G-Trainer: An Effective Training and Conditioning Tool

Introduction

The theory and practice of unweighting is fairly common, but the means of achieving reduced effective body weight can vary. Originally developed at NASA, Alter-G is the first commercial manufacturer to use a pressurized enclosure to provide a counterforce to a subject's body weight. We've combined this technology with a treadmill, allowing an individual to walk or run at a fraction of their normal weight, effectively reducing the impact force on their musculoskeletal system. This patented technology is unique and revolutionary in the marketplace.

The gravity differential technology behind Alter-G's G-Trainer allows for precision unweighting (which we call the anti-gravity effect) with adjustments in decrements of as little as 1%. Its air pressure regulation system provides exceedingly accurate body weight reduction that can be maintained throughout the stride cycle and over the course of a workout session. The use of air pressure and the physical configuration of the G-Trainer offers substantial advantages over alternative technologies. Precision unweighting and unrestricted mobility make the G-Trainer a highly effective tool for injury prevention and rehabilitation following injury or surgery, and it introduces a new paradigm for training and conditioning.

There is a great deal of emphasis on early mobilization following injury/surgery and there has been a revolution in this regard over the last decade. The importance of early mobilization is widely recognized for curbing the loss of range of motion and deconditioning that occurs. Exercising at a lower body weight in the G-Trainer has obvious advantages during this phase of rehabilitation by reducing the strain on recovering tissues and by providing an exercise stimulus to the cardiovascular and musculoskeletal systems. However, as an individual progresses in strength, and conditioning becomes the emphasis, the effect of exercise at reduced body weight on the metabolic and aerobic demands of exercise must be understood for effective application of the G-Trainer.

The Practical Application of Unweighting Technology

For an individual, the metabolic impact and aerobic benefit of an exercise session depends on the intensity and duration of the workout. On a traditional treadmill, the intensity is controlled with speed and grade. The G-Trainer introduces the additional ability to modify intensity by changing the effective body weight. This represents a new training variable that must be understood to achieve the full benefit of a G-Trainer workout. The question is:

> **How much longer or faster does a user have to run when body weight is reduced, to achieve the same caloric expenditure and aerobic conditioning received when running at full body weight?**

In simple terms, calories expended during a workout are dependent on:

Duration: How long you workout.
Intensity: How fast you run.
Weight: How much you weigh.

Traditionally, energy expenditure is calculated from running speed, exercise duration and body weight. The American College of Sports Medicine has popularized one such equation:

$$VO_2 = (0.2 * S) + (0.9 * S * G) + 3.5^1$$

Where VO_2 = oxygen consumption in milliters/kilogram body weight/minute
S = running speed in meters per second
G = Grade in fractional percent

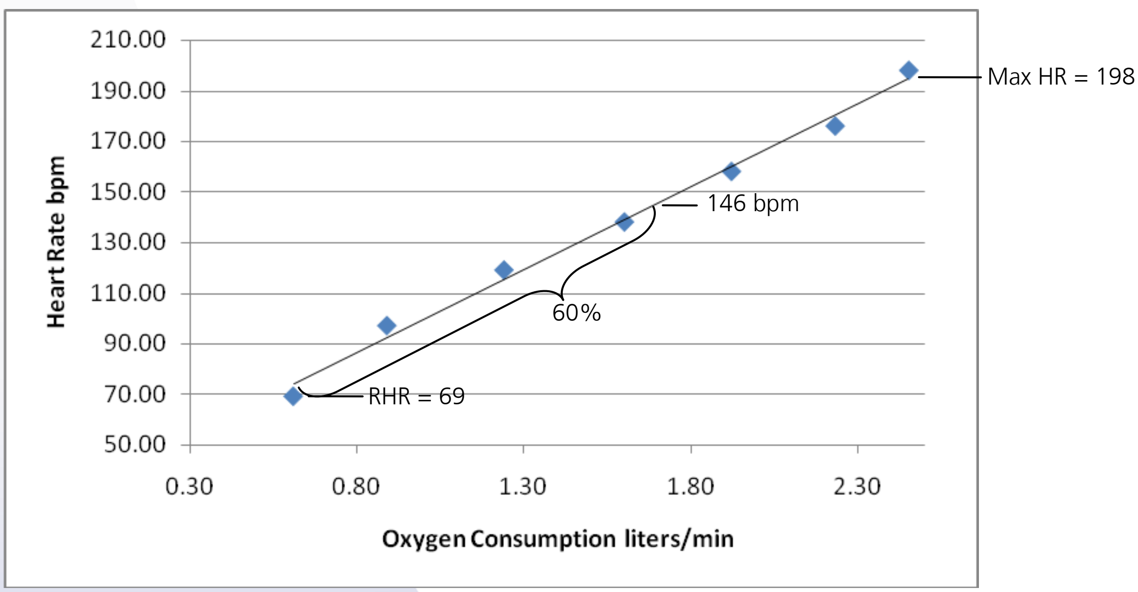
(In this equation, energy expenditure is calculated as the oxygen consumed per kilogram of body weight for any particular exercise session. To convert to Calories the following equation is used:
Calories/minute = VO_2 (ml/kg/min) * Body Weight (kg) * .005 Calories/ml O_2 consumed)

Speed and grade determine the intensity of the exercise, the duration determines the total energy requirement, and that energy is scaled to the size of the individual by multiplying by the body weight. The lighter the individual, the lower the metabolic demand for a given exercise intensity. One might reasonably conclude that exercising in the G-Trainer at reduced body weight will lower the metabolic demand and reduce the aerobic conditioning effect of the workout. Is there a way to take advantage of the lower biomechanical forces imparted to the body with reduced weight exercise, yet still maintain the metabolic and cardiovasular benefit of a reduced weight workout? Fortunately, the answer is yes.

Maintaining Exercise Intensity at Reduced Body Weight

Using a Heart Rate Monitor to Gage Intensity

Many of us are familiar with and routinely use heart rate monitors to determine our running pace. This means of determining exercise intensity is based on the observed linear relationship between heart rate and oxygen consumption. Exercise physiologists use the measurement of oxygen consumption as a means of gaging aerobic exercise intensity. The figure below demonstrates the linear relationship between oxygen consumption and heart rate for an individual that ran to exhaustion on a treadmill.



The relationship between oxygen consumption and heart rate is an individual characteristic dependent on age, gender, genetics, size and condition.

[1] ACSM Guidelines for Exercise Testing and Prescription, 7th Edition, 2005 pg. 289.

A typical exercise prescription will call for working at 60% of maximum oxygen consumption to elicit an aerobic training effect. Because there is this linear relationship between oxygen consumption and heart rate, we can use heart rate as an indicator of exercise intensity. For the one individual indicated, the 60% heart rate would be 146 beats/minute.

When exercising in the G-Trainer, the same principal applies for determining exercise intensity even at reduced body weight. The above individual would select a speed and weight combination to achieve their training heart rate of 146 bpm. For example, perhaps an individual would like to extend their weekly training mileage without a proportional increase in cumulative impact on their body. They may choose to exercise in the G-Trainer at 90% of body weight. At their normal pace and 90% body weight, they find their exercise heart rate only reaches 138 bpm. The solution is to increase treadmill speed until heart rate equals 146 bpm. This method ensures the user receives the same aerobic benefit for a given exercise duration as they would have received from their usual workout.

The astute observer may question whether or not the positive pressure used in the G-Trainer effects the heart rate/exercise intensity relationship. This relationship has not been directly studied using the G-Trainer, but has been studied in the laboratory using a bicycle ergometer contained within a lower body positive pressure chamber.[2] These investigators looked at several cardiovascular variables and measured oxygen consumption while subjects exercised upright with no lower body pressure, and with pressures of 25, 50 and 75 mmHg. This range of pressure is similar to that used in the G-Trainer (most people are able to obtain 80% unweighting at approximately 50 mmHg). They found no change in heart rate or oxygen consumption values when positive pressure was applied during exercise. They did observe an increase in stroke volume and a concommitant increase in cardiac output, but this did not result in a lower exercise heart rate as one might expect. Based on current data, it looks as though the exercise heart rate/exercise intensity relationship is unaffected by lower body positive pressure. Setting exercise intensity by using heart rate appears to be a legitimate technique for maintaining metabolic rate during reduced body weight exercise.

A Calculated Approach for Adjusting Intensity

Researchers at the University of Colorado, Boulder, have characterized the relationship between running speed, exercise weight and energy requirement on the G-Trainer.[3] That relationship is summarized by the following equation:

$$\Delta BW \times .0595 = \Delta Velocity$$

where

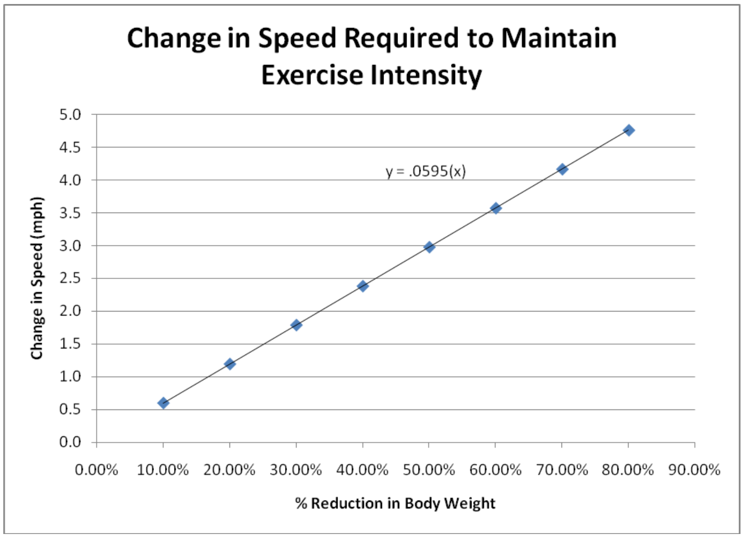
ΔBW = % reduction in body weight

and $\Delta Velocity$ = change in velocity needed to maintain exercise intensity in mph

The equation describes a simple linear relationship, plotted in the following graph. The slope of the line tells us that ***when running, for every 10% reduction in body weight, treadmill speed should be increased by approximately .6 mile per hour***. Notice that this increase is independent of the starting speed. That is, whether you start running at 6 mph or 12 mph, each 10% reduction in body weight will require you to increase treadmill speed by .6 mph.

[2] T. Nishiyasu, Nagashima K., Nadel E.R., and G.R. Mack. Journal of Applied Physiology 85(1): 160 – 167, 1998

[3] Alena Grabowski and Roger Kram. Interactive Effects of Running Speed and Weight Support on Metabolic Power and Ground Reaction Forces. Accepted for publication, Journal of Applied Biomechanics



A simple example demonstrates the usefulness of this relationship:

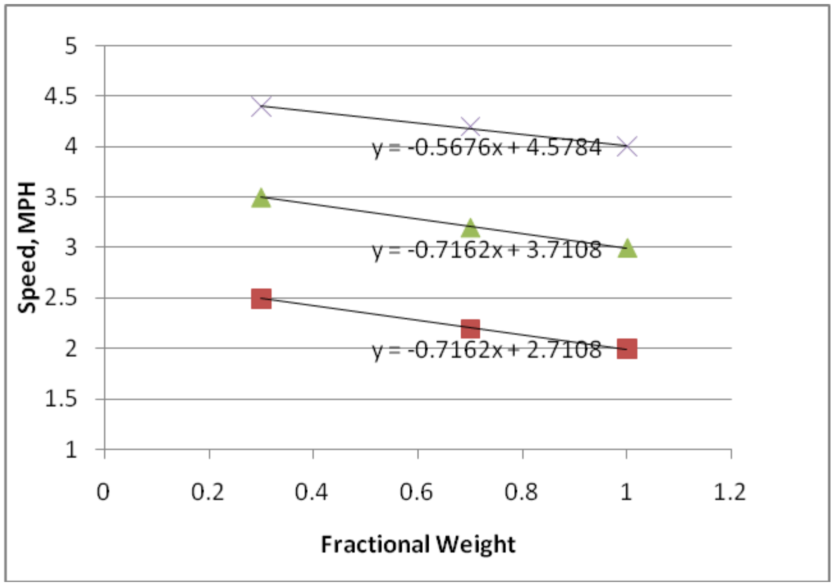
Example: I'm running at 5 mph and reduce my body weight by 50%, how fast do I need to run to maintain exercise intensity?

For every 10% reduction in weight, increase speed by .6 mph
5 X .6 mph = 3.0 mph
5 + 3 = 8 mph

Clearly, 8 mph is a big jump from 5mph, but so is a 50% reduction in your body weight. A reduction in body weight of 40% or greater is generally used by people training through, or recovering from injury. For healthy athletes using the G-Trainer as a conditioning and training tool, weight reductions of 5% or 10% are more common.

The subjects in the Kram/Grabowski experiment exercised at running velocities. It is a well known fact that walking is more efficient than running, so one might expect that the relationship between change in body weight and the required change in velocity to maintain metabolic rate may be different. A simple experiment performed at Alter-G would seem to indicate this is the case. An individual was asked to walk at 100% BW at 2 mph. Their heart rate was noted. They then exercised at body weights of .7 and .3 of full BW. At each reduced weight, treadmill speed was adjusted to maintain heart rate at the same value. This protocol was repeated beginning at speeds of 3 and 4 mph. Since heart rate and metabolic rate are linearly related, it is reasonable to assume that adjusting speed to maintain heart rate constant over the range of body weights would provide the same metabolic output at each body weight/speed combination. This allows one to determine the relationship between change in body weight and change in velocity needed to maintain the same metabolic rate.

The graph at the right shows the change in speed needed to maintain heart rate at each body weight for the 2, 3 and 4 mph beginning speeds. As the graph demonstrates, the slopes are very similar, indicating the change in speed required to maintain metabolic output seems to be unrelated to the starting velocity. The greatest difference seen is in the intercept of each line, a reflection of the different starting speeds. The three lines have an average slope of -.67, indicating that speed needs to change .067 mph for each 10% change in body weight to keep metabolic rate constant.



Using the estimate, the equation to determine your new running velocity becomes:

$$\Delta BW \times .067 \text{ mph} = \Delta Velocity$$

where

ΔBW = % reduction in body weight
$\Delta Velocity$ = change in velocity needed to maintain exercise intensity in mph

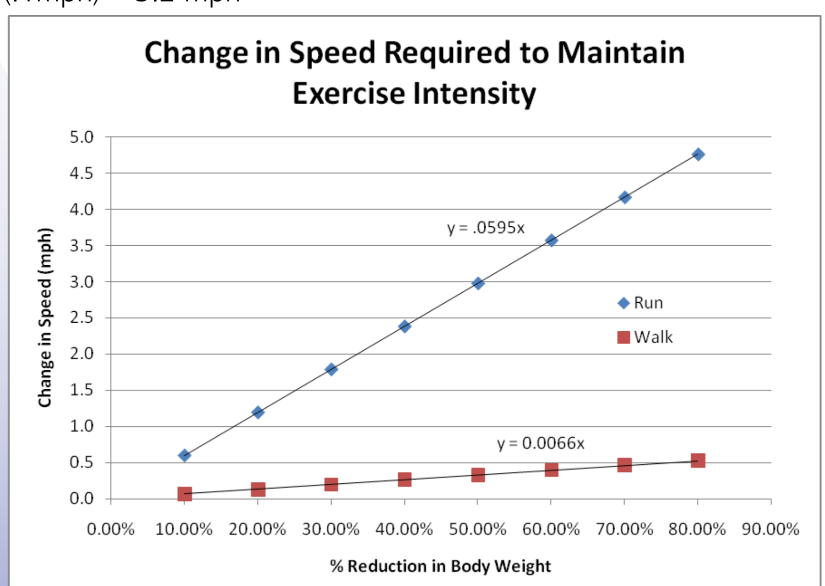
The factor, .067, is admittedly a rough estimate; for ease of use we are going to generalize and suggest that ***for walking, every 10% reduction in body weight requires an increase in velocity of approximately .1 mph to maintain exercise intensity***.

Example: I am walking at 2.8 mph and drop my body weight to 60%. What should my new walking speed be to maintain metabolic intensity?

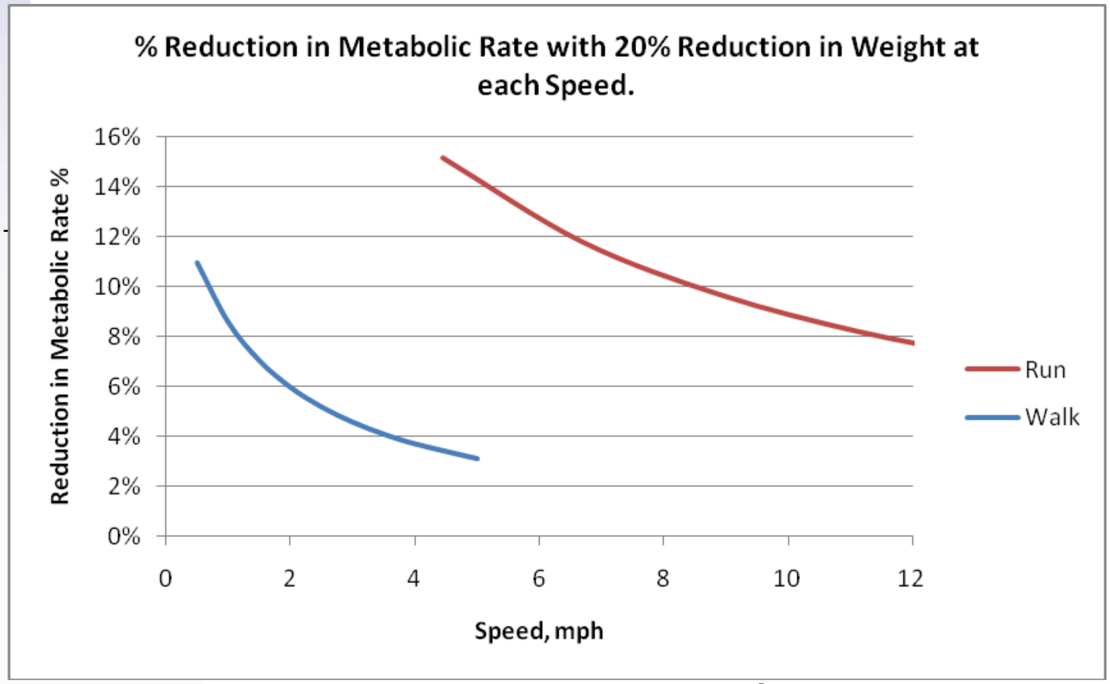
2.8 mph + 4 (.1mph) = 3.2 mph

For comparison, the walking and running relationships are shown in the graph to the right.

We see it is not difficult to compensate for the reduction in metabolic stimulus when exercising at reduced body weight by simply increasing running velocity.



An interesting observation is the faster you run, the less the change in metabolic rate observed as weight is reduced. The graph below illustrates this observation. For example, if one is running at 5 mph and reduces body weight by 20%, metabolic rate will drop by 15%. If one is running at 12 mph and reduces body weight by 20%, metabolic rate only drops 8%. The same appears to be true for walking. An estimate of this relationship was



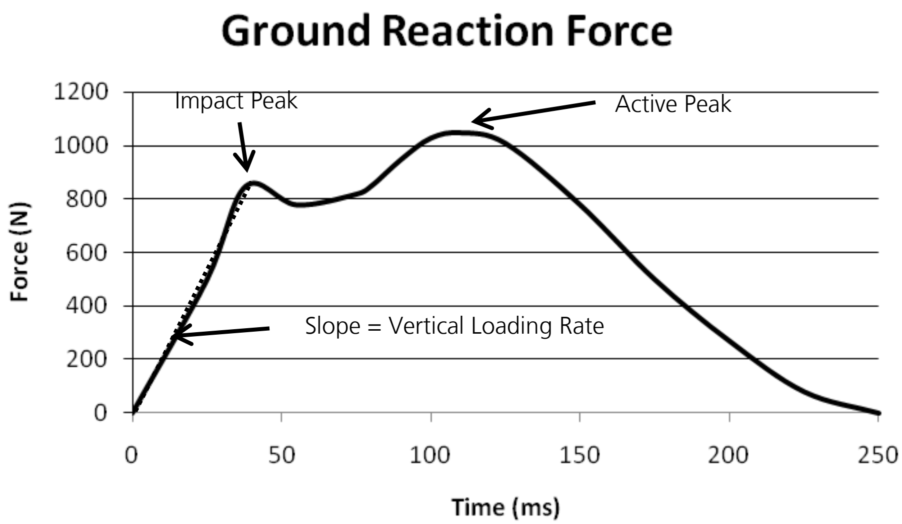
calculated from the ACSM metabolic calculation for walking[5] and data from Farley and McMahon[6], indicating a drop in metabolic rate of about .5 ml/kg/min when body weight is reduced by 20%. Using this estimate, the relationship for walking appears to be fundamentally the same as that seen in running, but with less dramatic reductions in metabolic rate with unweighting.

We know the biomechanical forces imparted to the musculoskeletal system decrease as body weight decreases, but does this advantage remain if we increase speed to maintain the aerobic benefit?

The running data from the University of Colorado study indicates the answer is yes and we would presume the same would hold true for walking. Grabowski and Kram describe the ground reaction force in terms of three variables: the **V**ertical **L**oading **R**ate (VLR), the **I**mpact **P**eak (IP) and the **A**ctive **P**eak (AP). These three variables are defined below using a typical ground reaction force curve.

The vertical loading rate is the rate at which force changes on heel strike. The impact peak describes the maximum force associated with heel strike, while the active peak is the result of active force development by the muscles at mid-stance. The relations between these three variables, body weight and running velocity are described by the following equations, derived by the investigators from the study data:

[5] ACSM Guidelines for Exercise Testing and Prescription, 7th Edition, 2005 pg. 289.
[6] Farely, Claire T. and Thomas McMahon. Journal of Applied Physiology 73(6): 2709-2712, 1992



VLR = 66.12(BW) + 20.35(V) – 55.53
IP = 1.8(BW) + .236(V) -.347
AP = 2.00(BW) + .166(V) - .062
BW = fractional body weight
V = velocity in meters/second

We can use these equations to determine if the increased speed with which we must run at lower body weights has a negative impact on the biomechanical forces. Using the running example from above, the following values are calculated for running at 5 mph, full body weight and 8 mph at 50% body weight:

Body Weight %	Speed (mph)	VLR (BW/sec)	IP (BW)	AP (BW)
100	5	56.1	1.98	2.31
50	8	50.4	1.4	1.53

As the calculations indicate, biomechanical forces are reduced across the board at the reduced body weight and increased speed. We have the fortunate circumstance that we maintain the aerobic stimulus at the lower body weight by running at higher velocity, while at the same time reducing the impact on the musculoskeletal system. There is an important qualification to this conclusion. The authors observed that in some instances, vertical loading rate and impact forces did not decline (although the active peak always declined) until body weight was reduced by more than 25%. In these cases, it appeared as though the runner was leaning back against the flexible seal around the waist. A more in-depth investigation of this phenomenon is required. It is suggested that as a user of the system, you maintain a natural running posture. Once aware of this issue, the increased pressure on the rear seal area is noticeable, and with a change in posture can be avoided.

Maintaining Total Caloric Expenditure During Reduced Body Weight Exercise

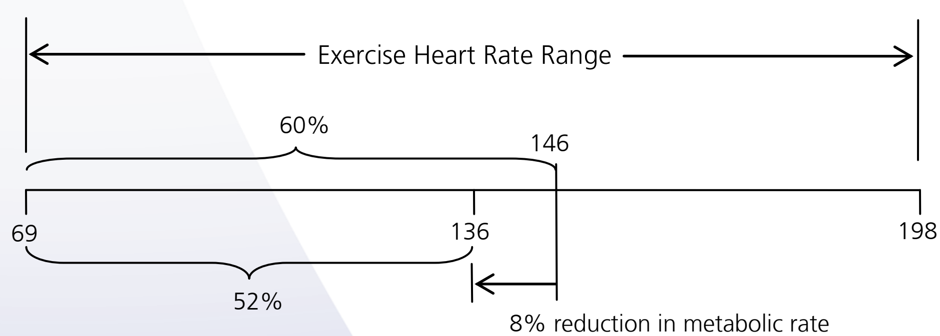
Use of a Heart Rate Monitor and Exercise Duration

If you choose to run at a reduced body weight, but compensate for this reduction by running at a higher velocity, we have seen that an individual can achieve the same exercise intensity. Using the G-Trainer in this manner, the total calories expended will depend only on the duration of the exercise and will be the same for all weight/speed combinations that produce the same metabolic rate. For example, if you usually exercise at a heart rate of 155 bpm for 30 minutes when running outside, you should attempt to replicate these same figures while exercising at reduced weight in the G-Trainer. Because heart rate and metabolic rate are linearly related, as long as you are at your usual exercise heart rate while using the G-Trainer, you can be assured that the total calories you burn for a given duration will be the same as those used during exercise for a similar period of time at full body weight.

Should you want to exercise at reduced body weight, but do not want to compensate for the reduction in exercise intensity by running at a higher velocity, you can increase the duration of your exercise to maintain your desired total energy expenditure. Your heart rate change at reduced weight can help you decide how much longer to exercise based on the fact that your heart rate and metabolic rate are linearly related. The following figure and example demonstrates how this is done.

Example: Let's assume your maximum heart rate is 198 bpm and your resting heart rate is 69. Your exercise heart rate range is 129 bpm. You normally exercise at 60% of this range, or 146 bpm for a period of 30 minutes. You find while exercising on the G-Trainer at 80% of body weight that your heart rate is 136 bpm. As shown in the figure, this value represents an 8% reduction in your metabolic rate. You must exercise 8% longer for a total duration of 32 minutes, 24 seconds.

30 x 1.08 = 32.4 minutes = 32 minutes 24 seconds

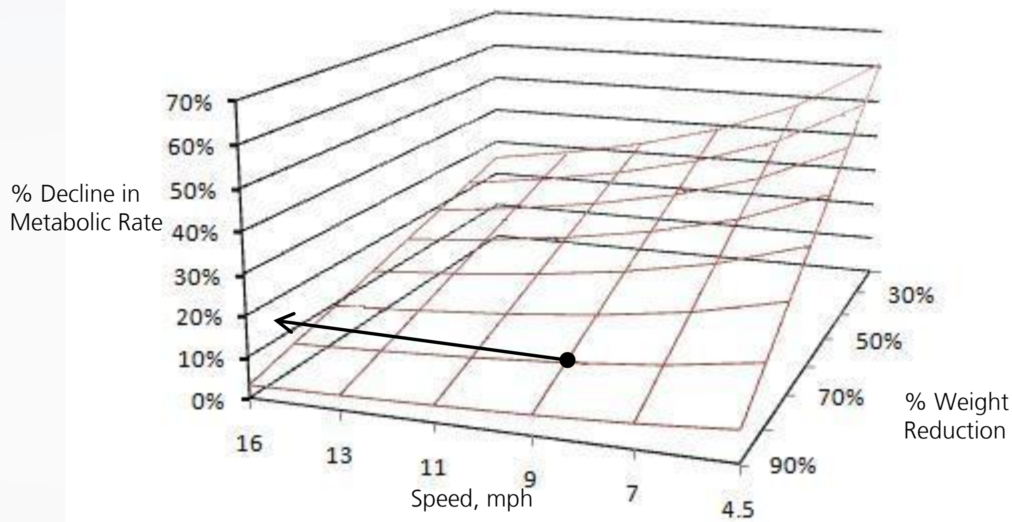


A Calculated Approach using Exercise Duration

In the absence of a heart rate monitor, we are still able to estimate how a reduction in body weight will effect exercise duration. Let us say that you want the benefit of reduced skeletal loading during exercise, and are concerned primarily with weight reduction. The question becomes: How much longer must I exercise at reduced body weight to burn the same number of calories used at full weight?

The graph below was developed from the relationship described by Grabowski and Kram relating body weight and speed to the metabolic rate. The metabolic rate was calculated at each speed from approximately 5 to 16 miles per hour at full body weight. The runners in the Grabowski/Kram study did not go above 11 mph, so we are taking some liberty at extending their observed relationship to 16 mph. The same equation was used at each fractional body weight and the difference between the two values is expressed as a percentage.

It is easy to see that as body weight declines so does the metabolic rate. The most extreme case occurs at a speed of 4.5 mph and 20% body weight where we can see that metabolic rate has declined by some 60%. This compares with exercising at 90% body weight at which the metabolic rate has declined by only about 8%.



How do we use this information to determine how much longer we should exercise at reduced body weight to burn the same number of calories we would at full weight? An example best illustrates the method.

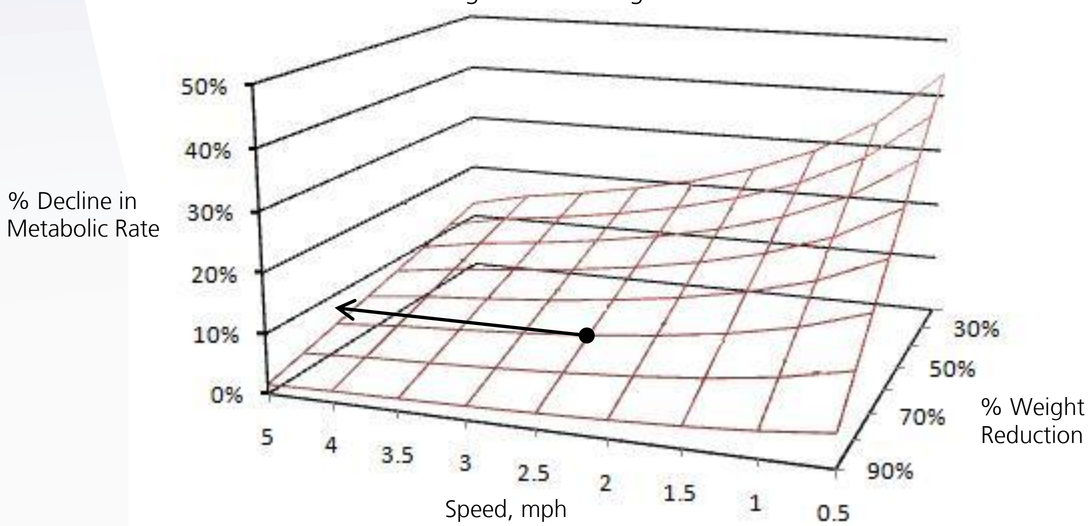
Example: A runner often runs at 9 mph for 40 minutes. That person has a shin splint and would like to continue to run at reduced body weight and burn the same number of calories as usual. They find they can comfortably run at 80% body weight. We see from the graph that metabolic rate is reduced by approximately 15%. With a 15% reduction in metabolic rate, they must run 15% longer:

1.15 x 40 minutes = 46 minutes

They have the benefit of reduced impact at 80% BW yet only need to exercise 6 minutes longer to achieve the same caloric expenditure.

The energy expenditure dependence on velocity as well as fractional body weight is far different for walking, so an estimate of the calories burned at any given body weight and walking speed recquires a new relationship. Unfortunately, this is an area that has not been fully studied by researchers, so we have to develop our own relationship and make certain assumptions. The data from Grabowski and Kram indicate that the reduction in metabolic rate is a constant value for each unit reduction in body weight, regardless of the running velocity. That value is approximately 1.8 ml O_2/min/kg for each 10% change in body weight. Using the data of Farley and McMahon, the calculated value for walking is about .26 ml O_2/min/kg for each 10%. We have used the ACSM equation for calculating the metabolic cost at a given walking speed and combined it with the relationship between reduction in body weight and corresponding reduction in metabolic rate observed by Farley and McMahon to produce the following graph.

Change in Metabolic Rate with Speed and Body Weight for Walking Velocities



The graph looks fundamentally the same as that observed for running, with the principal difference being a reduction in the magnitude of the metabolic impact as exercise body weight declines. Here again, an example is useful:

Example: An individual most commonly walks at 2.5 mph for 30 minutes. They find exercising at 70% body weight is much more comfortable on their arthritic knees. They want to continue to burn the same number of calories for each exercise session. How long should they exercise?

From the graph, the metabolic rate would be expected to decline by approximately 8% at a speed of 2.5 mph and 70% body weight.

30 minutes x 1.08 = 32 minutes, 24 seconds

They must extend their workout time by 2 minutes and 24 seconds to burn the same number of calories.

Summary

The G-Trainer Anti-Gravity Treadmill™ is a unique conditioning and training tool. With small modifications to a workout routine, an individual gains the substantial benefit of reduced musculoskeletal impact without compromising their aerobic conditioning or reducing their overall caloric expenditure.

Changing body weight has a direct effect on exercise intensity and energy consumption. Several means for modifying a reduced body weight workout to maintain these characteristics have been discussed. They are:

1. **To maintain intensity, increase treadmill speed to achieve your usual exercise heart rate.**
2. **-Or- estimate your new running velocity from the following:**
    a. **Walking: For each 10% reduction in weight, increase speed by approximately .1 mph.**
    b. **Running: For each 10% reduction in weight, increase speed by approximately .6 mph.**
3. **To maintain caloric expenditure, increase speed to maintain exercise heart rate and workout for your usual duration.**
4. **-Or- determine the reduction in exercise heart rate as a percentage of you heart rate range and increase the duration of your exercise by the same percentage.**
5. **-Or- estimate your % reduction in metabolic rate for any combination of speed and body weight from the graphs provided for running and walking. Increase the duration of your exercise by this same percentage.**

These are rather specific recommendations based on a limited set of data. Recognize that they are however, only estimates, and are offered to provide a context and perspective on the influence of reduced body weight exercise on intensity and energy expenditure. As more about reduced body weight exercise is understood, it would not be surprising to see these relationships change. In the mean time, use this information with discretion and check back with us periodically as we add to our knowledgebase through continuuing research, education and customer input.

Visit www.alter-g.com for testimonials, case studies and user experiences.