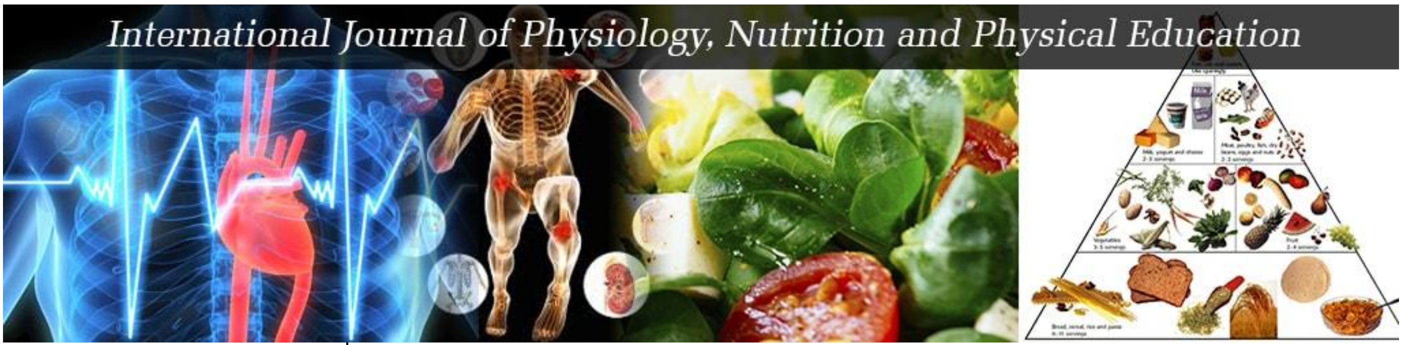

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Concepts in exercise dynamics for fitness and health essentials

Dr. Gerald SD Souza

Abstract
Man is essentially an aerobic animal, his health depending on the aerobic efficiency in which his body is functioning. As understood, aerobic metabolism refers to utilisation of oxygen to produce energy requirements for the functioning of the various systems of the body which can be collectively referred to as metabolism. Bringing about modifications in the metabolism which affect the fitness and health of an individual is of utmost importance in improving the health of an individual. This paper is the product of investigation into various training methodologies, nutritional practices and personal experiences and practices and probes into significant concepts which are essential for the development of a fit and healthy person. A few important concepts such as Heart rate based training, Diet and Respiratory exchange ratio are discussed in this paper.

Keywords: Aerobic, Heart based training, Diet, RER

Introduction
Man is essentially an aerobic animal, his health depending on the aerobic efficiency in which his body is functioning. As understood, aerobic metabolism refers to utilisation of oxygen to produce energy requirements for the functioning of the various systems of the body which can be collectively referred to as metabolism. Bringing about modifications in the metabolism which affect the fitness and health of an individual is of utmost importance in improving the health of an individual. This paper is the product of investigation into various training methodologies, nutritional practices and personal experiences and practices and probes into significant concepts which are essential for the development of a fit and healthy person. A few important concepts are discussed below:

Heart rate based training is an important aspect of the state of functioning of a person's body and is one of the important indices which can be used to monitor the physical effort of a person. Personal experiences and research has given physiological evidence that training at target heart rates will assist in developing goal based training.

Heart-rate training entails keeping the heart rate within a set range during a workout. The range is expressed as a percentage of maximum heart rate, which is the greatest number of times the heart can beat in a minute. For example, for a 30-minute elliptical workout, you might aim to keep your heart rate between 70 and 80 percent of your maximum heart rate. Heart-rate training reflects the fact that the harder you run, cycle, Nordic ski or do other forms of exercise, the higher your heart rate is. The ideal heart-rate range depends on the cardiovascular goals of a workout. This form of training is useful for aerobic exercise such as cycling and running, in which you sustain your effort for 20 or more minutes [3]

Heart Rate Training Zone

A heart rate training zone is a range that defines the upper and lower limits of training intensities. It is calculated using an age-related predicted maximum heart rate (HRmax) and a special equation called heart rate reserve. The values are expressed as a percentage of maximum heart rate (for example, 70% of HRmax), and the range is based on (1) metabolic systems in your body that fuel your muscles during exercise, and (2) how hard you want to train. Training from 40% to 85% of HRmax is aerobic exercise ("cardio"). Aerobic means "with oxygen." Training above 85% of HRmax is anaerobic exercise. Anaerobic means "without oxygen." [3]
Resistance exercise and sprinting are examples of anaerobic training, whereas walking and jogging are typically considered aerobic, although you could walk or jog fast enough to make it anaerobic. It's likely that you are working anaerobically (above 85%) if you're out of breath during a workout and working aerobically (less than 85%) if you're only slightly out of breath.

The HR range to be trained at

Most people train within an aerobic exercise training zone (40% to 85% of HRmax). Aerobic capacity (endurance) will improve faster if you train closer to 85% than if you train at 65%, but some individuals don't have the capacity to start training at 85%, or they simply prefer to start training at lower values and gradually increase the intensity over the time. Some individuals may even need to start at levels as low as 40% or 50%, depending on their age, level of fitness, or body weight. But the level that you start at isn't all that relevant. What matters most is that you get started, and then over time, as your endurance improves, you can gradually increase the intensity.

Table 1: Exercise Intensity

Level	Beginner	Intermediate	Advanced
Target HR	60% - 70%	70% - 80%	80% - 90%

A traditional method of aerobic training is to start at the low end of the aerobic training range, say 50% or 60%, and as training continues and the heart and muscles adapt to the challenge, the intensity is progressively increased. For example, a sedentary individual might start at 60% of HRmax and remain at that level for four weeks, and then during the fifth week increase the intensity to 65% (increases of 10% of intensity and/or duration is the standard recommendation). Again, the body accommodates to the work over time, and when higher levels of fitness are desired, the intensity needs to be increased. Training heart rate zones offer a quantifiable method of guiding workouts and determining exercise intensity.

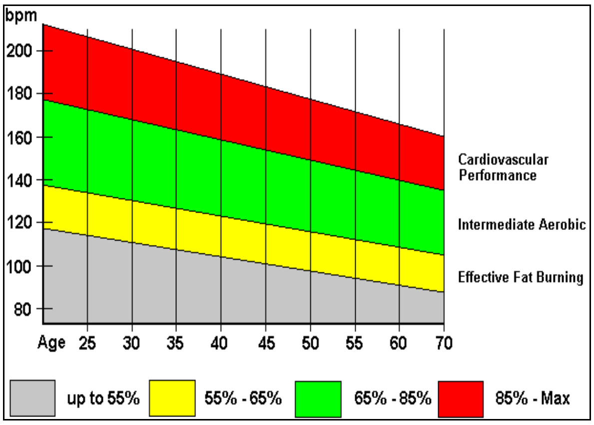

Fig 1: Target Heart Rate Chart

Table 2: Target Heart Rate Table

Age	Beginner Level 60%-70%		Intermediate Level 70%-80%		Advanced Level 80%-90%	
	Beats/Min	Beats/10 Sec	Beats/Min	Beats/10 Sec	Beats/Min	Beats/10 Sec
up to 19	120 - 140	20 - 24	138 - 155	23 - 25	150 - 174	25 - 29
20 – 24	120 - 140	20 - 24	138 - 155	23 - 25	144 - 174	24 - 29
25 – 29	115 - 137	18 - 22	135 - 152	22 - 25	144 - 166	24 - 29
30 – 34	110 - 133	18 - 22	131 - 147	21 - 24	138 - 162	23 - 27
35 – 39	110 - 130	18 - 21	128 - 142	21 - 23	136 - 160	22 - 26
40 – 44	96 - 126	16 - 21	124 - 139	20 - 23	128 - 151	21 - 25
45 – 49	96 - 123	16 - 20	121 - 135	20 - 22	126 - 146	21 - 25
50 – 54	90 - 119	15 - 19	117 - 132	19 - 22	120 - 142	20 - 23
55 – 59	90 - 116	15 - 19	114 - 130	19 - 21	110 - 139	18 - 23
60 +	90 - 112	15 - 18	110 - 127	18 -21	100 - 134	16 - 22

Methods of calculation of Target Heart Rate

Karvonen Formula [8]

The Karvonen Formula is a mathematical formula that helps you determine your target heart rate (HR) training zone. The formula uses maximum and resting heart rate with the desired training intensity to get a target heart rate.

Target Heart Rate = ((max HR − resting HR) × %Intensity) + resting HR

Example Training Heart Rate Zone

For example, for a 25 yr old who has a resting heart rate of 65, wanting to know his training heart rate for the intensity level 60% - 70%.

His Minimum Training Heart Rate:
220 - 25 (Age) = 195 (Maximum HR using formula 220-age)
195 - 65 (Rest. HR) = 130
130 x .60 (Min. Intensity) + 65 (Rest. HR) = 143 Beats/Minute

His Maximum Training Heart Rate:
220 - 25 (Age) = 195
195 - 65 (Rest. HR) = 130
130 x .70 (Max. Intensity) + 65 (Rest. HR) = 156 Beats/Minute
His training heart rate zone will therefore be 143-156 beats per minute.

Maximum Heart Rate
1. A simple, convenient formula based on a person's age [11] is extensively used nowadays [6, 7, 8] to calculate it: HRmax=220−age
2. A large number of studies have attempted to improve (1). Inbar *et al.* [10], for example, had 1424 healthy subjects perform treadmill exercises. They clarified that HR_{max} decreases by 0.685 bpm per year due to aging, and proposed the formula: HRmax=205.8−0.685×age.
3. Miller *et al.* [15] showed the equation: HRmax=217−0.85×age based on exercise by 86 obese and 51 normal-weight adults.
4. Tanaka *et al.* [4] pointed out the problem that insufficient data on the elderly was used to derive maximum-heart-rate formulas. They examined 351 samples involving 492 groups and 18712 subjects, and came up with HRmax=208−0.7×age.
5. Gulati *et al.* [9] speculated that HR_{max} should be different for men and women. They carried out exercise tests on 5437 asymptomatic women and came up with: HRmax=206−0.88×age.
6. Londeree and Moeschberge [1] pointed took age, sex, load level, and other factors into consideration, and suggested HRmax=206.3−0.711×age based on data collected from world-class athletes.

So, there are many methods of calculating HR_{max}; and we need to determine which of them are suitable for use in the Karvonen formula.

Perceived Rate of Exertion
Since monitoring the heart rate during activity requires heart rate monitors which are not always available or are expensive, one can still use the Borg Scale of Perceived Exertion (RPE) [2] to measure intensity. Simply select the number from below that best describes your level of exertion.
6 No exertion at all
7
7.5 Extremely light
8
9 Very light
10
11 Light
12
13 Somewhat hard
14
15 Hard (heavy)
16
17 Very hard
18
19 Extremely hard
20 Maximal exertion

*A high correlation exists between a person's perceived exertion rating times 10 and the actual heart rate during physical activity; so a person's exertion rating may provide a fairly good estimate of the actual heart rate during activity (Borg, 1998) [2]. For example, if a person's rating of perceived exertion (RPE) is 12, then 12 x 10 = 120; so the heart rate should be approximately 120 beats per minute. Note that this calculation is only an approximation of heart rate, and the actual heart rate can vary quite a bit depending on age and physical condition. The Borg Rating of Perceived Exertion is also the preferred method to assess intensity among those individuals who take medications that affect heart rate or pulse.

Recovery Heart Rate
The heart rate should be below 120 after 2 to 5 minutes after exercise stops depending on fitness level. If the heart rate is higher, insufficient cool-down or low fitness level may be the cause. Slow heart rate recovery can also be due to illness or exercising too vigorously. If this is the case, reduce the intensity of the exercise thereby adjusting the heart rate. Final heart rate check at the end of the aerobic workout should be below 100 bpm.

Diet
Diet is another important variable of the health of a person which has a direct effect on the metabolism and has an important influence in deciding the body composition of a person as well as metabolic health of an individual.

Role of Macronutrients for muscular work
Carbohydrates – is an important source of fuel for muscular work as well as other metabolic functions.
Fats – another important source of energy.
Proteins – Provides material for the structure of the body, repair of tissues but negligible source of energy.

Table 3: Difference in Carbohydrates and Fats in terms of supply of energy supply and O_2 consumption [16]

Carbohydrates - Glucose	Fats – Fatty acid
1 gm gives 4 calories of energy	1 gm gives 9 calories of energy
1 molecule requires 6 ml of O_2 to produce 38 ATP	1 molecule requires 23 ml of O_2 to produce 129 ATP
Requires 1/4 of O_2 to produce less than 1/3 of ATP as compared to fats	Requires almost 4 times oxygen to produce more than 3 times ATP as compared to O_2
Oxygen efficient but limited energy	Oxygen costly but abundant energy
Limited storage – 300-500 gms in body lasting for about 2 hours of effort.	Abundant storage lasting for days.

Table 4: Conventional ratio of macronutrients

Sedentary individual – requirement about 1500 calories per day			
Macronutrient	CHO	Fats	Proteins
%	60%	20%	20%
Calories – 1500 cal	900	300	300
gms to be taken	225 gms	33	75
Normally taken – 2120 cal	300 gms/1200 cal	80 gms – 720 cal	50 gms – 200 cal

Training the body to burn fat
1. Perform exercises at steady state/sub maximal level (50-80%) to achieve RER of about 0.8.
2. Restrict unnecessary carbohydrates in the diet. (Consumption of refined sugars, excess complex CHO

such as rice, sweets, icecreams and pastries, bakery products etc.)

3. Though food prepared by using additional fat is not advocated, do not restrict dietary fats (fats derived from normal foods such as meat, dairy products etc.)

Who should have a high carb diet?

High intensity sport athletes such as Sprints, Basketball, Football etc.

Athletes training for a long period of time etc. such as long distance runners etc.

Excess of carbohydrates has the following effects

1. CHO, in the form of glucose as it enters the blood stream is scuttled into muscles and liver in the form of glycogen. Muscle glycogen is used for muscular work which is minimal and does not deplete significant amount of glucose in sedentary individuals. Only about 5gm of glucose is present in the blood in resting conditions while 400 gm to 500 gm is stored in muscles and liver.
2. Insulin which regulates the amount of glucose in the blood is instrumental in shuttling it to the muscles for muscular work as well as storing excess as glycogen.
3. Glucose ingested which is in excess of storage in liver and muscles is converted to fat [17].
4. Constant ingestion of CHO leads to insulin spikes which overloads the system gradually leading to insulin intolerance (CHO intolerance) thereby creating a state of prediabetic conditions.
5. Excess glucose makes the body depend predominantly on CHO for aerobic work.
6. This unnecessarily usage of CHO causes a fat sparing effect, creating fat accumulation which is obvious in belly, arms, thighs and cheeks.

Arguments for Fats

1. Fats though not good excessively, is necessary for many metabolic functions and can be ingested as dietary fats through whole milk and milk products, non vegetarian food etc.
2. Brain requires fats for many of its functions [18].
3. Fats can reduce inflammation, increase insulin sensitivity and it is directly correlated to high Cholesterol.
4. Good fats such as omega 3 fatty acids are essential for many of the bodily functions such as hormonal functions, increasing insulin sensitivity and also to burn fat by activating the fat burning genes.

Table 5: Changes in Macro nutrient proportion as per the present research and arguments

Sedentary individual – requirement about 1500 calories per day			
Macronutrient	CHO	Fats	Proteins (1gm /kg BW)
%	20-30%	40-50%	30%
Calories	300-450 cal	600-750 cal	450 cal
gms to be taken	75-113 gms	66 – 83 gms	113 gms

Respiratory Exchange Ratio (RER)

It is accepted fact that activity in the form of exercise is essential for healthy growth and maintenance of metabolism of an individual. Analysing the substrate utilisation (CHO or Fats) during exercise is an invaluable tool in drafting the training programme aimed at improving the health of an individual. Is the result of the dietary practices and exercise intensity followed.

The intensity at which carb and fats are predominantly used.

It is understood from table 3 that carbohydrates produce energy using less oxygen than fat, (fat is a costly source of energy) but given the required amount of O_2 fat can supply energy for a long period of time. So since O_2 is a scarce commodity in high intensity exercises mostly CHO is used and in low intensity exercises where more O_2 is available for consumption fats are used for energy.

Evaluation of exercise intensity incorporates the influence of HR based training and substrate utilisation and is essential to document the process of Fitness and Health improvement. Managing the RER is a key factor in monitoring the substrate utilisation and training at optimum intensity.

Respiratory exchange ratio (RER) is a key concept to find out the substrate utilisation and helps in tweaking the training intensity and thereby giving a scientific touch and purpose to the development of fitness and health.

The two sources of energy available for human metabolism are carbohydrates (CHO) and fats. These molecules are broken down, or catabolized, into carbon dioxide, water, and energy. However, the oxidation of fats requires more oxygen than the oxidation of carbohydrates.

RER = VCO_2/VO_2 [7]

Oxidation of a molecule of *Carbohydrate* [16]:

$6\ O_2 + C_6H_{12}O_6 = 6\ CO_2 + 6\ H_2O + 38\ ATP$

As shown in this equation, 6 molecules of carbon dioxide are produced for every 6 molecules of oxygen consumed during the oxidation of carbohydrates, a ratio of1.0.

Oxidation of a molecule of *Fatty Acid* [16]

$23\ O_2 + C_{16}H_{32}O_2 = 16\ CO_2 + 16\ H_2O + 129\ ATP$

As shown in this equation, 16 molecules of CO_2 are produced for every 23 molecules of O_2 consumed during the oxidation of fatty acids, a ratio of 0.7.

The energy requirements of the body are met with a mixture of energy derived from carbohydrates and fats. The activity being performed determines the proportion of carbohydrates and fats being utilized. At rest, a body derives about 40% of its energy from carbohydrates and 60% from fats. As the intensity of activity increases, the demand for energy increases, and a greater proportion of this demand is met by the oxidation of carbohydrates. When maximal oxygen uptake is occurring at the most intense exercise level, 100% of the energy is being supplied by carbohydrates because the catabolism of fat is too slow to supply the amount of energy required.

The ratio of carbon dioxide produced to oxygen consumed during cellular metabolism can be measured by determining the changes in the concentrations of oxygen and carbon dioxide in the air that passes into and out of the lungs. These measurements are possible because the amounts of oxygen and carbon dioxide exchanged between the alveoli and the capillaries in the lungs are directly dependent on the amounts of carbon dioxide produced and oxygen consumed during cellular respiration.

Table 6: Respiratory Exchange Ratio (RER) as a Function of the Proportions of Energy [16]

RER	Energy kcal/liter O2	% Energy from CHO	% Energy from Fats
0.70	4.69	0	100
0.75	4.74	15.6	84.4
0.80	4.80	33.4	66.6
0.85	4.86	50.7	49.3
0.90	4.92	67.5	32.5
0.95	4.99	84.0	16.0
1.00	5.05	100	0

The fat and carbohydrate percentages utilized during an activity are determined using the following equations: [16]

((1.00-RER)/(1.00-0.70)) x 100 = %Fat utilized
100% - %Fat utilized = %CHO utilized

The energy expended during an activity is calculated from the RER and the volume of oxygen consumed. For example, if the RER is 0.90, the energy expended is 4.92kcal/liter O2. If 2.5 liters of oxygen are consumed per minute for 20 minutes, a total of 246 kcal are expended during the activity:

(2.5LO2/minute)(20min)(4.92kcal/liter O2) = 246kcal

At less intense activity levels, the rates of energy expenditure and RER values are lower. To expend the same amount of energy at a less intense level of activity, the duration of activity must be longer. For example, if the RER is 0.80, the energy expended is 4.80kcal/liter O2. If 1.7 liters of oxygen are consumed per minute, 8.16kcal are expended per minute:

(1.7LO2/minute)(4.80kcal/liter O2) = 8.16kcal/min

To expend 246 kcal at a rate 8.16kcal/min would require 30 minutes, 9 seconds:

246 kcal/(8.16 kcal/min) = 30.15 minutes.

Conclusion

Combination of aerobic training and scientifically based nutrition results in optimum health. Periodic evaluation through VO_2 max tests, RER at a given exercise intensity will indicate the physiologic health of an individual.

To conclude the paper discusses some of the important concepts and provides a training and fitness guide to developing a healthy and fit individual. Sedentary lifestyle increases the RER values, but decreases the insulin sensitivity, muscle oxidative capacity and contributes to decrease whole body fat oxidation (Morio and Hocquette, 2001; Smorawiński *et al*. 2001; Rimbert *et al*. 2004). For that reason, physical inactivity could promote increases in body fat. On the contrary, physically active and trained subjects exhibit lower RER than untrained subjects in response to comparable workloads (Jeukendrup *et al*. 1997; Bergman and Brooks, 1999). Also, endurance training decreases the RER values, increases the oxidative enzyme activity, O_2 uptake and delays the time necessary to reach fatigue status during exercise (Messonnier *et al*. 2005). The respiratory exchange ratio (RER) indirectly shows the muscle's oxidative capacity to get energy. Sedentarism, exercise and physically active lifestyles modify it.

It is important to exercise in the appropriate HR zone to derive the maximum benefits by way of optimum fat metabolism as indicated by RER. Achieving the desired RER is a function of diet as well, which means that we should train our body to burn more fat during aerobic and steady state exercise.

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