	2.134	1.067	1.44	0.238
Error	197	145.491	145.491	0.739		
Total	231	617.103				

Unusual Observations for RPE

Obs.	RPE	Fit	Stdev. Fit	Residual	St. Resid
2	12.0000	9.2839	0.3269	2.7161	3.42R
14	10.0000	11.5813	0.3452	-1.5813	-2.01R
69	11.0000	12.9675	0.3281	-1.9675	-2.48R
99	11.0000	13.5675	0.3281	-2.5675	-3.23R
154	15.0000	13.2258	0.3281	1.7742	2.23R
217	13.0000	15.0672	0.3269	-2.0672	-2.60R
224	16.0000	14.3591	0.3452	1.6409	2.09R
228	14.0000	15.9008	0.3452	-1.9008	-2.42R
232	11.0000	13.2792	0.3303	-2.2792	-2.87R
237	15.0000	16.6373	0.3281	-1.6373	-2.06R
239	17.0000	15.0289	0.3298	1.9711	2.48R

R denotes an obs.with a large st. resid.

General Linear Model

Factor	Levels	Values							
TIME	8	9	12	15	18	21	24	27	30
HEIGHT	3	6	8	10					
SUBJECT	10	1	2	3	4	5	6	7	8
9 10									
TEST	3	1	2	3					

Analysis of Variance for RPE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TIME	7	153.172	153.172	21.882	30.76	0.000
HEIGHT	2	81.484	82.207	41.104	57.78	0.000
SUBJECT	9	230.219	230.177	25.575	35.95	0.000
TEST	2	2.134	2.134	1.067	1.50	0.225
Error	211	150.093	150.093	0.711		
Total	231	617.103				

Term	Coeff	Stdev	t-value	P
Constant	13.8277	0.0561	246.29	0.000
TIME				
9	-1.7586	0.1465	-12.00	0.000
12	-0.8276	0.1465	-5.65	0.000
15	-0.0345	0.1465	-0.24	0.814
18	0.4828	0.1465	3.30	0.001
21	0.5862	0.1465	4.00	0.000
24	0.2414	0.1465	1.65	0.101
27	0.5862	0.1465	4.00	0.000
HEIGHT				
6	-0.70908	0.08043	-8.82	0.000
8	-0.03519	0.08270	-0.43	0.671
SUBJECT				
1	-0.0777	0.1639	-0.47	0.636
2	-2.1610	0.1639	-13.18	0.000
3	0.0741	0.2047	0.36	0.718
4	-0.2860	0.1639	-1.75	0.082
5	0.8807	0.1639	5.37	0.000
6	-0.5360	0.1639	-3.27	0.001
7	1.4223	0.1639	8.68	0.000
8	1.2557	0.1639	7.66	0.000
9	-0.2443	0.1639	-1.49	0.138
TEST				
1	0.13073	0.07832	1.67	0.097
2	-0.09449	0.08043	-1.17	0.241

Unusual Observations for RPE

Obs.	RPE	Fit	Stdev. Fit	Residual	St. Resid
2	12.0000	9.1627	0.2494	2.8373	3.52R
14	10.0000	11.7116	0.2590	-1.7116	-2.13R
69	11.0000	12.9705	0.2508	-1.9705	-2.45R
99	11.0000	13.4877	0.2508	-2.4877	-3.09R
154	15.0000	13.2047	0.2508	1.7953	2.23R
212	10.0000	11.6455	0.2494	-1.6455	-2.04R
217	13.0000	15.2288	0.2494	-2.2288	-2.77R
224	16.0000	14.1944	0.2590	1.8056	2.25R
228	14.0000	15.7360	0.2590	-1.7360	-2.16R
232	11.0000	13.2658	0.2535	-2.2658	-2.82R
237	15.0000	16.6239	0.2508	-1.6239	-2.02R
239	17.0000	15.0155	0.2530	1.9845	2.47R

R denotes an obs. with a large st. resid

Pearson Product Moment Correlation

% $\dot{V}O_{2\ max}$ and % HRR

Step Height		6	8	10
Subject	1	0.7656	0.9701	0.9768
	2	0.9017	0.9464	0.9701
	3	0.9495	*	0.9214
	4	0.8935	*	0.9680
	5	0.9657	0.9734	0.9854
	6	0.8573	0.9388	0.9612
	7	0.4527	0.7967	0.9003
	8	0.9493	0.9186	0.9116
	9	0.7744	0.9285	0.8918
	10	0.9161	0.9633	0.9519
Medians		0.8976	0.9426	0.9565

* denotes missing data.

% $\dot{V}O_{2\ max}$ and % HR_{max}

Step Height		6	8	10
Subject	1	0.7663	0.9702	0.9766
	2	0.9028	0.9477	0.9697
	3	0.9504	*	0.9208
	4	0.8948	*	0.9678
	5	0.9658	0.9736	0.9852
	6	0.8580	0.9383	0.9614
	7	0.4523	0.7983	0.9007
	8	0.9491	0.9182	0.9114
	9	0.7740	0.9286	0.8918
	10	0.9155	0.9633	0.9522
Medians		0.8988	0.9430	0.9568

* denotes missing data.

Pearson Product Moment Correlation

RPE and % $\dot{V}O_2$ max

Step Height		6	8	10
Subject	1	0.64682	0.73797	0.82280
	2	0.65200	0.58083	0.76029
	3	0.63048	*	0.80063
	4	0.58478	*	0.75959
	5	0.90538	0.91314	0.93465
	6	0.72006	0.68022	0.82986
	7	0.27438	0.61395	0.81996
	8	0.57577	0.52353	0.76181
	9	0.44235	0.63284	0.78926
	10	0.57706	0.91865	0.77377
Medians		0.60763	0.65653	0.79495

* denotes missing data.

RPE and % HRR

Step Height		6	8	10
Subject	1	0.86014	0.83463	0.90609
	2	0.67767	0.74429	0.74634
	3	0.64955	*	0.92778
	4	0.70118	0.80704	0.88443
	5	0.92757	0.96191	0.96691
	6	0.86368	0.85898	0.92396
	7	0.84954	0.85774	0.93539
	8	0.78259	0.76110	0.94422
	9	0.77854	0.78680	0.91606
	10	0.81179	0.96323	0.91326
Medians		0.79719	0.83463	0.9200

* denotes missing data.

Pearson Product Moment Correlation

RPE and $\%HR_{max}$

Step Height		6	8	10
Subject	1	0.86040	0.83369	0.90645
	2	0.67693	0.74252	0.74469
	3	0.64644	*	0.92833
	4	0.69945	0.80870	0.88490
	5	0.92893	0.96192	0.96727
	6	0.86333	0.85939	0.92372
	7	0.85075	0.85802	0.93592
	8	0.78271	0.76175	0.94473
	9	0.77843	0.78707	0.91608
	10	0.81256	0.96273	0.91321
Medians		0.79764	0.83369	0.9199

* denotes missing data.

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