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# SELECTED PHYSIOLOGICAL RESPONSES TO INTERVAL TRAINING IN THE ENHANCEMENT OF PHYSICAL FITNESS

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**Abstract**

*The impact of interval training programme (ITP) on people's health and sports performance have been well documented mostly as a substitute to endurance training, bringing about similar improvement of performance and health benefits. With training such as interval training, there would be constant physiological and psychological pressure among the athletes. In general, oxygen consumption increases more with high intensity form of interval training than moderate intensity interval training (MIIT) for a given training volume. During exercise, heart rate increases in proportion to the energy required for the performance of the task. As the task increases in intensity, there would be a corresponding increase in heart rate.* In addition, *maximum stroke volume increases more with high intensity type of interval training likewise there were reductions in resting BP in adults. It was therefore concluded that ITP improves cardiovascular fitness, cardiac output, blood volume, blood pressure and body composition, heart rate reserve, although,the effects of ITP on vital capacity was not well established.It was therefore encouraged that the physiological responses of vital capacity to interval training should be considered among male and female athletes. Also, the amount of air that can be inhaled or exhaled from the lung of obese and non-obese during ITP should be investigated.*

**Keywords: Interval training, Physiological responses, Cardiovascular fitness, Blood pressure, Vital capacity.**

## Introduction

Physical inactivity seems to be a major cause of ill health and death, therefore needs to be discouraged. Indeed, it ranks higher at inducing risks of tropical illness than those factors identified by (Ogunleye, 2006) as ignorance, poverty and insanitation which are linked to poor environment, poor environmental management and underdevelopment (Ogunleye, 2002). In the human society, as the young ones grow older, there is the possibility to spend more time being sedentary due to improved technological inventions at peoples' disposal and for comfortable living (Ojo, 2019). Due to this fact, there might be high incidence of obesity associated with increase in body mass index. These conditions affect the functionalities of the cardiovascular system which includes the heart. The heart is a vital organ of the body as it serves as the engine room while the lungs' major role is to transfer oxygen from the atmosphere to the bloodstream in order to reach the cells.

Interval training (IT) involves alternating between short period exercise with a rest time or an activity with less intensity as recovery.It has been reported to be a method for improving fitness (Macinnis & Gibala, 2016).With IT, physiological adaptation characteristics such as increased aerobic capacity and mitochondrial content are possible. High intensity interval training (HIIT) was reported as a strategy for improving health, building lean muscle, endurance and fat reduction. Laursen and Jenkins (2002) stated that HIIT is performed at an intensity that could prompt maximal heart rate of 80–95% while sprint interval training involves actions performed at moderate intensities and would still prompt supra-maximal efforts. More so, moderate intensity continuous training (MICT) involves relatively low intensity exercises in a continuous manner than HIIT. The interval training protocol pushes the body over the aerobic threshold for a few moments and then returns to the level of aerobic conditioning to improve performance such as speed, strength and endurance. Aerobic threshold is the intensity at which the body transits from burning a higher percentage of fat to burning a higher percentage of carbohydrates and is usually 85% of a single maximum heart.

Runner's interval training can be described as running faster than normal for a period of time, decrease and increase the pace and increase again after a certain pace. Interval training improves athletes speed and that makes trainers to include it in their cardiovascular exercises. Its effectiveness in stressing the cardiovascular system as well as for the possibility of better rounding of runners makes it a choice for coaches on their athletes. However, it is also applicable to exercise professionals as it helps to improve the aerobic capacity of exercise practitioners at different intensities for longer periods (Mayo Clinic, 2009).

Interval training can also be employed as an effective means of increasing athlete's lactate threshold. The lactate threshold has been shown to be an important factor in determining the performance of long-distance events. This training method is more effective at inducing fat loss than training for the same period at moderate intensity levels. This is due to the metabolic promotion effect of the high intensity intervals. The "Walkback Sprint" is another example of runner interval training. Sprint involves a short distance, then returning to the starting point (recovery period) and repeating the sprint a certain number of times (Gist, Fedeva, Dishman & Cureton, 2013). To increase the intensity of your workout, therefore, you can perform a sprint, such as a 200-meter sprint, start the sprint again every 3 minutes, and start at a given time interval.

Another way to improve endurance is for athletes to perform interval training by alternating sprint and jogging. HIIT workouts generally combine short bursts of strenuous exercise with rest or less intense exercise. In interval sessions, break intervals are interspersed during high-frequency work periods. In this wise, athletes can cover more distance with higher strength than they would with continuous work. IT is intense, so it is a great way to improve both aerobic and anaerobic fitness. Interval training sessions can be configured differently because three variables can be modified: intensity, work duration and rest duration (Tabata, Irishawa, Kuzaki, Nishimura, Ogita & Miyachi, 1997). For example, a run interval session consists of 200 meters of work for 25 seconds and 60 seconds of recovery. Another session will be 200m in 35 seconds with 20 seconds of recovery. In the first session, the athlete runs fast with a reasonably long recovery, while in the second session, the athlete runs quite fast but with a short recovery. Each session ends when the athlete cannot continue at the desired pace. Though one session may be faster than the other, at the end of the workout, both sessions might turn out tough.

An improved capacity for aerobic energy metabolism and fatigue resistance could be linked with endurance training more so, strength training can be associated to muscle hypertrophy (Baar, 2006).Adaptations that constitute endurance and strength training are bound with training or better still, the combination of both. For instance, interval training using repeated Wingate tests induces mitochondrial content and maximal aerobic capacity but intermediate training using exercises that required body weights increases maximum oxygen consumption and muscle strength (McRae et al., 2012). On the other hand, cardiovascular training does not significantly boost muscle strength or power. Knuttgen (2007) brings up that even first class long distance runners do not have curiously solid leg muscles yet their hearts and lungs cooperate at top execution. For an improved cardiovascular wellness, consistency in preparation is significant. At least, thrice a week or more is a good recommendation for any individual not less. In order to close possible gaps in theory and practical application as cavassed in Ogunleye (2014), the established benefits inherent in interval training need to be collated for the consumption of practitioners who need to either recommend or apply the intervention.

**Benefits of Interval Training**

Cardiorespiratory fitness improves with interval training most especially the heart's health within a short period of time compared to continuous forms of exercise. Sheff (2016) reported improved oxygen consumption determines endurance and the volume of oxygen utilized by the body. The heart would pump blood as it helps to prevent heart-related diseases and it would take longer time to get out of breath while helping the individual to be swifter with greater endurance during running or swimming.

Training with interval improves the neuromuscular coordination of athletes by increasing their speed. The increase derived from speed is usually complemented by the improvement that occurs as a result of endurance and stamina. Babalola and Ojo (2015) established that in the first few weeks of interval training, the athletes can usually have a better speed, endurance and strength performance. In Gillen, et al. (2016), a group of athletes had a workout for 10 minutes and the other group for 50 minutes uninterrupted. The two groups of exercisers' oxygen uptake improve at the same level. In another study by Gibala, et al. (2014), there were three repetitions of 20-second interval workout on an exercise bike for a total period of 30 minutes. The participants experienced improvements in their maximum oxygen consumption ($VO_2$ max). Reviews from researchers arrived at a logical conclusion that interval training programme (ITP) improves $VO_2$ max greatly when compared with shorter period of training. Furthermore, another study has concluded that with ITP, there could be retrogression of chronic diseases such as Type II diabetes among individuals (Weston, Wisloff & Coombes, 2014). Another great benefit of ITP is that it saves time as little time is required and individuals' would have time for other obligations.

**Interval Training Workouts for Beginners**

The type of interval training an athlete would include in their running routine depends on the type of running they want to perform. Depending on one's running style, the individual needs to develop a low or high intensity ITP. If the athletes is just starting with an interval training session the basic training session can begin with a 10-minute warm up run followed by a minute of jogging at an interval pace and end with a recovery run for 2-minute. When planning an ITP, efforts need to be made to ensure it is higher than what the athletes would be comfortable with so that it can make physiological impact. Such training should be repeated at least four times with a 5-minute cool down exercises such as stretching. The interval variation can be incorporated as:

i. **Standard:** In standard interval workout, the intensity of exercise is usually proportional.
   a. 3 – 5- minute warm up which may include light jogging with a gradual increase at the end of the warm up.
   b. 1 minute of moderate to high intensity exercise and 1 minute of low intensity with 6 – 8 repetitions.
   c. 3 – 5-minute cool down which may include light jogging with a gradual decrease.

ii. **Pyramid:** The pyramid structure is as follows:
   1. 3-5-minute warm up.
   2. 30 seconds of high intensity, 1 minute low intensity.
   3. 4 seconds of high intensity, 1 minute low intensity.
   4. 60 seconds of high intensity, 1 minute low intensity.
   5. 90 seconds of high intensity, 1 minute low intensity.
   6. 60 seconds of high intensity, 1 minute low intensity.
   7. 45 seconds of high intensity, 1 minute low intensity.
   8. 30 seconds of high intensity.
   9. 3-5-minute cool down

**iii. Sports Conditioning:** In this phase, an individual can mix and match the orders and repetitions as much as he/she wants and a longer period of rest is allowed. The design is as follows:

1. 3 – 5-minute warm up.
2. 2 minutes of moderate to high intensity exercise with 2 minutes low intensity at one repetition.
3. 30 seconds of high intensity with 30 seconds low intensity at four repetitions.
4. 10-second exercise or 50 meters race followed by 90 seconds rest for 6 -10 repetitions.
5. 3 – 5-minute cool down.

**Fundamentals of Interval Training Programme (ITP) Rules**

Interval training programme prescriptions depend mostly upon the following rules:

a. Recognizing the predominant metabolic system from which a given activity or exercise derives its energy. For example, explosive events such as the 100-yard dash, shot put, baseball throw, punt and high jump, to name a few, derive ATP from the ATP-PC system.
b. Employing the overload principle will allow the energy system to develop progressively. For example, such development of the ATP-PC system might involve increasing the speed of running 55 yards from 10 seconds during the first week to 7seconds during the last week of training and increasing the number of repetitions from 10 to 20 respectively. Understanding that the most efficient and effective training

programme is one which has been individually structured and this is termed specificity of training.

**Principles of Training**

According to Corbin (2000), as there is a right measurement of medication for treating an ailment, there is additionally a right dose of physical activity for promoting healthy life and creating physical wellness. A few significant standards of physical action give the premise to deciding the right portion or measure of physical activity. Physical activity principles can be represented as FITT explicated in the following:

1. **Frequency:** Physical activity should be done recurrently as much as possible without causing muscle soreness for it to be effective. This can be achieved for at least three to six days, though it depends on the definite benefit required.
2. **Intensity**: The exercise loading must be as intense as possible to produce the desired benefits. For example, the related health benefitrequires moderate intensity while the cardio respiratory fitness requires vigorous activity that raises the heart rate above normal.
3. **Time:** In other forphysical activity to be highly effective, there would be need to be highly engagedwith it for a longer duration. Generally, an exercise period must be at least 15minutes in length to be effective, while longer times are recommended for optimal benefits. As the length of time increases, intensities of exercise may be decreased. Time of physical activity involvement is also referred to duration.
4. **Type:** This is the mode of exercise being performed and since fitness development is specific, different type of activities builds different components of fitness. Activities such as jogging, rowing, cycling, stretching, and weight training are types of exercises that help identify specific fitness gains. Choosing the type of exercise should be guided by the fitness goal to be achieved.

The acronyms FITT can be used to help remember these prescriptive variables. These exercise variables are interrelated and can be manipulated to produce an exercise programme appropriate to an individual's need and to the outcomes required. For example, cardiovascular improvement can be realized by jogging (type) at 70% effort (intensity) for 40 minutes (time) 5 times a week (frequency) or at 85% intensity for 20 minutes 4 times a week. Individuals who are just starting a programme to improve their fitness may be more successful if they exercise at a lower intensity for longer session. Also, individuals who are obese may find it beneficial to exercise for shorter periods (duration) but more often during the week (frequency).

**Physiological Responses to Interval Training**

The mechanism essential in training adaptations is the focus of physiological responses. For instance, improvements in aerobic energy metabolism can primarily be linked to increased skeletal muscle, mitochondrial content, capillary density, increased maximal stroke volume, maximal cardiac output and blood volume (Bassett & Howley, 2000). These variables generally respond to changes in exercise volume, which is the product of exercise intensity, exercise duration and training frequency. In this study the following would be reviewed:

**1. Cardiovascular Adaptations to Interval Exercise Training**

As early as 2–4 weeks of training, improvements in $VO_2$ max usually occurs (Andersen & Henriksson, 1977). In a cross-sectional study, the variation in $VO_2$ max is predominately attributable to variation in maximum stroke volume and cardiac output as opposed to the arteriovenous $O_2$ difference (Bassett & Howley, 2000; Montero *et al*., 2015b) and training studies generally reach the same conclusion. The increase in maximum cardiac output observed after several weeks of endurance training was related to exercise-induced haematological adaptations as phlebotomizing subjects returned cardiac output and $VO_2$ max to baseline values (Bonne *et al*., 2014; Montero *et al*., 2015a). Improvements in maximum stroke volume have been reported after 2 to 6 weeks of training in some studies (Montero *et al*., 2015a) though in not all training protocols (Jacobs *et al*., 2013).

In a meta-analysis comparing the effects of interval and continuous training of healthy adults on their $VO_2$ max, Milanovic *et al*. (2016) reported greater adaptation of athletes to interval training. This conclusion is supported by an analysis from Bell and Wenger (1988), which demonstrated a linear improvement in $VO_2$ max as training intensity increased from 50 to 100% of $VO_2$ max and a meta-analysis from Bacon *et al*. (2013), which reported a greater increase in $VO_2$ max for high-intensity training relative to values typically reported in large studies. Similarly, a meta-analysis by Weston *et al*. (2014a) concluded that HIIT was more effective than work-matched MICT for improving $VO_2$ max in patients with induced cardio-metabolic disease. Finally, a recent large randomized control trial of different intensities of continuous exercise with obese adults supports these meta-analyses: greater increases in $VO_2$ max were demonstrated in response to 24 weeks of exercise performed at 75% of $VO_2$ max relative to iso-caloric exercise performed at 50% of $VO_2$ max with differences apparent after 8 weeks of training (Ross, *et al*., 2015).

The importance of exercise intensity in improving $VO_2$ max is further evident from comparisons various intensity of interval training. Low and high volume of interval training performed for 2–16 weeks increased $VO_2$ max (Gist, *et al*., 2013;Sloth, *et al*., 2013; Weston, *et al*., 2014b), with improvements elicited by the high-intensity protocols being equal to improvements from MICT protocols when compared (Gist, *et al*., 2013). In Gillen, *et al*. (2016), it was reported that low-volume SIT increases $VO_2$ peak as much as MICT does over a 12-week period despite difference in training volume. Relatively few studies have investigated changes in $VO_2$ max in response to different durations or frequencies of interval training; however, both variables appear to have relatively small effects on $VO_2$ max compared to the effect of exercise intensity. For example, the improvements in $VO_2$ max were not different in subjects who performed either one or four bouts of 4 min intervals (Tjonna, *et al*., 2013) or either 2 or 4 days per week of interval training (Fox, *et al*., 1975). Based on the fact that the effect of interval training duration on $VO_2$ max isunclear, meta-analyses suggested that longer interval bouts increased $VO_2$ max to a greater extent than shorter interval bouts (Bacon *et al*., 2013; Milanovic *et al*. 2016). In contrast, Knuttgen *et al*. (1973) and Helgerud *et al*. (2007) both reported similar increases in $VO_2$ max when comparable volumes of high-intensity exercise were performed as short (15 s) or long (3–4 min) intervals.

## 2. Cardiac Output and Blood Volume Responses to Interval Training

The intensity level had convincing influence in the improvement of $VO_2$ max,yet, some studies reported the effects of exercise intensity on maximum stroke volume and cardiac output or blood volume. In comparisons of studies, stroke volume was reported toincrease following HIIT relative to lower intensities of continuous exercise (Helgerud et al., 2007; Daussin et al., 2008; Bækkerud et al., 2016).Though when assessed, changes in haematological parameters did not explain the differences in stroke volume between groups (Helgerud et al., 2007; Bækkerud, et al., 2016). In contrast Macpherson et al., 2011, reported an increase in maximum stroke volume in response to MICT, though the increase was greater than the responses low-volume SIT and low-volume HIIT provoked. It is particularly tempting to conclude that, similar to the findings for $VO_2$ max, high-intensity exercise has a greater effect on central adaptations than moderate-intensity exercise. Based on the conflicting outcomes, it is however difficult ascertained the importance of exercise intensity for eliciting cardiovascular adaptations based on the limited number of comparisons in healthy individuals, particularly given the heterogeneity in the subjects, training programmes and methods of the studies.

## 3. Blood Pressure Responses to Interval Training

The pumping action of the heart, the peripheral resistance, the quantity of blood in the arterial system and the viscosity of blood all depends on blood pressure. The elasticity of the arterial walls determines the mean arterial pressures and the volume of blood within the arterial system. The volume in the system is dependent on cardiac output, which is a function of cardiac frequency and cardiac stroke volume. Cardiac frequency in turn is coupled with the rate of metabolism and modification in metabolism is reflected in alteration of the cardiac output. Hockey (1996) stated that as many times the heart contracts, the pressure in the blood rises at each cycle because more blood would be forced from the heart into the arterial system.

Mechanisms that take place in the heart include diastole which involves the relaxation of the chambers of the heart and systole which is the contraction of the heart chambers. In order to know the blood pressure, it is important to measuring the blood pressure regularly. A good example of a safe level accounted for around 120/80, figure 120 is measured as systole and 80 accounted for diastole. The pressure that the heart emits when blood is forced out of the heart is the systolic pressure, whereas diastolic pressure is the pressure that the heart shows when it is relaxing. Guyton (1996) describes blood pressure as the force vessel exerted by the blood against any cross sectional area of the blood vessel wall. Abbot (1998) asserted that blood pressure is equal to blood flow multiplied by resistance. The friction between the blood and the vessel walls cause resistance.

In Clark, et al. (2020), interval training was reported to be more effective for reducing BP (~3–5 mmHg) in the overweight to obese cohort. Exercise training induced positive changes in central (aortic) BP. More so, the BP lowering effects of exercise training are more prominent in those with higher baseline BP, with stronger correlation in interval training. Comparing changes in BP from pre to post intervention, there were no differences found in resting systolic BP and diastolic BP based on HIIT and MICT (Costa, et. al., 2018). Though Szwajcer and Costa (2017) reported that HIIT and MICT provided comparable reductions in resting BP in adults with pre- to established hypertension.

4. **Body Composition Responses to Interval Training**

In the human body, the composition includes body fat percentage, bone, water and muscles. In classifying the leanness of the body, body composition and weight are important while muscular tissue takes up less space in the body than fat tissue. There is high tendency that two individuals of the same gender and body type may appear differently as a result of different body composition. In other for men and women to maintain optimal body composition, the exercises they needed differ even among children, but the ideal types of fitness remain the same (Wagner & Heyward, 2000). Improving body composition, fat burning and cardiovascular exercises such as cycling and skipping among others are to be considered. With interval training programme, a well improved aerobic and anaerobic performances and body composition is guaranteed. It has been reported that interval training that is of high intensity shows similar effectiveness across all body composition measures suggesting time as a factor for efficiency in weight management programs (Wewege, Berg, Ward&Keech, 2017).

5. **Heart Rate Reserve Responses to Interval Training**

This is the distinction between the resting pulse and maximal pulse. It is an outflow of the expansion in pulse that happens above rest at maximal exertion. For instance, assume a 25years male athlete resting pulse was 62bpm and a maximal heart rate of 200bpm, hence his heart rate reserve 135bpm. Furthermore, as an individual expands their cardiovascular wellness, their resting heart rate will drop, subsequently, there will be increase in the heart rate reserve (HRR). In Babalola and Ojo (2015), it was reported that ITP increased the heart rate reserve of soccer platers. The level of HRR is proportionate to level of $VO_2$ saved. The preparation mediation of HIIT has been demonstrated to improve pulse hold (each $P<0.05$) in inactive matured men (Fergal, Peter, Adrian, Jo, Alexander &Nicholas, 2018). It supports recuperation of HRR in SED and improving maximal MET limit without inciting any neurotic cardiovascular rebuilding. HIIT permits improvement of one's pulse hold by 85 percent during work periods (Walrod, 2018). At that point an individual needs to permit the pulse to return at least 55-60 percent.

6. **Vital Capacity Responses to Interval Training**

Vital capacity (VC) is the maximum amount of air that can be inhaled or exhaled from the lung. It is equal to the inspiratory reserve volume plus the tidal volume plus the expiratory reserve volume. It can be measured by a spirometer which can be a wet or regular spirometer (Huprikar, Skabelund, Bedsole, Sjulin, Karandikar, Aden & Morris, 2019). In combination with other physiological measurements, the vital capacity can help make a diagnosis of underlying lung disease. Age, sex, height, weight and ethnicity are dependent of human's vital capacity as an adult has a vital capacity between 3 to 5 liters. Vital capacity has been found to increase with an increase in the height of a person, whereas, an increasing body mass index (BMI) is shown to correlate with a lower vital capacity (Lofrese, Lappin& StatPearls, 2019).

VC is a measurement taken during spirometry or pulmonary function testing. Vital capacity is a physiological character which is closely correlated with certain anthropometric characters. Of all these correlations the most reliable is that with body surface (Houssay, 1951). A suitable yardstick is required for comparing the vital capacities of people who differ from each other anthropometrically. For instance a small man will naturally have a lower vital capacity than a big man who should have a higher vital capacity. A direct comparison will be fallacious. A rational approach is to assess the degree of deviation of the observed vital capacity of the individual from his own norm. The difference between the actual observed vital capacity and his own norm is termed the residual. A man with a plus residual has a greater vital capacity than that of the average man of his own surface area. On the other hand, a minus residual mean that the actual vital capacity is less than that of the average man of his own surface area. Cureton (1947) postulates that a high plus residual indicates that an individual very probably has a greater flexibility of the chest wall, greater strength and range of action of the diaphragm, inspiratory muscles and the expiratory muscles of abdomen and chest.Babalola, and Ojo (2015) found out and reported a significant difference in the pretest and posttest measures of vital capacity following an eight weeks of interval training programme. Aerobic exercise has indeed been shown to increase a person's vital capacity.

**Conclusion and Suggestions for Practical Application**

Maximum Oxygen consumption has been well established to be well improved based on interval training of as early as 2–4 week. The difference that occurred in $VO_2$ max was attributed to variation in the improved stroke volume. Increase in maximum cardiac output was reported based on exercise-induced of endurance training after some weeks. The increase in maximum stroke volume in response to high intensity interval training improved just like the responses elicited by low-intensity IT. In a similar vein, interval training was reported to decrease BP among the obese. Adults with established hypertension were also reported to have reductions in resting BP.

Reviews had shown that interval training that is of high intensity shows similar effectiveness across all body composition. Based on a well-built cardiovascular fitness as a result of ITP, the resting heart rate was reported to decrease and subsequently, there was increase in the heart rate reserve. There were no reports on the impact of interval training on vital capacity, although, there were reports on the effects aerobic exercise on vital capacity. It is therefore recommended that physiological responses of vital capacity to interval training should be investigated among male and female athletes. Also, the amount of air that was maximally inhaled or exhaled from the lung of the obese and non-obese should be investigated.

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