PRE-EXERCISE ORS DRINK AND MUSCLE EFFICIENCY BY BICYCLE ERGOGRAPHY

Dissertation submitted to

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M.D. (PHYSIOLOGY)

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College : COIMBATORE MEDICAL COLLEGE

Dissertation Topic : PRE-EXERCISE ORS-DRINK AND MUSCLE EFFICIENCY BY BICYCLE ERGOGRAPHY

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This dissertation entitled **"Pre-Exercise ORS drink and muscle efficiency by bicycle ergography"** is submitted to The Tamil Nadu Dr.M.G.R Medical University, Chennai, in partial fulfillment of regulations for the award of M.D. Degree in Physiology in the examinations to be held during May 2018.

This dissertation is a record of fresh work done by the candidate**,** during the course of the study (2015-2018).

This work was carried out by the candidate herself under my supervision.

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DECLARATION

I, **Dr. K. AKILANDESWARI,** solemnly declare that the dissertation entitled **"PRE-EXERCISE ORS DRINK AND MUSCLE EFFICIENCY BY BICYCLE ERGOGRAPHY"** was done by me at Coimbatore Medical College, during the period from July 2016 to June 2017 under the guidance and supervision of **Dr.B.Sujatha, M.D.,D.A.,** Professor, Department of Physiology, Coimbatore Medical College, Coimbatore. This dissertation is submitted to The Tamilnadu Dr. M.G.R. Medical University towards the partial fulfillment of the requirement for the award of M.D. Degree (Branch - V) in Physiology. I have not submitted this dissertation on any previous occasion to any University for the award of any degree.

Place:

Date: **Dr. K. AKILANDESWARI**

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CERTIFICATE - II

This is to certify that this dissertation work titled **"Pre-Exercise ORS drink and muscle efficiency by bicycle ergography"** of the candidate **Dr. K. Akilandeswari** with registration Number **201515251** for the award of **Doctor of Medicine** in the branch of **Physiology**. I personally verified the urkund.com website for the purpose of plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows **3%** percentage of plagiarism in the dissertation.

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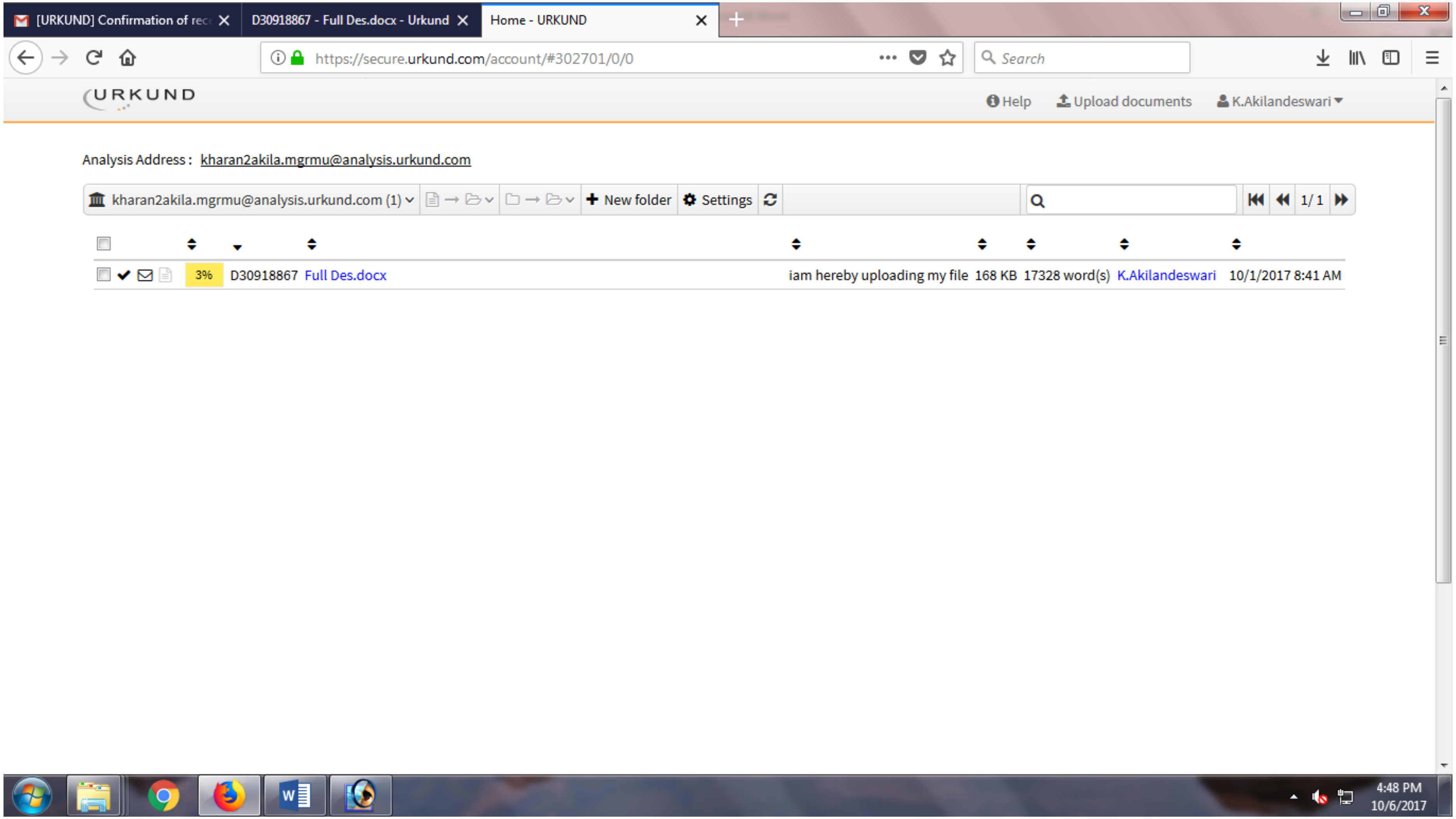
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INTRODUCTION

85% #1 Active

Exercise puts our body in a state of arousal, which translates into more vitality and a great sense of well-being".

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Exercise puts your body in a state of arousal, which translates into more vitality and a greater sense of well being,"

The application of physiological principles to sportive exertion is usually referred to as "work" or "exercise" physiology. It is a term that includes a wide collection of more specialized physiological topics including the chemistry of muscle contraction, muscle fiber types, the mechanical efficiency of muscle contraction, and energy storage in the muscle; the functioning of the circulatory system during rest and exercise, on oxygen uptake during rest and exercise; and nutrition, with special emphasis on the energy metabolism of muscular exercise.1 Exercise : Exercise can be defined as a planned, structural and repetitive physical activity. The final or the intermediate objective of doing exercise is to improve or maintain physical fitness.2 Types of Exercise : Exercise is classified based on the nature of muscle contraction. Inisotonic exercise, muscle contraction occurs against a constant load, with approximation of the ends of the muscle. There is a change in the length of the muscle, andthe tone remains the same. In isometric exercise, the muscles contract without an appreciable decrease in thelength of the muscle.3 Exercise can also be classified into endurance exercise and resistance exercise. Endurance exercise is characterized by continuous submaximal muscle contractions that is aimed at improving the aerobic capacity of the individual. Resistance exercise is characterized by short bouts of near maximal muscular contractions. It focuses mainly on developing muscular hypertrophy and thereby improving the muscular strength of an individual. 4 Aerobic poweris the maximum capacity of an individual's body to use

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CONTENTS

CONTENTS

ABBREVIATIONS

ACSM	American College of Sports Medicine
ATP	Adenosine Tri Phosphate
Bpm	beats per minute
BLC	Blood Lactate Concentration
BMI	Body Mass Index
c	calorie
CHO	Carbohydrate
EIMUF	Exercise Induced MUscle Fatigue
HRmax	Heart Rate maximum
HRrest	Heart Rate at rest
kj	kilojoule
kc	kilocalorie
LT	Lactate Threshold
METs	Metabolic Equivalent of Tasks
MTTI	Myocardial Tension Time Index
ORS	Oral Rehydration Solution
Pmax	Physical activity maximum
RPE	Ratings of Perceived Exertion
RPP	Rate Pressure Product
Rpm	revolutions per minute
SGLT	Sodium Glucose co-Transporter

SpO2	Oxygen saturation
VAS	Visual Analog Scale
VO_2max	Maximal Oxygen uptake
W	watts

PRE-EXERCISE ORS DRINK AND MUSCLE EFFICIENCY

BY BICYCLE ERGOGRAPHY

INTRODUCTION

INTRODUCTION

" EXERCISE IS THE MOST POTENT AND UNDERUTILIZED ANTIDEPRESSANT AND IT IS FREE"

"Exercise puts our body in a state of arousal, which translates into more vitality and a great sense of well-being". The application of physiological principles to sportive exertion is usually referred to as "work" or "exercise" physiology. It is a term that includes a wide collection of more specialized physiological topics including the chemistry of muscle contraction, muscle fiber types, the mechanical efficiency of muscle contraction, and energy storage in the muscle; the functioning of the circulatory system during rest and exercise, on oxygen uptake during rest and exercise; and nutrition, with special emphasis on the energy metabolism of muscular exercise.[1]

Exercise : Exercise can be defined as a planned, structural and repetitive physical activity. The final or the intermediate objective of doing exercise is to improve or maintain physical fitness.[2]

Types of Exercise : Exercise is classified based on the nature of muscle contraction. In isotonic exercise, muscle contraction occurs against a constant load, with approximation of the ends of the muscle. There is a change in the length of the muscle, and the tone remains the same. In isometric exercise, the muscles contract without an appreciable decrease in the length of the muscle.[3] Exercise can also be classified into endurance exercise and resistance exercise. **Endurance exercise** is characterized by continuous submaximal muscle contractions that is aimed at improving the aerobic capacity of the individual. **Resistance exercise** is characterized by short bouts of near maximal muscular contractions. It focuses mainly on developing muscular hypertrophy and thereby improving the muscular strength of an individual. [4]

Aerobic power is the maximum capacity of an individual's body to use oxygen while doing incremental exercise. This reflects the physical fitness of an individual. It depends on the capacity of the tissues to utilize oxygen in order to breakdown metabolic fuels like carbohydrates, fats, and proteins. VO_2max is considered as the single best indicator of cardiovascular fitness and maximal aerobic power. It is done by a graded exercise using a treadmill or a cycle ergometer in which the exercise intensity is increased in progression while measurements of ventilation and oxygen and carbon dioxide concentrations in the inhaled and exhaled air is done.[5]

There occurs a natural link between nutrition and exercise. The basic foundation for physical performance is proper nutrition. Nutrients provide energy and regulate physiological processes associated with exercise, although many believe that a well balanced diet is sufficient for better exercise performance. Improved athletic performance in many individuals is correlated with dietary modification. Carbohydrates, proteins and lipids are the macronutrients that maintain the structural integrity of any organism.[6]

As shown in many studies, nutrition is found to play an important role that mediates skeletal muscle adaptations during exercise performance of an individual. Carbohydrates and fats are the main substrates that power long lasting muscular contractions that are seen in endurance exercise.[4]

The positive influence of the role of life style, nutritional habits, training volume have a great role to bring down the occurrence of atherosclerotic heart disease in the life of an individual. Evidence suggests that individuals with higher levels of physical activity tend to have lower rate of prevalence of asymptomatic coronary artery disease problems. One of the reliable indicator of cardiorespiratory fitness of a person is considerably due to his aerobic capacity. Appropriate cardiorespiratory function effects can be produced by an exercise program done 3-5 times a week, for 20-60 minutes per session, at an intensity of about 50 - 85% of VO_2max.[7]

In human beings, glycogen is synthesized is stored in the hepatocytes (about 100 grams) and in muscles (about 350 grams – 700 grams) and it varies between individuals. Intra myofibrillar glycogen, when depleted correlates with fatigue of skeletal muscles.[8]

Muscular fatigue is a failure to maintain the expected force or power output. Causes could be due to those involving the muscles per se, substrate depletion and various metabolic events[9]. Causes of muscle fatigue could be shortage of substrates that help to maintain contraction of muscles like carbohydrates, calcium, sodium, potassium, ATP[10]. Carbohydrates, ascorbic acid, calcium, sodium, potassium, ATP are depleted during exercise[11].

Metabolic heat that is produced by muscular contractions gets transferred from actively contracting muscles to the blood and then to the core of the body[12]. Physiological adjustments facilitate heat transfer from the body core to the skin and is dissipated as sweat which gets evaporated into the environment[13]. Electrolytes are lost through the sweat and it depends on the total amount of sweat loss[14].

Dehydration, substrate and electrolyte depletion are the major problems seen during a prolonged bout of exercise. Hence, it becomes essential to restore these substances before exercise to build up the stores. Administration of Oral Rehydration Solution (WHO) can be of great benefit to those involved in the exercise programs of longer duration. ORS contains water, carbohydrates in the form of glucose and electrolytes like sodium, potassium and chloride.

Exercise provides many benefits. When ORS administration precedes the exercise program, it helps to restore the energy substrates in the body, thereby delaying muscle fatigue. This also helps to improve the exercise performance of the individual.

Measuring VO_2max, VO_2 kinetics while exercising provides the basis for biomarkers of exercise induced muscle fatigue. Cycling on an ergometer is one of the possibility to measure power output, with others being running, jumping types of exercises[8].

The position stand of the American college of Sports Medicine states that adequate fluid and electrolytes replacement helps to maintain hydration, thereby promoting the optimal physical performance of those individuals participating in regular physical activity[15].

Evidence suggests that people with high levels of physical activity tend to have a lower prevalence of asymptomatic coronary heart disease. An exercise program conducted three to five times/week, for twenty to sixty minutes per session, at an intensity of about 50% to 85% VO_2max has been shown to cause appropriate cardiorespiratory function effects.[16]

Benefits of regular exercise includes building up of stronger muscles, prevention of chronic illnesses, good sleep, lengthening of telomeres, releasing endorphins, improving memory, reducing the risk of hypertension, and improves high density lipoprotein levels in blood.[16]

AIM & OBJECTIVES

AIMS AND OBJECTIVES

AIM:

To record the muscle efficiency parameters by performing exercise in bicycle ergometer till fatigue in male students by administering Oral Rehydration Solution(WHO).

OBJECTIVES:

- To assess and to compare the work done when the subjects do cycling without and with ORS ingestion before exercise.
- To compare the Rate Pressure Product without and with ORS ingestion before exercise.
- To compare the METs without and with ORS ingestion before exercise.
- To compare the SpO_2 values without and with ORS ingestion before exercise.
- To compare the VO_2max values without and with ORS ingestion before exercise.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

HISTORY OF EXERCISE PHYSIOLOGY:

The history of exercise physiology dates back to the civilizations of early Greece and Asia Minor, and even earlier periods in history like the Minoan and Mycenaen cultures. It can even be dated back to the empires of Alexander the Great .

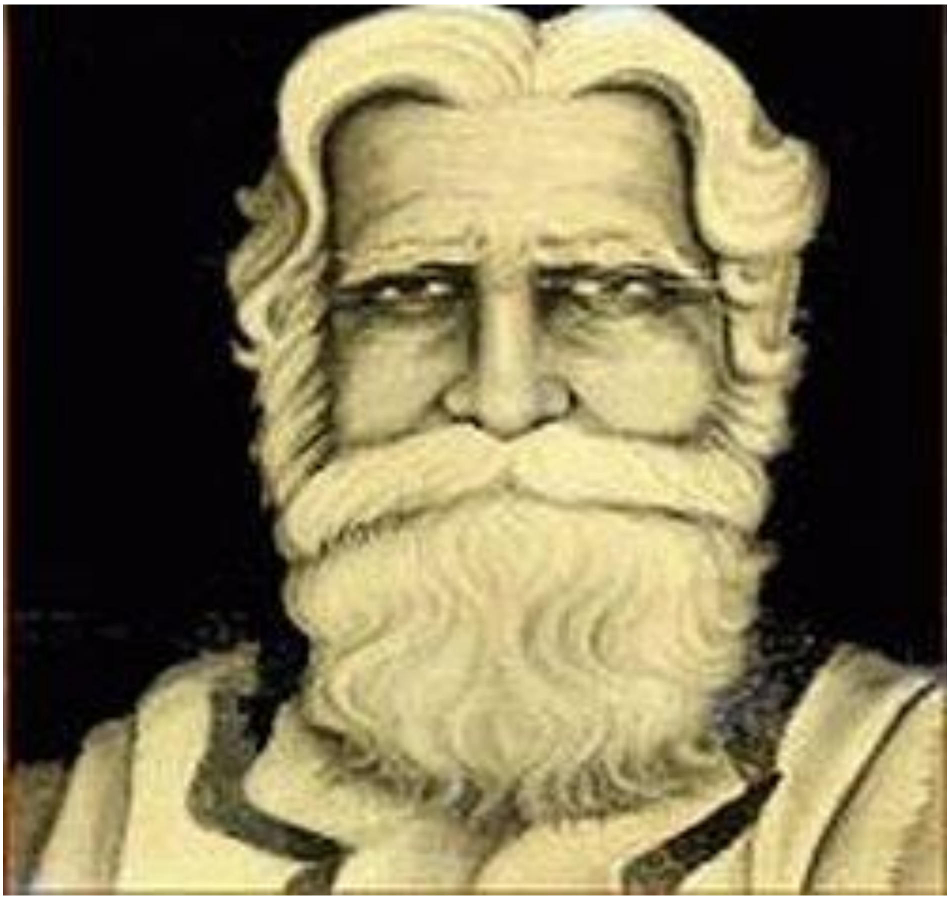
Sushrutha, a great plastic surgeon of the olden days, considered obesity as a disease and considered that sedentary lifestyle contributed to obesity.[6]

Herodicus (fifth century BC) a great Greek physician and an athlete, was the first person in the history of medicine who had combined sports with medicine. He considered, bad health as a result of imbalance between diet and physical activity. For this reason, he recommended strict diet, daily physical activity and regular training habits. He believed this combination as the ideal way to maintain good standards of health. He also applied this type of treatment method to his patients. His writings were said to have influenced Hippocrates, considered as the Father of Modern medicine[17].

Galen, born in the great city of Pergamos, had implemented and enhanced current thinking about health and scientific hygiene, an area some might consider "Applied" Exercise Physiology. Galen proposed and taught the laws of health: to breathe fresh air, to eat proper foods, to drink the right

HIPPOCRATES

SUSHRUTA



beverages, to do adequate exercise, to get adequate sleep, and to control one's emotions. Galen wrote prolific essays and proposed treatises on human physiology and nutrition, on the beneficial effects of exercise, and on the deleterious consequences of sedentary living, and also on various diseases including obesity and described treatments for the diseases. Galen proposed treatments which are common in use today, which included diet, exercise and medications. Galen wrote in detail about the various forms of swift and vigorous exercises, including their proper quantity and duration.

It was in the year 1539, the well known Italian physician **Hieronymus Mercurials** who had published *De Art e Gymnastica Apud Ancientes* **-** *The* art of gymnastics among the ancients. His presentation deeply influenced the great physicians Galen and other Latin and Greek authors. This profoundly affected subsequent writings on physical training and exercise, later called as gymnastics.

It was **Joseph Preistley** who had discovered oxygen. It was Antoine Laurent Lavoisier (1743-1794)' who had ushered in modern concepts of metabolism, nutrition and exercise physiology. Lavoisier also paved the way for studies of energy balance. Lavoisier along with his colleague, and chemist, Armand Seguin, conducted several experiments on the influence of muscular work on metabolism. In their experiments, it was found that the resting energy metabolism without food in a cold environment increased by

10% ; it increased 50% due solely to food; 200% with exercise and 300% by combining food intake with exercise.

Dr.Hitchcock, Jr. along with his colleague **Hiram H . Seelye , MD** published an anthropometric manual at the Amherst college, which was considered to be the first of its kind which was devoted to an analysis of anthropometric measurements. This manual influenced many of the physical education departments in the United States to include anthropometric measurements as part of the physical education and hygiene curriculum. And the foremost reason for these kind of interests in anthropometric measurements was to show that engaging in daily, vigorous exercise produced desirable bodily results, particularly for muscular development and fitness.

The first formal exercise physiological laboratory in the United States was established in the year 1891 at the Harvard University.

The nutrition laboratory in the Carnegie Institute in Washington, D.C, was created in 1904 to do studies on nutrition and metabolism of energy. This influenced many other institutes to start up laboratories to study on exercise physiology.

In the year 1927, the **Harvard Fatigue laboratory** was initiated to do experiments in exercise physiology. It was established under the guidance of

Dr.Franklin M. Henry. His studies included the individual differences in the kinetics of the fast and slow components of the oxygen uptake and recovery curves during light and moderate cycle ergometer exercise, muscular strength and cardio respiratory responses during steady rate exercises, assessment of heavy work fatigue, determinants of endurance performance, and neural control factors related to human motor performance.

It was **Frederick Gowland Hopkins** (Nobel prize winner in 1929 for isolating and identifying the structure of amino acid tryptophan) and **W.M. Fletcher** who studied muscle chemistry and discovered methods to isolate lactate in the contracting muscle.[6]

1846-1910: **Angelo Mosso** who invented the Mosso Ergograph (1890), was an experimental physiologist from Turin, Italy. This apparatus was used to measure the optimum stage of muscular performance in human beings. Mosso was interested in the instrument because of its potential to measure fatigue. It also enabled the testing of many complex variables and their effects on muscular strength, like lack of food, sleep, mental fatigue, and the effect of substances such as coffee, sugar, and emotional affect[18].

The word **ergograph** is derived from the Greek erg– meaning a unit of work, and graphe- writing from graphein (to write). The Mosso Ergograph is named after its founder Angelo Mosso. His experimental interests were focused in the areas of fatigue, sleep, intestinal movements, and animal behaviour.

ANGELO MOSSO

PROFESSOR PER OLOF ASTRAND

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The ergograph follows a practical framework, and it was an attempt to use modern scientific methods for study of muscular strength and fatigue. The ergograph is one of many of such laboratory devices used on isolated individual parts of the human body to determine the dynamic capabilities of the body.

As to a modern correlate of the ergograph, this can be seen in ergometers, such as rowing machines, stationary bikes, and treadmills. These technologies are used to quantify strength and incorporate modes of resistance, but do not create a graphic record like that of the ergograph[18].

Per – Olof Astrand, MD, PhD, is considered to be the most famous graduate in the college of physical education, Karolinska Institute Medical School, Stockholm. He did his doctoral thesis on physical work capacity of both sexes. He did this notable study along with his wife Irma Ryhming. They established a line of research that put Astrand to the forefront of exercise physiology [6].

Astrand had over two hundred research publications. His areas of research included work physiology and the human oxygen transporting system, physical performance, health and fitness, preventive medicine. He is very well known for developing the Astrand-Ryhming Cycle Ergometer Test in 1954 along with his wife Irma Ryhming. He is the author of the Textbook of Work Physiology and it has been translated to eight languages.[19]

SKELETAL MUSCLE PHYSIOLOGY

TYPES OF MUSCLE FIBRE:

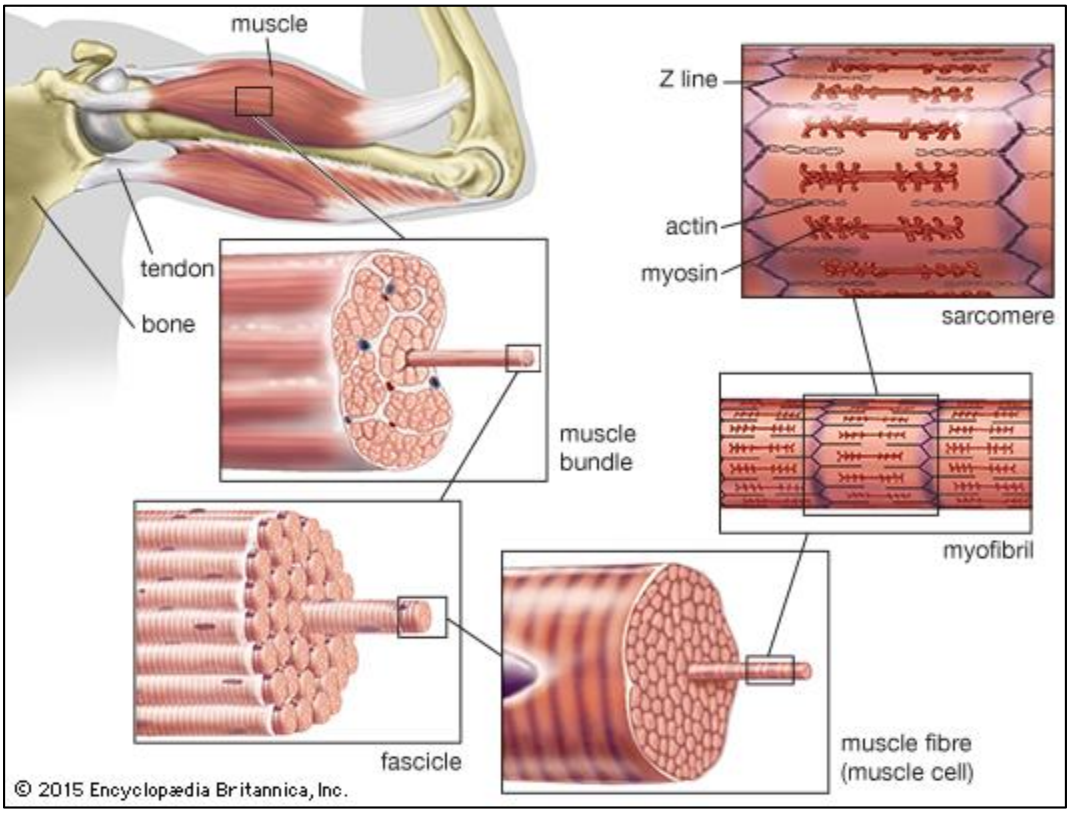
Muscle cells are a group of well specialized cells that convert chemical energy into mechanical energy. In particular, these cells utilize the synthesized energy in adenosine tri phosphate (ATP) to make force or do work. And also, stored energy could transform into various forms like locomotion, circulation of blood in the vessels, or peristalsis.

Skeletal muscle can be classified into fast-twitch (types IIA and IIB) or slow – twitch (otherwise called as the type I) muscle fibres[20].

DIFFERENCE BETWEEN MUSCLE FIBRE TYPES:

	Type I: Slow Oxidative (Red)	**Type IIB: Fast Glycolytic (White)**	**Type IIA: Fast Oxidative (Red)**
Myosin isoenzyme (ATPase rate)	Slow	Fast	Fast
Sarcoplasmic reticular Ca^{++} pumping capacity	Moderate	High	High
Diameter (diffusion distance)	Moderate	Large	Small
Oxidative capacity	High	Low	Very high
Glycolytic capacity	Moderate	High	High

SKELETAL MUSCLE FIBRE

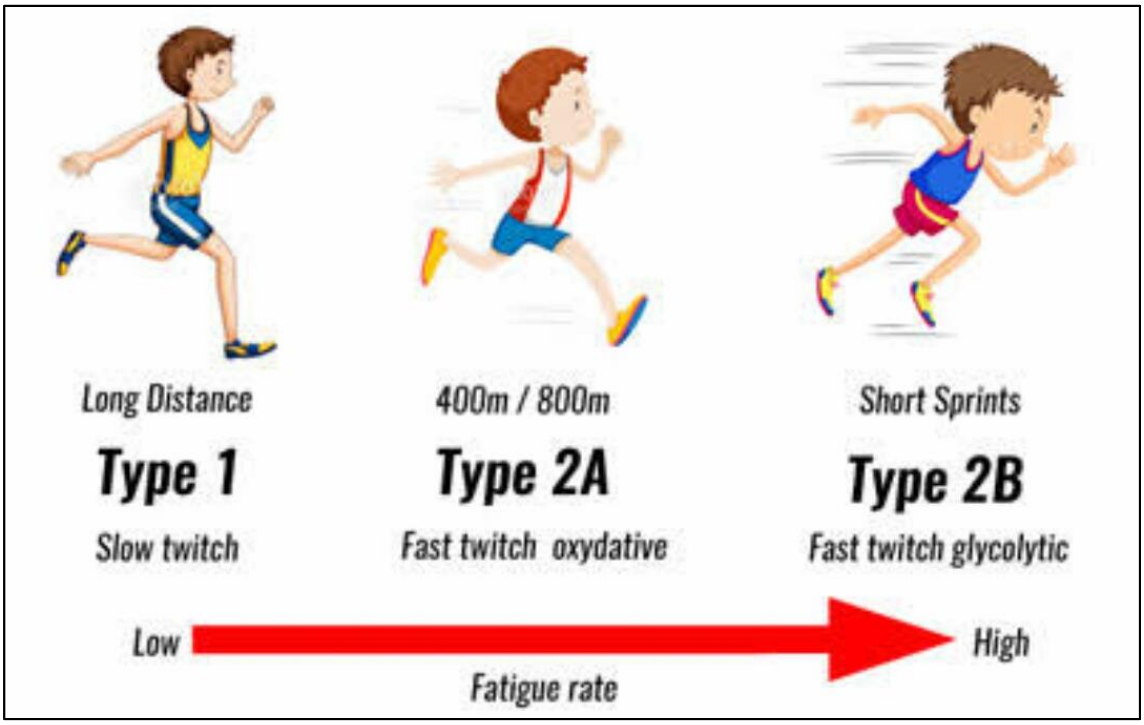


The lateral rectus muscle surrounding the eye ball contracts rapidly, and the maximum tension is obtained in 7.5 milli seconds following an adequate stimulation. But, the gastrocnemius muscle in the lower limb, in contrast, needs forty milliseconds to develop maximum tension. Also, the soleus muscle in the lower limb needs even long period of time duration that is, about ninety milliseconds for achieving maximal tension. Thus, soleus can be classified into a slow-twitch type of muscle, and the lateral rectus of the eyeball can be classified into a fast-twitch muscle. But the gastrocnemius of the legs contain both fast as well as the slow-twitch components, thereby exhibiting an average intermediate rate of tension when the muscle gets stimulated20.

EFFICIENCY OF MUSCLE CONTRACTION:

The efficiency of an engine or a motor is calculated as the percentage of energy input and this gets converted into work in the place of heat. The percentage of the input energy to muscle in the form of chemical energy in nutrients that can be converted into work, even under the best conditions, is < 25 %, and the remainder becomes heat. The basis for the low efficiency is that about one half of the energy seen in foodstuffs is lost when ATP is formed. Maximum efficiency can be obtained only when muscle contracts at moderate velocity. When the muscle contracts gradually, little amount of maintenance heat is released on contraction. On

TYPES OF MUSCLE FIBRE



the other hand, if there is a quick contraction, large amount of energy is used to overcome viscous friction within the muscle itself, and this also reduces the efficiency of muscle contraction. Usually, maximum efficiency develops when the velocity of contraction is about 30 % of maximum20.

Mechanical work done by the muscle is the product of quantity of force applied by the muscle and the distance through which the force is applied. The power of muscle contraction is a measure of the total amount of work output by the muscle over a unit period of time. Power is distance of contraction and the number of times that it contracts every minute. It is generally measured in kilogram meters (kg-m) per minute20.

Maximal Power Output in a well-trained athlete :

Duration	**Power (kg-m/min)**
First 8 to 10 seconds	7000
Next 1 minute	4000
Next 30 minutes	1700

Endurance is another measure of muscle performance. This greatly depends on the nutritive support of the muscle, especially on the quantity of glycogen stored in the muscle before the onset of exercise. A person on a high carbohydrate diet can store far more glycogen in muscles than a person on a mixed diet or a high fat diet. Therefore, endurance in a person is greatly improved by a high carbohydrate diet intake. The amount of glycogen stored in the muscle is approximately the following:

Type of diet and muscle glycogen storage:

TYPE OF DIET	**AMOUNT OF GLYCOGEN STORED**
High carbohydrate diet	40 g/ kg
Mixed diet	20 g/kg
High fat diet	6 g/kg

ENERGY SOURCES IN SKELETAL MUSCLES:

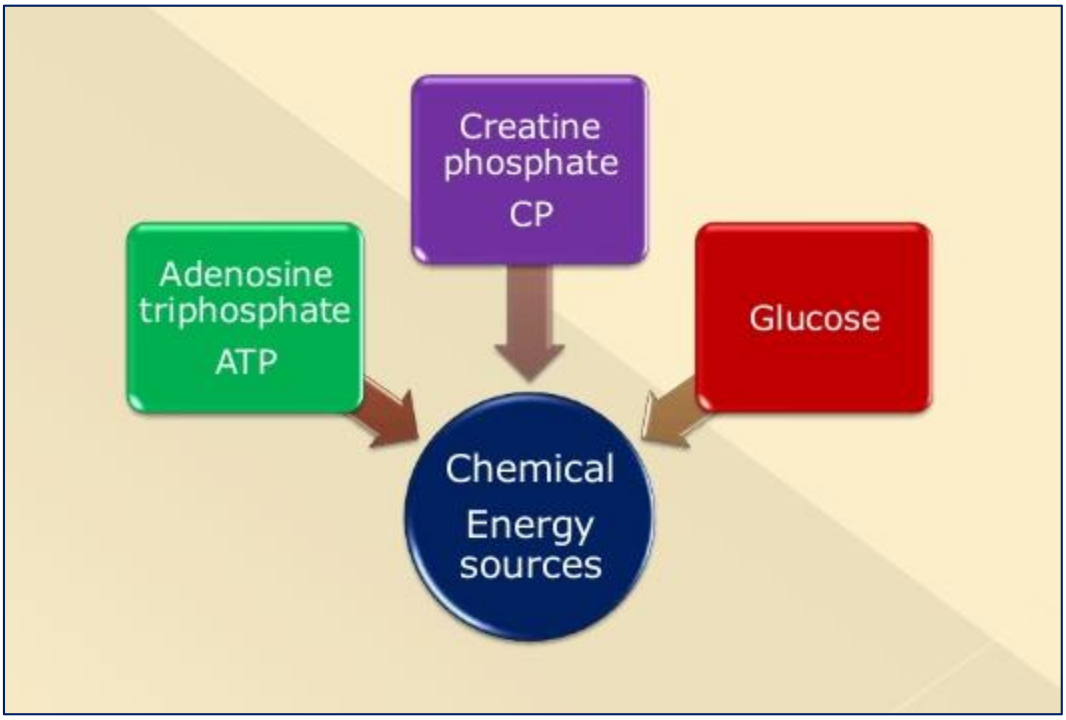
Muscle contraction depends on the energy supplied by ATP. Nevertheless, a great extent of this energy is essential to get going the walk-along process by which the cross – bridges pull the actin filaments, but small amounts are required for,

1. Pumping of the calcium ions into the sarcoplasmic reticulum after the contraction is over.

2. Pumping in and out of sodium as well as potassium ions across the muscle fiber membrane in order to maintain a suitable ionic environment for transmission of muscle fiber action potentials. The concentration of ATP in the muscle fiber, which approximately is about 4 millimoles, is adequate enough to uphold complete contraction for 1 to 2 seconds only. The ATP is split to form adenosine biphosphate (ADP), which transfers energy to the contracting machinery of the muscle fiber. The ADP in turn is rephosphorylated to form new ATP in another fraction of a second, which permits the muscle to go on with its contraction. There are several number of energy sources for this rephosphorylation.

The first and foremost source of energy that is used to replenish the ATP source is phosphocreatine, the compound that carries a high energy phosphate bond similar to the bonds of ATP. The second vital source of energy, which is used to replace both ATP and phosphocreatine, is “glycolysis”. The third and final energy source is oxidative metabolism. It is the process of combination of oxygen with the end products of glycolysis and with various other cellular foodstuffs to liberate ATP. More than 95 % of the energy used by the muscles for sustained, prolonged contraction is obtained from this source. The foodstuffs that are ingested are carbohydrates, fats, and proteins. For extremely long term maximal muscle activity that occurs over a period of many hours, by far the maximum fraction of energy comes from fats, but for a duration of about

ENERGY SOURCES IN SKELETAL MUSCLE



two to four hours, as much as 50% of the energy comes from stored carbohydrates[21].

1. CARBOHYDRATES:

The basic structural unit of a carbohydrate molecule is the monosaccharide. The major monosaccharides are glucose, fructose and galactose. Glucose is also called as dextrose or blood sugar, which is a six carbon compound. Hexose is found naturally in the food or is formed in the cells by means of digestion of more complex carbohydrates. Gluconeogenesis is the process which occurs mainly in the liver by which the body produces new glucose. In this process glucose is formed from some of the amino acids, glycerol and from lactate. Absorption of glucose from the small intestine is used up for:

1. Source of energy for cellular metabolism.

2. To form glycogen to be stored in liver and muscles.

3. Conversion to fat - triacylglycerol for later use as energy.

The daily carbohydrate intake of a normal 70 – kg man accounts to about 300 gram or 40 - 50% of the calories. Carbohydrate intake in physically active people and those involved in exercise training should be about 60% of the daily calories or 400 - 600 grams. Carbohydrate intake should increase upto 70% of the total calories consumed or approximately 8 – 10 gram / kg of the body mass[6].

ROLE OF CARBOHYDRATES IN THE BODY:

Carbohydrates act as main source of energy in our body, especially during intense physical activity. The contractile elements of the muscle are powered by the energy obtained from the breakdown of blood glucose and glycogen found in the muscle fibres. Relatively limited stores of glycogen are found in the body and an adequate daily intake of carbohydrate is very essential to sustain the stores.

Also, carbohydrates act as protein sparer as their sufficient intake aids to preserve tissue protein. Components of catabolism of carbohydrates serve as primer substrate for oxidation of lipids. The central nervous system needs an uninterrupted supply of glucose for the neurons to function properly[6].

CARBOHYDRATE DYNAMICS DURING PHYSICAL ACTIVITY:

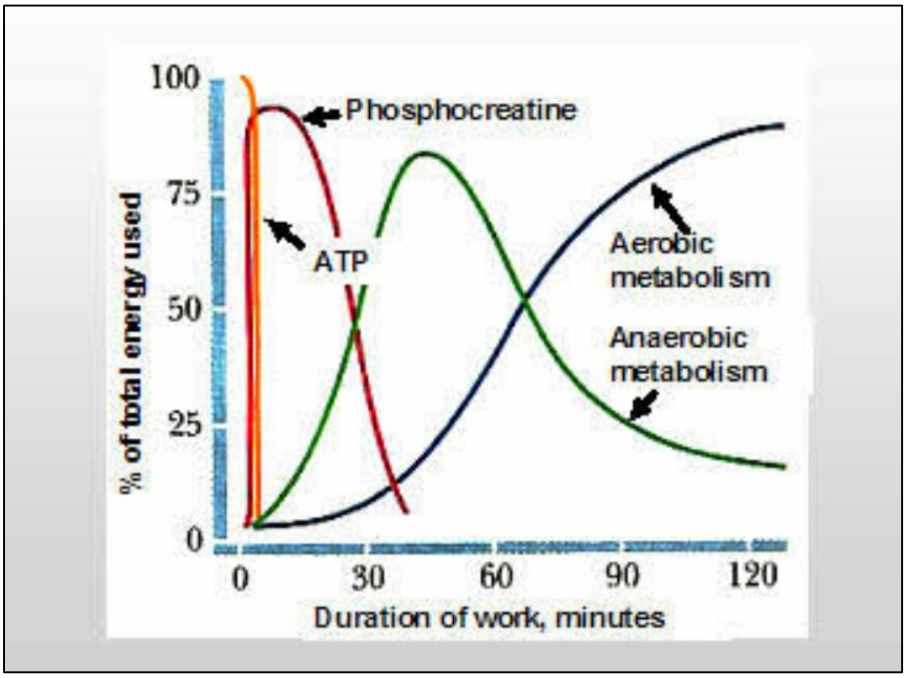
Carbohydrate remains the primary fuel during an intense physical or aerobic activity as it quickly provides energy as ATP in the oxidative phosphorylation. In addition to this, carbohydrate becomes the sole fuel for ATP resynthesis during anaerobic exercise that needs glycolysis. The concentration of blood glucose provides feedback regulation of the hepatic glucose output. Carbohydrate availability during exercise helps to regulate the mobilization of lipids and their use for energy. In the earlier periods of exercise, muscle glycogen provides energy and as exercise continues, blood glucose has a greater contribution as the metabolic fuel, which may account to upto 30% of the energy source of the muscle.[6]

CARBOHYDRATES AS ENERGY SOURCE IN MUSCLES:

Glycogen present in the myocytes gets metabolized during muscle contraction. It gets broken down to glucose for the purpose of oxidative phosphorylation as well as for glycolysis. Both these processes yield greater quantities of ATP. This leads to great amounts of ATP stores in the muscle cells. Myocytes can also take up glucose from the blood by insertion of GLUT-4 expression, and this step is mediated by insulin. During exercise, glucose is taken up by muscles even without GLUT-4 insertion.

The enzyme phosphorylase which is found in the cytosol mediates the release of glucose 1-phosphate residues from the glycogen molecule. Glucose is then metabolized by glycolysis which occurs in the cytoplasm and oxidative phosphorylation which occurs inside mitochondria thereby yielding an equivalent of about 37 mol of ATP for every one mole of glucose 1-phosphate. Blood glucose, on getting metabolized, liberates 36 mol of ATP for one mole of glucose. One ATP is utilized in the process of

ENERGY SOURCES IN WORKING MUSCLES



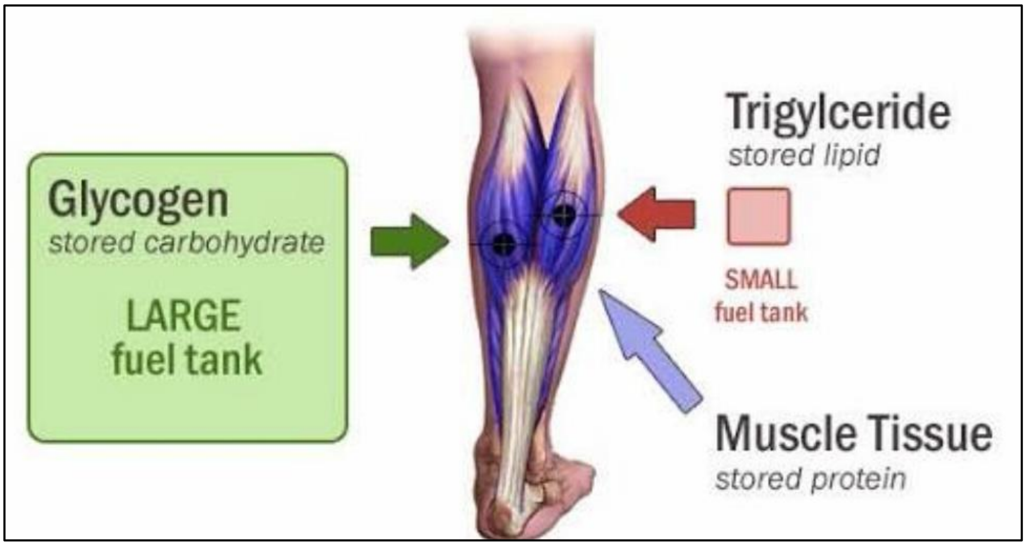
phosphorylating glucose at the beginning of glycolysis. All the above ATP yields, are dependent on an ample supply of oxygen. But, under anaerobic conditions, metabolism of glycogen and glucose yield only three and two mol of ATP for every mole of glucose 1- phosphate and glucose, respectively. It also yields two mol of lactic acid. Fatigue of muscles while undergoing prolonged exercise could be related with the dimunition of the glycogen stores of the muscle fibres[20].

Other sources of energy during muscle contraction:

1. FATTY ACIDS AND TRIGLYCERIDES AS ENERGY SOURCES:

Fatty acids signify an essential energy source for myocytes during prolonged periods of exercise. Muscle cells have plenty of fatty acid stores, but they can also utilize fatty acids from the blood. Added to this, muscle cells can accumulate triglycerides, which can be hydrolyzed in times of need to generate fatty acids. The fatty acids, in turn are subjected to β - oxidation inside the mitochondria. However, the fatty acids are converted to a compound called as acyl-carnitine within the cytoplasm and are then transported into the mitochondria, where they are transformed to acyl-CoA . Inside the mitochondria, the acyl-CoA undergoes beta oxidation and thereby yields acetyl-CoA, which then enters the citric acid cycle and at last produces ATP[20].

GLYCOGEN & FAT STORES IN MUSCLE

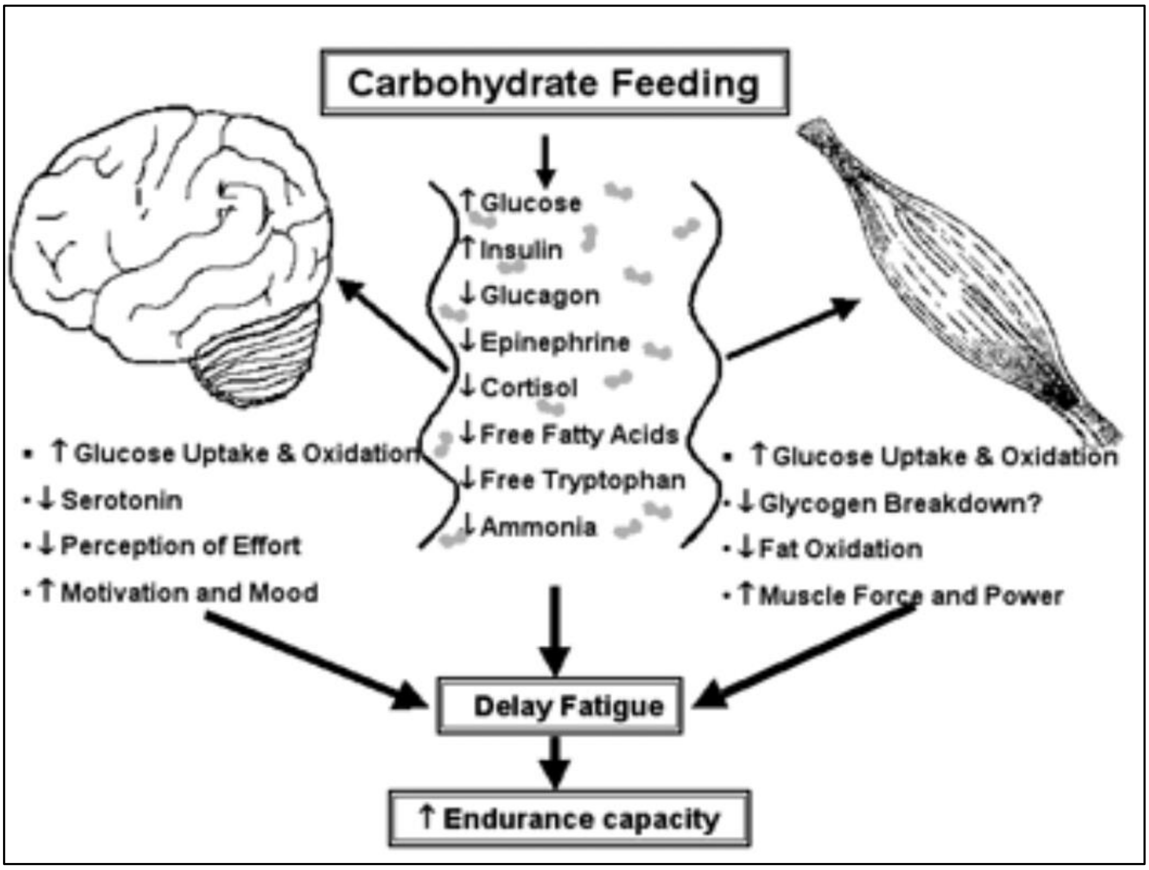


STUDIES ON CARBOHYDRATES AND EXERCISE:

Carbohydrate intake during extended exercise periods can enhance work capability by maintaining power output or speed or by prolonging the time to fatigue at a fixed, sub- maximal workload. Pre exercise carbohydrate ingestion has been demonstrated to increase both hepatic and muscle glycogen stores, and, therefore, this practice has the capacity to increase exercise performance. Combination of carbohydrate feeding before and during exercise has an additive effect on performance compared with when carbohydrate is ingested only before, or only during, exercise[22].

Studies continue to support obligatory high carbohydrate intakes before the physical activity to maximize muscle glycogen stores, during the exercise periods to prevent hypoglycaemia and following the event to optimize post – event restoration of body's carbohydrate stores. A critical component of good participation in ultra endurance activities is therefore the availability of both adequate substrate stores and the maintenance of hydration balance. It is well established that exercise can only be maintained for prolonged periods without the onset of fatigue if sufficient carbohydrate is available for combustion[23].

EFFECT OF CARBOHYDRATE FEEDING ON ENDURANCE CAPACITY



ROLE OF WATER, ELECTROLYTES IN EXERCISE

Water and electrolyte balance are vital for the functioning of all organs and, indeed, for maintenance of health[24]. Water acts as the medium for biochemical reactions which occur within the cells and tissues and is crucial for maintaining an ample blood volume and also for the integrity of the cardiovascular system. The ability of the body to redistribute water within its fluid compartments is to provide a reservoir to diminish the effect of water deficit[24]. Each body water compartment is composed electrolytes, the concentration and composition of which are critical for shifting fluid between intracellular and extracellular compartments and for the maintenance of membrane electrochemical potentials. Daily requirements for sedentary to physically active persons range from 2–4 L / d in temperate climates and from 4–10 L / d in tropical climates.

Sodium chloride is the main electrolyte in sweat, along with potassium, calcium, and magnesium which is present in smaller quantities. The sodium concentration in sweat averages from 35 mmol / L (range: 10–70 mmol / L) and is varied by diet, sweat rate, intake of fluids , and degree of heat acclimation.[25]

The goal of hydrating prior to the start of physical activity is to begin the activity euhydrated and with normal serum electrolyte levels. Pre hydration with beverages, in addition to normal food and fluid intake, should be started when needed as early as possible before the activity to enable fluid absorption. The goal of drinking fluids during exercise is to prevent excessive dehydration and excessive changes in electrolyte balance.

During exercise, consuming beverages containing electrolytes and carbohydrates can provide benefits over water alone. After exercise, the aim is to restore any fluid and electrolyte deficit. The hypohydration that occurs during exercise is usually described as hyper osmotic hypovolemia. Depending upon the metabolic rate, environmental conditions and clothing worn, exercise can bring on significant elevations in body temperatures. Besides containing water, sweat contains electrolytes that are lost which, when not suitably replaced, dehydration and hyponatremia can increase and can cause a negative impact on the individual's exercise performance. Sweat electrolyte losses depend on the total sweat losses and sweat electrolyte concentrations. Sweat sodium concentration averages ~35 mEq/hr (range 10–70 mEq/hr). Sweat concentrations of potassium averages 5 mEq/ L (range 3–15 mEq/L) , calcium averages 1 mEq/L (range 0.3–2 mEq/L), magnesium average 0.8 mEq/L (range 0.2–1.5 mEq/L), and chloride averages 30 mEq/L (range 5–60 mEq/L). Sweat glands reabsorb sodium and chloride, but the ability to reabsorb these electrolytes does not increase proportionally with the sweat rate.[12]

Exercise performances of longer duration are enhanced by the addition of carbohydrate. The form of carbohydrate is not found to be critical. Glucose, sucrose as well as oligosaccharides have been shown to be efficient in improving endurance capacity. Some studies have suggested that long-chain glucose polymer solutions are more effectively used up by the muscles during exercise than those of glucose or fructose solutions. (Noakes, 1990)[26].

Numerous studies have examined the influence of dehydration on maximal aerobic power and physical work capacity (Sawka, Montain & Ladzka, 1996). The physical work capacity for aerobic exercise of progressive intensity is decreased when a person is dehydrated (Sawka*et al.*, 1996). Physical work capacity has been shown to be decreased even with marginal (1–2% body weight loss) water deficits and the reduction is larger with increasing water deficits (Armstrong *et al.*, 1985; Caldwell, Ahonen & Nousiainen, 1984). Dehydration results in much larger decrements of physical work capacity in hot than in temperate climates (Buskirk, Lampietro & Bass, 1958; Caldwell *et al.,* 1984; Craig & Cummings, 1966; Webster, Rutt & Wettman, 1990).[26]

On the effects of dehydration on physiologic tolerance to submaximal exercise, Adolph (1947) reported that 16% and 2% of the soldiers suffered exhaustion from heat strain during an endurance (2-23 h) desert walk (at 4-6.5 km/h) (Ta ~38°C) when they did not drink and when they did drink water *ad libitum*, respectively. Ladell (1955) had subjects to attempt 140-min walks in a hot (Ta ~38°C) environment while ingesting different combinations of salt and water. They reported that exhaustion from heat strain occurred in 75% of their subjects when not receiving water and in 7% of their subjects when receiving water. Clearly, dehydration increases the incidence of exhaustion from heat strain. Sawka *et al.* (1985) had subjects attempt lengthy treadmill walks (~25% of VO_2max for 140 min) in a hot-dry (Ta = 49°C, rh = 20%) environment when euhydrated and when dehydrated by 3%, 5% and 7% of their body weight. All eight subjects completed the 3% dehydration experiments, and seven subjects completed the 5% dehydration experiments. In the 7% dehydration experiment, six subjects discontinued after completing only 64 min (mean value). Clearly dehydration increases the incidence of exhaustion from heat strain.[27]

EXERCISE – ASSOCIATED HYPONATREMIA:

Symptomatic hyponatremia can occur when plasma sodium quickly drops to ~130 mmol/L and lower. With plasma sodium 125 mmol/L and less, symptoms become increasingly severe and include headache, vomiting, edema of hands and feet, restlessness, undue fatigue, confusion and disorientation as a result of progressive encephalopathy, and dyspnea due to pulmonary edema. When plasma sodium falls well below 120 mmol/L, the chances increase for severe cerebral edema causing seizure, coma, and death occurs. Contributing factors to exercise –associated hyponatremia include consuming excess of hypotonic fluids and excessive loss of total body sodium content through sweat. The prehydration program will help ensure that any previously incurred fluid - electrolyte deficit gets corrected prior to initiating the exercise task. Consuming beverages with sodium and / or salted snacks or small meals with beverages can help stimulate thirst and retain needed fluids. Carbohydrate consumption can be beneficial especially during high-intensity exercise events of ~1 hour or prolonged duration. Carbohydrate - based sports beverages are sometimes used to meet carbohydrate needs, while attempting to replace sweat water and electrolyte losses. Carbohydrate consumption at a rate of ~30–60 g/hour has been demonstrated to maintain blood glucose levels and sustain exercise performance. Consumption of beverages containing electrolytes and carbohydrates can help sustain fluid and electrolyte balance and thereby the exercise performance[28].

Ingestion of fluid before and during exercise reduces the detrimental effects of dehydration on cardiovascular dynamics, temperature regulation and also exercise performance. Also, when carbohydrate is added to the oral rehydration solution gives added energy. By determining the optimal fluid and carbohydrate mixture, the occurrence of muscle fatigue and dehydration can be brought to minimal levels[6].

Water and electrolytes lost in excess impairs heat tolerance and also affects physical performance, thereby leading on to severe dysfunction culminating in heat cramps, heat exhaustion and heat stroke. But intake of plain water should be reduced, and instead , fluids with electrolytes are recommended[6].

ROLE OF GASTRIC EMPTYING:

The rate at which the stomach empties affects the absorption of fluid and nutrient absorption by the small intestines. A high fluid volume in the stomach is a major determining factor that speeds up the gastric emptying. Consuming 400 ml to 600 ml of fluid immediately before the exercise optimizes the beneficial effect of increased stomach volume on fluid and nutrient passage into the intestine. Then , regularly drinking 150 - 250 ml of fluid at a gap of about 15 minute intervals continually replenishes the fluid that passes into the small intestine.

PURPOSE OF ADDING SODIUM TO GLUCOSE IN REHYDRATION SOLUTIONS:

1. Glucose and sodium together facilitate the fluid uptake by the intestinal mucosa. Due to the rapid, active transport of glucose and sodium across the intestinal epithelium by the SGLT - sodium glucose transporter and thereby water is also absorbed to maintain osmotic equilibrium.
2. Addition of sodium to a fluid helps in maintaining the plasma sodium concentrations that is, it prevents the occurrence of hyponatraemia, a complication that occurs when large quantities of plain water is taken.
3. Maintaining plasma osmolality by the addition of sodium to the rehydration beverage helps also in reducing the urine output and in sustaining the sodium dependent osmotic drive to drink.

RECOMMENDED ORAL REHYDRATION BEVERAGE:

A 5-8 % carbohydrate electrolyte beverage consumed during exercise in the heat contributes to temperature regulation and fluid balance more effectively than plain Water[6].

Prolonged periods of exercise could lead on to progressive fluid and electrolytes loss from the body because sweat is secreted to help heat loss. Because dehydration can lead onto impairment of exercise capacity and can impose a problem to health, the drinking of fluid while exercising to make up for sweat losses is imperative. Carbohydrate + electrolyte fluid drinking for the extent of exercise has the twin role of giving a source of carbohydrate fuel to supplement the body's limited stores as well as providing with water and electrolytes to substitute the losses incurred due to sweating. The composition of the drinks to be taken will be inclined by the comparative significance of the want to provide fuel and fluids which, in turn depend on the intensity and duration of exercise activity, the ambient temperature, as well as humidity. Carbohydrate + electrolyte drinks seem to be much more effective in improving performance than that of plain water. Total re establishment of fluid balance following exercise is an essential part of the recovery process. Rehydration following exercise does not only necessitate replacement of volume losses, but also substitution of electrolytes, principally sodium. Some of the studies have shown that rehydration following exercise can only be obtained if the electrolytes lost in the sweat and water are replaced. Drinks with low sodium content are futile at rehydration and they could only reduce the motivation to drink water. Adding small quantities of carbohydrates to the rehydrating solutions could progress the rate of intestinal absorption of sodium and water and will give a better taste. The quantity of the rehydration beverage ingested should be greater than the amount of sweat loss to offer the enduring obligatory loss of urine. Tastiness of the beverage is a major issue when a large volume of fluid has to be taken[29].

In hyperhydration, there is intake of greater than normal body water than that is recommended to promote thermoregulation and exercise heat performance above that achieved with that of hypohydration. Increasing body water might decrease the cardiovascular and heat strain caused in exercise by increasing blood volume and reducing blood tonicity.[30]

To maintain a higher rate of work output and thereby the better exercise performance requires substitution of water losses in order to prevent dehydration. Nevertheless, exercise performance might also get limited by the availability of carbohydrate as energy source for the exercising muscles. Therefore, carbohydrate + electrolyte fluid intake during exercise, has the double role of supplying water to restore the losses produced as a result of sweating and thereby it provides a source of carbohydrate fuel to enhance the body's limited stores. (Lamb & Brodwicz, 1986; Coyle &

Coggan, 1984; Maughan & Shireffs, 1998; Murray, 1987; Singh *et al.*, 1997; Singh *et al.*, 1995; Tsintzas *et al.*, 1995). Also, Below *et al*. (1995) have shown that drinking water and carbohydrate have independent and added effects on exercise performance. When water substitution is the first priority, any isotonic or moderately hypotonic solution containing glucose and sodium will be the most effective ones (Farthing, 1988)[31].

PRE- EXERCISE GLUCOSE DRINK:

The decline in muscle tension due to previous contractile activity is called fatigue. When carbohydrate is supplemented during exercise, it delays fatigue by 30–60 minutes. Consumption of glucose drink 30 minutes before the exercise helps to improve the muscular performance and delays the incidence of fatigue[32].

EXERCISE AND NUTRITION

ORAL REHYDRATION SOLUTION:

COMPOSITION OF ORAL REHYDRATION SOLUTION(by WHO):

INGREDIENTS	g/L
Sodium chloride	3.5
Trisodium citrate	2.9
Potassium chloride	1.5
Glucose	20

WHO FORMULATION

ORAL REHYDRATION SOLUTION

Composition of Oral Rehydration Solution after reconstitution with one litre of water:

COMPOSITION	**mmol/L**
Glucose	111
Sodium	90
Potassium	20
Chloride	80
Citrate	10
Osmolarity	311

COMPARISON OF ORS, WATER, AND SPORTS DRINKS:

Various studies done so far have proved that exercise induced dehydration causes a negative impact on the exercise performance. Fluid balance should be maintained even after exercise is over. Also, muscle glycogen stores should be restored following an exercise performance. Sports drinks fulfill both these roles. Although solid food consumption can restore muscle glycogen, hydration status of an individual can be maintained only by intake of fluids. The second consensus conference on nutrition for sport held by International Olympic Committee in 2003 was concluded with the consensus statement of 2004 as follows: Sufficient fluids should be consumed during exercise to limit dehydration to < 2 % of body mass. Also, sodium should be included when there are higher sweat losses. Also, it stated that, before the start of exercise, there should be a state of euhydration[34].

SPORTS DRINK : Is a drink consumed in association with sports or exercise, either prior to or during or as recovery drink. By definition, a drink is a liquid with water as the main ingredient. Also, sports drink can contain a variety of nutrients and other substances, that would otherwise be got from food.

Their formulation is related to that of oral rehydration solutions in that water, carbohydrate, sodium are the key ingredients. Most of the sports drinks contain a carbohydrate content approximately < / = 6 % weight per volume and sodium as the main electrolyte[34].

COMPARISON OF ORS WITH OTHER DRINKS, WATER AND SPORTS DRINK VARIETIES:

	Carbohydrate (%)	**Sodium (mmol/L)**	**Potassium (mmol/L)**	**Osmolality mosm/kg**
ORS	2	45	20	250
Water	0	0	0	9
Commercial Sports drink 1	6	20	3	280
Commercial Sports drink 2	7	30	*	289
Commercial Sports drink 3	6	23	2	280
Commercial Sports drink 4	11	3	1	700
Orange Juice	10	4	45	660
Tomato Juice	3	10	7	*

*Not measured.

High carbohydrate concentrations will delay gastric emptying thereby decreasing the amount of fluid absorbed. Also, very high concentrations leads to secretion of water into intestinal lumen, thereby worsening dehydration.

Cola and lemonade variety have less sodium at 1-2 mmol/L only. But sports drinks contain about 20-25 mmol/L sodium. ORS has a higher concentration of sodium about 45 mmol/L . Though it makes drinks unpalatable, this high sodium content is an important stimulating factor in the jejunal absorption of glucose and water.

Studies by Vrijens and Rehrer, 1999 showed that most of the carbohydrate electrolyte drinks have low sodium content about 20-25 mmol/ L and although this seemed to be adequate in most situations, but may not be enough when sweat losses and fluid intake is higher, especially in long duration events.

Drinking a properly formulated carbohydrate – electrolyte drink allows for an improved exercise performance, but if the exercise leads to excess sweat loss, there should be a moderately high amounts of sodium in the drink, about 50 mmol/L. A source of substrate is not necessary for rehydration, but, a small quantity of carbohydrate about 2% as in ORS may improve the rate of intestinal uptake of sodium and water[34].

Studies by Andrews et al, 2003 and Arkinstall MJ et al 2001 have shown that one of the major causes of fatigue during prolonged exhaustive exercise is loss of fluid, electrolyte and reduction of body's carbohydrate stores[35].

Studies by G.L.Khanna and I.Manna have demonstrated that there were significant improvements in total endurance time, heart rate responses, and in blood lactate removal during exercise at 70% VO_2max after addition of 5 g % carbohydrate + electrolyte drink. It was interpreted that carbohydrate + electrolyte drink can increase endurance performance and activate lactate removal thereby delaying the onset of fatigue[29].

ELECTROLYTE SUPPLEMENTATION AND EXERCISE

Studies done by Noakes et al 1985 and Maughan et al 2001 have shown that sodium stimulates glucose and water uptake in small intestine. This helps to maintain extracellular fluid volume as well as maintain the stimulus to drink[50].

Recent studies show that Exercise Associated Hyponatremia (EAH) has emerged as an important complication of protracted endurance activity. It denotes the occurrence of hyponatremia in individuals who engage in physical activity of longer duration and is defined by a serum or plasma sodium concentration below the normal reference range of the laboratory which performs the test. For most laboratories, this is a $[Na+] < 135$

mmol / L. EAH can either occur during or after the physical activity, and very often it occurs in such events that last for a period of more than four hours although very rare incidents have been reported in events of shorter duration. In general, milder forms of hyponatremia ([Na+] between 130 – 134 mmol / L) are somewhat asymptomatic and they resolve without treatment. Early features are bloating, ‘‘puffiness’’, nausea, vomiting, and headache. As the severity progresses, more serious signs and symptoms can develop due to the worsening cerebral edema, which includes confusion, disorientation, and agitation, seizures, respiratory distress (pulmonary edema), obtundation, coma and death[13].

Exercise associated hyponatraemia is caused primarily by the consumption of fluid in excess of urinary and sweat losses.[13]

SODIUM SUPPLEMENTATION IN EXERCISE

Sodium, potassium and chlorine, collectively termed ‘electrolytes’, remain dissolved in the extracellular and intracellular fluids as electrically charged particles or as ‘ions’. Electrolytes are substances that can modulate fluid exchange between body fluid compartments. Sodium is one of the important electrolyte present in the plasma as well as in the extra cellular fluid compartment[6].Sodium chloride is the major electrolyte in sweat. Potassium, calcium, and magnesium are the other electrolytes present in sweat in smaller amounts[25]. The requirement for sodium replacement originates from its role as the major ion in the extracellular fluid[29].

POTASSIUM SUPPLEMENTATION IN EXERCISE

Potassium is the chief intracellular mineral[6].Potassium is a cation that is commonly included in rehydration beverages. It is primarily distributed in the intracellular space. Thereby, it favours refilling of intracellular fluid space following rehydration[36].

It is suggested that addition of potassium, the major cation in the intracellular space, to sports drinks and other rehydration drinks, would enhance the replacement of intracellular water after exercise thereby promoting rehydration (Nadel *et al*., 1990: Maughan *et al*., 1994)[29].

Electrolytes that are lost in sweat like sodium and potassium must be completely restored to re-establish euhydration among persons involved in intense physical activity.(Evidence statement)[28].

The purpose of pre – exercise fluid intake is to top up body stores of water in order to accommodate any of the future sweat losses. Also, water intake during exercise has the value of preventing dehydration that occurs late in the exercise period. Drinking water following exercise is recommended to replace the body water deficits. Several reports show that humans obtain 20–25% of their daily water ingestion from food. Fruits, vegetables and other high - moisture content foods, for that reason, contribute to total fluid intake. In addition, ingestion of other nutrients and ingredients can impact drinking behavior, absorption, distribution and retention of water. All these factors contribute to the person's hydration state. Therefore, a food's hydration value is got from the relations between its water content and the presence of co-nutrients and ingredients. Commercial sports drinks are formulated with carbohydrates and electrolytes. This serves to provide the individual with energy, also facilitates water absorption. It also helps to replace the electrolytes lost through sweat. It also helps to enhance flavouring in order to increase voluntary drinking behavior[36].

MUSCLE FATIGUE

The chief and foremost determining factor of the continuation of exercise for longer duration is the ability of the muscle to meet out its energy demands. Conversely, fatigue is not only dependent on the result of depletion of energy supplies. As a substitute, metabolic by products seem to be imperative factors in the onset of fatigue. Fatigue may potentially come at any of the points implicated in muscle contraction, starting from the brain to the muscle cells. In addition to that, the cardiovascular and respiratory systems which maintain energy supplies like fatty acids, glucose and oxygen delivery to the exercising muscle, can also contribute[20].

Fatigue denotes the decline in muscle tension or force capacity with repeated stimulation or during a given time period. It also indicates the perceived alterations of increased difficulty to achieve a desired submaximal or maximal outcome in a physical activity. Many complex voluntary movements produce motor fatigue, with each type of movement relating to specific activity that needs it.

Voluntary muscle actions exhibit four main components of fatigue and fatigue occurs from disruption in the chain of events between the central nervous system and the muscle fibre.

1. Central nervous system : Exercise induced alterations in the levels of neurotransmitters like serotonin, dopamine and acetyl choline can alter the psychic or perceptual state to disrupt one's physical activity.
2. Reduced glycogen content in the active muscle fibres relates to fatigue during prolonged intense physical activity. This "nutrient fatigue " occurs even with adequate oxygen available to create energy through aerobic pathways. Depletion of phosphocreatine and a reduction in total adenine nucleotide pool also accompanies the fatigue state in extended submaximal effort.
3. Lack of oxygen and augmented levels of blood and muscle lactic acid relate to muscle fatigue in short term maximal exertion.
4. Fatigue occurs at the neuro muscular junction when an action potential fails to navigate from the motor neuron to the muscle fibre[6].

TYPES OF FATIGUE:

There are two types of fatigue, the peripheral and central fatigue. Peripheral fatigue involves the reduction in the ability of the muscles to do work due to problems occurring anywhere from the chain of command from the neuro muscular junction transmission upto the level of actin – myosin cross bridging. But, the stimulus for the initiation begins in the brain.

Central fatigue, can occur if changes that occur within the central nervous system reduce the ability to send a voluntary signal to the neuro muscular junction. Approaches designed to counteract peripheral fatigue and thereby increase the athletic and physical performance involves alterations in the nutritional and training aspects. Both central and peripheral fatigue can occur in individuals at rest as well as during vigorous types of exercise. Central fatigue is commonly seen during normal daily activities. The central fatigue hypothesis states the role of serotonin and dopamine in the causation of central fatigue during prolonged exercise. Newsholme et al were the first to report the role of 5-HT in the causation of central fatigue. This hypothesis suggests that whenever there is an increased serotonin amounts in the brain, it could be the cause of central fatigue during vigorous and prolonged exercise. This affects the sports as well as exercise performance[37].

FACTORS IMPLICATED IN MUSCLE FATIGUE:

During heavy exercise, when P_i (Phosphate) and lactate accumulate in the cytoplasm of the muscle fibre, it accounts for fatigue of the muscle fibres. When the lactate accumulates to levels as high as 15 to 26 mM, it decreases the myoplasmic pH (from ≈7 to ≈6.2) and inhibits actin – myosin interactions. This decrease in pH reduces the sensitivity of the actin - myosin interaction to calcium by altering calcium binding to troponin C and by decreasing the maximum number of actin – myosin interactions. Fast – twitch fibers appear to be slightly more sensitive than slow – twitch muscle fibers to the effects of pH. P_i has also been implicated as an important factor in the development of fatigue during intense exercise. A number of other factors, including glycogen depletion a localized increase in ADP, intracellular elevation of K^+, and generation of oxygen free radicals, have also been implicated in various forms of exercise induced muscle fatigue. Finally, the central nervous system contributes to fatigue, particularly the manner in which fatigue is felt by the person. Fatigue has been described as a protective mechanism to lessen the risk of muscle cell injury.

Generally, physical fatigue may be defined as a homeostatic disturbance produced by work. The basis for the perceived discomfort (or even pain) probably involves many factors which may include a decrease in plasma glucose level and metabolite accumulation[20].

FATIGUE MODELS :

According to a study by Professor T D Noakes, University of Cape Town, South Africa, catastrophic model of muscle fatigue proposes that exercise is regulated by metabolic changes in the peripheral muscles, independent of any regulation by the central nervous system . The classical theory, since defined as the cardiovascular / anaerobic / catastrophic model of exercise physiology postulates that fatigue during high intensity exercise of short duration is due to a skeletal muscle ‘‘anaerobiosis’’. It occurs when the oxygen required by the active skeletal muscles exceeds the heart's capacity to further supplement oxygen delivery to exercising muscle by increasing the cardiac output. Because of this any supplementary increase in energy generation in the active muscles can come only from ‘‘anaerobic’’ metabolism leading on to fatigue, as the maximum oxygen intake is insufficient, lactic acid accumulating, a continuously increasing oxygen debt being incurred, thereby leading to fatigue[38].

THE CENTRAL FATIGUE HYPOTHESIS:

Muscular fatigue is commonly defined as a failure to sustain the needed or expected force or power output. The causes of muscle fatigue involve specific alterations within the muscle fibre itself, which includes transmission of the neural stimulus to the muscle at the motor end plate and propagation of that stimulus along and into the muscle fibre, interruption in calcium release, and its uptake into the sarcoplasmic reticulum, and several other metabolic events that impair energy stores and muscle contraction[39]. All these are the causes of peripheral fatigue[40]. Whereas, in central fatigue the changes are related to the central nervous system function and it cannot sensibly be explained by peripheral markers of muscle fatigue[41].

SEX DIFFERENCES IN HUMAN SKELETAL MUSCLE FATIGUE:

Definition of fatigue proposed by Bigland – Ritchie et al : A reduction in the maximum force generating capacity of the muscle. The term muscle endurance is used to express the ability to resist fatigue[42]. It can also be defined as the time to failure to maintain target tension. Females generally exhibit greater relative resistance to fatigue than males as per the studies done by Fulco C.S et al, Maughan R.J et al, Miller, A.E.J et al and West W et al. In studies by Maughan et al[43], females had an advantage in fatigue resistance that incorporate submaximal contractions involving knee extensors, elbow flexors (in studies by Miller A.E.J et al). Also, various studies in the handgrip muscles, adductor pollicis muscles have demonstrated this.[44]

MUSCLE BLOOD FLOW:

A hypothesis was proposed by Rowell, 1974, 1983, 1986, Johnson & Rowell, 1975 that when exercise is done in heat stress, blood flow to the actively contracting skeletal muscle would be reduced because of the elevated skin blood flow. Going against this proposal, studies in humans by Kirwan et al 1987, Savard, 1988, Nielsen et al 1990, 1993, 1997, in rats by Laughlin & Armstrong, 1983 and in miniature swine by Armstrong et al 1987 & McKirnan et al 1989 showed that blood flow to active skeletal muscles is either maintained or even gets increased when heat stress is superimposed while undergoing exercise[45].

RECENT STUDIES IN SKELETAL MUSCLE FATIGUE:

Studies by Hakan Werterblad et al : Skeletal muscles are like extraordinary motors which can respond quickly and accurately to instructions from the motor cortex. They can increase their force production up to 40 N / cm^2 in < 100 milliseconds. But, whenever there is a repeated activation of the muscles, it leads on to a reduction in the force production and fatigue sets in. Fatigue occurs acutely in high intensity exercise which is mainly due to factors related to increased energy metabolism. Peripheral and central fatigue are the two types of fatigue in humans. Peripheral causes of fatigue include : 1) those which are related to excitation contraction coupling leading to reduced intracellular calcium concentrations during contractions and 2) related to damage to the individual contractile proteins. Energy consumed by skeletal muscles increases by about 100 fold when one goes from rest to do high intensity exercise. When the aerobic capacity of muscles is exceeded, they become dependent on anaerobic metabolism. When the glucose gets broken down by anaerobic pathway, it leads to lactic acid accumulation. Lactic acid dissociates into lactate and hydrogen ions. H^+, than lactate, is one of the important cause of muscle fatigue[46].

BORG CRITERIA

The subjective perception of effort, and fatigue is of a relatively complex nature and consists of contributing factors: sensation from the organs of circulation and respiration, from the muscles, the skin, the joints, etc. from a subjective point of view it can be described as pedal resistance, effort, fatigue, strain exertion, heat, pressure, pain, anxiety, etc. while doing short duration work on the bicycle ergometer, where the muscle force appears to be crucial for achievement, it may be suitable for healthy persons to speak of perceived or evident force, effort, exertion, or pedal resistance. For work of rather long duration, where there is more stress on the organs of circulation and where the length of time and amount of work play a major part, it may be more suitable to speak of perceived exertion, laboriousness, or fatigue or if the work is stressing, perceived exhaustion. The perception of exertion can be defined as the perception which makes the subject to respond to stimulus in accordance with the given psychosocial method and the instruction:

1. How heavy it feels to pedal, how great the pedal resistance is, as in short time work and

2. How laborious it feels to work, as in work of long duration.

The simple rating scale used by Borg in 1962 explains a study on the method for determining physical working capacity from subjective ratings. This scale has been studied in a more extensive investigation of physical working capacity. The scale consists of 21 grades where all the odd scale values from 3 to 19 have been indicated with the aid of verbal expressions. These verbal expressions were chosen in such a way that the scale should receive a good inter - individual validity, i.e. only well – defined terms with a comparatively good inter- subjective, constant meanings were chosen[47].

BORG – PERCEIVED EXERTION SCALE:

SCALES	PERCEIVED EXERTION-VERBAL SCALES
3	Extremely light.
5	Very Light
7	Light
9	Rather Light
11	Neither light, nor laborious.
13	Rather laborious.
15	Laborious
17	Very laborious
19	Extremely laborious

RATING OF PERCEIVED EXERTION

RPE and PHYSICAL EXERTION:

Studies by Joyce Steed et al showed RPE- Rating of Perceived Exertion to be a useful tool for prescribing exercise intensity. It may also serve as an added measure to standard physiological responses associated with blood lactate concentration. RPE may be considered as an effective tool to estimate lactate threshold and blood lactate concentrations when determining exercise intensity. In this study, nine subjects did a continuous, incremental level running treadmill protocol to determine VO_2 and velocity, associated with lactate threshold and blood lactate concentration of 2.5 mM and 4.0 mM. The subjects were given directions for interpreting the RPE using Borg 6-20 point scale to give an overall rating of perceived exertion. The results indicated that RPE provides a good estimate of blood lactate concentration during a 30 minutes running at exercise intensities corresponding to lactate threshold and blood lactate concentration of 2.5 Mm and 4.0 Mm.[48]

BICYCLE ERGOMETER:

Ergometer in general, is an exercise machine that is equipped with an apparatus for measuring the work performed by exercising. It is an instrument for measuring the amount of work done by human muscles. In Greek, ergon means work and metron means to measure. Therefore, a bicycle ergometer is a bike fitted with a device to measure mechanical work expended during a period of physical exercise[49].

Submaximal performance testing is a way of estimating VO_2max or aerobic fitness in sports medicine. The test protocol do not reach the maximum of the respiratory and cardiovascular systems. First submaximal cycle test was developed by Astrand and Ryhming in 1954, called Astrand Test[50].

PARAMETERS IN BICYCLE ERGOMETRY:

Calorie : A small calorie or a gram calorie (symbol : cal or c) is the amount of energy needed to raise the temperature of one gram of water by 1 degree centigrade. The large calorie or kilogram calorie or dietary calorie or nutritionist's calorie or food Calorie (symbol : Cal / kcal) is the amount of energy needed to raise the temperature of kg of water by 1 degree centigrade[6].

WORK DONE & POWER OUTPUT:

Refers to the flow and exchange of energy within a living system. The first law of thermodynamics is related to the bioenergetics and it states that the energy cannot be created or destroyed but transforms from one form to another without being depleted.

Biologic work takes one of the three forms:

1. Mechanical work of muscle action : Work done by the muscle during its action provides the most obvious example for energy transformation. The actin and the myosin filaments of the muscle fibre directly convert chemical energy into mechanical energy.

2. Chemical work.

3. Transport work.

Calculation of cycle ergometer work:

Mechanical efficiency (%) = External work accomplished * % of energy expenditure * 100.

External work accomplished or energy output = F * D (kg * m)

and is expressed as kcal units.

1 kcal units = 3087 ft – lb (or) 426.4 kg.m

This can be determined easily by cycle ergometry or by stair climbing or bench stepping[6].

MET – METABOLIC EQUIVALENT OF TASK

MET is defined as multiples of resting metabolic rate. One MET equals a resting Oxygen consumption of about 250 ml / minute for an average sized man and 200ml / minute for an average sized woman.

Physical activity performed at 2 METs requires twice the resting metabolism about 500ml of O_2 / minute for a man.

Oxygen consumption per unit body mass can also be expressed as :

1 MET = 3.5 ml / kg / minute.

2 MET = 7.0 ml / kg / minute.

The five level classification of physical activity based on energy expenditure:[6]

LEVEL OF ACTIVITY & METs

LEVELS	ENERGY EXPENDITURE IN kcal/minute	ENERGY EXPENDITURE METs
Light	2.0 – 4.9	1.6 – 3.9
Moderate	5.0 – 7.4	4.0 – 5.9
Heavy	7.5 -9.9	6.0 – 7.9
Very Heavy	10.0 – 12.4	8.0 – 9.9
Unduly Heavy	>/=12.5	>/= 10.0

RATE PRESSURE PRODUCT(RPP)

One common estimate of myocardial workload and resulting oxygen consumption is the product of peak systolic pressure which is measured at the brachial artery and the maximum heart rate. This is an index of relative cardiac work and is also termed as the Double Product and it is closely related to the myocardial oxygen consumption and coronary blood flow in healthy subjects over a wide range of exercise intensities.

RPP is calculated as follows:

RPP = Systolic blood pressure * Heart rate.

Changes in the heart rate and systolic blood pressure contributes equally to changes in rate pressure product. Typical values for RPP range from : 6000 at rest (at a heart rate of 50 beats / minute and systolic blood pressure 120 mm Hg) to 40,000 (at a heart rate of 200 beats / minute and a systolic pressure of 200 mm Hg) or above depending on the intensity and mode of activity. RPP provides an objective yardstick to evaluate the effects on cardiac performance. Prolonged and intense aerobic training allows cardiac patients to achieve a higher exercise RPP[6].

The rate pressure product (RPP) is correlated very well to myocardial oxygen consumption in young individuals (Kitamura .K et al) as well as in cardiac patients (Gobel FL et al). An acute bout of low intensity exercise decreases the post exercise RPP below the resting levels, thereby reducing myocardial oxygen consumption. This reduces the cardiovascular risks following exercise. Whereas, moderate and high intensity exercise bouts cause greater increase in RPP during exercise and a failure of RPP to fall below the baseline values. This has got clinical implications in relation to prescribing exercise in cardiac rehabilitation programs. The cause for the post exercise decrease in heart rate, blood pressure and RPP in low intensity exercise is due to the reduction in the sympathetic activity to the heart and blood vessels following exercise. In moderate and high intensity exercise, according to the studies of Halliwill et al, baroreflex control of heart rate and blood vessels get distinctly regulated[51].

VO_2max:

Maximal oxygen uptake (VO_2max) is the basic measure of exercise physiology. VO_2max, in combination with the conception of a VO_2 plateau, has been described as “the single most influential concept in modern exercise physiology” according to Noakes TD et al. VO_2max is extensively documented as both a depiction of the functional limits of the cardiovascular system as well as a gauge of aerobic fitness[53].

VO_2max NORMAL VALUES:

Group	VO_2max values(ml/(kg.min)
Untrained adult males	35-40
Untrained adult females	27-31
Elite male runners	Upto 85
Elite female runners	Upto 77

METHODS TO MEASURE VO_2max:

1. Fick equation:

$$VO_2max = Q*CaO_2 - CvO_2$$

Where, Q=cardiac output

CaO_2 =Arterial oxygen content.

CvO_2=venous oxygen content

$CaO_2 - CvO_2$=Arterio – Venous Oxygen difference.

2. **Uth-Sorensen-Overgaard-Pederson Estimation:**

   Based on maximal and resting heart rate.

   VO_2max = (HRmax/HRrest)/(15.3 mL/kg.min)

3. **Cooper Kenneth test:**

   VO2max=d_{12}-(504.9/44.73)

   Where d_{12}= distance in metres covered in 12minutes.

4. Astrand Ryhming Nomogram (Indirect method).

5. Rockport fitness walking test.

6. First beat method[53].

AEROBIC CAPACITY:

The **ACSM (American College of Sports Medicine)** had previously recommended 20 to 60 minutes of exercise performed at 40 / 50 – 85 % HRR (Heart Rate Reserve) or $\dot{V}O_2R$ for most adults, where 40% is considered a threshold level for deconditioned individuals and 50 % is a threshold for average adults. There has been previous evidence suggesting that exercise of a higher intensity will result in greater gains in cardiovascular fitness[54].

Since the formulation of the Exercise Is Medicine (EIM) initiative, American College of Sports Medicine has published a position stand, and provided a universal recommendation that healthy adults to undergo 150 minutes of moderate dynamic physical activity per week[55].

MATERIALS & METHODS

MATERIALS & METHODOLOGY

MATERIALS:

STUDY DESIGN:

This is a Cross Sectional study.

STUDY PLACE:

This study was performed in the Research laboratory of the Department of Physiology, Coimbatore Medical College, Coimbatore.

STUDY PERIOD:

Study period was for one year. The study period extended from July 2016 to June 2017. About fifty male students were recruited after obtaining consent to participate in the study.

The ethical committee of the Coimbatore Medical College approval was obtained prior to the commencement of the study.

INCLUSION CRITERIA:

1. Healthy males.
2. Age: 18 - 25 years.

EXCLUSION CRITERIA:

1. Women.
2. Anaemic individuals.

3. Smokers.

4. Presence of diabetes mellitus, hypertension.

5. Those who are on drugs for any illness.

6. Those who refused to consent for the study.

SELECTION OF SUBJECTS:

The subjects were 50 healthy male students in the Peelamedu area, Coimbatore were recruited to the study. The subjects were explained in detail about the study and informed consent was obtained. Each subject served as his own control.

MATERIALS USED FOR THE STUDY:

Proforma - To obtain detailed history and to record the clinical examination findings. Subjects were given a pre - test questionnaire for assessing nutritional status, cardio respiratory profile.

- Portable standard weighing machine – to record the body weight in kilograms.
- Stadiometer – was used to measure the standing height of the subject in centimeters.
- Mercury Sphygmomanometer - To record the systolic and diastolic blood pressure in millimeters of mercury.
- Finger Pulse oximeter - To record the oxygen saturation as percentage.
- Computerised Bicycle ergometer (Ergobike 8008 TRS Pro) – Electronically braked.

METHODOLOGY

The institutional ethical committee approval was obtained prior to the commencement of the study and the subjects were selected and grouped. The subjects in this study included healthy males aged 18-25 years the procedure was explained in detail to the subjects and written informed consent form was obtained from the subjects who were willing to participate in the study and the study was carried out.

PRE-REQUISITES:

1. Subjects are requested not to take any nutritional supplements or ergogenic aids atleast for two weeks prior to the study.

2. Subjects are also advised not to consume any of the supplements during the course of the study.

The study was conducted in many sessions. The subjects were advised to come at a standardized time of the day, preferably in the morning. They were advised to wear light clothing. They were advised not to take breakfast. The subjects were asked to report at the department by 8.30 A.M. Subjects were explained about the whole procedure in detail and were motivated before the start of exercise. They were advised to inform immediately if they felt any sort of discomfort, fatigue or dizziness.

Subjects rested in supine position for 15 minutes before the start of exercise.

Then, the basic parameters were recorded in the proforma provided to them.

STUDY PROTOCOL:

1. Detailed history was elicited from the subjects.

2. Measurement of anthropometric indices:

Weight of subject: By using a portable standard weighing machine, weight in kilograms was recorded . The weight of the subjects were recorded on the same platform beam balance, with barefooted and with minimum clothing on the body. The subject was made to stand erect on the center of the platform without touching anything else. Weight of the subjects were recorded in kilograms up to an accuracy of 100 grams.

Height of subject : By using a stadiometer , height of subjects in centimetres was measured. The subject was made to stand on a flat floor without wearing shoes with feet parallel and with heels, buttocks, shoulders and back of the head touching the rod. The head was held perfectly erect with lower border of the orbit placed in the same horizontal plane as the external auditory meatus and arms hanging by the sides in a normal manner. By using this vertical measuring rod, height was measured.

A wooden block was gently lowered to make contact with pressure just to crush the hair and the reading was taken.

BMI of subject: Body Mass Index was calculated using the Quetelet's index.

$$BMI = Weight\ (Kg) / Height^2\ (m).$$

A thorough clinical examination of the study subjects was done. It consists of general examination, systemic examination of the respiratory system, cardiovascular system, abdomen and central nervous system in order to rule out any systemic illnesses.

1.After the subject was made to sit calmly for about ten minutes, the pulse rate, systolic blood pressure, diastolic pressure, oxygen saturation respiratory rate were recorded.

SESSIONS IN THE STUDY:

SESSIONS	**WATTS**	**ORS INGESTION**
I	50 W	Without ORS
II	50 W	With ORS
III	75 W	Without ORS
IV	75 W	With ORS
V	100 W	Without ORS
VI	100 W	With ORS

2. In the first session, the subjects performed cycling exercise in bicycle ergometer without ingestion of ORS. They performed exercise at 50 watts power at 60 revolutions per minute, until they were able to maintain doing cycling at moderate range of Borg criteria, (heart rate level between 110-130/minute). The SpO_2 at peak of the exercise level was also recorded. The systolic blood pressure and diastolic blood pressure were recorded at the end and also at five and fifteen minutes of completion of exercise. The subjects were asked to discontinue the exercise if they found any difficulty like dizziness, breathing difficulty or undue fatigue. The following parameters were also recorded.

3.RECORDING OF PARAMETERS:

I. WORK DONE:

1. Energy expenditure(c).
2. Total distance travelled(in km).
3. Cycling duration (minutes) for which the subjects maintained in the moderate level of Modified Borg Criteria (110-130 beats per minute).

The subjects were asked to come for the second session of exercise after a gap of two days. They were asked to consume WHO – Standard ORS solution – ORS mixed in a liter of water two hours prior to the study.

BICYCLE ERGOMETRY EXERCISE

RECORDING OF PARAMETERS IN PROGRESS

They were advised not to take breakfast in the morning. They were advised to wear light clothing.

After resting for ten minutes and recording of basic parameters, the subjects did exercise at 50 watts in bicycle ergometer. The parameters were then recorded.

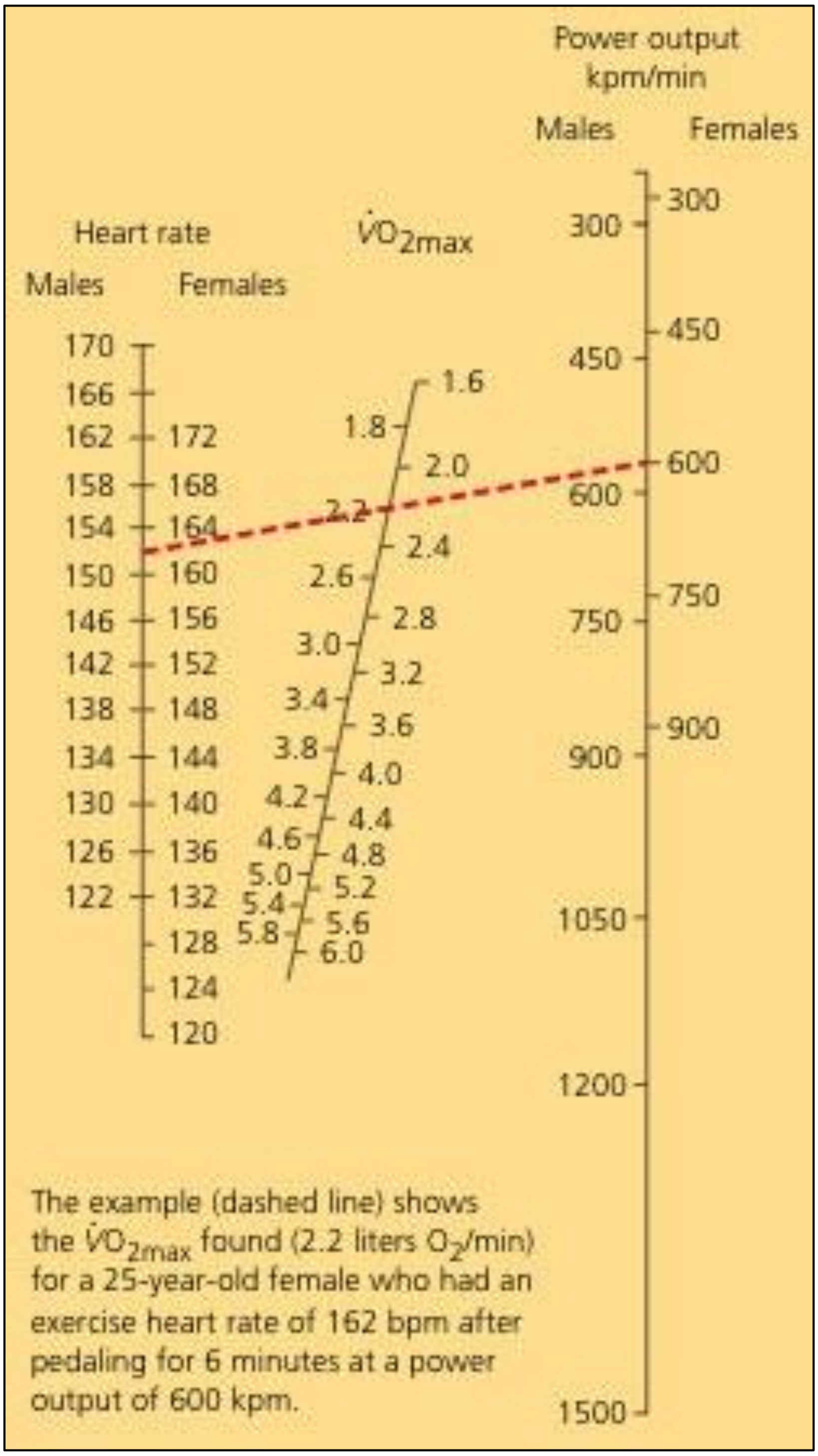
The subjects did the cycling exercise in a similar manner, two sessions each, without and with ORS consumption, at 75 watts and at 100 watts and the recording of parameters were done.

II. VO_2max:

In the last session, the subjects were asked to come for the recording of VO_2max. Indirect method was used to calculate VO_2max as the direct method is tedious and time consuming. The subjects were asked to do cycling exercise in two sessions, without ORS and with ORS.

The subjects underwent a 6 – minute cycling exercise, a sub-maximal test at 5 minutes to 6 minutes duration. Then the Astrand Ryhming Nomogram was used to plot the VO_2max. The watts was plotted against the maximal heart rate at which the person can cycle to maximum limit and the VO_2max value was obtained from graph. This is an indirect method of measuring the VO_2max. Single-stage, six minute submaximal cycling protocol to estimate VO_2max using an Astrand – Ryhming Nomogram is as follows:

ASTRAND RYHMING NOMOGRAM



Pre – test procedure:

85% of maximum heart rate using formula 208 – (0.7*age) is estimated. It was made sure that the subjects did not exceed this maximum heart rate limit during the testing. The rating of perceived exertion (RPE) was discussed with the subject and he was asked for perceived exertion levels throughout the test period. The seat height was adjusted and the subject was asked to do a 2-3 minute warm up at a lower intensity cycling.

Then the subject was asked to do a 6 - minute cycling during which time the heart rate was maintained between 120 to 170 beats per minute. The test was terminated if the subject exceeded 85 % of the age predicted maximum heart rate. The subject is also advised to stop cycling if he had any chest pain, shortness of breath, dizziness or nausea.

The workload for the subjects was from 50-100 watts(unconditioned males). The exercise intensity was increased if the heart rate was < 120 bpm and decreased if the heart rate was nearing 170 bpm. RPE and HR were recorded each minute. Blood pressure was recorded at the 4th minute mark. The subject's heart rate at 5th and 6th minutes were recorded and the average of the values were taken. After completion of cycling, the subject was asked to cool down, by doing a 3-5 minutes cycling at a lower intensity, till the HR and breathing returned to normal.

Using Astrand Ryhming Nomogram, a line was drawn from the averaged pulse rate / heart rate through to the workload (watts) at which the subject was cycling. The place in VO_2max at which the line intersects is used to determine the subject's maximum oxygen uptake. VO_2max is then calculated using the age correction factor (15 years -25 years: 1.10 -1.00). In the next session, the subjects performed the same after consumption of ORS.

III. RATE PRESSURE PRODUCT:

The Rate Pressure Product (RPP) was calculated using the formula :

RPP = Maximal heart rate * systolic blood pressure.

It is also called as MTTI – Myocardial Tension Time Index. It was calculated for all the sessions.

IV. METABOLIC EQUIVALENT OF TASKs (METs):

The METs was also calculated for different sessions. This was done using the parameters like watts, body weight and the time duration of the exercise.

All the data were collected and entry made in Microsoft excel sheet and statistical analysis was done using SPSS version 22.

RESULTS

STATISTICAL ANALYSIS

The data collected from the selected subjects were recorded in a Master Chart. Using **Statistical Packaging of Social Science (SPSS 22) version** software, mean, standard deviations and 'p' values were calculated. **Unpaired 't' test** was used to compare the mean values of cycling parameters like cycling distance, duration and energy expenditure. From the basic parameters, the RPP, VO_2max and the METs were calculated and mean values were derived. **ANOVA** test was used for comparing the means of METs and RPP values. **Pearson's correlation coefficient** was calculated using Excel software. 'p' value less than 0.05 was considered to denote a significant relationship.

Microsoft word & excel were used to create the tables, charts and graphs.

RESULTS

Study population

A total of 50 males were included in the study. The subjects served as their own controls. Among them 25 males had normal BMI and 21 subjects were overweight males and 4 were obese.

The mean age among the study population was 21.58. The mean weight and height was 59.16 and 152.3 respectively. The mean BMI was 25.56.

Table 1: Data showing mean values of different parameters among study population

Variables	Subjects
Participants	N=50
Mean age (years)	21.58
Mean Height(cm)	152.3
Mean Weight(kg)	59.16
Mean BMI	25.56

Of the total 50 subjects who had participated in the study, the mean age was 21.58. Their mean weight was 59.16 and mean height was 152.3. Their mean BMI was 25.56.

Fig:1: Age distribution in study population

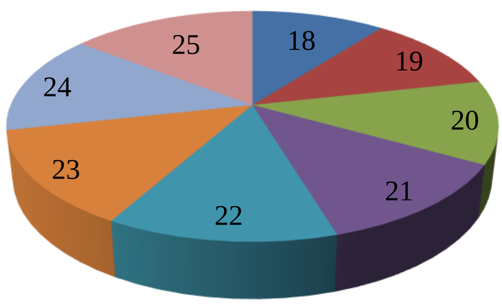


Table:2 : Group of subjects based on BMI.

Group	Number	Percentage(%)
Normal	25	50
Overweight	21	42
Obese	4	8
Total	50	100

Of the total 50 subjects, 25 were in the normal BMI group, 21 were in overweight group and 4 were in the obese group.

Fig:2:Percentage distribution of BMI groups

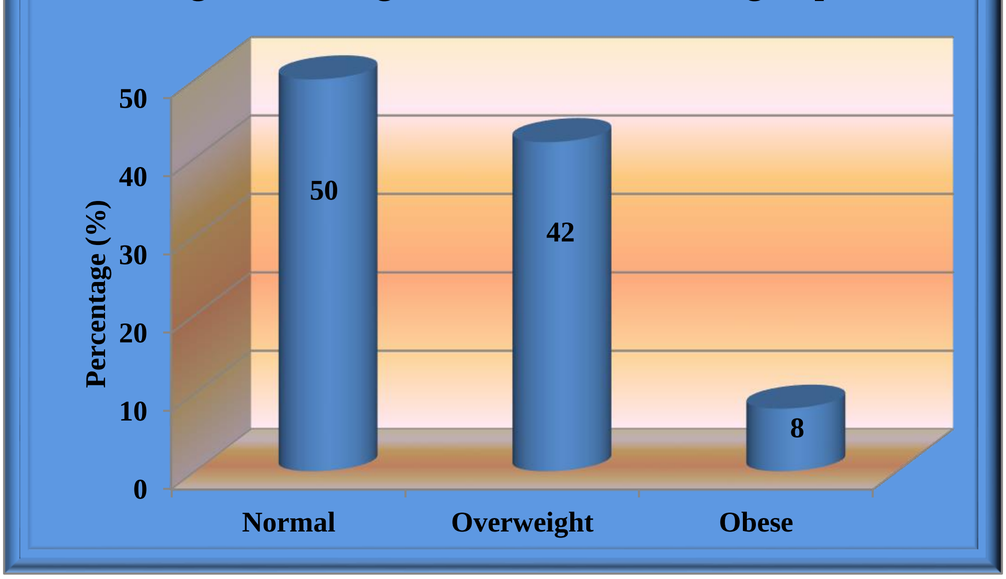


Table 3: Comparison of cycling distance in 50W session I (without ORS) and II(with ORS)

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session I	2.60	0.56	2.96	1.26	2.85	0.31	0.047*
Session II	2.95	0.53	3.03	0.70	3.30	0.37	

***-p value <0.05 – significant.**

There was significant difference in cycling distance between 50 Watts session I(without ORS) and session II(with ORS). Hence the groups were comparable.

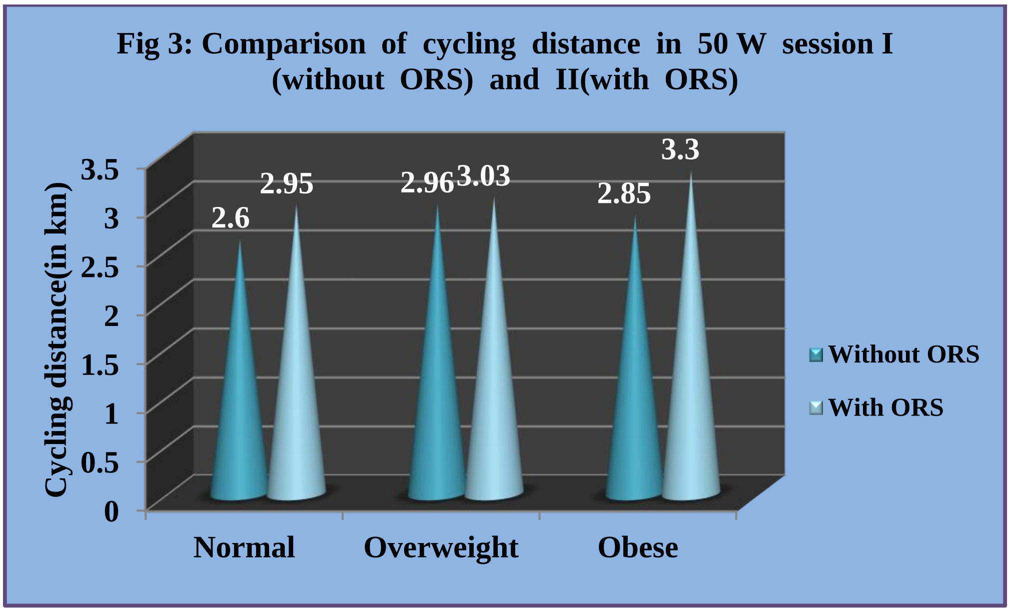


Table 4: Comparison of energy expenditure (in calories) in 50 W sessions I (without ORS) and II (with ORS).

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session I	225.95	77.88	233.92	76.29	171.50	20.27	0.047*
Session II	250.10	75.25	250.92	78.45	195.75	32.98	

***p value< 0.05 -significant**

There was significant difference in energy expenditure between 50 Watts sessions I (without ORS) and session II (with ORS). Hence the groups were comparable.

Fig 4: Comparison of energy expenditure in 50 W session I(without ORS) and session II(with ORS)

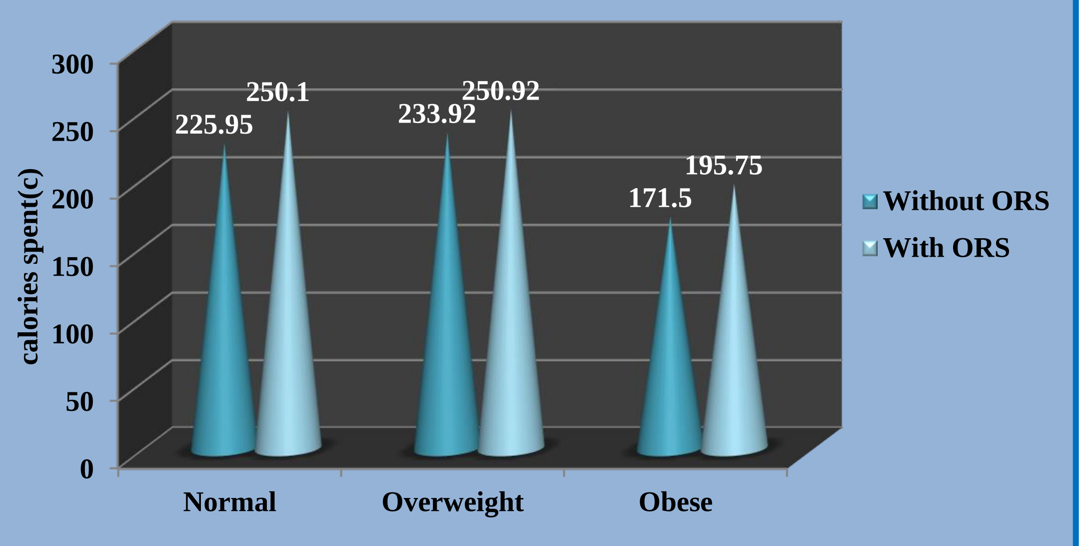


Table 5: Comparison of cycling duration in 50 W session I(without ORS) and II (with ORS)

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session I	11.90	3.59	13.56	4.84	13.50	1.91	0.00*
Session II	14.95	4.00	15.84	5.03	17.75	2.98	

***p value< 0.01 - Significant**

There was significant difference in cycling duration between 50 Watts session I(without ORS) and session II(with ORS). Hence the groups were comparable.

Fig 5: Comparison of cycling duration in 50 W session I (without ORS) and II(with ORS)

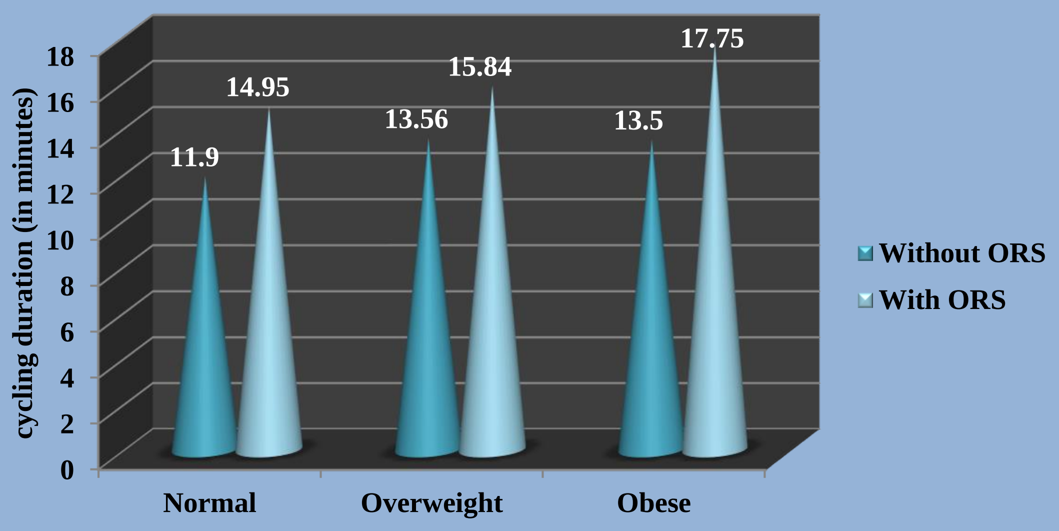


Table: 6: Comparison of cycling distance in 75 W session III (without ORS) and IV (with ORS)

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session III	2.52	0.49	2.61	0.55	2.7	0.25	0.000*
Session IV	2.67	0.45	2.82	0.48	2.87	0.33	

*** p value< 0.001 - significant**.

There was significant difference in cycling distance between 75 Watts sessions III (without ORS) and session IV(with ORS). Hence the groups were comparable.

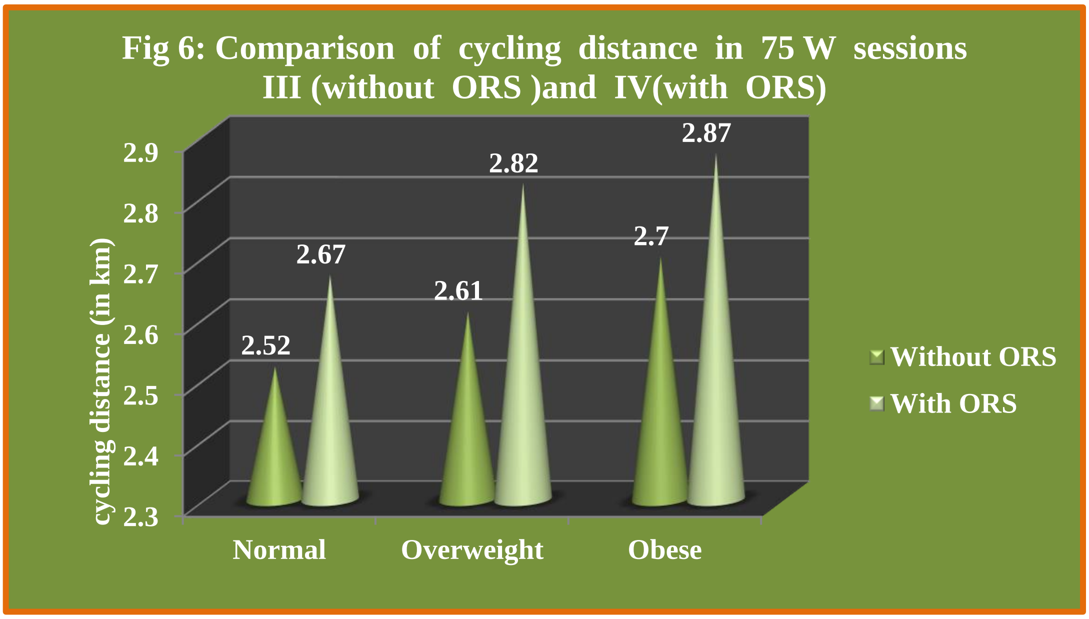


Table 7: Comparison of energy expenditure in 75 W session III (without ORS) and IV (with ORS).

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session III	221.90	71.71	227.04	66.23	182	29.08	0.001*
Session IV	233.19	70.35	232.52	69.03	204	32.58	

***p value <0.01-significant.**

There was significant difference in energy expenditure between 75 watts sessions III (without ORS) and session IV(with ORS). Hence the groups were comparable.

Fig 7: Comparison of energy expenditure in 75 W sessions III (without ORS) and IV(with ORS)

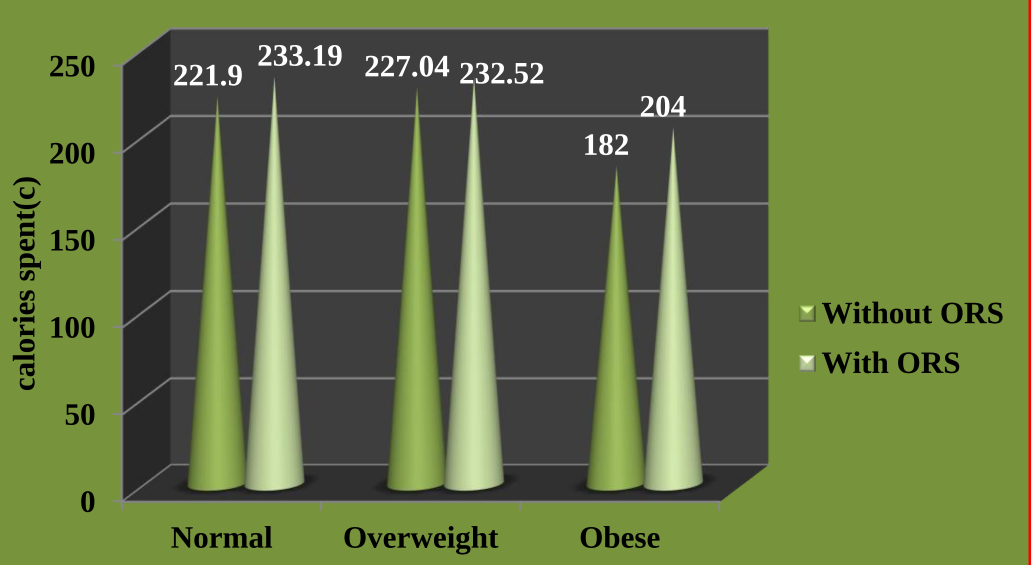


Table 8: Comparison of cycling duration in 75 W sessions III (without ORS) and IV (with ORS).

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Session III	13.62	3.59	13.96	3.92	15.75	2.98	0.000*
Session IV	16.19	3.91	16.68	3.81	18.25	2.5	

***p value < 0.001 - significant**

There was significant difference in cycling duration between 75 watts session III (without ORS) and session IV(with ORS). Hence the groups were comparable.

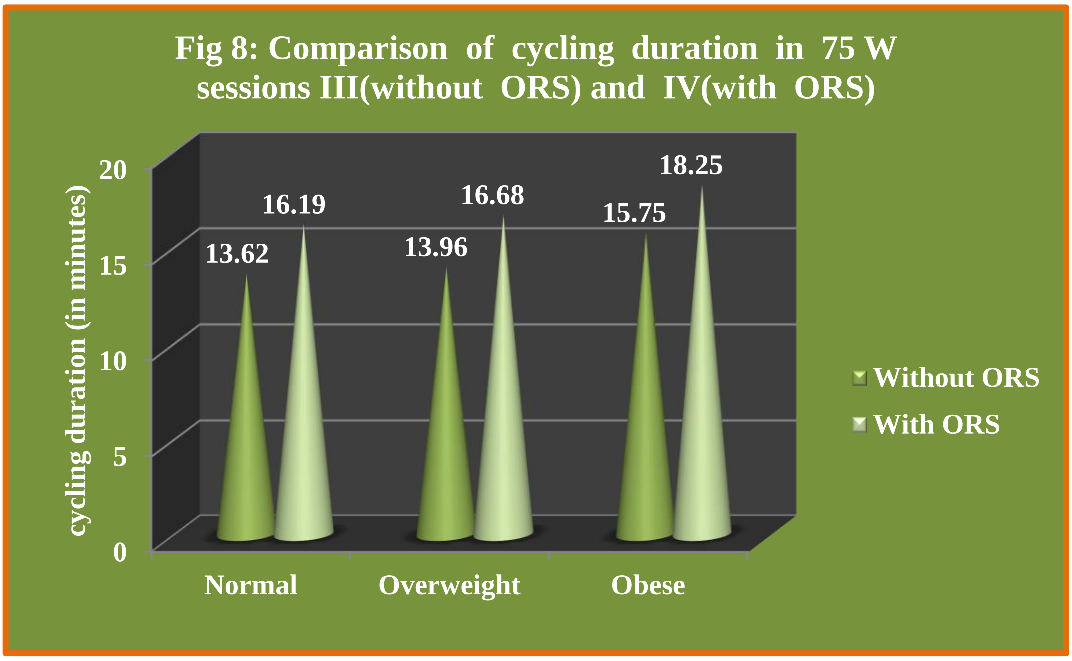


Table 9: Comparison of cycling distance in 100 W session V(without ORS) and VI(with ORS)

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session V	2.01	0.39	2.02	0.52	2.27	0.22	0.000*
Session VI	2.35	0.45	2.24	0.46	2.5	0.21	

***p value < 0.001-significant.**

There was significant difference in cycling distance between 100 watts sessions V (without ORS) and session VI (with ORS). Hence the groups were comparable.

Fig 9:Comparison of cycling distance in 100 W sessions V (without ORS)and VI(with ORS)

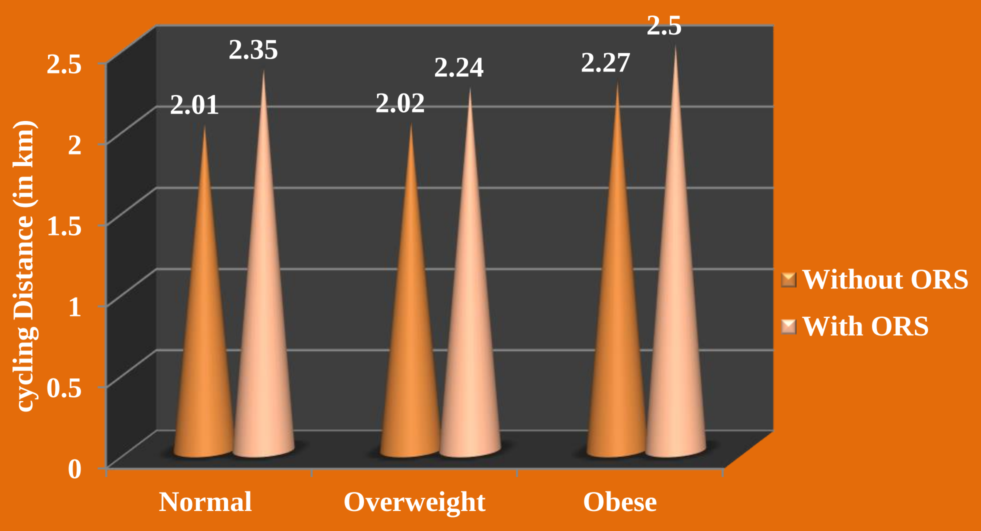


Table 10: Comparison of energy expenditure in 100 W sessions V (without ORS) and VI (with ORS).

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session V	186.19	51.05	185.16	48.6	151.50	26.71	0.000*
Session VI	200.67	53.25	197.4	46.54	167.75	26.76	

***p value< 0.001-significant.**

There was significant difference in energy expenditure between 100 watts sessions V (without ORS) and session VI (with ORS) . Hence the groups were comparable.

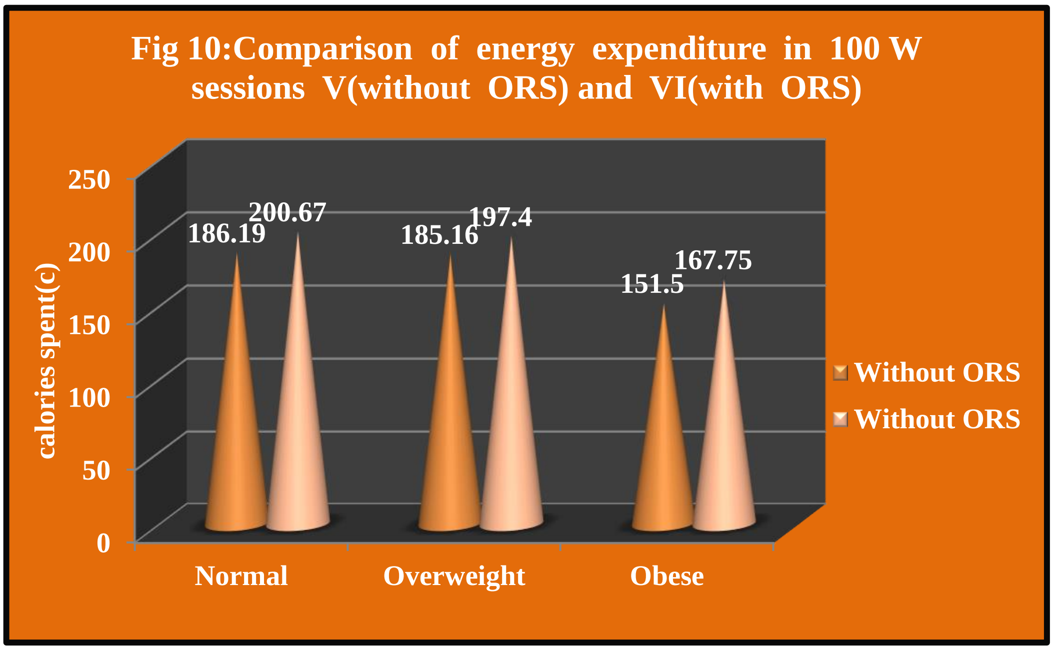


Table 11: Comparison of cycling duration in 100 W sessions V (without ORS) and VI (with ORS).

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session V	11.10	3.53	11.20	2.82	12.25	2.5	0.000*
Session VI	13.05	3.90	12.32	2.73	13.75	1.89	

*** p value < 0.001 – significant.**

There was significant difference in cycling duration between 100 Watts session V (without ORS) and session VI(with ORS). Hence the groups were comparable.

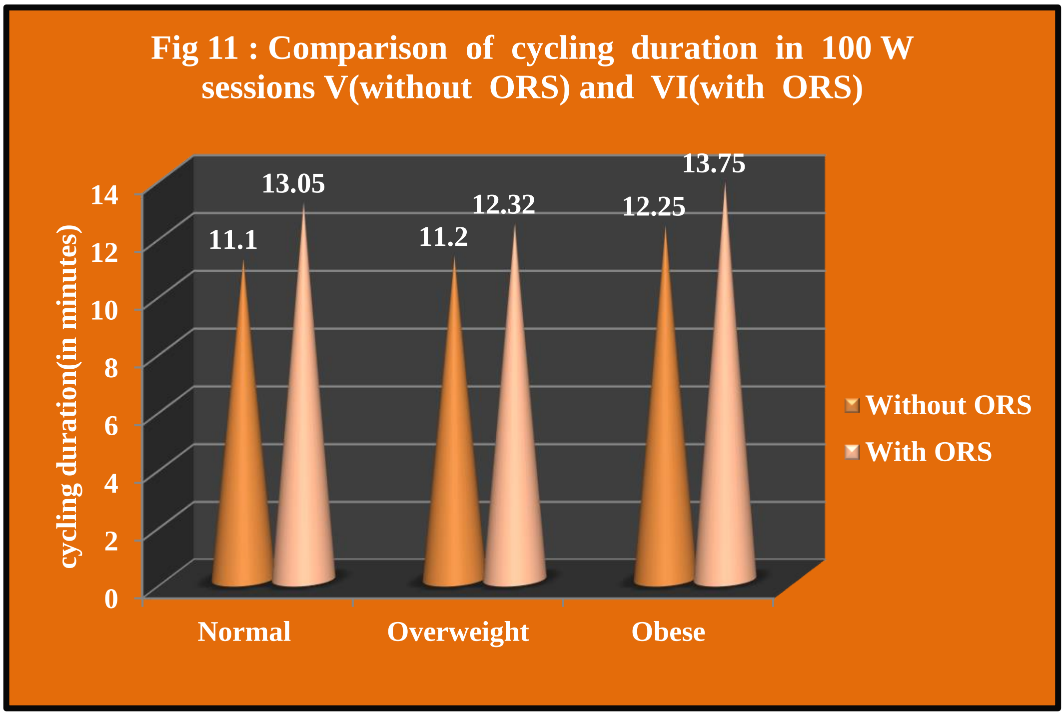


Table 12 : Comparison of SpO_2 in Normal BMI subjects in all sessions

Sessions	Mean	Standard deviation	p Value
I	97.14	0.793	0.00*
II	98	1.00	
III	97.29	0.78	0.207**
IV	96.86	0.85	
V	97.10	0.88	0.558**
VI	96.86	0.79	

***p value <0.01 - Significant   ** p value > 0.05 - Not Significant**

There was significant difference in SpO_2 values between sessions I and II. There was no significant difference between SpO_2 values between sessions III and IV, V and VI.

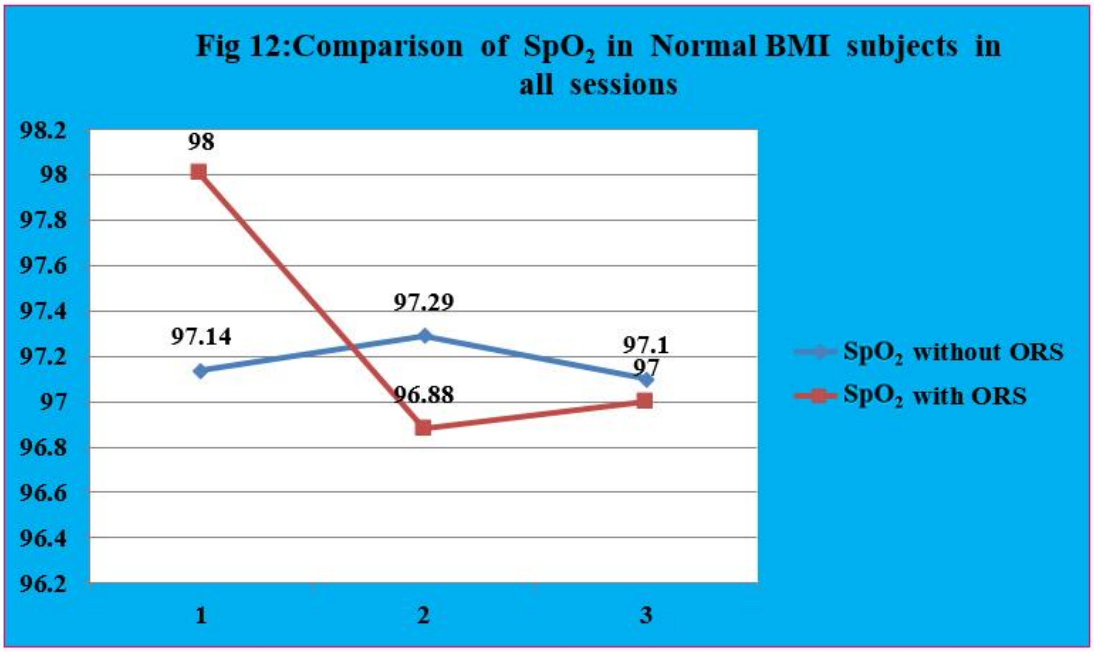


Table 13 : Comparison of SpO_2 in overweight subjects in all sessions

Sessions	Mean	Standard deviation	p Value
I	96.72	0.93	0.00*
II	98	0.91	
III	96.84	0.74	0.207**
IV	96.88	0.97	
V	96.92	0.90	0.558**
VI	97	0.86	

***p value < 0.01-Significant, **p value > 0.05 - Not Significant**

There was significant difference in SpO_2 values between sessions I and II. There was no significant difference between SpO_2 values between sessions III and IV, V and VI.

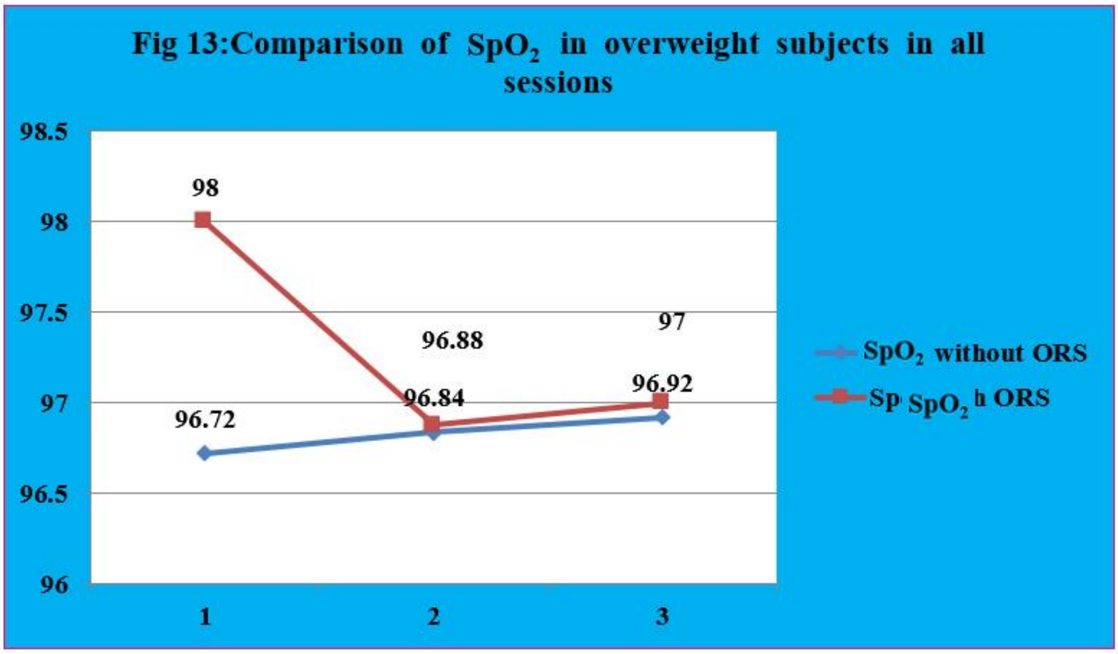


Fig 13:Comparison of SpO_2 in overweight subjects in all sessions

Table 14 : Comparison of SpO_2 in obese subjects in all sessions

Sessions	Mean	Standard deviation	p Value
I	96.25	1.70	0.00*
II	98	0.81	
III	97.25	0.50	0.207**
IV	96.75	0.95	
V	97	0.00	0.558**
VI	96.50	1.00	

***p value < 0.01- Significant. **p value> 0.05 - Not Significant**

There was significant difference in SpO_2 values between sessions I and II. There was no significant difference in SpO_2 values between sessions III and IV, V and VI.

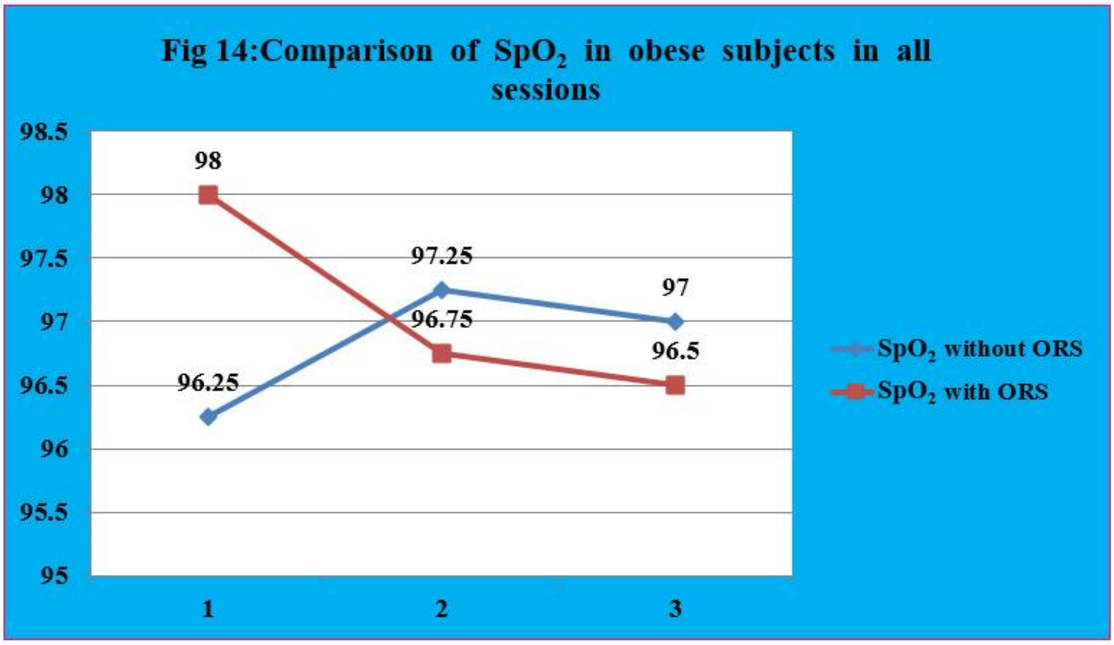


Table 15: Comparison of VO_2max in session I (without ORS) and II (with ORS).

Sessions	NORMAL		OVERWEIGHT		OBESE		p Value
	Mean	SD	Mean	SD	Mean	SD	
Session I	2.25	0.21	2.16	0.46	2.17	0.17	0.000*
Session II	2.52	0.23	2.46	0.20	2.40	0.08	

***p value <0.001-significant**

The mean VO_2max values between the cycling sessions without and with ORS was statistically significant with a p value <0.001.

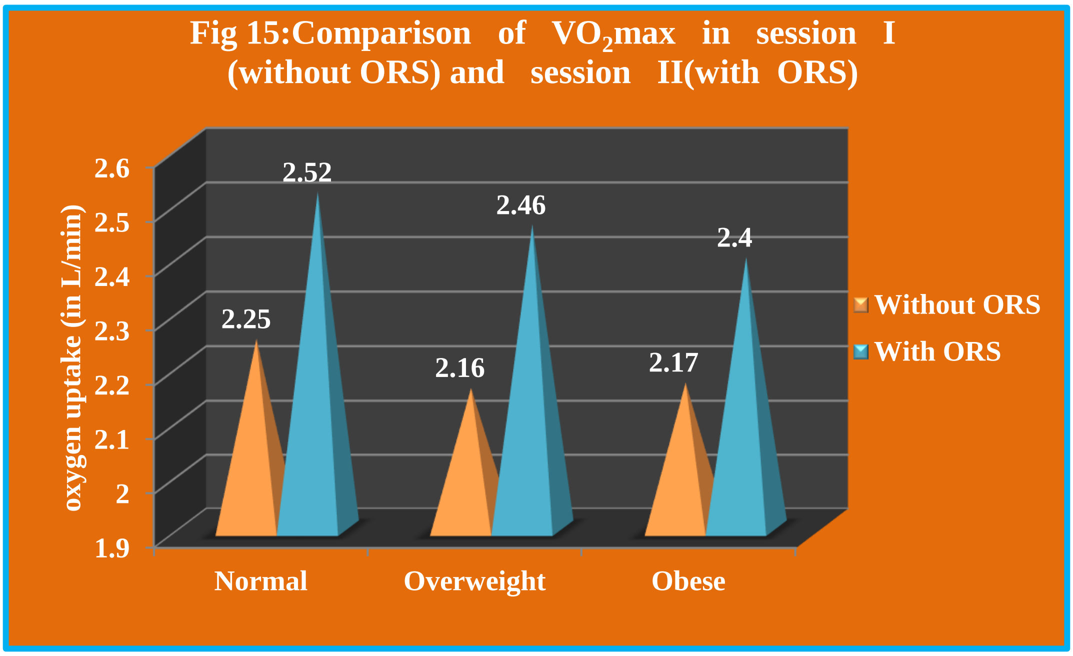


Table 16: Comparison of METs in all sessions without and with ORS.

		Sum of Squares	df	Mean Square	F	Significance
MET I,III,V (without ORS)	Between Groups	2.032	2	1.016	62.379	0.000*
	Within Groups	0.766	47	0.016		
	Total	2.798	49			
MET II,IV,VI (with ORS)	Between Groups	4.121	2	2.060	54.897	0.000*
	Within Groups	1.764	47	0.038		
	Total	5.885	49			
MET (without and with ORS)	Between Groups	6.889	2	3.444	36.363	0.000*
	Within Groups	4.452	47	0.095		
	Total	11.341	49			

***p value < 0.001 – significant.**

The mean METs values between the cycling sessions without and with ORS was statistically significant with a p value <0.001.

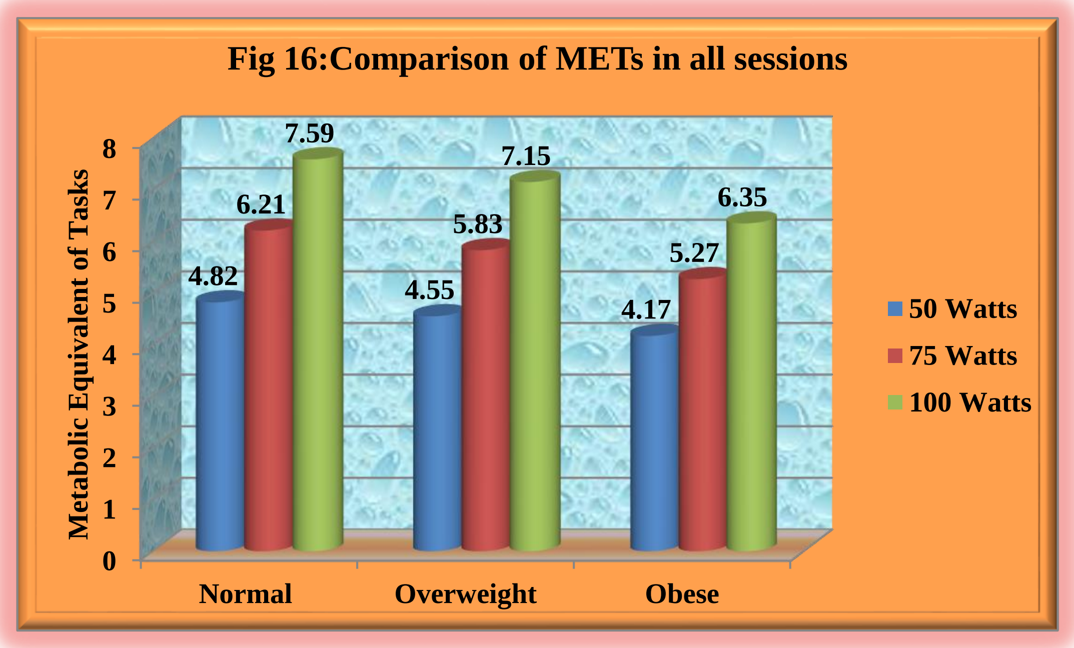


Table 17: Comparison of RPP in all sessions without and with ORS.

		Sum of Squares	df	Mean Square	F	Signifi-cance.
RPP I,III,V (without ORS)	Between Groups	20,076,633.33	2	10,038,316.66	8.749	0.000*
	Within Groups	168,654,602.70	147	1,147,310.22		
	Total	188,731,236.036	149			
RPP II,IV,VI (with ORS)	Between Groups	27,304,433.33	2	13,652,216.66	14.82	0.0000*
	Within Groups	135,371,027.49	147	920,891.34		
	Total	162,675,460.82	149			
RPP (without and with ORS)	Between Groups	151,539,800	5	30,307,960	29.30	0.000*
	Within Groups	304,025,630	294	1,034,100.78		
	Total	1,034,100	299			

***p value < 0.001 – significant.**

The mean RPP values between the cycling sessions without and with ORS was statistically significant with a p value <0.001.

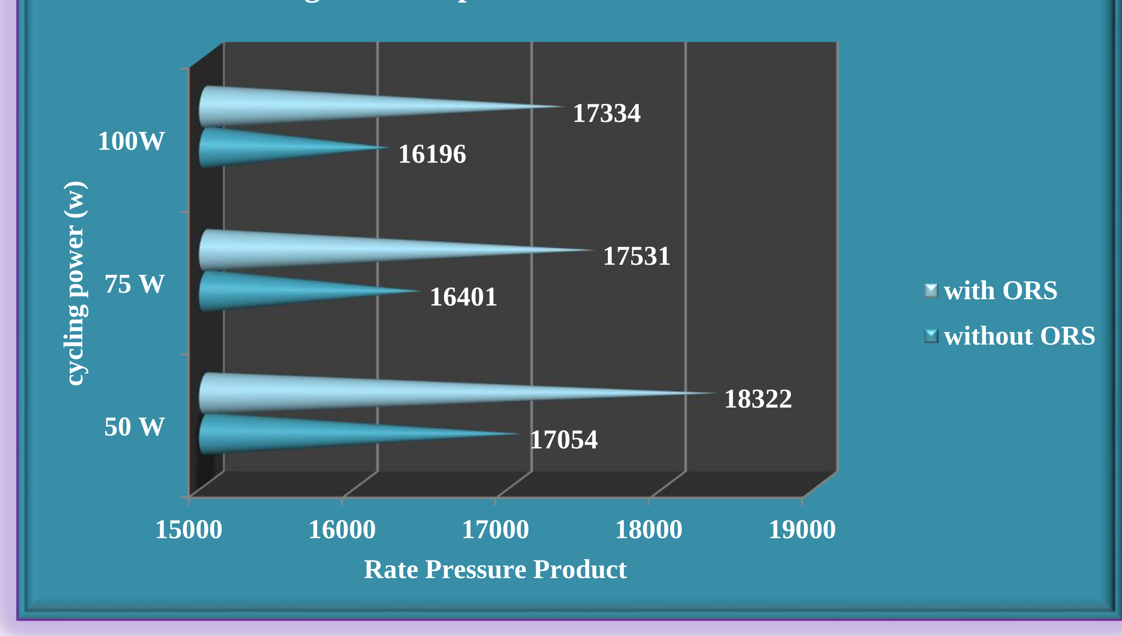


Fig : 17:Comparison of RPP in all sessions

DISCUSSION

DISCUSSION

The present study shows the relationship between the administration of oral rehydration solution and the improvement in muscle efficiency at different exercise intensities during cycling exercise on a bicycle ergometer. The energy expenditure, cycling duration and distance cycled have improved in the exercise session following ORS administration, than when exercise was done without any prior intake of ORS. The muscle efficiency has increased due to the delay in muscle fatigue thereby leading to an enhanced performance. This is due to the increased uptake of glucose by the muscles and storage as glycogen. This glycogen can be utilized during exercise, delaying the muscle fatigue. There is an increased level of glucose oxidation by the exercising muscles. Also, water present in the ORS helps to prevent dehydration and also to delay fatigue, especially when exercise is performed in hot and humid climatic conditions like in the tropical countries.

This study correlates well with the study by **Preetesh Parakh et al** in male medical students who performed exercise on a bicycle ergometer in two sessions, each session separated by 1 week. In second session, subjects consumed a glucose drink 30 minutes before doing exercise. Work done was calculated and the time to fatigue, total distance travelled was noted in both the sessions. There was a significant difference in the time to fatigue with 12.09 ± 7.42 minutes, work done 6964.00 ± 4517.96 J, total distance travelled in the first session was 2.12 ± 1.54 km and in the second session with greater values than in the time to fatigue 7.09 ± 4.96 minutes, work done 4305.33 ± 3065.19 J, and total distance travelled was 3.55 ± 2.42 km in the first session with p values <0.001 which was highly significant. This study showed that performance is better and time to fatigue is delayed in exercise performed after ingestion of glucose drink[32].

Michael N.Sawka and Scott J.Montain showed in their studies that hypohydration affects maximal aerobic power as well as physical work capacity of individuals. Especially this happens in hot climates where water deficits of 2 – 4 % body water loss occurs as in studies by Craig and Cummings. Studies by Allen Te et al , Sproles LB et al and Saltin B showed that hypohydration decreases plasma volume, increases blood viscosity and causes a reduction in venous return leading to a decrease in stroke volume and cardiac output during maximal exercise with hypohydration[25].

Studies by **Ricardo G. Fritzche et al** investigated the role of water and carbohydrate ingestion when subjects did prolonged cycling on bicycle ergograph and Pmax was measured – maximal neuromuscular power of an individual. Eight endurance trained cyclists did cycling for 122 minutes at

62% VO_2max. This study is in correlation with my study wherein ingestion of water and carbohydrates before the exercise period has proven to be of great benefit[56,57].

Studies by **Alan P. Jung** in thirteen men who performed a calf fatiguing protocol to induce exercise associated muscle cramps in the calf muscle group. In the carbohydrate electrolyte group, subjects consumed a carbohydrate electrolyte beverage with sodium chloride added to it. In the hypohydration trial, fluids were not allowed. The exercise duration in the carbohydrate electrolyte trial was prolonged compared with hypohydration trial. This study showed that a carbohydrate electrolyte beverage before and during exercise delays the onset of exercise associated muscle cramps. This allows the participants to exercise longer[59,60].

The mean values of RPP in sessions I and II among normal subjects was 18036+/-1275.36 and 18671.90 +/- 1075.83 respectively with a p value of < 0.001. There was a significant difference in between the sessions I and II. There was an increase in the rate pressure product in session with ORS administration among the normal subjects. The mean values of RPP in sessions I and II among overweight subjects was 18474.80 +/-932.83 and 18865.44 +/- 1005.82 respectively. This was found to be statistically significant p value < 0.001. This shows that the rate pressure product increased following ORS administration among overweight subjects. The mean values of RPP in sessions I and II among obese subjects was

18853.00 +/- 755.09 and 19043.50 +/- 737.41 respectively. This was found to be statistically significant with a p value < 0.001. This shows that the rate pressure product increased following ORS administration among obese subjects.

The RPP, being a product of heart rate and systolic blood pressure, increases following ORS ingestion because of the increase in the work output by the exercising muscles. This also reflects a better myocardial oxygen consumption due to ORS intake prior to exercise.

C.L.M Forjaz et al did studies in 12 young normotensive subjects in randomized three cycle ergometer exercise bouts of 45 minutes at 30% VO2max, 50% and 80% VO_2max. 12 other subjects acted as controls in a non - exercise control trial. Blood pressure, heart rate and rate pressure product were measured at baseline and at 5 – minute intervals following the completion of exercise. Exercise at 30% VO_2max significantly reduced rate pressure product during entire recovery period, while exercising at 50% VO_2max caused no change in RPP . In the present study, the RPP increased following prior ingestion of ORS from a value of 18036.10 without ORS ingestion to a value of 18671.90 following ORS ingestion [61,62].

The mean values for METs among normal subjects in session I and II were 4.82+/-0.144. among the overweight subjects the mean METs values were 4.55+/- 0.15. Among the obese subjects, the mean values were

4.17+/- 0.95. Though there was a significant difference between the METs in normal, overweight and obese subjects, there was no significant difference between sessions i.e., without and with ORS. There was significant difference between the METs values of 50, 75 and 100 watts sessions.

METs values show an increase when the cycling intensity increases due to the enhanced energy expenditure by the exercising muscles.

This study correlates with studies by **Dalia A. Biswas et al** 1996, the Myocardial Tension Time Index showed a linear increment during the peak of the exercise period. The mean value dropped during recovery. In that study, the VO_2max recorded using the Astrand Nomogram was 2.10 +/- 0.0047 which also correlates with the present study[64].

The mean values for VO_2max during cycling without ORS administration among the normal group was 2.25 +/- 0.21 and in the cycling session with ORS administration was 2.52 +/- 0.23. This was found to be statistically significant with a p value < 0.01. This shows that there is an increase in the maximal oxygen uptake following cycling with ORS ingestion. The mean values for VO_2max in the overweight group in session I (without ORS) was 2.16 +/- 0.46 and in session II (with ORS) was 2.46 +/- 0.20. This was also statistically significant with a p value < 0.01. The mean values for VO_2max in obese subjects without ORS was 2.17 +/- 0.17 and in cycling session with ORS was 2.40 +/- 0.08. This was found to be statistically significant with p value < 0.01.

The increase in the VO_2max values following ORS ingestion is due to the increase in the oxygen consumption by the exercising muscles, while performing the six minute submaximal cycling exercise protocol.

This study correlates with the study by **Tarnopolsky, M.A., et al** which had shown that the subjects were able to cycle 55% longer at 85% VO_2max when they ingested carbohydrate protein supplements during recovery from an earlier bout when compared with a sports drink with carbohydrate alone. The subjects in the former group had 26% more functional muscle glycogen compared with the latter carbohydrate only group [33].

Studies by **Vike BB et al** showed that predicted VO_2max (in L/minute) in the control (normal) male subjects was 3.2L / min and 2.5 L / min in the anemic male subjects. The actual VO_2max in control (anemic) subjects was 3.24+/-1.13 in control male subjects and 2.78 +/-1.06 in anemic male subjects. This shows that anemia reduces the physical activity by decreasing O_2 deliver to the tissues. In the present study, the VO_2max without and with prior ORS ingestion was 2.25 L/min and 2.52 L/min respectively[48].

In studies by **Smilee Johncy et al,** the age predicted maximum heart rate was determined using the formula : HRmax = 208 – (0.7*age) and the maximal and submaximal load of the subjects were determined. The subjects performed submaximal bicycle exercise that lasted for a duration of six minutes on a bicycle ergograph at the rate of 60 rpm (revolutions per minute). Aerobic capacity (VO_2max) was determined indirectly using work rate in kpm / min using Astrand Ryhming Nomogram. VO_2max value was 2.73+ /- 0.2 (L/min) among north Indians and in south Indians group VO_2max value was 2.67+ /- 0.22 (L/ min). The VO_2max values in the present study was 2.25 L/min[5].

Studies by **Mona Kharbanda et al,** correlated well with the present study, wherein Physical activity Rating scale and VO_2max was used to assess the physical fitness of medical students who did short term, limited duration exercise on bicycle ergograph. There was a positive correlation between physical fitness score and normal BMI value. The study also showed that aerobic capacity of an individual improves with training[7].

The mean values of SpO_2 between sessions I and II in normal subjects was 97.14+/- 0.79 and 98+/-1.00 respectively. It was found to be significantly different (p value < 0.01). But the mean values between sessions III and IV was not significantly different. (p value: 0.20). Also, the SpO_2 values between sessions V and VI with a p value > 0.05, which was not significant. The SpO_2 values at the peak of cycling among normal subjects in 75 W session without ORS was 97.14 +/- 0.79 and with ORS was 98 +/- 1.00. This shows that there was an increase in the SpO_2 values following cycling after ORS administration. Whereas, in the 100 W and in the 125 W sessions, there was not much of a significant difference in mean SpO_2 values.

The SpO_2 values among overweight subjects in 75 W session at the peak of exercise without ORS was 96.72 +/- 0.93 and with ORS was 98 +/- 0.91 with a p value < 0.05. This shows that there was an increase in the SpO_2 values following cycling after ORS administration. Whereas, in the 100 W and in the 125 W sessions, there was not much significant difference in SpO_2 values (p value > 0.05). Also, in the obese group, the mean SpO_2 value in the 75 W session without ORS and cycling was 96.25 +/- 1.70 and in the session with cycling after ORS administration had a mean SpO_2 value of 98+/- 0.81 and this was found to be statistically significant with a p value < 0.05. The sessions at 100 W and at 125 W did not show a significant difference in the mean SpO_2 values (p value > 0.05).

The present study correlates with the studies conducted by **G.L.Khanna et al,** done at Sports Authority of India, wherein ten male endurance athletes participated in two phases: in the first phase, no supplementation was given and during the second phase, carbohydrate + electrolyte was given during exercise and at an interval of fifteen minutes upto twenty minutes to exhaustion. The recording of endurance time with and without carbohydrate electrolyte drink supplement was 94.1+/- 17.7 and 62.3+/-10.4 minutes respectively. It was also seen that supplementation of 5 g% carbohydrate electrolyte drink helps to keep blood lactate at lower levels[42].

In the experiments by **Mark A. Febbraio et al,** seven endurance trained men participated and they had to cycle in bicycle ergometer for 120 minutes at an equivalent of about 70% VO_2max. The results of this study is that pre exercise carbohydrate ingestion lead to a higher plasma glucose levels at 10, 20, and at 30 minutes following beverage ingestion in the carbohydrate electrolyte group when compared with the placebo group. Also, it was evident from the study that glucose oxidation was rapid in the carbohydrate +electrolyte group. Thereby it showed that glucose to energy turnover was higher when carbohydrate intake was started before the exercise, which correlates with the present study[22].

The present study also correlates with the studies by **John M.Berardi et al** which showed that ingestion of liquid supplements containing carbohydrate + protein (33% maltodextrin, 33% glucose and 33% whey protein hydrolysates) in one group and carbohydrate alone (100% maltodextrin) and when NMR Spectroscopy of the vastus lateralis muscle was done showed that the muscle glycogen concentrations were higher in the group which received the carbohydrate protein supplements.

Based on this description of the habitual physical activity of the subject, a subjective evaluation of his fitness level was made and initial work loads of 150W, 100W and 75W at 50 pedal revolutions per minute were used for well-trained, moderately trained, and untrained subjects, respectively. The predicted VO_2 max was read from the nomogram (I. Astrand, 1960). In the present study, the values of VO_2max without and with prior administration of ORS was 2.25 L/min and 2.52 L/min respectively [71,72]. These inferences show that when a person is well hydrated and sufficiently supplied with carbohydrates and electrolytes prior to the exercise, there occurs an increase in muscle efficiency as can be seen in the statistically significant values of cycling duration, cycling distance and energy expenditure. Also, there was an increase in the rate pressure product in the study following prior ingestion of ORS and exercise, which indicates the better myocardial oxygen consumption. The VO_2max values showed an increase following ORS ingestion prior to cycling. This shows that there is an increase in the aerobic capacity, and that is there is an increased oxygen uptake due to increased work efficiency by the exercising muscles. All these findings reflect an increased glucose and electrolytes uptake by the muscles due to ingestion of oral rehydration solution prior to cycling exercise. There also occurs an improved glucose oxidation by the exercising muscles. The fluid ingested along with carbohydrates and electrolytes help to prevent dehydration and thus delays the muscle fatigue.

Therefore, ORS proves to be a good supplementation of water, electrolytes and carbohydrates which had caused a delay in muscle fatigue, thereby increasing the muscle efficiency. Also, ORS can be freshly prepared and it is also free from preservatives unlike other commercial sports drinks. It is a cost effective way of replenishing water , carbohydrate and electrolytes prior to the exercise.

SUMMARY

SUMMARY

- The muscle efficiency parameters were recorded in various cycling sessions at 50 watts, 75 watts and 100 watts without and with ORS ingestion before exercise in normal healthy males.
- The cycling exercise parameters were compared between various sessions of exercise in bicycle ergometer.
- There was a significant prolongation of the cycling duration, cycling distance and energy expenditure during exercise after ingestion of ORS.
- The rate pressure product was also significantly increased in the exercise sessions following ORS ingestion.
- The Metabolic Equivalent of Tasks showed no significant change with or without ORS ingestion.
- The VO_2max was significantly increased in the session with ORS ingestion.
- The SpO_2 values were significantly increased in the normal BMI group subjects.

CONCLUSION

CONCLUSION

Exercise has many proven benefits like maintaining a good physical fitness, improved memory and concentration, decreased anxiety levels and helps with good sleep.

Carbohydrates, electrolytes and fluid intake before exercise can enhance work capability by maintaining power output or speed or by prolonging the time to fatigue at a fixed, sub maximal workload. Pre exercise carbohydrate ingestion has been demonstrated to increase both hepatic and muscle glycogen stores, and, therefore increase exercise performance. The goal of drinking fluids during exercise is to prevent excessive dehydration and excessive changes in electrolyte balance.

In the present study there is an increase in the muscle efficiency parameters, RPP, METs and VO_2max values following ORS ingestion and exercise by bicycle ergometry.

To conclude, substituting water, carbohydrates and electrolytes in the form of Oral Rehydration Solution helps the individuals involved in exercise to perform better, to and to develop good endurance capacity.

FUTURE SCOPE OF THE STUDY

- This study can be done with ORS administration not only before the exercise, but also during and after the completion of exercise.
- This study can be done by comparing the parameters after glucose ingestion alone in one group and ORS ingestion in other group of subjects.
- Study population can be increased.

BIBLIOGRAPHY

REFERENCES

1. CJ Casperson, K E Powell, GM Christenson, Physical activity, exercise and physical fitness: definitions and distinctions for health related research, Public Health Rep, Mar-Apr 1985;100(2):126-131

2. Pendo, Frank J,Dahn, Jason R, Exercise and well being: A review of mental and physical health benefits associated with physical activity, Current opinion Psychiatry and behavioural medicine.Mar 2005;18(2):189-193.

3. William F.Ganong, Review of medical physiology,24th edition,152-156
.

4. Pim Knuiman, Maria T.E. Hopman and Marco Mensink, Glycogen availability and skeletal muscle adaptations with endurance and resistance exercise, Nutrition and Metabolism.2015;12(59):1-11

5. Smilee Johncy S, Vivian Samuel T. Comparative Study of Aerobic Power in North and South Indians, Smilee Johncy S, Vivian Samuel T. J Biomed Sci and Res.2010;2(3):155-161

6. William D McArdle, Frank I.Katch, Victor L.Katch, Wolters Kluwer Health,8th edition---2016,126-180

7. Mona Kharbanda,G Indra KumarShweta Kumari Shah. Effect of BMI and nutritional status on physical fitness index in response to short term moderate intensity exercise in sedentary young adults. International Journal of Recent Trends in Science and technology. Dec 2014;(2): 298-303.

8. Josef Finsterer and Vivian E. Drory, Wet, volatile, and dry biomarkers of exercise -induced muscle fatigue, BMC Musculoskeletal Disorders .2016;2(4): 17-40.

9. Palacios G, Pedrero-Chamizo R, Palacios N, Maroto-Sánchez B, Aznar S, González-Gross M, et al. Biomarkers of physical activity and exercise. Nutr Hosp. 2015;31 Suppl 3:237–44.

10. Halson SL. Monitoring training load to understand fatigue in athletes. Sports Med. 2014;44 suppl 2:139–47.

11. Steinberg JG, Delliaux S, Jammes Y. Reliability of different blood indices to explore the oxidative stress in response to maximal cycling and static exercises. Clin Physiol Funct Imaging. 2006;26:106–12.

12. Michael N. Sawka, Facsm (Chair); Louise M. Burke, Facsm, E. Randy Eichner, Facsm, Ronald J. Maughan, Facsm, Scott J. Montain, Facsm, Nina S. Stachenfeld, Facsm Exercise And Fluid Replacement, Medicine & Science In Sports & Exercise2007;377-390

13. Coyle, E. F. Fluid and fuel intake during exercise. J. Sports Sci;2004; 22:39–55.

14. Coyle, E. F., and S. J. Montain. Carbohydrate and fluid ingestion during exercise: are there trade-offs? Med. Sci. Sports Exerc;1992;24:671–678.

15. Convertino, Victor A. Ph.D., FACSM,(Chair);Armstrong, Lawrence E.Ph.D., Armstrong, Lawrence E. Ph.D., FACSM; Coyle, Edward F. Ph.D., FACSM; Mack, Gary W. Ph.D; Sawka, Michael N. Ph.D., FACSM; Senay, Leo C. Jr. Ph.D., FACSM; Sherman, W. Michael Ph.D., FACSM, ACSM Position Stand, Exercise and Fluid Replacement. Medicine & Science in Sports & Exercise; October 1996; 28(10):1-9

16. Mona Kharbanda, Angesh Bagade, Aniruddha Jibhkate. Effect of Exercise on Aerobic Power and Correlation of Aerobic Power with Body Mass Index and Physical Fitness Score in Medical Students. Asian Journal of Biomedical and Pharmaceutical Sciences, 2015;20:21-26

17. Kiapidou IS, Velogianni L, Stergiou N, Boland A. Herodicus, the father of sports medicine.Georgoulis AD, Knee Surg Sports Traumatol Arthrosc. 2007 Mar;15(3):315-8.

18. Camillo Di Giulio, Franca Daniele, Charles M.Tipton, Angelo Mosso and muscular fatigue:116 years after the first congress of physiologists: IUPS commemoration, Adv physiol Educ, June 2006;30(2):51-57

19. Bjorn Ekblom, Per Olof Astrand, B engt Saltin, Jesper Stenberg and Brittmari Wallstrom, Effect of training on circulatory response to exercise, Journal of Applied Physiology;24(4):518-524

20. Bruce M.Koeppan, Bruce A.Stanton, Berne & Levy physiology,6th edition.P 246-248.

21. Arthur C. Guyton, M.D. John E. Hall, Ph.D.,Textbook of medical physiology,11th edition,P 1055-1057

22. Mark a. Febbraio, Alison Chiu, Damien J. Angus, Melissa J. Arkinstall, and John A. Hawley, effects of carbohydrate ingestion before and during Exercise on glucose kinetics and performance. J Appl Physiolog;,2000(89): 2220–2226.

23. Nutritional aspects in ultra-endurance exercise Edith M. Peters, Clin Nutr Metab Care 2003; 6:427–434

24. Murray R. The effects of consuming carbohydrate-electrolyte beverage on gastric emptying and fluid absorption during and following exercise. Spt Med.1987; 4:322-351.

25. Michael N Sawka And Scott J Montain, Fluid And Electrolyte Supplementation For Exercise Heat Stress1, Am J Clin Nutr 2000;72(Suppl):564S–72S.

26. Sawka MN. Body fluid responses and hypohydration during exercise heat stress. In: Pandolf KB, Sawka MN, Gonzalez RR, eds. Human performance physiology and environmental medicine at terrestrial extremes. Indianapolis: Cooper Publishing Group, 1988;227–66

27. Mack GW, Nadel ER. Body fluid balance during heat stress in humans. In: Fregly MJ, Blatteis CM, eds. Environmental physiology. New York: Oxford University Press, 1996;3:187–214.

28. Michael N. Sawka, Facsm (Chair); Louise M. Burke, Facsm, E. Randy Eichner, Facsm, Ronald J. Maughan, Facsm, Scott J. Montain, Facsm, Nina S. Stachenfeld, Facsm Exercise And Fluid Replacement, Medicine & Science In Sports & Exercise2007;5:377-390.

29. Rabindarjeet Singh, Fluid Balance And Exercise Performance, Mal J Nutr 2003;9(1): 53-74.

30. Andrews JL, Sedlock DA, Flynn MG, Navalta JW, Ji H, Carbohydrate loading and supplementation in endurance trained women runners. J Appl Physiol 2003;95:584-90

31. Applegate E.Effective nutritional ergogenic aids. Int J Sports Nutr 1999;9:229-39.

32. Preetesh Parakh, Anitha K, Manjunath H, Pre-exercise glucose drink and muscle performance by bicycle ergography, International Journal of Medical Science and Public Health 2016 ; 5 (05):1-3

33. Sri Pandam Pulungsih1, Narain H. Punjabi2, Kustedy Rafli1, Atti Rifajati1, Swiandy Kumala1, Cyrus H. Simanjuntak3, Yuwono4, Murad Lesmana5, Decy Subekti2, Sutoto†1, and Olivier Fontaine6, Standard WHO-ORS Versus Reduced-osmolarity ORS in the Management of Cholera Patients, J HEALTH POPUL NUTR 2006 Mar;24(1):107-112.

34. S.M.Shirreffs,Hydration in sport and exercise: water, sports drinks and other drinks,Nutrition bulletin.2009;34:374-379.

35. Supplementary effect of carbohydrate-electrolyte drink on sports performance, lactate removal & cardiovascular response of athletes G.L. Khanna & I. Manna*Indian J Med Res. May 2005;665-669.

36. Rick L. Sharp PhD, Role of Whole Foods in Promoting Hydration after Exercise in Humans, Journal of the American College of Nutrition.2007,26:(sup5):592S-596S

37. J Mark Davis, Nathan L Alderson, and Ralph S Welsh. Serotonin and central nervous system fatigue: nutritional Considerations, Am J Clin Nutr. 2000;72(suppl):573S–8S.

38. T D Noakes, A St Clair Gibson, Logical Limitations To The ‘‘Catastrophe’’ Models of fatigue during exercise in humans. Br J Sports Med 2004;(38):648–649.

39. J. Mark Davis. Carbohydrates, branched-chain amino acids and endurance: The central fatigue hypothesis. Sports science exchange.1996;9(2):34-39.

40. Enoka, R.M., and D.G. Stuart. Neurobiology of muscle fatigue. J. Appl. Physiol;1992: 72(5):1631-1648

41. Fitts, R.H., and J.M. Metzger. Mechanisms of muscular fatigue. In Principles of Exercise Biochemistry, J.R. Poortmans (Ed.), Basel, Switzerland: Karger, 1993,38(2): 248-268)

42. Audrey L. Hicks,1 Jane Kent-Braun,2 and David S. Ditor1, Sex Differences in Human Skeletal Muscle Fatigue. Exercise and Sport Sciences Reviews. 2001;29(3):109–112.

43. Maughan, R.J., M. Harmon, J.B. Leiper, D. Sale, and A. Delman. Endurance capacity of untrained males and females in isometric and dynamic muscular contractions. Eur. J. Appl. Physiol;1986(55),:395–400.

44. Miller, A.E.J., J.D. MacDougall, M.A. Tarnopolsky, and D.G. Sale. Gender differences in strength and muscle fibre characteristics. Eur. J. Appl. Physiol;1993;66:254 –262

45. Jos.e Gonz.alez-Alonso, Jos.e A. L. Calbet and Bodil Nielsen, Muscle blood flow is reduced with dehydration during prolonged exercise in humans. Journal of Physiology 1998; 513(3):895-905.

46. Hakan Westerblad, MD, PhD, and David G. Allen, MD, PhD, Recent advances in the understanding of skeletal muscle fatigue Current Opinion in Rheumatology 2002;14:648–652.

47. Gunnar A.V.Borg, physical performance and perceived exertion, studia psychological et pedagogica investigations XI,45-46.

48. Joyce Steed, Glenn A.Gasser, and Arthur Weltman, Rating of of perceived exertion and blood lactate concentration during submaximal running, Medicine and science in sports and exercise,May 1993;3:793-803.

49. Mats O.Ericson, ake Bratt, Ralph Nisell, Ulf P.Arborelicus, Jan Ekholm, Power output and work in different muscle groups during ergometer cycling, European Journal of Applied Physiology and Occupational Physiology, June 1986;55(3):229-235.

50. P.O.Astrand, Irma Ryhming, A Nomogram for calculation of aerobic capacity from pulse rate during submaximal work, Journal of applied Physiology, Sept 1954;7(2):218-221.

51. C.L.M. Forjaz, Y. Matsudaira, F.B. Rodrigues, N. Nunes and C.E. Negrão, Post-exercise changes in blood pressure, heart rate and rate pressure product at different exercise intensities in normotensive humans Brazilian journal of medical and biological research.1998;31:1247-1255.

52. Todd A. Astorino, Robert A. Robergs, Farzaneh Ghiasvand, Derek Marks, And Steve Burns, Incidence Of The Oxygen Plateau at VO_2max During Exercise Testing To Volitional Fatigue, Official Journal of The American Society of Exercise Physiologists (ASEP).2000;3(4):1-12.

53. Storer TW, Davis JA, Caiozzo Vj, Accurate prediction of VO_2max in cycle ergometry, Medicine and science in sports and exercise, Oct 1990;22(5):126-131.

54. Shannan E. Gormley, David P. Swain, Renee High, Robert J. Spina, Elizabeth A. Dowling, Ushasri S. Kotipalli, And Ramya Gandrakota. Effect of Intensity of Aerobic Training on $V˙O_2max$. The American College Of Sports Medicine.2008;21(2):1336-1342.

55. J. M. Parkin, M. F. Carey, S. Zhao, and M. A. Febbraio. Effect of ambient temperature on human skeletal muscle metabolism during fatiguing submaximal exercise. the American Physiological Society.1999;3:902-908.

56. Ricardo G. Fritzsche, Thomas W. Switzer, Bradley J. Hodgkinson, Suk-Ho Lee, James C. Martin, And Edward F. Coyle, Water and carbohydrate ingestion during prolonged exercise increase maximal neuromuscular power, J. Appl. Physiol;2000, 88: 730–737

57. Halson SL. Monitoring training load to understand fatigue in athletes. Sports Med. 2014;44 suppl 2:S139–47. doi:10.1007/s40279-014-0253-z.

58. P. R., R. Mora-Rodrı´guez, J. Gonza´ lez-Alonso, and E. F. Coyle. Fluid and carbohydrate ingestion independently improve performance during 1 h of intense exercise. Med. Sci. Sports Exer;1995. 27: 200–210

59. Steinberg JG, Delliaux S, Jammes Y. Reliability of different blood indices to explore the oxidative stress in response to maximal cycling and static exercises. Clin Physiol Funct Imaging. 2006;26:106–12.

60. Alan P. Jung, Phillip A. Bishop, Ali Al-Nawwas, R. Barry Dale, Influence of Hydration and Electrolyte Supplementation on Incidence and Time to Onset of Exercise-Associated Muscle Cramps, Journal of Athletic Training 2005;40(2):71–75

61. J. L., C. Williams, J. Booth, B. H. Choo, S. Growns. Effect of water ingestion on endurance capacity during submaximal treadmill running. J. Sports Sci. 14: 497–502, 1996.

62. C.L.M. Forjaz, Y. Matsudaira, F.B. Rodrigues, N. Nunes and C.E. Negrão, Post-exercise changes in blood pressure, heart rate and rate pressure product at different exercise intensities in normotensive humans Brazilian journal of medical and biological research,;1998:31:1247-1255

63. Coyle, E. F., J. M. Hagberg, B. F. Hurley, W. H. Martin III, A. A. Ehsani, and J. O. Holloszy. Carbohydrate feeding during prolonged strenuous exercise can delay fatigue. J. Appl. Physiol;1988: 55: 230–235

64. Daliaa. Biswas and Jayant R. Kher. Cardio respiratory changes associated with graded exercise and determination of aerobic power in male medical students (18-19 years), Indian J physiol pharmacol 1996; 40(1): 79-82.

65. Mack GW, Nadel ER. Body fluid balance during heat stress in humans. In: Fregly MJ, Blatteis CM, eds. Environmental physiology. New York: Oxford University Press, 1996:187–214.)

66. Engel D, Kramer M, Malafi T, Salomon M, Lesher L. Effect of effort and social modeling on drinking in humans ,Appetite. 1996;26:129Y138.

67. Fitts, R.H., and J.M. Metzger. Mechanisms of muscular fatigue. In Principles of Exercise Biochemistry, J.R. Poortmans (Ed.), Basel, Switzerland: Karger, 1993,38(2): 248-268)

68. Vikhe BB,Badwe AN, Latti RG, Astudy on work efficiency of anemic and non-anemic subjects of rural area Pravara med rev 2015;7(2)(4-6).

69. Sawka MN. Body fluid responses and hypohydration during exercise heat stress. In: Pandolf KB, Sawka MN, Gonzalez RR, eds. Human performance physiology and environmental medicine at terrestrial extremes. Indianapolis: Cooper Publishing Group, 1988:227–66.

70. G.L.Khanna and I.Manna, Supplementary effect of carbohydrate-electrolyte drink,sports performance, lactate removal & cardiovascular response of athletes, Indian J Med Res 121, May 2005, pp 665-669

71. John.M. Berardi, Thomas B. Price, Eric E. Noreen, And Peter W. R. Lemon, Postexercise Muscle Glycogen Recovery Enhanced With A Carbohydrate–Protein Supplement, Medicine & Science In Sports & Exercise,Nov 2005;1106-1113.

72. Enoka, R.M., and D.G. Stuart. Neurobiology of muscle fatigue. J. Appl. Physiol;1992: 72(5):1631-1648

73. amara Hew-Butler, DPM, Christopher Almond, MD, MPH, J. Carlos Ayus, MD, Jonathan Dugas, BSc(Hons), Willem Meeuwisse, MD, PhD, Timothy Noakes, MBChB, MD, DSc, Stephen Reid, MBBS, PhD,k Arthur Siegel, MD, Dale Speedy, MBChB, MD, Kristin Stuempfle, PhD, Joseph Verbalis, MD, and Louise Weschler, MAT, PT, Consensus Statement of the 1st International Exercise-Associated Hyponatremia Consensus Development Conference, Cape Town, South Africa 2005.Clin J Sport Med 2005;15:208–213.

ANNEXURES

CONSENT FORM

Dr. K. Akilandeswari, Post graduate student in the Department of Physiology, Coimbatore Medical College is studying the “Pre-exercise ORS drink and muscle efficiency by bicycle ergography”. The procedure of recording the parameters were explained to me clearly.

I hereby give my consent to participate in this study. The data obtained herein may be used for research and publication.

Name :

Place :

Signature :

ஒப்புதல் படிவம்

பெயர் ______________________ வயது _____ முகவரி _________ _________________________ ஆகிய நான் உடலியங்கியல் துறை, கோவை மருத்துவக்கல்லூரி பட்ட மேற்படிப்பு மாணவி மரு. கு. அகிலாண்டீஸ்வரி அவர்கள் "மிதிவண்டி உடற்பயிற்ச்சிக்கு முன்பு வாய்வழி உப்பு சர்க்கரை கரைசல் நீரைப் பயன்படுத்தி தசை திறமையை அறிதல்" என்ற தலைப்பில் செய்யும் ஆய்வில் என்னை உட்படுத்திக் கொள்ள சம்மதிக்கிறேன். இந்த ஆய்வில் செய்முறை மற்றும் இது தொடர்பான அனைத்து விளக்கங்களையும் கேட்டுக் கொண்டு எனது சந்தேகங்களையும் தெளிவுபடுத்திக் கொண்டேன் என்பதையும் தெரிவித்துக் கொள்கிறேன்.

இந்த ஆய்வில் என்னை உட்படுத்த முழு மனதாக சுய சிந்தனையுடன் ஒத்துக்கொள்வதுடன் எந்த நேரத்திலும் இந்த ஆய்வில் இருந்து விலகிட எனக்கு உரிமை உண்டு என்பதையும் அறிவேன். முடிவுகள் ஆய்விதழில் வெளியிடப்படுவதில் ஆட்சேபனை இல்லை என்பதை தெரிவித்துக் கொள்கிறேன்.

இடம்: கோவை

தேதி:

கையொப்பம் / கைரேகை

PROFORMA

Name:

Age:

Sex:

Occupation:

Address:

Contact No:

Any complaints:

GENERAL EXAMINATION:

Built:

Height:

Weight:

BMI:

VITALS:

Temperature:

PR:

RR:

BP:

SYSTEM EXAMINATION:

CVS:

RS:

Abdomen:

CENTRAL NERVOUS SYSTEM:

1. Examination of the Motor System
2. Examination of the Sensory System
3. Examination of Reflexes

PROFORMA FOR RECORDING OF PARAMETERS:

Session	PR	BP	SpO_2	Work done	Duration	Distance	RPP	METs	VO_2max
I									
II									
III									
IV									
V									
VI									

MASTER CHART

COMPARISON OF MUSCLE EFFICIENCY IN 50 W SESSION I (WITHOUT ORS) AND SESSION II (WITH ORS)

S.No	Age	Sex	Height	Weight	BMI	PR	SBP	DBP	SpO2 I	SpO2 II	TIME I	DISTANCE I	CALORIES I	TIME II	DISTANCE II	CALORIES II	MET 1	MET II	RPP I	RPP II	VO2max I	VO2max II
1	20	M	156	54	22.2	74	130	80	98	97	2.5	152	8	2.8	167	12	4.9	4.9	17316	19096	2.2	2.4
2	23	M	160	60	23.4	78	124	76	97	96	3.0	162	13	3.2	180	15	4.6	4.6	17316	18688	2.4	2.6
3	25	M	149	67	30.2	68	120	74	98	97	2.5	143	11	2.9	168	14	4.3	4.3	17316	18176	2.2	2.4
4	19	M	154	53	22.3	70	120	70	98	96	1.9	138	8	2.2	150	10	4.9	4.9	16380	18104	2.1	2.3
5	20	M	150	59	26.2	69	110	70	96	98	1.5	106	5	1.8	124	7	4.6	4.6	16560	18648	2.0	2.4
6	24	M	145	57	27.1	70	118	68	95	98	3.2	180	16	3.4	192	18	4.7	4.7	18352	19404	2.2	2.5
7	23	M	150	61	27.1	80	120	78	96	97	3.5	186	16	3.8	203	19	4.5	4.5	17388	18980	1.9	2.2
8	25	M	158	65	26.0	76	118	68	95	96	2.5	152	11	2.9	165	13	4.4	4.4	15368	17856	2.0	2.4
9	19	M	159	70	27.7	79	120	70	96	99	3.1	192	12	3.3	202	15	4.2	4.2	16128	17408	2.1	2.5
10	20	M	155	58	24.1	67	110	68	97	97	3.5	179	15	3.1	185	20	4.7	4.7	16800	18352	2.2	2.6
11	19	M	159	60	23.7	70	120	80	95	98	2.6	170	8	2.9	186	13	4.6	4.6	18056	19456	2.1	2.5
12	19	M	148	63	28.8	73	110	70	96	99	4.1	284	20	4.3	320	25	4.4	4.4	17112	19240	2.0	2.4
13	21	M	148	71	32.4	70	120	68	94	98	3.2	171	15	3.8	180	21	4.2	4.2	18688	18104	2.1	2.3
14	25	M	157	75	30.4	76	110	70	97	99	3.0	186	13	3.3	192	17	4.1	4.1	16864	18432	2.4	2.5
15	23	M	152	54	23.4	72	126	70	97	98	2.8	175	11	3.5	201	18	4.9	4.9	14740	18500	2.3	2.5
16	21	M	149	56	25.2	74	120	82	98	98	2.0	156	9	2.2	169	10	4.8	4.8	15680	18000	2.1	2.3
17	23	M	150	60	26.7	68	110	74	97	98	8.0	189	12	3.2	204	15	4.6	4.6	16472	18352	2.4	2.6
18	24	M	153	61	26.1	75	112	70	96	97	3.1	201	13	3.6	214	18	4.5	4.5	18944	20280	2.1	2.4
19	24	M	147	72	33.3	80	110	68	96	98	2.7	186	15	3.2	243	19	4.1	4.1	19350	19712	2.0	2.4
20	19	M	148	55	25.1	69	122	80	97	98	3.1	293	18	3.6	325	20	4.8	4.8	17316	18480	1.9	2.4
21	18	M	150	53	23.6	69	124	80	97	99	3.8	385	19	4.1	402	21	4.9	4.9	17936	19592	2.3	2.4
22	18	M	148	52	23.7	72	120	70	96	98	2.5	371	10	2.9	313	12	5.0	5.0	16320	17608	2.1	2.5
23	19	M	151	51	22.4	76	110	70	97	97	2.7	285	11	2.8	320	14	5.0	5.0	16348	17940	2.3	2.3
24	20	M	159	56	22.2	70	126	74	98	99	2.1	170	10	2.8	332	12	4.8	4.8	19240	20124	2.1	2.4
25	21	M	162	59	22.5	75	120	80	97	99	1.5	125	9	2.5	181	10	4.6	4.6	17136	17608	2.2	2.5
26	25	M	153	62	26.5	69	124	74	98	98	1.6	130	6	1.9	139	8	4.5	4.5	18250	19200	2.1	2.5
27	19	M	156	65	26.7	70	116	70	97	96	2.8	145	11	3.0	158	12	4.4	4.4	16632	18688	2.2	2.6
28	25	M	145	58	27.6	74	120	80	96	98	2.4	284	10	2.7	298	13	4.7	4.7	18576	17920	2.1	2.4
29	23	M	149	59	26.6	69	128	78	98	99	2.8	240	12	3.1	252	15	4.6	4.6	16592	16560	2.4	2.3
30	23	M	150	60	26.7	70	130	82	97	98	2.6	290	11	2.9	301	12	4.6	4.6	15912	18176	2.1	2.5
31	23	M	154	62	26.1	74	124	84	96	99	3.0	290	16	3.4	320	20	4.5	4.5	18432	19240	2.0	2.3
32	24	M	150	66	29.3	80	120	70	97	97	3.0	302	18	3.2	342	21	4.3	4.3	18834	19760	2.1	2.4
33	19	M	160	58	22.7	82	130	82	98	98	2.1	265	12	2.5	287	14	4.7	4.7	16320	17608	2.3	2.8
34	20	M	153	56	23.9	73	128	76	97	99	2.6	230	16	2.9	245	17	4.8	4.8	17360	19456	2.2	2.4
35	23	M	148	55	25.1	72	130	80	96	99	3.9	395	25	4.3	429	27	4.8	4.8	16632	17920	2.3	2.6
36	21	M	150	62	27.6	78	128	70	97	97	2.1	189	11	2.2	204	12	4.5	4.5	18176	19240	2.0	2.0
37	25	M	147	54	25.0	72	110	80	98	99	2.4	186	10	2.5	210	13	4.9	4.9	16640	16080	2.1	2.7
38	20	M	160	53	20.7	76	120	80	96	99	2.6	250	11	2.8	261	14	4.9	4.9	17280	18648	2.1	2.5
39	18	M	150	60	26.7	74	110	66	98	99	3.5	315	18	3.8	346	21	4.6	4.6	14336	15840	2.1	2.5
40	25	M	157	59	23.9	77	120	80	97	98	2.3	250	12	2.5	263	16	4.6	4.6	15576	17112	2.0	2.5
41	22	M	154	52	21.9	80	122	76	98	97	2.6	246	12	3.1	270	15	5.0	5.0	16100	17608	2.4	2.6
42	21	M	149	59	26.6	76	124	80	98	99	2.1	210	10	2.3	231	13	4.6	4.6	17280	18204	2.7	2.9
43	20	M	150	60	26.7	68	130	70	97	99	1.5	186	8	1.9	210	10	4.6	4.6	16864	17526	2.3	2.6
44	21	M	151	57	25.0	68	128	80	98	98	2.4	201	9	2.7	231	12	4.7	4.7	17920	18500	2.2	2.0
45	23	M	156	54	22.2	75	120	72	97	99	3.8	390	22	4.5	427	27	4.9	4.9	16320	17500	3.0	3.2
46	24	M	155	51	21.2	74	110	80	97	99	2.5	212	13	3.0	230	16	5.0	5.0	16632	17802	2.6	2.8
47	21	M	152	61	26.4	73	120	82	98	98	2.1	252	12	2.5	284	15	4.5	4.5	17920	17750	2.3	3.0
48	18	M	150	54	24.0	72	124	80	97	98	2.5	203	11	2.7	211	13	4.9	4.9	17280	18500	2.2	2.6
49	19	M	149	56	25.2	78	110	70	96	98	3.5	371	20	3.4	340	19	4.8	4.8	15456	18060	2.6	2.4
50	25	M	150	63	28.0	76	122	80	97	98	3.1	310	19	3.2	301	18	4.4	4.4	16240	17040	2.0	2.4

M: Male
Ht: Height
Wt: Weight
BMI: Body Mass Index

PR: Pulse Rate
SBP: Systolic Blood Pressure
DBP: Diastolic Blood Pressure
SpO_2: Oxygen Saturation

METs: Metabolic Equivalent of Task
RPP: Rate Pressure Product
VO_2max: Maximal Oxygen Uptake

COMPARISON OF MUSCLE EFFICIENCY IN 75 W
SESSION I (WITHOUT ORS) AND SESSION II (WITH ORS)

S.No	Age	Sex	Height	Weight	BMI	PR	SBP	DBP	SpO2 III	SpO2 IV	TIME III	DISTANCE III	CALORIES III	TIME IV	DISTANCE IV	CALORIES IV	MET III	MET IV	RPP III	RPP IV
1	20	M	156	54	22.2	112	128	80	96	97	10	1.6	134	13	1.5	144	6.3	6.3	14336	15544
2	23	M	160	60	23.4	114	132	78	97	98	12	2.5	161	14	2.7	170	5.9	5.9	15048	16560
3	25	M	149	67	30.2	117	136	76	97	98	12	2.5	152	15	2.5	175	5.5	5.5	15912	17220
4	19	M	154	53	22.3	121	138	78	98	97	9	1.8	139	12	2	168	6.4	6.4	16698	17892
5	20	M	150	59	26.2	128	126	70	97	98	7	1.5	118	9	1.6	124	5.9	5.9	16128	17160
6	24	M	145	57	27.1	131	128	74	96	95	16	2.9	182	19	3.1	190	6.1	6.1	16768	17420
7	23	M	150	61	27.1	125	130	70	96	96	15	3	190	18	3.3	201	5.8	5.8	16250	17920
8	25	M	158	65	26	120	136	68	97	95	12	2.5	156	15	2.8	180	5.6	5.6	16320	17750
9	19	M	159	70	27.7	112	140	68	96	96	13	2.9	189	16	2.8	201	5.3	5.3	15680	18000
10	20	M	155	58	24.1	126	142	72	98	97	17	2.5	178	19	2.7	185	6	6	17892	18944
11	19	M	159	60	23.7	121	146	70	97	96	11	2.8	179	15	2.9	180	5.9	5.9	17666	19304
12	19	M	148	63	28.8	123	142	74	96	97	20	3.2	278	24	3.4	290	5.7	5.7	17466	18432
13	21	M	148	71	32.4	121	136	72	98	96	19	3.1	169	21	3.3	189	5.3	5.3	16456	17640
14	25	M	157	75	30.4	114	138	72	97	97	15	2.8	187	19	2.9	202	5.1	5.1	15732	17040
15	23	M	152	54	23.4	120	142	74	98	98	16	2.9	187	19	3	207	6.3	6.3	17040	18500
16	21	M	149	56	25.2	116	136	78	96	97	10	1.9	150	13	2.1	165	6.1	6.1	15776	16800
17	23	M	150	60	26.7	121	134	70	97	98	14	2.8	189	15	3	211	5.9	5.9	16214	17272
18	24	M	153	61	26.1	115	140	80	98	97	15	3.1	203	16	3.3	240	5.8	5.8	16100	17280
19	24	M	147	72	33.3	121	128	68	97	96	17	2.7	220	18	2.8	250	5.2	5.2	15488	16764
20	19	M	148	55	25.1	118	138	70	98	95	19	2.8	289	20	2.9	294	6.2	6.2	16284	17466
21	18	M	150	53	23.6	121	140	74	97	95	19	3.4	378	16	3.2	389	6.4	6.4	16940	18204
22	18	M	148	52	23.7	120	138	70	96	96	12	2.5	269	15	2.7	279	6.5	6.5	16560	16884
23	19	M	151	51	22.4	130	134	78	98	97	13	2.6	286	12	2.7	297	6.5	6.5	17420	18216
24	20	M	159	56	22.2	127	140	82	97	96	11	2.3	298	14	2.6	321	6.1	6.1	17780	18460
25	21	M	162	59	22.5	129	142	80	98	97	11	2	175	15	2.3	200	5.9	5.9	18318	18944
26	25	M	153	62	26.5	120	146	78	96	97	9	1.8	129	12	2.5	134	5.7	5.7	17520	18750
27	19	M	156	65	26.7	116	134	76	97	98	10	2.5	141	13	2.9	152	5.6	5.6	15544	16560
28	25	M	145	58	27.6	121	136	74	98	97	10	2.6	259	15	3	156	6	6	16456	17500
29	23	M	149	59	26.6	118	140	80	96	97	14	2.7	233	17	3	250	5.9	5.9	16520	17712
30	23	M	150	60	26.7	130	128	74	97	97	11	2.4	275	14	2.7	280	5.9	5.9	16640	16750
31	23	M	154	62	26.1	121	138	72	97	98	17	2.8	279	20	2.9	285	5.7	5.7	16698	17892
32	24	M	150	66	29.3	116	142	70	97	97	18	2.7	297	21	2.8	302	5.5	5.5	16472	18204
33	19	M	160	58	22.7	115	148	80	97	98	13	2.1	255	14	2.5	267	6	6	17020	18240
34	20	M	153	56	23.9	121	132	82	98	97	16	2.6	223	19	2.8	230	6.1	6.1	15972	17526
35	23	M	148	55	25.1	126	140	68	98	98	22	3.8	376	24	3.5	403	6.2	6.2	17640	18176
36	21	M	150	62	27.6	112	136	80	97	97	10	2	187	15	2.3	192	5.7	5.7	15232	16800
37	25	M	147	54	25	114	140	82	98	96	11	2.4	190	14	2.7	198	6.3	6.3	15960	16848
38	20	M	160	53	20.7	121	138	78	98	97	12	2.6	245	15	2.9	240	6.4	6.4	16698	17750
39	18	M	150	60	26.7	128	132	74	97	98	18	3.4	311	21	3.5	324	5.9	5.9	16896	17940
40	25	M	157	59	23.9	124	134	78	96	96	15	2.1	234	18	2.4	245	5.9	5.9	16616	17920
41	22	M	154	52	21.9	127	140	76	98	98	13	2.8	250	16	2.9	259	6.5	6.5	17780	18720
42	21	M	149	59	26.6	124	136	74	97	97	11	2.1	210	13	2.5	206	5.9	5.9	16864	17664
43	20	M	150	60	26.7	125	124	78	98	96	10	1.6	198	12	1.9	180	5.9	5.9	15500	16640
44	21	M	151	57	25	121	130	74	98	97	12	2.4	200	14	2.6	210	6.1	6.1	15730	16750
45	23	M	156	54	22.2	118	128	78	97	97	25	3.8	379	30	3.9	382	6.3	6.3	15104	16120
46	24	M	155	51	21.2	120	134	76	97	98	15	2.7	120	20	2.6	132	6.5	6.5	16080	17112
47	21	M	152	61	26.4	121	126	78	96	98	14	2.5	256	17	2.5	262	5.8	5.8	15246	16250
48	18	M	150	54	24	120	130	72	96	96	13	2.7	180	16	2.6	194	6.3	6.3	15600	17018
49	19	M	149	56	25.2	116	138	72	97	96	18	3.1	302	20	3.2	309	6.1	6.1	16008	17040
50	25	M	150	63	28	114	140	70	96	97	16	2.8	279	18	3	282	5.7	5.7	15960	17040

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RPP: Rate Pressure Product
METs: Metabolic Equivalent of Task

COMPARISON OF MUSCLE EFFICIENCY IN 100 W
SESSION I (WITHOUT ORS) AND SESSION II (WITH ORS)

S.No	Age	Sex	Height	Weight	BMI	PR	SBP	DBP	SpO2 V	SpO2 VI	TIME V	DISTANCE V	CALORIES V	TIME VI	DISTANCE VI	CALORIES VI	MET V	MET VI	RPP V	RPP VI
1	20	M	156	54	22.2	120	128	80	98	98	7	1.2	120	8	1.4	128	7.7	7.7	15360	16632
2	23	M	160	60	23.4	112	130	82	96	97	8	1.7	140	9	1.8	148	7.1	7.1	14560	16800
3	25	M	149	67	30.2	114	140	78	97	96	9	2	130	11	2.2	142	6.6	6.6	15960	17228
4	19	M	154	53	22.3	116	132	72	96	97	7	1.4	121	8	1.6	130	7.8	7.8	15312	17040
5	20	M	150	59	26.2	120	130	70	97	98	6	1.3	110	9	1.5	140	7.2	7.2	15600	17608
6	24	M	145	57	27.1	124	138	70	96	98	12	2.3	178	14	2.5	188	7.4	7.4	17112	18200
7	23	M	150	61	27.1	130	136	72	95	97	10	2.3	181	12	2.4	186	7.1	7.1	17680	18318
8	25	M	158	65	26	126	140	74	96	98	11	2.1	140	13	2.4	156	6.7	6.7	17640	19350
9	19	M	159	70	27.7	120	142	70	97	97	12	2.4	162	14	2.5	171	6.4	6.4	17040	18500
10	20	M	155	58	24.1	124	130	76	98	96	14	2	152	16	2.5	180	7.3	7.3	16120	17920
11	19	M	159	60	23.7	126	134	78	95	96	8	2.3	145	8	2.5	165	7.1	7.1	16884	17802
12	19	M	148	63	28.8	124	138	74	96	97	15	2.6	231	16	2.8	254	6.9	6.9	17112	17750
13	21	M	148	71	32.4	120	140	70	97	98	15	2.5	135	15	2.7	158	6.3	6.3	16800	18696
14	25	M	157	75	30.4	124	130	76	97	96	12	2.2	152	14	2.5	166	6.1	6.1	16120	18034
15	23	M	152	54	23.4	126	134	74	96	96	19	2	146	20	2.3	154	7.7	7.7	16884	17664
16	21	M	149	56	25.2	123	138	70	95	97	10	1.5	136	11	1.8	159	7.5	7.5	16974	18250
17	23	M	150	60	26.7	121	140	72	97	98	12	2.2	179	12	2.4	211	7.1	7.1	16940	17750
18	24	M	153	61	26.1	117	134	72	98	98	12	2.5	187	11	2.7	194	7.1	7.1	15678	17080
19	24	M	147	72	33.3	121	130	70	97	96	13	2.4	189	15	2.6	205	6.3	6.3	15730	17000
20	19	M	148	55	25.1	119	124	68	98	97	13	2.3	231	15	2.5	254	7.6	7.6	14756	15730
21	18	M	150	53	23.6	125	124	70	97	96	14	3	302	15	3.2	311	7.8	7.8	15500	15744
22	18	M	148	52	23.7	123	128	70	97	97	10	2.2	234	11	2.5	260	7.9	7.9	15744	15840
23	19	M	151	51	22.4	125	130	80	97	98	12	2.3	251	12	2.5	274	8.1	8.1	16250	19240
24	20	M	159	56	22.2	125	138	70	98	96	11	2	257	13	2.4	270	7.5	7.5	17250	18744
25	21	M	162	59	22.5	123	132	68	98	97	12	1.5	146	12	1.6	152	7.2	7.2	16236	18900
26	25	M	153	62	26.5	126	140	70	97	98	8	1.2	110	8	1.5	128	7	7	17640	16560
27	19	M	156	65	26.7	123	136	70	98	97	8	2.1	138	7	2.3	146	6.7	6.7	16728	16520
28	25	M	145	58	27.6	121	136	72	97	96	11	2	196	12	2.2	203	7.3	7.3	16456	17850
29	23	M	149	59	26.6	118	134	74	98	97	12	1.4	148	11	1.6	154	7.2	7.2	15812	18480
30	23	M	150	60	26.7	120	128	78	97	96	9	1.5	179	10	1.8	168	7.1	7.1	15360	16974
31	23	M	154	62	26.1	116	134	70	97	98	13	2	234	12	2.5	246	7	7	15544	16560
32	24	M	150	66	29.3	115	128	70	98	96	14	2.4	259	12	2.6	262	6.7	6.7	14720	15360
33	19	M	160	58	22.7	114	130	78	97	97	10	1.7	213	11	1.9	234	7.3	7.3	14820	16320
34	20	M	153	56	23.9	119	132	70	98	96	12	2.2	197	12	2.5	203	7.5	7.5	15708	14640
35	23	M	148	55	25.1	120	134	72	97	95	18	3.1	295	17	3	270	7.6	7.6	16080	16728
36	21	M	150	62	27.6	124	140	74	98	97	7	1.5	146	8	1.6	153	7	7	17360	16764
37	25	M	147	54	25	120	136	78	97	96	8	2	153	10	2.5	162	7.7	7.7	16320	16256
38	20	M	160	53	20.7	121	134	72	98	97	7	2.2	210	10	2.5	214	7.8	7.8	16214	15500
39	18	M	150	60	26.7	124	128	74	97	98	14	3	260	16	2.8	281	7.1	7.1	15872	15470
40	25	M	157	59	23.9	129	130	70	98	97	12	1.7	170	15	2.9	196	7.2	7.2	16770	18200
41	22	M	154	52	21.9	128	138	70	96	98	10	2.3	211	14	2.7	230	7.9	7.9	17664	17280
42	21	M	149	59	26.6	120	140	72	97	96	8	1.5	154	12	1.7	168	7.2	7.2	16800	19350
43	20	M	150	60	26.7	112	146	74	96	97	8	1.3	150	11	1.6	159	7.1	7.1	16352	19240
44	21	M	151	57	25	126	128	70	97	96	9	2.1	172	20	2.5	186	7.4	7.4	16128	17018
45	23	M	156	54	22.2	120	134	72	97	98	20	2.5	248	21	2.8	265	7.7	7.7	16080	18200
46	24	M	155	51	21.2	124	128	74	97	97	12	2	190	15	2.3	210	8.1	8.1	15872	17931
47	21	M	152	61	26.4	127	130	74	96	96	10	1.8	180	13	2.2	194	7.1	7.1	16510	18318
48	18	M	150	54	24	120	134	74	98	98	11	2.1	132	14	2.5	142	7.7	7.7	16080	17780
49	19	M	149	56	25.2	115	128	70	97	96	14	2.2	234	16	2.7	252	7.5	7.5	14720	16236
50	25	M	150	63	28	110	136	70	98	97	13	2	211	16	2.4	238	8.2	8.2	14960	15360

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