What is Interval Training?
# WHAT IS INTERVAL TRAINING?

## CONTENTS

<table>
<thead>
<tr>
<th>Part One: Background</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>3</td>
</tr>
<tr>
<td>1.1 Aim</td>
<td>4</td>
</tr>
<tr>
<td>1.2 History of Interval Training</td>
<td>4</td>
</tr>
<tr>
<td>1.3 Other Names for Interval Training</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part Two: Exercise Methodology</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 Introduction</td>
<td>10</td>
</tr>
<tr>
<td>2.1 What is Continuous Training?</td>
<td>11</td>
</tr>
<tr>
<td>2.2 What is Repetition Training?</td>
<td>12</td>
</tr>
<tr>
<td>2.3 What is Interval Training?</td>
<td>12</td>
</tr>
<tr>
<td>2.4 The Training Principles</td>
<td>13</td>
</tr>
<tr>
<td>2.5 Determining Your Correct Interval Training Pace</td>
<td>16</td>
</tr>
<tr>
<td>2.6 The Recovery Period</td>
<td>17</td>
</tr>
<tr>
<td>2.7 Why Interval Training?</td>
<td>18</td>
</tr>
<tr>
<td>2.8 Rules of Effective Interval Training</td>
<td>19</td>
</tr>
<tr>
<td>2.9 Seeing What Happens to the Amount of Oxygen You Consume</td>
<td>20</td>
</tr>
<tr>
<td>2.10 Ventilatory Threshold</td>
<td>21</td>
</tr>
<tr>
<td>2.11 Frequency of Interval Training</td>
<td>22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part Three: Types and Variations of Interval Training</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 Introduction</td>
<td>23</td>
</tr>
<tr>
<td>3.1 ‘Old’ Interval Training</td>
<td>23</td>
</tr>
<tr>
<td>3.2 ‘New’ Interval Training</td>
<td>24</td>
</tr>
<tr>
<td>3.3 The Fartlek Method</td>
<td>25</td>
</tr>
<tr>
<td>3.4 The Tabata Method</td>
<td>26</td>
</tr>
<tr>
<td>3.5 High-Intensity Interval Training</td>
<td>27</td>
</tr>
<tr>
<td>3.6 The Wingate Anaerobic Test</td>
<td>28</td>
</tr>
<tr>
<td>3.7 The Timmons Method</td>
<td>29</td>
</tr>
<tr>
<td>3.8 The Copenhagen Method</td>
<td>30</td>
</tr>
<tr>
<td>3.9 The Paarlauf Method</td>
<td>31</td>
</tr>
<tr>
<td>3.10 Interval-Circuit Training</td>
<td>31</td>
</tr>
<tr>
<td>3.11 Interval Training Variations</td>
<td>31</td>
</tr>
<tr>
<td>3.12 Who Uses Interval Training?</td>
<td>34</td>
</tr>
<tr>
<td>3.13 Interval Training in the Military</td>
<td>34</td>
</tr>
</tbody>
</table>
Part Four: Advantages and Disadvantages

4.0 Introduction
4.1 Advantages of Interval Training
4.2 Disadvantages of Interval Training
4.3 Points to Consider When Planning an Interval Session
4.4 Points to Consider When Conducting an Interval Session
4.5 Points to Consider After Interval Training
4.6 Safety Factors

Part Five: Miscellaneous

5.0 Summary
5.1 Useful Books, Magazines and Journals
5.2 Useful Links
5.3 References

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https://bootcampmilitaryfitnessinstitute.com/run/what-is-interval-training/
PART ONE: BACKGROUND

1.0 Introduction


This article provides an overview of interval training from the perspective of exercise and fitness. Interval training, a derivative of intermittent training, is a ‘fitness craze’ that has been ongoing for a number of decades, although intermittent training (in some form) can be traced back to at least the 1500s (Mendez, 1960).

Although many may recognise the term high-intensity interval training (aka HIIT), which was popularised in the 1990s, professional athletes have been using some form of interval training since the 1950s. Some sports personalities were utilising a rudimentary form of interval training, from the 1920s, before the term was coined.

Regardless of its origins, interval training has subsequently grown into a hug business and, according to IT Brief, Linkedin (a business networking site) had 450 million members worldwide in 2016 (Barker, 2016), of which 37,185 of these members stated they had interval training as a skill (Linkedin, 2017).

Defining interval training precisely can be somewhat problematic as it means slightly different things to different people. However, most commentators agree that it is higher-intensity bouts of exercise followed by lower-intensity bouts of passive or active recovery which is repeated a number of times.

Interval training can be applied to a variety of sports and exercises, for example running, swimming and press-ups – limitations are generally the imagination of the individual/coach.

As the reader will (hopefully) come to realise from reading this article, the underlying purpose of interval training, and its permutations, is sound. However, for many, the meaning of interval training has been distorted/confused through the plethora of definitions, hybridisation and accretion of its original purpose.

This article will provide the reader with an outline of interval training within the context of the exercise and fitness industry. Section One provides a background to the topic which looks to define some of the terms used, highlight the myriad of definitions in use and offer a brief history. Section Two explains what interval training is, outlines the plethora of substitute terms and the purpose of it. Section Two continues with the training variables to consider and the role of the recovery period, an important variable in interval training. It will discuss some rules for effective training, as well as the ventilator threshold and frequency of training. Section Three outlines some of the types and variations of interval training. Section Four highlights outlines some of the advantages and disadvantages of interval training, as well as points to consider before, during and after a training session. Finally, Section Five provides a summary of the article before providing the reader with some useful publications, links and references.
1.1 Aim

The aim of this article is to provide a broad overview of interval training, and its permutations. It is not intended to be a comprehensive, all-encompassing article, but will provide the reader with a fundamental understanding of what interval training is about.

1.2 History of Interval Training

This section of the article provides a select, but broad outline of the, history of interval training. For a fuller historical outline on the subject of exercise physiology read the excellent book ‘History of Exercise Physiology’ edited by Charles Tipton, and published in 2014, and for an excellent outline of training theory read Bourne’s 2008 doctoral dissertation.

One of the earliest references to intermittent training is by a Spanish physician, Cristobal Mendez (1500-1561), who published in 1553, in Latin, the ‘Book of Bodily Exercise’ (Mendez, 1960). View Section 1.3 for an outline of alternative names for interval training.

Tipton (2014, p.11) tells us that Mendez suggested that:

“To be beneficial, exercise must be moderate, performed frequently, enjoyable, and continuous (intermittent exercise failed to consume and dissipate humors, causing them to leave by pores opened by the heat of movement), and be associated with a shortness of breath (caused by the increased heat in the heart and the need for more air via increased ventilation).”

During the 1600s, “few physicians advocated strenuous or violent exercise [aka maximal intensity] because they felt, as did Hippocrates and Galen, that it was unhealthy.” (Tipton, 2014, p.11).

From the earliest advocates of exercise, such as Hippocrates and Galen, to the 1600s there was a school of thought that strenuous or violent exercise was unhealthy due in part to the heat produced.

Santorio Santorio (1561-1636), a student of Galileo Galilei, stated that to maintain a ‘youthful face’ individuals should avoid excessive sweating in the heat. He also believed that violent exercise would reduce body weight, advance the aging process, and promote an early death (Santorio, 1676, aphorism 19).

From an anatomy and physiology perspective, the 1600s and 1700s were a major period of scientific discovery and advancement of exercise and fitness knowledge.

In his book, published in 1707, John Foyer (1649-1734, a physician) considered a normal pulse rate to be between 70 and 75 beats per minute (bpm) with, interestingly, a pulse of 140 bpm the highest recorded value. Foyer suggested that if bpm became higher, then death could occur (Foyer, 1707). In 1734, Bryan Robinson (1680-1746), an Irish Physician, noted a bpm of 140 and 150 when individuals ran as hard as possible (Robinson, 1734).

In 1894, the maximum heart rate (MHR) during exercise was identified as being between 160 and 170 bpm (Christ, 1894); in 1913, it was 180 bpm (Cook & Pembrey, 1913); and another decade before 200 bpm was recorded (Tipton, 2014) – Although George Kolb noted heart rates in excess of 230 bpm in rowers in his 1893 book ‘Physiology of Sport’ (Kolb, 1893).
In 1835, Robley Dunglison (1798-1869) was opposed to violent exercise because it caused less oxygen to be inspired and more carbon dioxide to be produced, resulting in suffocation, because it caused aneurysms, haemorrhaging, hernias, and dislocations and sprains. Consequently he favoured moderate-intensity exercise because it promoted blood flow, enhanced the actions of the heart, increased muscle firmness and bulk, and reduced fat around the muscles (Tipton, 2014).

In 1871, Austin Flint Jr. (1836-1915) concluded that violent exercise caused muscle breakdown and resulted in an increased loss of proteins (Flint, 1871).

R. Tait KcKinzie suggested that (McKinzie, 1909):

- Active exercise (aka high-intensity) was an effort that could be violent in nature, involved extensive muscle groups, associated with hypertrophy and muscle damage, and would lead to fatigue (the inability to sustain a given power output).
- Endurance exercise was associated with less effort (reduced intensity), longer durations (>1 hour), and elimination of poisonous waste matter before fatigue occurred. Endurance exercises were advocated because they powerfully affected the heart, lungs, and muscular and nervous systems.
- Passive exercise, which essentially was massage and manipulation, was advocated for conditions of fatigue because it had a beneficial effect on muscles, ligaments, and the circulatory, respiratory, and nervous systems.

In 1910, the association between muscular performance and lactic acid concentration begins when Ryffel mentions that running 12 laps in 2 minutes 45 seconds causes blood lactic acid levels to increase from 12.5 mg/100 ml of blood to 71 mg/100 ml of blood, and that urine values are elevated from 4 mg/h to 362 mg/h after 17 minutes of recovery (Ryffel, 1910a; 1910b).

Billat (2001a, p.14) informs us that “in 1912, the 10,000m Olympic championship runner, Hannes Kolehmainen (Finland), had already used interval training at the specific 10km pace. He had trained using 5 to 10 repetitions of 3 minutes 5 seconds every 1000m (19 km/h). 80 years later the 10km specific interval training is run at 22.7 km/h.”

“LSD training became extremely popular in the 1960s. [and was] introduced in the 1920s by Dr. Ernst Van Auken, a German physician and coach…” (Kenney, Wilmore & Costill, 2012, p.222).

Bourne, writing a doctoral dissertation on the history of training theory, suggests training loads can be divided into one of three periods (Bourne, 2008, p.viii):

- Light Training Load: Leading up to World War I, “where athletes stayed competitive with very little training”;
- Moderate Training Load: Between World War I and II, with “the introduction of innovative training methods – fartlek and interval training.”; and
- Heavy Training Loads: “that occurred between 1945 and 1975”.

Although the 1800s witnessed huge advances in the knowledge and understanding of exercise physiology, Carter (2011, p.67) suggests there was a time lag in regards to training paradigms:

“Beamish and Ritchie have argued that during the inter-war years a ‘paradigm shift’ took place in the understanding of the training of athletes, when a scientific body of knowledge was built concerning human physiology through recorded observations related to exercise, human anatomy and physiology.”
In the 1920 Olympics, Paavo Nurmi (1897-1973), a well-respected Finnish runner and known as the ‘Flying Finn’ or ‘The King of Runners’, won his first Olympic medals: gold in the 10,000, cross-country and team competition events; and a silver in the 5,000 metre event. In the 1924 Olympics Nurmi won the 1,500 metre, 5,000 metre and cross-country events using a rudimentary concept that came to be known as interval training (Racing Past, 2016). He is the only person to complete this treble, and he also set a number of world records during 1924 (1,500, mile, 2,000, 3,000, 5,000 and 10,000 metres). Walking, running and calisthenics were the main elements of Nurmi’s harsh training regimen, as well as interval training (Billat, 2001a). He learned to measure his pace and its effects with a stop watch, and generally never raced without one in his hand. Finnish runners, using Nurmi’s training techniques, went on to dominate distance running until World War II (Racing Past, 2016).

“Analysis of Nurmi’s training program reveals the structured manipulation of running different distances (or intervals) including repeated sprints. The pioneer in this area of training was the Finnish coach, Lauri Pikhala, who in 1920 stressed the balance between work and rest in a method he called “Terrace Training,” with each layer built on the previous [Smit, 1959]. The basic principle of alternating work with recovery periods was further developed (as we shall see later in this chapter) in the late 1930s in the form of interval training.” (Bourne, 2008, p.158).

Mihaly Igloi, a Hungarian coach, was a pole-vaulter prior to becoming a 1,500 metre sprinter (Racing Past, 2015a). Igloi’s motivation for becoming a sprinter was “from watching Polish 10,000 OG [Olympic Gold] champion [Janusz] Kusociński, who according to Frank Litsky would run 200 repetitions in training.” (Racing Past, 2015a). Janusz Tadeusz Kusociński, a Polish athlete, won Gold at the 1932 Olympics, setting a new world record. Athletes coached and trained by Igloi achieved 49 world records and 35 European records. Igloi also broke down runs into sets (e.g. 3x20x200) and utilised pace variety (using the terms easy, fresh, good and hard) (Racing Past, 2015a). Like Woldemar Gerschler, Igloi concluded that interval training was better than LSD training – preferring intense work periods with short rests, in part due to the build-up of lactate (Racing Past, 2015a). Although, unlike Gerschler, Igloi was very secretive about his training methods. However, we know he “had his runners do intervals not once, but twice a day.” (Moore, 2006, p.89-90).

Gerschler develops his interval training method in 1932 (Colwin, 2002) using trial and error (Gerschler, Roskamm & Reindell, 1964). “Between 1935 and 1940 Gerschler and Dr. Herbert Reindell, a celebrated German cardiologist, worked in tandem to provide scientific validation to this method of training.” (Bourne, 2008, p.175). Gerschler and Reindell studied the cardiovascular (CV) effects of interval training, proving that the stimulus for CV improvement occurs during the recovery intervals between runs, when the heart rate decreases from an elevated value. Thus, the emphasis of the workout was placed on the recovery interval, prompting Gerschler and Reindell to call it an ‘interval workout’ or ‘interval training’.

In 1935-36, Rudolf Harbig (1913-1944), a German middle distance runner, started training under Gerschler (Thompson, 2010; Racing Past 2015b), essentially serving as his “guinea pig” (Bourne, 2008, p.176). Under Gerschler’s coaching, Harbig went on to set a number of world records at the 400, 800 and 1,000 metre events (Racing Past, 2015b).

“Fartlek training, developed in 1937 by Gösta Holmér (1891–1983), means ‘speed play.’” (Katch, McArdle & Katch, 2011, p.436). Holmér was a Swedish coach who developed this method of training to counteract the dominance of the Finnish athletes. Thompson (2010) informs us that Holmér developed the fartlek method of training “about the same time that Gerschler and Reindell...”
were experimenting with the original Interval Training.” (Thompson, 2010). Fartlek did not require a track like other forms of training.

Edgar Atzler (1887-1937) and Otto Graf (1894-1965) coined the phrase lohnende Pausen (or worthwhile breaks) to describe the recovery phrases during work intervals (Atzler, 1938; Graf, 1943).

“After the second world war, interval training became a widespread training method used by European runners.” (Billat, 2001a, p.14).

In 1947, Ernst van Aaken (1910-1984), a general practitioner in the small town of Waldneil, formally published his Speed through Endurance Method in Sport und Gymnastik (reprinted in English in van Aaken and Berben in 1971). His method was also known as the van Aaken Method and the Waldneil Endurance Run (in German Waldnieler Dauerlauf). Van Aaken’s method relied on long, ‘slow’ runs with a heart rate of 120-130 bpm, initially with short breaks, after the principle of interval training (Colwin, 2002; The Science of Running, 2016). Van Aaken is reported to have first developed his method after watching Paavo Nurmi break the world record in 1928 for the one hour run (Colwin, 2002). A number of successful athletes used van Aaken’s method of training, including Harold Norpoth (a German runner). The interval principle in endurance training is used only to enable the athlete to cover more distance without fatigue (Colwin, 2002).

Emil Zátopek (1922-2000), a Czechoslovakian long-distance runner and nicknamed the ‘Czech Locomotive’ “adopted the interval training system pioneered by Nurmi” (Racing Past, 2014). Zátopek is best known for winning three gold medals (5,000, 10,000 and marathon events) at the 1952 Summer Olympics in Helsinki (the only person to complete this treble, and it was his first marathon!). In 1951, he broke the hour for running 20 km and, in 1954, broke the 29 minute barrier for the 10,000 metres. He also had considerable success in the late 1940s, breaking a number of records in the 1940s and 1950s. Runner’s World tells us that “Emil Zátopek was inventing interval training, a methodology that would become standard for athletes across almost all disciplines.” (Collins, 2012).

“He [Zátopek] ran in his army boots to save money, claiming they also protected his ankles and developed leg strength. One legend has it that to maximize his training load, he would run on the spot in his boots while on guard duty.” (Racing Past, 2014).

In the 1950s, Woldemar Gerschler (1904-1982) established himself as one of the world’s leading running coaches, developing “...a very specific training regime that became known as interval training.” (Racing Past, 2015b). Gerschler worked at the Institute of Physical Education at the University of Freiburg from 1950 to 1971. As a coach, Gerschler trained a number of successful athletes including Rudolf Harbig, Joseph Barthel, Gordon Pirie and Tomás Barris. Gerschler claimed that his version of interval training produced greater endurance than running long unbroken distances, and in a shorter time period.

Working with Reindell, Gerschler’s training regime emphasised “that it is not necessarily the speed of running repetitions that can provide the primary training effect. In ‘Interval Training’ this primary training effect clearly takes place during the ‘recovery’ intervals between the faster repetition runs or efforts.” (Thompson, 2010). Gerschler and Reindell “claimed that the maximal expansion stimulus on the left ventricle occurred during the immediate postexercise recovery phase. Stroke volume of the heart is larger in the best-trained subjects (17 [Bevegard, Holmgren & Jonsson, 1963], 190 [Wang et al., 1961]).” (Tipton, 2014, p.256).
Gordon Pirie (1931-1991, a British runner) was inspired by Emil Zátopek after witnessing his performances in the 1948 Olympics. As a 21 year old, Pirie raced against Zátopek in the 1952 Olympics, finishing fourth in the 10,000 metre event. “Immediately after the Games Pirie met the German coach Woldemar Gerschler.” (Racing Past, 2011). In 1953, Pirie, under Gerschler’s coaching, achieved two world records and ten British records (Racing Past, 2011). From 1953 to 1961, Pirie had a range of successes mixed with a number of injuries. Pirie also won national titles in orienteering in 1967 and 1968 (Racing Past, 2011).

In 1953, Roger Bannister, a British runner, under the guidance of Franz Stampfl, an Austrian coach, commenced an intensive training programme in which he ran a series of 10 consecutive quarter miles, each in 66 seconds, with two minute rest intervals between them. Gradually, through January and February 1954, he stepped up the pace until by April he could manage the series in an average time of 60 seconds while keeping to the two minute rest intervals. Consequently, Roger Bannister ran the first sub four minute mile. Stampfl advocated a combination of fartlek, interval and repetition training. Bannister’s feat captured the imagination of followers of many sports, consequently creating interest in Stampfl’s training methods. Further, Stampfl’s book Franz Stampfl on Running and Bannister’s First Four Minutes, both published in 1955, were instant bestsellers.

In 1955, three athletes trained by Mihaly Igloi (Sandor Iharos, Laszlo Tabori and Istvan Rozsavolgyi) achieved nine world records (Racing Past, 2016). Unfortunately, due to the Soviet invasion of Hungary in October 1956, the Hungarians were unable to fully demonstrate their prowess at the 1956 Olympics in December.

“Interval training was first described, in [Schweiz und Sportmed] a scientific journal” (Billat, 2001a, p.13), by Reindell and Roskamm (1959) and then a book by Reindell, Roskamm and Gerschler in 1962.

Gerschler’s method of interval training evolved and was most clearly described in a 1963 Track Technique article in which Gerschler (1963) justifies interval training against LSD training, “which through Arthur Lydiard was gaining popularity through runners.” (Racing Past, 2015b). In the article, Gerschler states three reasons why he preferred interval training:

- It takes less time;
- It imposes a more powerful stimulus;
- It permits a more exact control on the intensity of the stimulus and on the duration of the effort.

In swimming in the 1960s, James Counsilman, a US swimming coach, developed a “hurt-pain-agony: scale to assist sensory perception of fatigue at different levels of work intensity, further developing a “hurt-pain-agony” chart (Counsilman, 1968,
p.338). “…Counselman was responsible for the introduction of interval training to swimming…” (Bourne, 2008, p.272).

It was not until the 1960s that famous Swedish physiologist Per-Olaf Åstrand (1922-2016) discovered, using a stationary bicycle in a laboratory, what many coaches and runners already knew – that by breaking up a set amount of work into smaller segments, a person can perform a greater amount of work at higher intensity (Åstrand et al., 1960).

Åstrand and colleagues concluded that heavy work (aka high-intensity) when split into short periods of work and rest (of 0.5 or 1 minute duration) was transformed to a submaximal load on circulation and respiration and was well tolerated during one hour. With longer periods (of 2 or 3 minutes duration) the work output got close to the upper limit of performance and could be fulfilled only with the utmost strain (Åstrand et al., 1960).

The 1920s to 1990s is generally considered the era of the ‘old’ interval methods, and from the 1990s as the era of the ‘new’ interval training methods, of which a number are outlined in Part Three.

### 1.3 Other Names for Interval Training

There are a variety of alternative terms for interval training, including:

#### ‘Old’ Interval Training (1920s to 1990s):
- Repetition Training or Traditional Repetition Training;
- Original, Classic or Traditional Interval Training;
- The Gerschler-Reindell law;
- Freiburg Interval or Freiburg Method;
- Intermittent Training or Intermittent Method;
- Non-Exhaustive or Exhaustive Intermittent Training;
- Non-steady State Work or Workout; and
- Interval Workout.

#### ‘New’ Interval Training (NIT) (1990s to Present):
- High-intensity Interval Training (HIIT), sometimes abbreviated as HIT;
- High-intensity Aerobic Interval Exercise (HIIE) or Training;
- High-intensity Interval Exercise;
- Power Interval Training (PIT) or Power Intervals (PIs);
- Sprint Interval Training (SIT) or Short Sprint Interval Training (SSIT);
- Short-term Sprint Interval;
- Short-term Intensity Training;
- High-intensity Intermittent Exercise (HIIE);
- Functional Threshold Power (FTP) Intervals;
- Lactate Dynamics Training;
- VO2max Intervals;
- Tabata Method, Tabata Protocol or Koichi Protocol;
- Steady State Intervals;
- Short Work-to-Rest Ratio Intervals; and
- HIIT Aqua, Aqua HIIT, HIIT Splash or Water-based HIIT.

For some commentators, terms such as intermittent, repetition and interval can be used interchangeably. The term interval training will be used throughout this article to avoid confusion.
PART TWO: EXERCISE METHODLOGY

2.0 Introduction

“Interval Training is always Repetition Training – not all Repetition Training is Interval Training.” (Thompson, 2010).

This section of the article looks at the methodology behind interval training. Areas discussed in this section include:

- What is continuous training?
- What is repetition training?
- What is interval training?
- The training variables.
- Determining your ‘correct’ interval training pace.
- The recovery interval.
- Why interval training?
- Rules of Effective Interval Training.
- Seeing What Happens to the Amount of Oxygen You Consume.
- Ventilatory threshold.
- Frequency of interval training.

Figure 1 provides an outline of the various methods of training discussed in this article.

![Diagram of Methods of Training]

Two types of aerobic training include the continuous and intermittent methods. Both the resistance and functional methods of training have developed interval training models.

Some training regimens, such as Fartlek Training (Section 3.3), combine both continuous and interval approaches.
2.1 What is Continuous Training?

“Continuous training involves continuous activity without rest intervals. This can vary from long, slow distance (LSD) training to high-intensity endurance training.” (Kenney, Wilmore & Costill, 2012, p.222).

The continuous method, more commonly known as continuous training, is any type of physical activity/exercise without rest intervals – it is often contrasted with the intermittent method and is generally viewed as a traditional method of training.

It is also known as (not an exhaustive list) continuous exercise, continuous moderate exercise (CME), continuous cardiovascular exercise, steady state run, long steady/slow distance (LSD), and (traditional) endurance training.

Continuous training requires sustained, steady state aerobic exercise and, because of its submaximal nature, may continue for a considerable time in relative comfort - distance rather than speed is the main objective of continuous training. This makes LSD training ideal for people beginning an exercise programme or wanting to reduce excess body fat.

“LSD training became extremely popular in the 1960s. [and was] introduced in the 1920s by Dr. Ernst Van Auken, a German physician and coach…” (Kenney, Wilmore & Costill, 2012, p.222).

Continuous training can be performed at one of three intensities:

- Low-intensity Continuous Training (LICT), approximately 60% to 70%-75% maximum heart rate (MHR);
- Moderate-intensity Continuous Training (MICT), approximately 70%-75% to 85% MHR; and
- High-intensity Continuous Training (HICT), approximately 85% to 90% MHR.

Sometimes referred to as low-, moderate- or high-intensity aerobic continuous exercise (LICE, MICE and HICE respectively).

Elite endurance athletes overload the cardiovascular and energy transfer systems using continuous exercise training at nearly the same intensity as competition. This specifically activates the slow-twitch muscle fibres in sustained exercise. A champion middle-distance runner may run 5 miles continuously in 25 minutes during workouts at a heart rate of 180 beats per minute; this pace does not exhaust the athlete but still nearly duplicates race conditions. By finishing each exercise session with several all-out sprints stopped 30 to 40 seconds before exhaustion, the athlete also trains the short-term anaerobic system (glycolysis) that contributes to race performance, particularly at the finish. A marathon runner trains as a slightly slower pace than a middle-distance athlete to simulate the intensity, distance and energy requirements of actual competition.

Exercise methodologies noted as suitable for continuous training include (not an exhaustive list):

- Indoor and outdoor cycling;
- Walking, jogging and running
- Indoor and outdoor rowing;
- Stair climbing and simulated climbing;
- Nordic skiing;
- Elliptical training;
2.2 What is Repetition Training?

“Let’s first take a quick look at traditional ‘Repetition Training’, since all interval training is a specific type of repetition training. You are aware that coaches and athletes frequently use repetition training by breaking training distances down into parts, with the parts being repeated, hence ‘Repetition Training’. A typical, simple repetition session might be 15 repetitions of 400m, which would be referred to as a ‘400m rep session’ or doing ‘400m reps’. (Thompson, 2010).

With classic repetition training the recovery period, unlike other forms of interval training, is long enough for the athlete to get their ‘breath back’. As such, a longer recovery period is required (e.g. 4-6 minutes) unlike newer forms of interval training where the recovery period maybe reduced to 2-4 minutes or even less than 60 seconds.

2.3 What is Interval Training?

“Researchers, coaches and athletes have a variety of concepts of interval training, the only point of agreement being that interval training involves alternating bouts of exercise and recovery.” (Daniels & Scardina, 1984, p.327).

With this in mind, just as there are a variety of alternative names for interval training, there are a variety of definitions, including:

- “High-intensity interval training (HIT), which involves repeated 30–300-s bouts of aerobic exercise at an intensity ranging from 85 to 100% of VO2max interspersed by recovery periods of equal or shorter duration.” (Daniels and Scardina 1984).
- “One can exercise at an intensity that normally proves exhausting within 3 to 5 minutes using preestablished spacing of exercise-to-rest intervals. This approach forms the basis of the interval training program. From a practical perspective, the exerciser applies various work-to-rest intervals using “supermaximum” effort to overload the specific systems of energy transfer. (Katch, McArdle & Katch, 2011, p.200).
- “Interval training consists of repeated bouts of high- to moderate-intensity exercise interspersed with periods of rest or reduced-intensity exercise.” (Kenney, Wilmore & Costill, 2012, p.220).
- “Interval exercise refers to the basic pattern of alternating periods of more intense effort with period[s] of less intense effort, or complete rest, within a single training session.” (Gibala, 2016).
- “Interval Training’ is simply and very specifically any repetition training where the training effect takes place during the recovery intervals between the faster paced runs.” (Thompson, 2010).
- “Interval training involves repeated short to long bouts of rather high intensity exercise (equal or superior to maximal lactate steady-state velocity) interspersed with recovery periods (light exercise or rest).” (Billat, 2001, p.13).
- “In general, muscular activity can be sustained beyond 10 min at a level demanding about 75% to 80% VO2max, called the lactate or ventilatory threshold. Interval training allows
short periods of muscular contraction for 1 to 2 min at 100% to 110% VO2max.” (Tipton, 2014, p.260).

“The idea that interval training can be identified by a specific intensity, duration, or number of exercise bouts or by the amount or type of recovery between bouts of exercise is not valid. Rather, interval training has come to mean any type of intermittent training which, with manipulation of the number, intensity and duration of work bouts and amounts of recovery, is used to produce a particular type of stress on the body.” (Daniels & Scardina, 1984, p.327).

Saltin et al. (1976, p.23-51) suggest that – using an interval training of 3 minutes at 100% of the minimal velocity associated with the maximal oxygen consumption (vVO2max) determined in an incremental test interspersed with 3 minutes at 50% vVO2max - interval training has the following characteristics:

- The **intensity** is defined as the average power output; for the interval training described above, the average intensity is equal to (100 + 50)/2 = 75% vVO2max [about 75% of maximal oxygen uptake (VO2max)];
- The **time-ratio** for the high and low exercise duration; for the interval training described above, the time ratio 3/3 = 1;
- The **amplitude** is the ratio of the difference between the intensity of the different periods (heavy or recovery run) with the average velocity; for the interval training described above, since the average velocity is 75% vVO2max, the amplitude is: 100 - 75/75 = 33%;
- The **duration** and the **distances** run at high and low velocities.

In summary, periods of intense activity interspersed with moderate to low energy expenditure characterise many sport and life activities.

Interval training simulates this variation in energy transfer intensity through specific spacing of work and recovery periods. With this approach, an individual trains at an inordinately high exercise intensity with minimal fatigue that would normally prove exhausting if done continuously. Rest-to-exercise intervals vary from a few seconds to several minutes depending on the energy system(s) overloaded.

There are a number of factors or variables which help to formulate the interval training session as outlined below.

### 2.4 The Training Variables

There is general agreement that rather specific guidelines are available which determine the amount and intensity of work and the amount of rest necessary to produce specific results, and it is suggested that types of training be identified based on the specific characteristics of each particular type of training rather than placing all types of intermittent training in an all-inclusive category called ‘interval training’. In other words, the training should be specific to the athlete and their sport.

With this in mind, when undertaking interval training, many would suggest there are four variables to consider, easily remembered by the mnemonic DIRT:

- **Distance of each speed interval:**
  - Refers to the distance to be covered (or time taken) during each work period.
- **Interval of recovery between speed intervals:**
What is Interval Training?

- Aka the ‘recovery period’.
- It is during this recovery period, especially the first 10 to 15 seconds, that most of the training effect occurs.
- Besides the duration of the recovery period, the activity figures into the equation (e.g. rest, walking, jogging or running).
- One of the original principles of interval training, that is still generally accepted, is that the next speed interval should not begin until the individual’s pulse has lowered to 120 beats per minute.
- Work-to-Recovery Ratio (WR Ratio) (Section 2.6):
  - 2:1 WR Ratio: Recovery times are half as long as the interval work time.
  - 1:1 WR Ratio: Recovery times are equal to the interval work time.
  - 1:2 WR Ratio: Recovery times are twice as long as the interval work time.
- WR Ratio is an important characteristic that differentiates ‘old’ interval training and its younger high-intensity interval training relative.

- Repetitions of speed intervals:
  - The number of fast sprints/runs to be performed.
  - In longer training sessions, repetitions can be broken down into sets, with a longer recovery interval than between individual repetitions.

- Time of each repetition:
  - How fast each repetition should be run.
  - Time can be constant or variable depending on the goal of the training session.

McArdle, Katch and Katch (2006, p.457) utilise slightly different phrasing, but mean the same thing:

- Intensity of exercise interval;
- Duration of exercise interval;
- Duration of recovery interval; and
- Repetitions of exercise-recovery interval.

Kenney, Wilmore and Costill (2012, p.221) note six “primary variables” to consider:

- Rate of the exercise interval: Determine the intensity of the exercise interval either by establishing a specific duration for a set distance or by using a fixed percentage of the person’s maximal heart rate (MHR). Intensity can be described as:
  - Supra-maximal (or supermaximum), maximal and submaximal; or
  - High-intensity, moderate-intensity or low-intensity.

- Distance of the exercise interval: The distance of the exercise interval is determined by the requirements of the event, sport, or activity. Individuals who run or sprint short distances, such as track sprinters, basketball players, and football players, will utilise short exercise intervals of 30 to 200 metres (33-219 yards), although a 200 metre sprinter will frequently run over distances of 300 to 400 metres (328-437 yards). A 1,500 metre runner may run exercise intervals as short as 200 metres to increase speed; but most their training would be at distances of 400 to 1,500 metres (437-1,640 yards), or even longer distances, to increase endurance and decrease fatigue or exhaustion during a race.

- Number of repetitions and sets during each training session: The number of repetitions and sets should be determined by the needs of the sport, event or activity. Generally, the shorter and more intense the exercise interval, the greater should be the number of repetitions and sets. As the exercise interval is lengthened in both distance and duration, the number of repetitions and sets should be correspondingly reduced.
**Duration of the rest or active recovery interval:** The duration of the recovery interval (whether active or passive) will depend on how rapidly the individual recovers from the exercise interval. The extent of recovery is best determined by the reduction of the individual’s heart rate to a predetermined level during the recovery interval. For younger individuals (30 years of age or younger), heart rate is generally allowed to drop to between 130 and 150 bpm before the next exercise interval begins. For those over 30 years, since MHR decreases ~1 bpm per year, one subtracts the difference between the individual’s age and 30 years from both 130 and 150. So, for a 45-year-old, one would subtract 15 bpm to obtain the individual’s recovery range of 115 to 135 bpm. The recovery interval between sets can be established in a similar manner, but generally the heart rate should be below 120 beats/min.

**Type of activity during the active recovery interval:** The type of activity performed during the recovery interval for land-based training can vary from complete rest (passive recovery) to slow walking or rapid walking to jogging/slower running (active recovery). In the pool, slow swimming using alternative strokes or the primary stroke is appropriate. In some cases, usually in the pool, total rest can be used. Generally, the more intense the exercise interval, the lighter or less intense the activity performed in the recovery interval. As the individual becomes better conditioned, they will be able to increase the intensity of the exercise interval or decrease the duration of the recovery interval, or both.

**Frequency of training per week:** The frequency of training will depend largely on the purpose of the interval training. A world-class sprinter or middle-distance runner typically works out five to seven days a week, although not every workout will include interval training. Swimmers use interval training almost exclusively. Team sport athletes can benefit from two to four days of interval training per week when interval training is used only as a supplement to a general conditioning programme. The coach or athlete who is interested in the specific details of how to organise and administer an interval training programme should refer to the classic text by Fox and Mathews (1974). These authors have provided many excellent examples of how interval training can be used for various types of sports. For beginners and those with medical ailments, one session per week may be appropriate.

Billat (2001a, p.15) presents ‘variables’ through a classification system “…of the different types of interval training according to the specific velocities of a race, the time limit at these velocities and ‘physiological velocities’: the velocity at maximal oxygen uptake (VO2max), the critical velocity (i.e. the asymptote of the velocity-time limit relationship), and the velocity at maximal lactate steady state.”

For most people, running continuously at a 4 minute mile pace will exhaust them within a minute due to rapid lactate accumulation. However, running at this speed for only 15 seconds followed by a 30 second recovery interval enables a person to accomplish 4 minutes of running at this near record pace. Of course, this does not equate to a 4 minute mile, but during 4 minutes of running, the person covers a one mile distance even though the combined exercise and recovery intervals require approximately 11 minutes 30 seconds.

Further, the variables are interrelated, and changing one will affect the others and even the training effect/output. Understanding how these variables and the training output interact will enable a person to modify their workout to their advantage.

As a practical example, a person could complete eight repetitions of 400 metres in 90 seconds with a 2 minute recovery interval (8 x 400 @ 90; 2). To increase the difficulty of this interval training session a person could make four changes to the above variables (although it is wise to only alter ONE of them at a time):
The number of repetitions could be raised to 10 or 12;  
The distance could be increased to 600 or 800 metres;  
The pace could be dropped to 85 or 80 seconds a lap; or  
The recovery time could be reduced to 1:45 or 1:30.

In contrast, if the original interval training session was considered too challenging, changing any of the variables the other way would make it easier to complete.

As a final thought, the shorter the distance a person runs, the faster they can run the total distance of the workout. For example, 5 x 1,000 metre exercise intervals with recovery intervals can be run faster than 5,000 metres continuously; 10 x 500 metre exercise intervals with recovery intervals can be run faster than 5 x 1,000 metres; and 20 x 250 metre exercise intervals with recovery intervals can be run faster than 10 x 500 metres.

“Exercise duration is probably the most appropriate variable to manipulate initially, building the exercise session by 10%, or 5 to 10 minutes every week or two over the first 4 to 6 weeks. Thereafter, and once adherence is developed, progressions can be implemented by increasing exercise frequency and then exercise intensity, but the progressions should always remain consistent with the individual’s goals.” (Porcari, Bryant & Comana, 2015, p.391).

With so many possible combinations of these variables, there is nearly unlimited potential to vary workouts and ‘never get bored’. Although runners tend to pay more attention to the pace and distance of each running period, the benefit from interval training sessions occurs from a combination of running and recovery. The recovery intervals are very important to the design and effectiveness of the workouts. That combination of running and recovery is what makes interval runs different from continuous runs.

2.5 Determining Your Correct Interval Training Pace

“Brief, all-out exercise interspersed with recovery represents a specific application of interval training for anaerobic conditioning.” (Katch, McArdle & Katch, 2011, p.432).

There are a number of different ways to determine an individual’s ‘correct’ interval training pace, with three examples using distance, VO2max and rate of perceived exertion given below. Further, an individual may perform a single-paced or multi-paced session.

Katch, McArdle and Katch (2011, p.435-436), referencing Fox and Matthews (1974), suggest the following distance method is appropriate for determining a person’s correct interval training pace for running and swimming:

- Add 1.5 to 5 seconds to the person’s ‘best time’ for training distances between 60 and 220 yards (55 to 200 metres) for running and 15 and 55 yards (14 to 50 metres) for swimming.
  - If a person covers 60 yards from a running start in 8 seconds, the exercise duration for each repeat equals 8 + 1.5 or 9.5 seconds.
  - Add 3 seconds to the best running time for interval training distances of 110 yards (100 metres).
  - Add 5 seconds to a distance of 220 yards (200 metres).
- This particular application of interval training most effectively trains the intramuscular high-energy phosphate component of the anaerobic energy system.
For training distances of **440 yards (400 metres) running** or 110 yards (100 metres) swimming, determine the exercise rate by subtracting 1 to 4 seconds from the average 440 yard portion of a mile run or 110 yard portion of a 440 yard swim.

- If a person runs a 7 minute mile (averaging 105 seconds per 440 yards), the interval time for each 440 yard repeat ranges between 104 seconds (105 - 1) and 101 seconds (105 - 4).

For run training intervals **beyond 440 yards** (and swim intervals beyond 110 yards) add 3 to 4 seconds to the average 440 yard portion of a mile run or 110 yard portion of a 440 yard swim.

- In running an **880 yard (800 metre) interval**, the 7 minute miler runs each interval in about 216 seconds \((105 + 3) \times 2 = 216\).

Another method of determining a person’s correct interval training pace is through VO2max pace – the maximum volume of oxygen your muscles consume per minute (or how efficiently your body uses oxygen). The Cooper VO2 Max Test [LINK] is an aid to determining a person’s VO2max.

For recreational runners, generally, VO2max pace is:

- Between mile and 2-mile (3k) race pace;
- About 20 to 25 seconds per mile faster than 5k race pace;
- About 40 to 45 seconds faster per mile than 10k race pace; and
- 95 to 100 percent of maximum heart rate.

For competitive and highly trained runners, generally, VO2max pace is:

- Equal or very close to 2-mile (3k) race pace;
- About 10 to 15 seconds per mile faster than 5k race pace;
- About 25 to 30 seconds per mile faster than 10k race pace; and
- 95 to 100 percent of maximum heart rate.

To improve VO2max, running faster than VO2max pace is not any better than running at VO2max pace; doing so adds more fatigue, causing the current or next training session to suffer.

Rate of perceived exertion (RPE) is for those who do not use heart rate monitors, or other technology, and wish to rate their training effort by ‘how it feels’. Further information can be found here [LINK: https://bootcampmilitaryfitnessinstitute.com/run/effort-based-training/].

Regardless of the method an individual uses to determine their correct interval training pace, they should not run the first exercise interval of the training session so fast that they cannot match that pace during the rest of the session. Finally, the pace desired will be affected (amongst other factors) by the individual’s sport/event and motivation level.

### 2.6 The Recovery Period

“Anaerobic and aerobic power training programs are designed to train the three metabolic energy systems: ATP-PCr system, anaerobic glycolytic system, and oxidative system.” (Kenney, Wilmore & Costill, 2012, p.223).

The recovery interval (also known as recovery period or relief interval) occurs either (Katch, McArdle & Katch, 2011):

- Passively, known as rest-relief or passive recovery; or
- Actively, known as exercise-relief or active recovery.
The recovery interval duration represents a multiple of the exercise interval, and is known as the work-to-rest ratio (WR Ratio) or exercise-to-relief interval (Katch, McArdle & Katch, 2011):

A 1:3 WR Ratio overloads the immediate energy system (ATP-PCr).
- For a person who runs 10 second intervals, the recovery interval equals 30 seconds.

For training the short-term glycolytic energy system, the recovery interval doubles (WR Ratio of 1:2), i.e. a 2 minute recovery interval follows a 1 minute exercise interval.
- These specified ratios allow sufficient restoration of high-energy phosphates and lactate removal so subsequent exercise proceeds with undue fatigue.

For training the long-term aerobic energy system, the WR Ratio usually equals 1:1 or 1:1.5.
- For example, during a 60- to 90-second exercise interval oxygen uptake increases rapidly to a high level.
- Although some lactate accumulates during this relatively intense exercise, the duration remains brief enough to prevent exhaustion.
- A 1 to 2 minute recovery interval permits exercise to begin again before oxygen uptake returns to its pre-exercise level.
- Consecutive repeat exercise-relief intervals ensures that cardiovascular response and aerobic metabolism eventually maintain near-maximal levels throughout the exercise intervals and recovery intervals.
- Performing continuously at this exercise intensity exhausts the person within several minutes, and training would cease.

A 2:1 WR Ratio: For a person who runs 20 second intervals, the recovery interval equals 10 seconds. HITT-type sessions general utilise a 2:1 WR Ratio.

“The onset of fatigue, or the inability to continue exercise at a given intensity, depends on fitness level and training status, exercise intensity, and environmental conditions.” (Porcari, Bryant & Comana, 2015, p.78).

During the recovery interval, an individual’s heart rate declines at a proportionally greater rate than the return of blood to the heart (In other words, a lot of blood is coming back to the heart), but the heart rate drops quickly because the individual has stopped running fast. The slower heart rate allows more blood to enter the left ventricle and results in a brief increase in stroke volume (the amount of blood the heart pumps with each beat). The increase in stroke volume overloads the heart, making it stronger and enabling the skeletal muscles to be cleared of waste products quickly because of the increased blood flow to the muscles. Because stroke volume peaks during the recovery interval and because interval training sessions have many recovery intervals, stroke volume peaks many times, providing a stimulus for improving maximum stroke volume and therefore the capacity of the oxygen transport system.

### 2.7 Why Interval Training?

“Research has shown that athletes can perform a considerably greater volume of exercise by breaking the total exercise period into shorter, more intense bouts, with rest or active recovery intervals inserted between the intense bouts.” (Kenney, Wilmore & Costill, 2012, p.220).

A sound rationale forms the basis for interval training. In the example of a continuous run by an average person at a 4 minute mile pace (Section 2.4, above), the predominant energy for exercise comes from the short-term anaerobic energy pathway with rapid lactate accumulation. The individual becomes exhausted within 60 to 90 seconds. In contrast, running at this speed for 15 second intervals or less places significant demands on the immediate energy (ATP-PCr) system.
with little lactate accumulation. Recovery becomes predominantly ‘alactic’ in nature and occurs rapidly (The anaerobic alactic energy system provides massive bursts of energy in very short periods of time. Generally speaking, the anaerobic alactic energy system can only be dominant for, at most, 20 seconds before the anaerobic lactic and aerobic energy systems take over.). The subsequent exercise interval can begin after only a brief recovery interval. Repetitively linking specific exercise intervals and recovery intervals eventually places considerable demand on aerobic energy metabolism.

“In interval training, as with other forms of physiologic conditioning, exercise intensity must overload the specific energy system(s) desired for improvement through sport-specific muscle activation.” (Katch, McArdle & Katch, 2011, p.435).

One of the attractions of interval training is its measured, precise nature. Training sessions can be tailored to an individual’s current level of ability/fitness and can also provide an accurate benchmark of their fitness, enabling achievable (and competitive) goals to be set. Interval training’s repeatability facilitates comparisons of past and present performance.

Manipulation of the training variables (Section 2.4) enables a great variety of sessions, with the opportunity to create a new session every time you train!

Interval training sessions have a nil/low choreography level and there is no fancy footwork patterns or complicated arm movements (subject to the requirements of the sport/activity). Interval training provides an excellent cardiovascular workout and, although interval training features a high-intensity level, this can be adjusted to the individual's fitness level, meaning each individual can work at a level of intensity suited to them.

The best part about interval training is that everyone can benefit. The only real restrictions are:

- The fitness level of the participants;
- The contraindications of the participants (if applicable);
- The space available; and
- The imagination of the instructor/trainer/coach (see Part Three).

### 2.8 Rules of Effective Interval Training

These ‘rules’ are aimed at the recreational exerciser rather than professional/elite athletes, although the general ideas can be applied to both.

**Rule One:**

- Go to each interval training session with a goal, and a plan.
- Do not just say “I need to get fast and I am going to work-out on the track.”
- Different workouts have different training effects; 20 x 200 and 4 x 1,000 have little in common besides the total distance being the same.
- A marathon runner and a 1,500 metre runner will perform different types of workouts; the former might do repeat miles to increase stamina, the latter, sets of 200s to hone a finishing kick.
- Know what your seasonal racing goals are, what phase of your training you are in, and what you need to work on at the current time.
- With this knowledge, and the understanding of the basic principles of interval training, you can sensibly follow the next rule:

**Rule Two:**
Be flexible in your workouts, but within reason.
An elite athlete will not go to the track to increase their midrace performance, witness another athlete working on their sprint finish, and suddenly swap. However, some individuals are prone to swap and change during a session. Some consider that speed-work is speed-work, and it does not matter what they do, it has just got to make them faster.
Beware of falling prey to group mentality (aka groupthink), for example doing what everyone else is doing because you may feel embarrassed.
Refer back to Rule One, and see if you can adapt or modify the workout to fit your training goals.
If not, you are probably better doing a workout on your own, even if it is psychologically tougher than training within a group.

Rule Three:
Knowing this principle allows you to tailor a workout to your own needs and ability.
Say a group or training partner is doing the above workout (Rule One), but it is just a bit beyond your current fitness level, or you are tired from the weekend’s long run or race.
To bring it within your reach, you could slightly slow the pace, for example finishing your laps in 95 or 100 seconds or stop after reaching the 150 metre mark.
Alternatively, you could do only six repetitions, which would also lessen your total workload (if the workout proved even tougher than you thought, you could make two or even three of these reductions).
Theoretically, you could also lengthen your recovery interval, but in a group setting that may be impractical.
What change(s) you make will depend on your goal(s) for the given training session.
To learn to run six minute miles in a race, keep the pace the same and reduce the distance and/or reps this time, trying to increase them in the future when your fitness improves.
On the other hand, if you are working on being able to run farther at a higher pace, slowing down but completing the total distance may be a better option.

Rule Four:
Be flexible and honest when assessing your own training for the day (and over the season) and realise that, like continuous/endurance training, speed-work’s benefits do not appear immediately but accrue gradually through a steady accumulation of workouts.
Intervals are supposed to be tough, to provide the training stimulus for physiological callousing and improvement, and it is sometimes difficult to differentiate between physical fatigue and mental fatigue.
However, if your body is really not up to the day’s workout, make it easier, using these rules and the training principles above, or even have the courage and common sense to skip it entirely, knowing that in workouts as well as warfare, discretion is the better part of valour (aka pick the battles you are going to win).

2.9 Seeing What Happens to the Amount of Oxygen You Consume

Interval training sessions are very demanding, but they are an excellent method for improving an individual’s cardiovascular conditioning. Figure 2 illustrates what occurs during an interval training session.
What is Interval Training?

During the first exercise interval, the volume of oxygen you consume (VO2) initially rises rapidly and begins to plateau toward the end of the exercise interval.

During the recovery interval, VO2 decreases rapidly, at first, because the individual has stopped running hard and, therefore, quickly decreased demand for oxygen.

If the recovery interval is short and active (equal to or less than the time spent running, a 1:≤1 WR Ratio), VO2 will not decrease all the way back down to what it was when the session began.

That is exactly what you want to happen because the next exercise interval then begins with your VO2 elevated.

VO2 then rises again during the subsequent exercise interval, to a point higher than during the first exercise interval.

If planned right, VO2 reaches VO2max after a couple of exercise intervals, which is the goal of the workout. These workouts are difficult because your muscles are consuming oxygen as fast as they can and also relying on some anaerobic metabolism (to produce energy without oxygen) so you can hold the fast pace. Of course this is just an illustration, a beginner exerciser, for example, will generally start and progress at a lower intensity, although the principle of a rising and falling VO2max applies.

2.10 Ventilatory Threshold

Exercise intensity is recognised as the most important variable factor of exercise programming to optimise maximal oxygen uptake. Echoing this is a slow, but inexorable trend, to move away from ‘antiquated’ models of percentage of maximal heart rate (% MHR) and percentage heart rate reserve (% HRR) to the concept of ventilatory threshold (VT) (ACE, 2011).

Research demonstrates that HIIT builds ventilatory power (the speed and magnitude with which individuals move air into and out of the lungs). In contrast, low-intensity exercise builds ventilatory endurance (the capacity of the endurance muscles to sustain work and resist fatigue). Porcari, Bryan and Comana (2015, p.388) suggest that “Both are critical to ventilation and the delivery of adequate levels of oxygen to the muscle cells.”
The American Council on Exercise Integrated Fitness Training (ACE IFT™) Model was one of the first cardio training models to adopt the VT concept, stating that research demonstrates how certain markers reflect significant events occurring within the energy pathways and with fuel utilisation during exercise. ACE (2011) describes the two VT categories:

- VT1 represents the transition in one’s primary fuel from fats to carbohydrates, representing the onset of our loss in aerobic efficiency (caloric quality) and a noticeable increase in blood lactate levels.
- VT2 represents the point where carbohydrates contribute exclusively to energy production via the aerobic and fast glycolytic pathways, and where we begin to overwhelm our capacity to tolerate lactate spillover into the blood (scientifically defined as OBLA, although most refer to it as lactate threshold).

Onset of blood lactate accumulation or OBLA is the point during exercise at which lactic acid builds up in the blood and fatigue sets in. The point when an individual “hits a wall,” so to speak. It is also known as the lactate threshold or anaerobic threshold.

ACE (2011) suggests that while many cardio programmes focus on maximising caloric quantity (i.e. burn more calories per unit of time), they should also consider building caloric quantity (i.e. greater fat utilisation per unit of time and faster recoveries) – combining both “implies training your body to continue to burn fat into higher intensities of exercise.” (ACE, 2011).

For an example of an ACE 2-zone training model to improve VT1 look here [LINK: https://www.acefitness.org/blog/1498/aerobic-interval-training-and-moving-away-from-antiquated-models].

2.11 Frequency of Interval Training

The exact frequency with which an individual performs interval training will be person- and sport-specific. For example some track athletes may undertake one or two interval training sessions each day of training, whilst recreational sprinters may only perform one or two per week.

Professional athletes will follow a specific, tailored and seasonal training programme which will most likely incorporate interval training as an integral component. Training intensity will fluctuate depending on factors such as upcoming races, altitude, season (winter versus summer) and so on.

Most recreational exercisers will most likely wish to limit their interval training sessions to between one and three per week. However, they may increase the frequency for an upcoming race or event.

When discussing obesity and weight management Porcari, Bryant and Comana (2015, p.676) state “Include some cardiorespiratory workouts that are of higher intensity for a shorter period. This may best be realized with high-intensity, continuous training or with interval training. To avoid physiological and orthopedic stress and injury, complete only one higher-intensity workout per week.” (Porcari, Bryant & Comana, 2015, p.676).
PART THREE: TYPES & VARIATIONS OF INTERVAL TRAINING

3.0 Introduction

As outlined in Section 1.3, there are a variety of terms for interval training, although the basic principle of varying between bouts of faster and slower periods is consistent. Generally, what defines the form of interval training is how the variables (Section 2.4) are used by the coach and/or athlete.

In simple terms, academic wisdom suggests there are two different types of interval training (Billat, 2001a):

- **Aerobic Interval Training**: “Aerobic training is defined as an interval training which elicits aerobic metabolism at a higher ratio than anaerobic metabolism.” (Billat, 2001a, p.21), which can be further divided into:
  - Short aerobic interval training (10-30 seconds each exercise interval).
  - Long Aerobic Interval Training (30-60 seconds each exercise interval).
- **Anaerobic Interval Training** (Billat, 2001b): An anaerobic activity is defined as energy expenditure that uses anaerobic metabolism (without the use of oxygen) that lasts less than 90 seconds, utilising an exhaustive effort (Wilmore & Costill, 2004).

This section outlines some of the well-known, amongst many, interval training methods available.

3.1 ‘Old’ Interval Training

“One of the most influential coaches of the inter-war years who adopted a more scientific approach was the German physiologist Woldemar Gerschler. Along with his colleague Herbert Reindell at Freiburg University [Germany], he pioneered scientific interval training.” (Carter, 2011, p.67).

Gerschler used extensive physical and psychological tests to help guide and advise his runners. Gerschler and his colleagues, Hans Reindell (a medical doctor and physiologist) and Helmut Roskamm authored and published (together and separately) a number of scientific papers, articles and books on interval training.

Gerschler’s method was designed to maximise cardiovascular fitness using a series of short, fast runs that were repeated a number of times. It trained the development of the heart during the
recovery intervals. The time of the exercise interval and the recovery interval was crucial and therefore a stopwatch was required – with a common criticism being that this form of training was a slave to the stopwatch.

Gerschler’s method focused on cardiac physiology and the adaptations that can be made in training the heart, and was based on three principles:

- Exercise increases heart rate and rest slows it down;
- Repeated physical exercise will slow heart rate while pumping the same volume of blood; and
- The volume of blood for each individual is constant.

Based on their work, Gerschler and Reindell formulated the Gerschler-Reindell Law. Gerschler and Reindell concluded from their experiments that the heart rate did not surpass 180 bpm - that represented the limit. From this point they allowed 90 seconds to return to 120-125 bpm and then the next interval could commence. If it took longer, it was because the effort was too hard or too long. Gerschler felt it was the recovery that strengthened the heart. He felt that there was a strong stimulus of the stroke volume immediately after the beginning of the recovery phase, so the recovery became a big focus hence the name interval training. The recovery was a walk in the beginning stages and then a jog as the runner gained fitness.

Gerschler’s method gave very rapid improvements in performance and as the heart became fitter and returned to 120 bpm more quickly the recovery intervals became naturally reduced. This natural reduction in the recovery interval due to increased fitness was combined with increasing the total number of repetitions to progress the training, rather than increasing the speed of the repetitions.

Early on, this form of interval training was very rigid and strictly guided by the Gerschler-Reindell Law. However, as it became more accepted and widespread, coaches and athletes began to experiment and move beyond the strict guidelines developed by Gerschler and Reindell.

### 3.2 ‘New’ Interval Training

“'New Interval Training' is simply and very specifically any repetition training where what the athlete does during the 'recovery intervals' is crucial and actually has a profound effect on the training of the metabolic energy systems.” (Thompson, 2010).

Although a stopwatch can be used with this form of training, it is meant to be more rhythmic and dictated by the perception of pace (i.e. the athlete judges how fast they are running). New interval training is based on a concept first developed in 1975 and formulised in 1994 by John Thompson, a British coach, known as Lactate Dynamics Training (LDT) (Thompson, 2010). Thompson (2010) describes LDT as:

“...any form of training where lactate production is deliberately increased by the intensity of exercise and then alternated with periods of less intense activity. In this way the muscle cells learn how to both use and clear the produced lactate during the less intense recoveries. This alternating of pace produces a massive improvement in running economy, the \( \text{vVO2max} \) and \( \text{tlimvVO2max} \), all of which are very strong predictors of performance.”
Thompson states that LDT is very similar to fartlek training, further commenting that “Properly done, Fartlek training is a classic form of Lactate Dynamics Training and trains the lactate shuttle in an environment away from the track.”

The major difference between the old and new interval training techniques is the transition from the work period to the recovery period, which Thompson (2010) describes as a “Roll-on Recovery”. Unlike Gerschler’s method in which a runner could stop, walk or jog during the recovery period, Thompson’s method entails a continuation of running but at a less intense pace, as he describes:

“What does ‘a very active, roll-on running recovery’ really mean in practice to the athlete? To get an idea of this it can be useful to ask an athlete to imagine that they are riding a bicycle. When you are pedalling along it is like being in the faster repetition distance of the session. When you come to the recovery interval it should feel like you stop pedalling but you do not touch the brakes at all you just roll on, naturally maintaining the active recovery pace.”

3.3 The Fartlek Method

“... this relatively unscientific blending of interval and continuous training introduced to the United States in the early 1940s had particular application to exercise outdoors over natural terrain. The system used alternate running at fast and slow speeds over both level and hilly landscape.”

(Katch, McArdle & Katch, 2011, p.436).

Katch, McArdle and Katch (2011, p.436) inform us that “Fartlek training, developed in 1937 by Gosta Holmer (1891–1983), means ‘speed play.’” Fartlek training is also known as alternative pace training, the Swedish natural method or just the Swedish method. Holmer, a Swedish coach and runner, based this new training method after the Finnish runner Paavo Nurmi.

Unlike traditional interval training that involves specific timed or measured segments, fartlek training sessions are less structured and do not require systematic manipulation of work-rest intervals. For example, varying the pace throughout the run by alternating between fast runs and slow jogs. In a manner similar to the rate of perceived exertion (or RPE), when conducting a fartlek session the runner determines their pace based on ‘how it feels’ at the time (Katch, McArdle & Katch, 2011), meaning the runner can experiment with their pace and endurance and is therefore a useful method for beginners. It provides an ideal means of general conditioning and off-season training, but it obviously lacks the systematic quantified approached of interval and continuous training.

However, when applied properly, the fartlek method “will overload one or all of the energy systems.” (Katch, McArdle & Katch, 2011, p.436). Porcari, Bryant & Comana (2015, p.391) state:

“This training format provides a sequence of different intensities that stress both the aerobic and anaerobic systems, something rarely achieved with exclusive steady-state training (aerobic), and different from traditional interval training (anaerobic with specific work-to-rest ratios). Consequently, this training format can be adapted to meet the needs of intermittent-sport athletes by essentially mimicking the changes of pace that occur during these events (e.g., rugby, soccer, football, hockey, and lacrosse).”

Fartlek can be conducted virtually anywhere but is great on a soft surface, ideally the pinewood needle surface of a forest path and on undulating ground so that there is plenty of uphill and downhill running. It can then be a combination of great quantities of easy running, interspersed with sprints and periods of resistance running up hills. The sprints and uphill work will force the
body into periods of anaerobic work, resulting in oxygen debt. This debt must be repaid during the lower intensity parts of the run. Consequently, this method educates the body to improve its oxygen uptake and speed of recovery.

Variables in fartlek include (Thompson, 2010):

- **Distance**: originally 12 km, with up to 5,000 metres at faster than race pace.
- **Speed (or pace or intensity)**: varying from gentle jog to faster than race pace.
- **Terrain**: flat, soft, undulating and hilly.
- **Frequency**: three to five times per week.

During the 1950s, Percy Cerutty, an Australian coach, adopted the fartlek method. “He combined beach running in heavy sand, sand dune training on dunes over 25 metres high with speed play over the undulating trails of the cliff tops, as well as on the flat beach and dirt roads.” (Thompson, 2010).

In summary, the fartlek method of training combines aspects of continuous and interval training and stresses both the aerobic and anaerobic energy pathways.

### 3.4 The Tabata Method

During the 1990s, Izumi Tabata and his colleagues published what is considered a landmark paper (Izumi et al., 1996). In their study using 14 physically fit, young, male subjects, Tabata and colleagues compared two training protocols, examining improvements in both aerobic and anaerobic fitness.

- In experiment one, seven subjects performed steady state exercise (moderate-intensity endurance training) five days per week on mechanically braked cycle ergometers, with each session performed at 70% of VO2max for 60 minutes (total of 300 minutes per week).
- In experiment two, seven subjects performed exhaustive intermittent training (high-intensity interval training) five days per week on mechanically braked cycle ergometers, with four sessions performed at workloads equivalent to 170% of VO2max. The subjects completed seven to eight reps, with the workload progressing by 11 watts on subsequent sessions when more than nine intervals could be completed. Each set involved a 20-second work interval followed by a 10-second recovery interval, totalling approximately 4 minutes of work per session. On the fifth day, the subjects completed a 30-minute interval at 70% of VO2max, followed by only 4 sets at 170% of VO2max.

Both protocols improved aerobic capacity, but only experiment two increased anaerobic capacity.

- **Experiment 1**:
  - Aerobic capacity: increased by 9% (52.9 to 58 mL/kg/min); and
  - Anaerobic capacity: no increase.
- **Experiment 2**:
  - Aerobic capacity: increased by 13% (48.2 to 55 mL/kg/min); and
  - Anaerobic capacity: increased by 28%.

Tabata and colleagues made reference to Medbø and Burgers 1990 work on the effect of training on anaerobic capacity with regards to intense exercise of short duration, stating that it was heavily dependent on energy from anaerobic sources (Medbø & Burgers, 1990).
An anaerobic activity is defined as energy expenditure that uses anaerobic metabolism (without the use of oxygen) that lasts less than 90 seconds, utilising an exhaustive effort (25).

Unfortunately, the nature and results of this study have largely been misinterpreted by many fitness professionals who market Tabata training (and other permutations) to the general public. Although the study used 14 physically fit, young, male subjects exercising on bicycle ergometers, this form of training has a number of permutations and is now performed with many different population groups (e.g. deconditioned individuals, females and older adults) and includes other forms of cardiorespiratory exercise (e.g. treadmill, elliptical and sprints), and even resistance training (e.g. body weight and externally loaded resistance), were it can be problematic to conduct training at 170% of VO2max. It could be argued that the only commonality between these forms of exercise is the 2:1 WR Ratio. Some have also moved away from the eight interval protocol.

“The training protocol used in experiment 2 was first introduced by Kouichi Irisawa, who was a head coach of the Japanese National Speed Skating Team. The training has been used by the major members of the Japanese Speed Skating Team for several years.” (Tabata e al., 1996).

Although Irisawa developed the training method, it was Tabata’s paper and his name that became inexorably linked with this form of interval training. The Tabata method of interval training is also known as the Tabata Protocol and, occasionally, the Koichi Protocol. Tabata lent his name to a protocol that helped to promote the interval training movement to the general populace. Prior to the 1990s, interval training had generally been the preserve of elite athletes.

Horst (2008, p.94) suggests that the Tabata method differs from traditional interval training in three ways:

- First, the twenty-second work interval is much shorter than traditional intervals.
- The second difference, then, is that this shorter work interval must be performed with 100 percent exertion; and
- Third, the rest interval is just ten seconds, which is so brief that very little recovery can occur before the next work interval begins.”

Peter Coe, the father and coach of the famous British runner Sebastian Coe, used an early model in the 1970s (Coe, 2013, p.38-39).

In summary, the ‘original’ Tabata method of training is twenty seconds of high-intensity exercise followed by ten seconds of rest (a 2:1 work-to-rest ratio). This interval is repeated eight times to create four minutes of the most gruelling training you can imagine. There are now a number of permutations.

3.5 High-Intensity Interval Training

“High intensity interval training (HIIT) involves repeatedly exercising at a high intensity for 30 seconds to several minutes, separated by 1-5 minutes of recovery (either no or low intensity exercise).” (Gibala & McGee, 2008, p.58).

“HIIT generally involves alternating bouts of higher-intensity exercise (20 seconds to 5 minutes) sessions with either true rest or light- to low-intensity recovery workloads throughout an exercise routine and has traditionally been used to train athletes who require high levels of both aerobic and anaerobic fitness (e.g., track, team sport athletes).” (Porcari, Bryant & Comana, 2015, p.92).
Individuals work at 90% or more work rate (high-intensity) for a set time, followed by recovery (low-intensity) for a set time. The WR Ratio is usually unequal, with the work rate lasting seconds or minutes. This is repeated approximately 2-6 times, with sessions lasting between 10 and 30 minutes – although the exact structure is sport- and person-specific.

Rest periods are intended to be too short to provide complete recovery, and completing subsequent intervals in a partially recovered state is a key part of what makes these efforts effective.

HIIT training, also sometimes known as High-intensity Intermittent Exercise (HIIE), attempts to decrease the overall volume of training by increasing the effort expended during the high-intensity intervals – which are brief but challenging.

Alternative names and variations of HIIT include:

- Power Interval Training (PIT; or Power Intervals).
- Sprint Interval Training (SIT; or Short Sprint Interval Training):
  - Functional Threshold Power (FTP) Intervals, which explicitly considers lactate threshold (LT), and (All Out) Miracle Intervals. Both are typically used in cycling.
  - A commonly studied SIT model is repeated Wingate Tests.
  - “Training adaptations are highly specific to the type of activity and to the volume and intensity of the exercise performed. […] Similarly, the marathon runner would not concentrate on sprint-type interval training.” (Kenney, Wilmore & Costill, 2012, p.212-213).

- VO2Max Intervals.
- Steady State Intervals.
- Short Work-to-Rest Ratio Intervals, performed in series.
- HIIT Aqua (also known as Aqua HIIT, HIIT Splash or Water-based HIIT). HIIT training in the water generates cardiovascular and metabolic benefits without high impact, and with additional benefits facilitated by the properties of water:
  - The pressure and resistive forces of water (hydrostatic pressure) aids venous return (blood flow back to the heart), which results in an increase in stroke volume.
  - This effect decreases heart rate even though the exercise intensity is at a peak level.
  - This decrease in heart rate and rapid recovery time makes water-based HIIT suitable for a range of participants.

HIIT, and its variants, is not for new or beginning exercisers; you need to have a basic level of cardiorespiratory fitness first.

The most common HIIT intervention used in studies is the Wingate Anaerobic Test developed in the 1970s (Bar-Or, Dotan & Inbar, 1977).

### 3.6 The Wingate Anaerobic Test

Developed in the 1970s in Israel (Bar-Or, Dotan & Inbar, 1977), the Wingate Anaerobic Test (WAnT), also known as the Wingate Test and Wingate Protocol, measures (Bar-Or, 1987; Cooper et al., 2004):

- Lower-body peak power;
- Anaerobic capacity; and
- The reduction of power, known as fatigue index (FD).
The WAnT, usually on a cycle ergometer, is conducted as follows:

- It is a 30-second all-out exhaustive (at an intensity of over 90% of maximal oxygen uptake, also known as 90% of VO2 max) ergometry test where the athlete pedals against a resistance that is set at a certain percentage of their body weight.
- The power output is measured throughout the test by the number of revolutions the athlete can achieve on the ergometer during those 30 seconds.
- The peak power recorded is the maximal power output achieved for 5 seconds of the test, usually the first 5 seconds.
- The anaerobic capacity, or average power, is recorded and averaged over the entire 30 seconds of the test.
- The lowest power output is an average of the lowest 5 seconds seen during the test, usually the last 5 seconds.
- Finally, the difference in power output from highest to lowest is recorded as the FI.

Each 30 seconds of cycling at maximum effort is separated by 4 minutes of recovery, repeated 4-6 times per session, with three sessions per week (Bar-Or, Dotan & Inbar, 1977; Boutcher, 2011). This results in only 2-3 minutes of exercise at maximum intensity and 15-25 minutes of low intensity exercise per session, making it a time efficient method of exercise. The ability to evaluate these measurements makes the WAnT a valuable test for coaches, athletes, and research scientists.

Two major energy sources are required during the WAnT (Wilmore & Costil, 2004):

- The first is the adenosine triphosphate-phosphocreatine (ATP-PCr) system, which lasts for 3 to 15 seconds during maximum effort.
- The second system is anaerobic glycolysis, which can be sustained for the remainder of the all-out effort.

Thus, the WAnT measures the muscles’ ability to work using both the ATP-PCr and glycolytic systems. Many sports (including football, sprinting, football, baseball, lacrosse and gymnastics) use anaerobic metabolism extensively during competition.

Less demanding protocols may be utilised for sedentary, overweight populations, which is important to remember when considering exercise as prevention and management of cardiovascular and metabolic disease.

**3.7 The Timmons Method**

In 2012, Doctor Michael Mosley undertook a form of interval training, that came to be known as the Timmons Regime, as part of a BBC documentary ‘Horizon: The Truth About Exercise’ (Mosley, 2012).

Jamie Timmons, professor of ageing biology at the University of Birmingham, is a proponent of a few short bursts of flat-out intensity. Mosley (2012) describes Timmons method:

“It’s actually very simple. You get on an exercise bike, warm up by doing gentle cycling for a couple of minutes, then go flat out for 20 seconds. A couple of minutes to catch your breath, then another 20 seconds at full throttle. Another couple of minutes gentle cycling, then a final 20 seconds going hell for leather. And that’s it.”
Mosley repeated this routine over four weeks, “making a grand total of 12 minutes of intense exercise and 36 minutes of gentle pedalling.” Mosley also completed pre- and post-regime testing for:

- Insulin sensitivity, which improved by 24%; and
- Aerobic fitness, which did not improve at all – it was revealed that Mosley was a ‘non-responder’.

“There was a possibility that I wouldn't improve. Not because HIT [high intensity training] doesn't work but because I've inherited the wrong genes.” (Mosley, 2012).

In research conducted as part of the HERITAGE Family Study [LINK: http://www.pbrc.edu/heritage/index.html], results suggest that individuals will respond to exercise in very different ways, with some of this difference due to their genes. In one international study (see link) 1,000 people were asked to exercise four hours a week for 20 weeks. Their aerobic fitness was measured before and after starting this regime and the results were striking. Although 15% of people made huge strides (known as super-responders), 20% showed no real improvement at all (known as non-responders). There is no suggestion that the non-responders were not exercising properly, it was simply that the exercise they were doing was not making them any aerobically fitter.

3.8 The Copenhagen Method

Another more recent interval training method follows the research of Gunnarsson and Bangsbo published in 2012, called the 10-20-30 Training Concept, more commonly known as the Copenhagen method (Gunnarsson & Bangsbo, 2012).

In this study, 18 moderately trained runners (6 females and 12 males) were divided into a high-intensity training (10-20-30) group and a control group to compare the effects of both methods on the health profile, muscular adaptations, VO2max, and running performance of the study participants.

While the control group continued their normal training methods during the seven-week study, the 10-20-30 group implemented a format of 30 seconds of low-intensity running at less than 30% of maximal intensity, 20 seconds of moderate-intensity running at less than 60% of maximal intensity, and 10 seconds of high-intensity running at more than 90% of maximal intensity (i.e., a 60-second exercise interval). This interval was repeated five times (i.e., 5 minutes of continuous exercise) before taking a 2 minute recovery, and the entire circuit was repeated three to four times.

At the conclusion of the study, VO2max in the 10-20-30 group was 4% higher, and performance in a 1,500 metre and a 5 km run improved by 21 and 48 seconds, respectively. Furthermore, in the 10-20-30 group, systolic blood pressure was lower by 5 mm Hg, and total and LDL cholesterol were lower by 0.5 and 0.4 mmol/L, (19.3 and 15.5 mg/dL) respectively, in comparison with the control group.

The results demonstrated that this method of training, with short, near-maximal bouts (e.g., 10 seconds), can improve health, fitness, and performance despite large reductions in training volume. This format of training with slightly longer recovery intervals is generally better suited for most individuals contemplating HIIT.
3.9 The Paarlauf Method

The Paarlauf method, or Paarlauf training, is a competitive form of interval training and is not a very commonly used form of running. Paarlauf means ‘pair run’, and it is a competitive relay for two or more people.

The relay comprises at least two teams of two runners, with one team member running whilst the other(s) rests, and can be used as a team version of a fartlek session. Formal areas to run the session include athletics tracks and informal can be areas marked out in outdoors/green spaces (i.e. a parks).

Although the exact structure differs, the distance of the race is (usually) unspecified with only a minimum and maximum time being given (so the runners can determine their pace), thus a race could last from 10 to 45 minutes. Number of laps can be used instead of a time.

After a certain time has elapsed - this time is decided prior to the race but unknown to the runners - the referee blows a whistle and the competitors ‘rest’ for a period of one minute. The winning team is the one who has carried the baton the furthest.

The two runners can decide how they wish to share the running. For example, they can either run interval quarter miles or every other furlong, jogging across the track to regain the baton.

As a training workout, the number of runners can be increased to a team of 4, 6 or 8. With 8 runners, they could spread out over 400 metres and move with the baton from 60-100 metres with about 55 seconds rest before the next effort.

3.10 Interval-Circuit Training


The circuit may be 3,000 to 10,000 metres in length, with stations every 400 to 1,600 metres (437-1,750 yards). The individual jogs, runs, or sprints the distance between stations; stops at each station to perform a strength, flexibility, or muscular endurance exercise in a manner similar to that in actual circuit training; and continues on, jogging, running, or sprinting to the next station. Trim Trails are very similar.

These courses are typically located in parks or in the country where there are many trees and hills. Such a training regimen can benefit almost any type of individual and provide diversity to what might be an otherwise monotonous training regimen.

3.11 Interval Training Variations

Manipulation of the interval training principles (Section 2.4) provides the opportunity for a wide variety of interval training sessions. Outlined below are some of the more commonly used variations:

- **Individual Interval Training Options:**
  - **Repeats (see Section 3.11.1):** The same distance, done a set number of times. Repeats of 400 metres, one lap of the track, are the most common, but distance
runners may do repeat 1,000s or miles to improve their stamina. Repeats can also be run at anticipated race speed to develop a sense of pace and avoid going out too hard.

- **Ladders (see Section 3.11.2):** Progress from shorter to longer repetitions; i.e. 200, 400, 600, 800, 1000. Recovery interval can be constant or increase. Ladders can also be run long to short.
- **Pyramids (see Section 3.11.3):** An up and down ladder together, i.e. 400, 600, 800, 600, 400. Advanced runners may be able to do multiple pyramids.
- **Cut-downs (see Section 3.11.4):** Designed to improve one’s finishing kick. Several longer repeats are done to create fatigue, then the runner performs shorter, faster reps to develop the ability to run hard when tired.
- **‘Ins-and-Outs’:** Usually done over a mile or longer, accelerate the straightaways and jog the turns, or sprint 50 metres, jog 60.

**Group Interval Training Options:**

- **Indian Runs:** As everyone runs in single file, the last person in line sprints to the front. When he gets there, the next person goes, and so on.
- **Relay Races:** Pick teams, then pick a lane, then pick a workout. Try six times 400 metres with two-person teams, the last place team buys refreshments.
- **Handicapping:** ‘The last shall be first and the first shall be last.’ Runners stagger their start of each repetition by ability level, from slowest to fastest. The faster runners try to catch the slower ones.

### 3.11.1 Aerobic Power Repeats

An aerobic power repeat workout is exactly what it sounds like: You run several periods of the same distance, with a rest interval between each work period. Here are three ways to do aerobic power repeats:

- Run 800 metres (1/2 mile) at VO2max pace four to six times, with a 1:≤1 WR Ratio [work-to-rest ratio].
- Run 1,000 metres (5/8 mile) at VO2max pace three to five times, with a 1:≤1 WR Ratio.
- Run 1,200 metres (3/4 mile) at VO2max pace three to four times, with a 1:≤1 WR Ratio.

As a practical example, imagine you run 5 km in 21:42, an average pace of 7 minutes per mile. Your VO2max pace is approximately 6:42 to 6:47 per mile, and the three above workouts would look like:

- Run 800 metres (1/2 mile) in 3:17 to 3:20, four to six times, with 2 ½ to 3 minutes recovery between repetitions.
- Run 1,000 metres (5/8 mile) in 4:07 to 4:10, three to five times, with 3 to 3 ½ minutes recovery between repetitions.
- Run 1,200 metres (3/4 mile) in 4:56 to 5:00, three to four times, with 4 to 4 ½ minutes recovery between repetitions.

If you cannot complete the 1,200 metres in 5 minutes or less when running at VO2max pace, then complete the 1,000 metre or 800 metre repeats instead.
3.11.2 Aerobic Power Ladders

An aerobic power ladder workout mixes the distance (or time) you run in a single workout by increasing the distance (or time) of the work period, like climbing a ladder. To perform this type of workout, run two sets of 800, 1,000 and 1,200 metres at VO2max pace with a 1:≤1 WR Ratio.

As a practical example, imagine you run 10 km in 47:05, an average pace of 7:35 per mile. Your VO2max pace is approximately 7:00 to 7:05 per mile, and the distance workout would look like:

- Run 800, 1,000 and 1,200 metres in 3:30-3:32, 4:22-4:25 and 5:15-5:18 respectively, with 3 to 4 minutes recovery between each repetition.

Based on time, the workout would look like:

- Two sets of 3, 3½ and 4 minutes at VO2max pace, with 3 minutes recovery between repetitions.
- Two sets of 3, 4 and 5 minutes at VO2max pace, with 3 to 4 minutes recovery between repetitions.

3.11.3 Aerobic Power Pyramids

An aerobic power pyramid workout mixes the distances (or time) you run in single workout, first by increasing and then decreasing the distance (or time) of the work period. To perform this type of workout, run 800, 1,000, 1,200, 1,000 and 800 metres at VO2max pace with a 1:≤1 WR Ratio.

As a practical example, imagine you run 5 km in 22:20, an average pace of 7:12 per mile. Your VO2max pace is approximately 6:54 to 6:59 per mile, and the distance workout would look like:

- Run one to two sets of 800, 1,000, 1,200, 1,000 and 800 metres in 3:27-3:29, 4:18-4:21, 5:10-5:14, 4:18-4:21 and 3:27-3:29 respectively, with 3 to 4 minutes recovery between each repetition.

Based on time, the workout would look like:

- 3, 3½, 4, 3½ and 3 minutes at VO2max pace, with a 1:≤1 WR Ratio.
- 3, 4, 5, 4 and 3 minutes at VO2max pace, with a 1:≤1 WR Ratio.

3.11.4 Aerobic Power Cut-downs

An aerobic power cut-down workout mixes the distances (or time) you run in a single workout by decreasing the distance (or time) of the work period. You start off a bit slower than VO2max pace and finish a bit faster than VO2max pace. To perform this type of workout, run one to two sets of 1,600, 1,200, 1,000, 800 and 400 metres, varying your speed throughout. You run at slightly slower than VO2max pace (about 5 km race pace) for the 1,600; VO2max pace for the 1,200, 1,000 and 800; and slightly faster than VO2max pace for the 400, all with a 1:≤1 WR Ratio.

As a practical example, imagine you run 5 km in 20:20, an average pace of 6:33 per mile. Your VO2max pace is approximately 6:17 to 6:22 per mile, and the distance workout would look like:
What is Interval Training?

Run one to two sets of 1,600, 1,200, 1,000, 800 and 400 metres in 6:33, 4:42-4:46, 3:55-3:58, 3:08-3:11 and 1:31-1:33 respectively, with 3 to 4 minutes recovery between each repetition.

Based on time, the workout would look like:

Run one to two sets of 6, 5, 4, 3, and 2 minutes at slightly slower than VO2max pace (about 5k race pace) for the 6 minute work period, VO2max pace for the 5, 4 and 3 minute work periods, and slightly faster than VO2max pace for the 2 minute work period, all with 3 to 4 minutes recovery between each repetition.

3.12 Who Uses Interval Training?

“While interval training is traditionally associated with track, cross country, and swimming, it is appropriate for all sports and activities.” (Kenney, Wilmore & Costill, 2012, p.220).

Kenney, Wilmore and Costill (2012, p.221) informs us that “One can adapt interval training procedures for each sport or event by first selecting the form or mode of training and then manipulating the following primary variables [Section 2.4] to fit the sport and athlete...”

Seiler and Seiler (2008, p.33) state “Interval training is a common practice among sprint runners, basketball players, hockey players and all other athletes that train their bodies to provide short periods of intense power and speed.” They also state that interval training is useful for practitioners of martial arts (Seiler & Seiler, 2008).

Horst (2008, p.94) informs that “The Tabata Protocol is a highly specific method of interval training that is popular among elite speed skaters, cyclists, middle-distance runners, and swimmers; but serious climbers can benefit from this training strategy too.”

In summary, with an understanding of interval training, almost any coach and athlete can utilise interval training within their training programme provided that the training variables fit the sport and athlete.

3.13 Interval Training in the Military

Fitness is paramount to being successful in the military, especially the army. Recruits are expected to be able to excel in all physical tests and meet the physical demands of being a soldier.

The key to this success is a training regimen aimed at (amongst other components of fitness) increasing cardiovascular capacity, both aerobic and anaerobic. As such interval training in the military environment is designed to provide exercise to groups of soldiers at intensities which suit each individual’s fitness level.

Interval training can promote fitness in a broad range of areas, including aerobic capacity, anaerobic capacity and speed. It can also aid in delaying the onset of mental and physical fatigue, an important element on the battlefield.

In addition, interval training can be organised to exercise a number of fitness components in a short period of time. A little imagination can make interval training an excellent addition to a unit’s total physical fitness programme.
The British Army has been using interval training since at least the 1980s. From 1990, as a recruit and then trained soldier, I participated in interval training and, as a military fitness instructor, I designed and delivered interval training.

At the end of the 1960s, an American group of researchers focused on interval training in a military context (Fox et al., 1966; Mathews et al., 1967). The purpose of their study was to determine which of the following three interval training programmes produced the greatest cardiorespiratory fitness:

- A programme consisting entirely of short, repetitive running;
- A programme consisting entirely of long but less repetitive running; and/or
- A programme consisting equally of short- and long-distance running.

In the first of two papers, Fox and colleagues (1966) found that:

- Short repetitive running was necessary for maximum improvement of cardiorespiratory endurance;
- Long less frequently repeated running was less necessary than was short distance running for improvement of cardiorespiratory endurance; and
- Both types of running, however, are probably necessary physiologically and for proper leg conditioning, reduction of leg injuries and for variety and motivational purposes.

In the second of two papers, Mathews and colleagues (1967) found that:

- Cardiorespiratory endurance was increased significantly by a 7 week interval training programme;
- A training frequency of 4 days per week compared with 2 per week produces greater improvement only in submaximal exercise and recovery heart rates; and
- Maximal oxygen consumption is improved by the same magnitude by a 7-week interval training programme with 2 workouts per week as it is with 4 and 5 workouts per week.

Since the 1960s, interval training has evolved as a training methodology within the military, just as other aspects of the military have evolved in recognition of a modern and 360 degree battlespace.

High-intensity functional training (HIFT) programmes, known by some as extreme conditioning programmes (Poston et al., 2016), are designed to address multiple fitness domains and have become very popular, especially in the US. CrossFit, SEALFIT and the US Marine Corps’ High Intensity Tactical Training (HITT) are well-known versions (Haddock et al., 2016). Poston et al. (2016, p.627) describe modern military interval training:

“High-intensity functional training (HIFT) is a promising fitness paradigm that has gained popularity among military populations. HIFT programs emphasize varied functional movements (i.e., movements requiring universal motor-recruitment patterns in multiple movement planes such as lifting, pulling, and throwing) done at relatively high intensity. Rather than biasing workouts toward maximizing a specific fitness domain (e.g., running programs for aerobic endurance), HIFT workouts are designed to promote general physical preparedness. This is particularly important for military populations who need to have superior physical conditioning to respond to occupational and warfare-specific tasks.”

HIFT programmes stress both aerobic and anaerobic energy pathways and are balanced in addressing power, strength, flexibility, speed, endurance, agility, and coordination (USMC, 2006; Roy et al., 2010; Haddock, Poston & Jahnke, 2011).
The USMC HITT programme was first visualised under the ‘Concept for Functional Fitness’ in 2006. It is endorsed by the National Strength and Conditioning Association’s (NSCA) Tactical Strength and Conditioning (TASC) Department, and is available online and via a mobile application (USMC, 2014). Train the Trainer courses are delivered by certified Strength and Conditioning Specialists and Combat Fitness Specialists. Each HIIT session provide an active dynamic warm up; core stability and flexibility; speed, agility and endurance; and strength and power.

The USMC also offers an aquatic version of the HITT programme known as Aquatics Maximum Power Intensity Training (AMP-IT). It is designed as a high intensity fitness class that will increase muscle endurance, improve cardiovascular-respiratory function and aid in injury rehabilitation.

Although Haddock and colleagues (2016) recommend HIFT programmes becoming the standard for military physical training, they observed that no large scale randomised trials comparing traditional military physical training with HIFT programmes on both health and injury outcomes had been conducted. The same researchers had announced earlier in the year they would be undertaking such a study (Poston et al., 2016).

Ultimately, military personnel (especially Infantry) require competence in multiple fitness domains, being able to undertake both aerobic and anaerobic activities over short-, mid- and long-distances often carrying heavy rucksacks (20-100 lbs). Long distances may include patrolling (from 5 to 50 km) carrying equipment and then being involved in a fire-fight moving from cover to cover over short distances (1-400 m), whereas mid-distances (400 to 5000 m) may involve a unit moving across town to reinforce another unit in a fire-fight with superior opponents.

PART FOUR: ADVANTAGES AND DISADVANTAGES

4.0 Introduction

“The debate concerning high- versus low-intensity exercise continues, and although a significant amount of more recent research has focused on the aerobic benefits of high-intensity interval training (HIIT), experts cannot reach any single conclusion regarding its efficacy, because it all depends on the perspective from which they approach the argument.” (Porcari, Bryan & Comana, 2015, p.388).

In the third edition of their book, McArdle and Colleagues (2006, p.457) informed us that “Available evidence does not support superiority for either continuous or intermittent training to improve aerobic fitness. Both methods probably can be applied interchangeably.” This view is repeated in the fourth edition of their book (Katch, McArdle & Katch, 2011, p.435) “No one method has proved superior for either continuous or interval training to improve aerobic fitness. Both methods probably can be applied interchangeably.”

However, Katch and colleagues (2011, 435) do go on to state “Importantly, continuous LSD training gives the endurance athlete a more “task-specific” cardiovascular and metabolic overload that more closely mimics the duration and intensity of race conditions. Likewise, sprint and middle-distance athletes benefit from the intense metabolic demands and specific neuromuscular and fiber-type activation that interval training provides.”
In 1985, Robinson and colleagues suggested that ten days of either HIIT or MICT could improve cardiorespiratory fitness and glucose control and lead to reductions in TLR2 and TLR4 expression (markers of inflammation) in previously inactive, overweight/obese adults at elevated risk of developing type 2 diabetes. Robinson et al. (1985) also stated that MICT, which involved a longer duration of exercise, may be superior for reducing fasting glucose. In a study by Martins et al. (2016) involving 46 sedentary obese individuals (30 women) undertaking 12 weeks of isocaloric (having the same or a similar calorific value) programmes of HIIT, MICT or a short-duration HITT, their results indicated that the isocaloric training protocols exerted similar metabolic and cardiovascular improvements in sedentary obese individuals (no significant differences were observed between groups).

Thompson (2010) states “It is now recognised that a longer lasting fitness can be achieved if the original interval training is combined with sufficient aerobic endurance development to stabilise the improved cardio-respiratory response.”

Although there is now a larger body of research comparing HIIT with MICT, the methodology employed by researchers varies. For example, bikes versus running, varying duration of training, exercise intensities, exercise intervals and recovery intervals, and so on. This makes it somewhat problematic to accurately compare these studies. By the late 2010s, researchers are still reporting that none of the observed changes significantly differ between the training groups (Eskelinen et al., 2016; Heiskanen et al., 2016).

Kenney, Willmore and Costill (20012, p.337) outline the differences between high-intensity, low volume training and low-intensity, high volume training, stating:

“High-intensity, low-volume training can be tolerated only for brief periods. While this type of training does increase muscular strength in resistance training and total body speed and anaerobic capacity in high-intensity interval training, it provides little or no improvement in aerobic capacity. Conversely, low-intensity, high-volume training stresses the oxygen transport and oxidative metabolic systems, causing greater gains in aerobic capacity, but has little or no effect on muscular strength, anaerobic capacity, or total body speed.”

As well as training being person- and sport-specific, one must also note that a programme of regular exercise should include four elements (Garber et al., 2011):

- Cardiorespiratory training (think aerobic and anaerobic, and power and endurance);
- Resistance training (generally for strength);
- Flexibility training; and
- Neuromotor exercise training (i.e. functional training).

Porcari, Bryant and Comana (2015, p.391) also suggest “It may be particularly important to include multiple modalities of exercise (e.g., walking, cycling, and elliptical training) and even variations within a modality (e.g., steady-state exercise, interval training, and Fartlek training) to limit the risk for boredom, burnout or orthopedic injury from overuse as the volume of exercise builds.”

Keeping this in mind, this section of the article provides some of the perceived/actual advantages and disadvantages of interval training.
4.1 Advantages of Interval Training

Research suggests that interval training has a variety of benefits or advantages, and across multiple populations from athletes to the elderly. The following is a list of some of the perceived/actual advantages of interval training:

- Individuals of mixed ability groups can work at the same time;
- Generally, small numbers work at the same time;
- Can be adapted for most sports; and
- Can help to improve:
  - Cardiorespiratory fitness (aerobic and anaerobic).  
  - Mental determination; and
  - Resistance to fatigue.
- Interval training is a time-efficient way of obtaining the health benefits of exercise. It usually takes less time than a comparable MICT session.
- “The advantage of the original interval training was that it brought about very rapid and significant improvements in performance.” (Thompson, 2010).
- “Certainly, some research demonstrates how HIIT increases levels of free fatty acids (FFA) in the blood because of greater levels of circulating epinephrine, which is supposed to drive greater aerobic metabolism in the cells.” (Porcari, Bryan & Comana, 2015, p.388).
- Research also suggests that high-intensity interval running is perceived to be more enjoyable than moderate-intensity continuous exercise (Bartlett et al., 2011). Despite a higher intensity and peak cardiorespiratory strain, participants generally prefer interval training versus moderate exercise (Astorino & Thum, 2016).
- “Research has revealed that HIIT results in similar improvements in VO2max and mitochondrial density as bouts of lower-intensity exercise (LIE), but which form of exercise is more appropriate for a sprint athlete versus the overweight business executive simply seeking to improve health?” (Porcari, Bryan & Comana, 2015, p.388).
- The shorter the distance of the run, the faster you can run the total distance of the workout.
- One of the attractions of interval training is its measured, precise nature. Workouts can be tailored to an individual’s current ability level; similarly, they provide an accurate benchmark of one’s fitness, allowing achievable personal/competitive goals to be set.
- Interval training’s repeatability facilitates comparisons to past and present performances.
- Interval training possesses an almost infinite variety. By altering different segments of the workout, it is possible to come up with a new training session each time.
- Interval training gives an individual a chance to challenge themselves. To put it bluntly, interval training is physically demanding, but there is something intriguing about that physical discomfort, about what it allows the individual to learn about themselves.
- “Part of their popularity lies with the efficiency with which they can improve cardiovascular fitness and various other physiological parameters.” (Porcari, Bryant & Comana, 2015, p.92).
- “Emerging research suggests HIIT may be a time-efficient strategy for improving the health of all populations if properly supervised.” (Porcari, Bryant & Comana, 2015, p.92).
- “High intensity deep water training can improve aerobic power in elderly women.” (Quintana et al., 2006, p.117).
- “[High-intensity] Deep water running with wet vest is a safe form of exercise for elderly with mobility limitations.” (Quintana et al., 2006, p.117).
- “In conclusion, high intensity deep water running with vest improves submaximal work capacity, maximal aerobic power, and maximal ventilation with the effects transferable to land-based activities in elderly women.” (Quintana et al., 2006, p.123).
“A series of recent studies from McMaster University in Hamilton, Ontario (Canada), has clearly demonstrated that very high intensity, low-volume interval training can markedly increase aerobic capacity. Substantial increases in muscle oxidative capacity and endurance performance have been obtained in a training period as short as two weeks [Gibala & McGee, 2008]. These studies tend to seriously question the concept of specificity of training as discussed in chapter 11.” (Kenney, Wilmore & Costill, 2012, p.510).

“The “fat burning zone” at low intensities of exercise does NOT exist. The best approach is to think of energy expenditure as “a calorie is a calorie is a calorie,” rather than partitioning into carbohydrate and fat calories. To burn maximum calories in support of ongoing fat/weight loss, progress to a moderate-to-vigorous intensity/higher-volume exercise program and include interval training.” (Porcari, Bryant & Comana, 2015, p.111).

“Although there are not a lot of well-controlled studies, it appears that interval training with relatively brief (30-second) high-intensity elements is just as effective in terms of producing gains in anaerobic capacity as longer high-intensity bursts (where phosphagen depletion and lactate accumulation might be larger, and thus be expected to be more provocative of change).” (Porcari, Bryant & Comana, 2015, p.405).

Despite a higher intensity and peak cardiorespiratory strain, research suggests that participants prefer interval training versus moderate exercise.

In a group of nine adults with spinal cord injury (duration = 6.8 ± 6.2 year), peak oxygen uptake and heart rate were higher (p < 0.05) with HIIT (90% peak oxygen uptake and 99% peak heart rate) and sprint interval training (80% peak oxygen uptake and 96% peak heart rate) versus moderate intensity exercise (Astorino & Thum, 2016).

In a study of thirty-nine inactive, overweight/obese adults (32 women), biomarkers of cardiovascular risk and endothelial function were unchanged. However, HIIT and moderate intensity continuous training (MICT) produced different vascular adaptations in obese adults, with HIIT improving brachial artery flow-mediated dilation (FMD) and MICT increasing resting artery diameter and enhancing low flow-mediated constriction (L-FMC). HIIT required 27.5% less total exercise time and ∼25% less energy expenditure than MICT. (Sawyer et al., 1985).

Karlsen and colleagues (2017) argue that a growing body of evidence suggests that higher exercise intensities may be superior to moderate intensity for maximising health outcomes. In their review, Karlsen et al. (2017) discuss how aerobic high-intensity interval training (HIIT), in comparison to moderate continuous training, may maximise outcomes. They also provide practical advice for successful clinical and home-based HIIT.

4.2 Disadvantages of Interval Training

Research suggests that interval training has a variety of negatives or disadvantages. The following is a list of some of the perceived/actual disadvantages of interval training:

- Can get boring (e.g. if continually using the same session).
- Although interval training develops stamina, it can fail to condition the mind to racing hard over a continuous/prolonged racing period.
- “The disadvantages were that it could be incredibly monotonous and the rapid improvements in fitness were matched by an almost as quick loss of fitness on cessation of training.” (Thompson, 2010).
- According to Eskelinen and colleagues (2016), HIIT and MICT induce similar metabolic and functional changes in the heart, although myocardial vascular hyperaemic reactivity is impaired after HIIT. They further suggest this should be taken into account when prescribing very intense HIIT for previously untrained subjects.
Reactive hyperaemia or post-ischemic reactive hyperaemia is the increased blood flow to an organ or a tissue following a temporary blockage of an artery. The affected tissue can cause hyperaemia in one of two ways:

- Through a response with release of vasodilatory substances such as adenosine, carbon dioxide, adenosine phosphate compounds, histamine, potassium ions and hydrogen ions.
- Hyperaemia could be caused by a lack of oxygen which could affect opening of more pre-capillary sphincters in the affected tissue, thereby increasing blood flow.

“But research also demonstrates that the increased levels of blood lactate that follow HIIT begin to inhibit hormone-sensitive lipase activity, the enzyme responsible for mobilising fats. Furthermore, increased lactate levels act as a precursor for glycerol 3-phosphate, promoting the re-esterification of those FFAs into triglycerides within adipocytes (fat cells) if the FFAs are not taken into the muscle cells, but instead remain in the blood.” (Porcari, Bryan & Comana, 2015, p.388).

“The influx of this form of training with the mainstream and even special populations groups is raising concerns regarding overall safety and appropriateness.” (Porcari, Bryan & Comana, 2015, p.92).

“So, yes, intervals worked. But there was a catch. Runners often improved their times dramatically for a few weeks or months, but then tore Achilles tendons, or [p.90] one weird day woke up with bones that seemed to have aged forty years in the night and devastated by the conviction that running was infantile and meaningless. Such runners had gone (and the word is too feeble) stale.” (Moore, 2006, p.89-90).

“Runners who overdose on intervals can often need months before their systems are once more able to handle the lactic acid stress of repeatedly going in and out of oxygen debt. Then, six weeks later, they can be devastated all over again.” (Moore, 2006, p.89-90).

If the training overload is too much or improperly applied, for example the pace of the exercise intervals is too great, then maladaptation may occur. The first step toward maladaptation may be overreaching, a short-term decrease in performance capacity that is easily recovered from and generally lasts from a few days to two weeks. Overreaching may result from planned shock micro-cycles, as described in periodisation [LINK], or result inadvertently from too much stress and too little planned recovery (Fry et al., 1991; Fry & Kraemer, 1997; Kuipers, 1998).

### 4.3 Points to Consider When Planning an Interval Session

“It is now recognised that a longer lasting fitness can be achieved if the original interval training is combined with sufficient aerobic endurance development to stabilise the improved cardio-respiratory response.” (Thompson, 2010).

There are a number of practical points to consider when planning an interval training session (not an exhaustive list):

- Determine Objectives:
  - The designer must consider specific parts of the body and the components of fitness on which soldiers/participants need to concentrate.
  - How does this interval session fit with the mission objectives of the soldiers or training programme for participants/athletes?

- Select the Activities:
  - The interval designer should list all the exercises or activities that can help meet the objectives.
4.4 Points to Consider When Conducting an Interval Session

There are a number of practical points to consider when conducting an interval training session (not an exhaustive list and delete as applicable):

- The route is clearly marked and easy to follow (if not using a running track/swimming pool) or the exercises are easy to follow if gym-based.
- If gym-based, the exercises are laid out in the correct order.
- Avoid exercises that demand (too much) skill, especially in HIIT, as this will slow down the pace.
- Teach exercises to participants on the first visit.
- Gain benchmark indicators on first visit (e.g. heart rate).
- Ensure participants have a ‘good’ baseline fitness (e.g. through PAR-Q [LINK]).

4.5 Points to Consider After Interval Training

Once the interval training session has been completed the following points should be considered (not an exhaustive list):

- Record times/distances for each participant.
- Adjust each participant’s standards and targets as necessary (e.g. exercise intervals, recovery intervals, repetitions and sets).
- Discuss the effect of DOMS [LINK] and other running related injuries (especially applicable for untrained participants).

4.6 Safety Factors

“The influx of this form of training with the mainstream and even special populations groups is raising concerns regarding overall safety and appropriateness.” (Porcari, Bryant & Comana, 2015, p.92).
While injury is always possible in any vigorous physical activity, few interval workouts are really unsafe or dangerous. The keys to avoiding injury while gaining training benefits are using correct form, intensity and progression.

Further, participants with low fitness levels, such as trainee soldiers or new clients, should not do the higher-intensity forms of interval training highly fit soldiers/athletes can do. For example, it may be advisable for participants new to interval training to undertake a modified version first (e.g. low volume, moderate-intensity interval training) progressing to low volume, high-intensity and, perhaps later on, then to moderate-high volume, high intensity interval training.

It is not sensible to have recruits/new clients do multiple sets of exercise interval repetitions because they probably are not conditioned for them. On the other hand, a conditioned Royal Marine Commando company or elite athletes may use multiple sets of repetitions with good results.

The risk of injury to untrained participants will be increased due to their unconditioned status. For example, lower limb injuries due to the stress of fast running.

The key to doing gym-based interval training exercises safely is to use common sense (and interval training in general). Also, ballistic (that is, quick-moving) exercises that combine rotation and bending of the spine increase the risk of back injury and should be avoided, especially in HIIT workouts where form may deteriorate due to the pace of the workout. This is especially true if someone has had a previous injury to the back. If this type of action is performed, slow stretching exercises, not conditioning drills should be used.

HIIT-type workouts are beneficial when the participant is fit and conducts these workouts in a regular, progressive manner. However, a certain level of fitness is needed to do them safely. Therefore, participants should train progressively to build up to these workouts. Using such workouts for unconditioned participants increases the risk of injury and accident.

When a participant fails to maintain proper form/speed during interval training, they should slow down to regain proper form. Typically, inexperienced participants will perform the first one or two repetitions too quickly. When this happens, it causes form to break down and affects the ability to maintain speed for the specified number of repetitions. Participants should be instructed to pay attention to their speed in order to maintain precision.

Particular areas for concern include:

- **Progression**: This is the systematic increase in the intensity or duration of exercise activities. Proper progression allows the body to positively adapt to the stresses of training. When intensity or duration is increased too rapidly, the participant cannot adapt to the demands of training, and is unable to recover, leading to overtraining and possible injury. The variables should be gradually increased to produce the desired physiological effect:
  - Intensity (resistance and pace);
  - Exercise volume (number of sets and repetitions); and
  - Duration (time).

- Adhering to the scheduled intensity and duration prevents the participant from progressing too fast. How fast the participant should progress also depends on how regularly they perform challenging activities and how much rest and recovery time they get.

- **Overtraining**: This occurs when training involves excessive frequency, intensity and/or duration of training that may result in extreme fatigue, illness or injury. This may occur within a short period of time (days) or cumulatively (weeks/months) over the length of the
training cycle and beyond. Overtraining often results from a lack of adequate recovery, rest or in some cases, a lack of nutrient intake. Thus, too much training, too little recovery, and/or poor nutrient intake (i.e. fuelling) may elicit both the physical and psychological symptoms associated with overtraining syndrome.

**Overreaching**: The term ‘overreaching’ refers to the earliest phase of overtraining. Overreaching consists of extreme muscle soreness that occurs as a result of excessive training with inadequate rest/recovery between hard training sessions. This process of overreaching occurs quickly after several consecutive days of hard training. Overreaching has both positive and negative results. When planned as part of the periodised training programme, for soldiers and athletes, overreaching is a planned component of their training for peak performance. Their higher fitness levels allow for a tolerance to this more intense training with proper rest/recovery and nutrient intake. Short-term overreaching followed by an appropriate tapering period can elicit significant strength and power gains. Muscle soreness and general fatigue are normal outcomes following a series of intense workouts; however, if these outcomes are never completely resolved and performance continues to decline, these may be the first indicators of overtraining syndrome. Coaches/trainers need to be able to recognise these symptoms, especially in the early stages of a training programme and need to adjust training and recovery for these participants.

**Continued overreaching** will lead to overtraining and elicit negative results. In many instances, participant that experience a degradation of performance (a loss of strength or speed) feel the need to train even harder. Contrary to their belief, pushing harder not only decreases the chance of improved performance, but increases the risk of injury. Recovery, rest, and proper nutrient intake will elicit more improvement than training harder. When the volume and intensity of exercise exceeds participants’ capacity to recover, they cease making progress and may even lose strength and endurance. Overtraining is a common problem in both resistance training and running activities. Improvements in strength and endurance occur only during the rest period following hard training. This process, referred to as supercompensation [LINK], takes 12 to 24 hours for the body to completely rebuild. If sufficient rest is not available, then complete recovery cannot occur. Overreaching as a training practice is not appropriate, nor is it recommended for beginners/trainee soldiers, especially for those who have low fitness levels, high foot time, and high training operational tempo. Overreaching may lead to overtraining syndrome and overuse injuries when hard training continues beyond a reasonable period of time.

**Continued overreaching** without adequate rest/recovery and nutrient intake leads to overtraining and eventually overuse injuries. The effects of overtraining syndrome may last weeks or months, inhibiting performance and possibly causing acute or chronic injuries that may limit or end training. Specific examples include rhabdomyolysis, pubic ramus stress fractures, compartment syndrome and femoral neck stress fractures.

**Multiple training sessions** per day have both positive and negative effects as they relate to performance improvement and injury control. Highly conditioned participants may respond well to an additional daily training session that challenges them differently than the one conducted earlier that same day. For example, speed training may be conducted during the morning session, with the use of endurance training machines (ETM) and agility exercises in the afternoon. Participants with lower fitness levels, such as those entering basic training or beginners, those recovering from injury, and soldiers returning from extended deployment, are better served with a second training session of lower intensity that targets specific needs for improvement, but does not lead to overtraining. Coaches/trainers should understand that “more is not better” and additional recovery time (rest) may elicit higher performance than the conduct of additional sessions.

**Punitive Sessions**: Soldiers commonly refer to these training sessions as ‘smoke sessions’ in the US and as ‘beastings’ in the UK. Many times in these types of sessions, the difficulty,
intensity, and volume of exercise is too high and the purpose may be to punish soldiers by bringing them to the point of exhaustion. This type of training is a dangerous practice that inhibits building resiliency because performance is degraded, motivation is lowered, and risk of injury is high. Thus, training sessions for the sole purpose of smoking/beasting soldiers should have no place in a formal, structured training programme. Many times, in the past, these types of sessions have produced life-threatening conditions for soldiers such as heat fatalities, debilitating overuse injuries, and rhabdomyolysis and, in some cases, even led to permanent disability or death.

PART FIVE: MISCELLANEOUS

5.0 Summary

Interval training is a form of repetition training, which in turn is a form of intermittent training – which is often contrasted with continuous training.

It was first mentioned, in written form, during the 1500s but was frowned upon for several centuries for a variety of reasons, and subsequently faded as a method of training. However, during the early 1900s interval training slowly started to re-emerge when pioneer athletes were looking for an advantage over their competitors.

It was not until the 1950s that interval training started to become widespread among athletes, and another 40 years before recreational athletes became gripped with ‘HIIT fever’.

The 1950s and 1960s witnessed the publication of scientific studies regarding the merits of interval training, and its physiological effects. However, the debate concerning high- versus low-intensity exercise continues, and although a significant amount of more recent research has focused on the aerobic benefits of HIIT, experts cannot reach any single conclusion regarding its efficacy, because it all depends on the perspective from which they approach the argument.

Research has revealed that HIIT-type workouts result in similar improvements in VO2max and mitochondrial density (amongst other physiological attributes) as bouts of lower-intensity exercise, but there is little consensus on which form of training is most appropriate for a sprint athlete versus a participant looking to improve their health (and is perhaps overweight).

Research suggests that interval training can improve both aerobic and aerobic capacity versus continuous training, which generally improves aerobic capacity. However, academic wisdom informs us that cardiorespiratory training should be one of four training methods employed as part of a wider training programme.

There are now a variety of interval training methods, and the manipulation of the training variables enables an almost infinite range of sessions – although the session should be person- and sport-specific.

Although interval training sessions are hard, some research suggests participants prefer them to continuous training sessions – perhaps due to the stop/start nature of the intervals. However, this stop/start element may make it difficult for participants to adjust psychologically to the demands
of continuous workouts, were mental fatigue may trump physical fatigue. But, of course, it depends on the outcome the participant is aiming for - general health or competition.

Within the military environment, interval training is evolving and HIFT programmes are being developed which stress both aerobic and anaerobic energy pathways and are balanced in addressing power, strength, flexibility, speed, endurance, agility, and coordination.

5.1 Useful Publications

**Books:**

**Research:**


What is Interval Training?

5.2 Useful Links

- New Interval Training website by Peter John L Thompson, a coach of British birth who has coached athletes to world record performances for over 40 years: http://www.newintervaltraining.com/index.php.
- USMC MCCS Forward: http://www.usmc-mccs.org/topics/fitness/.

5.3 References


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What is Interval Training?


What is Interval Training?

