Applied Ergonomics

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Lecture – 09

Good morning and welcome to this lecture which is a sub part of a Physical Ergonomics. So, far we have discussed about the various components of the physical ergonomics, in which we discussed about the physiological aspects and muscular efforts and what are the basic mechanism which takes place when you perform any physical work.

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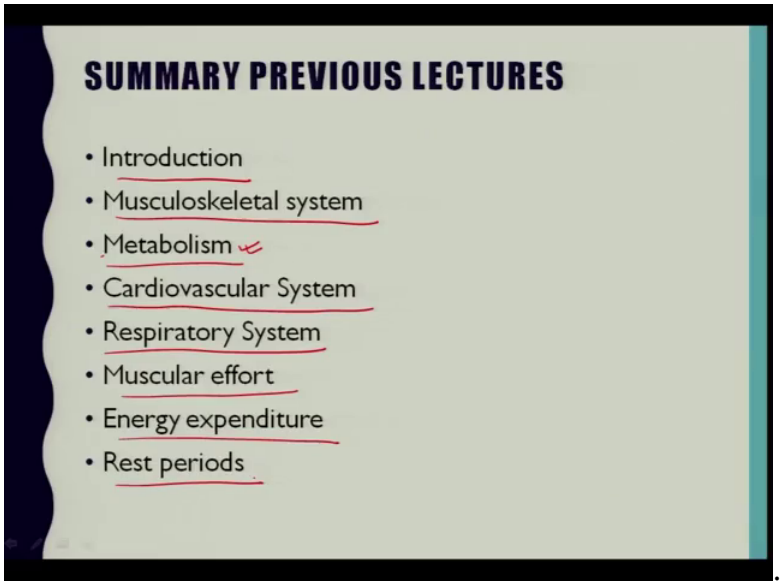

In continuation with that lecture as for as summary of this previous lecture is concerned so we have covered this Introduction about the Musculoskeletal system, what is Musculoskeletal system and what are it is basic components, about the Metabolism, what are what is this metabolism and what is it is function in performing any physical work, about the basic function of Cardiovascular System, Respiratory System and now today we will be going to discuss we discussed about the muscular effort energy expenditure which is in relation with any physical effort performed the human body and the rest period which is an essential component while performing a work for a pro long period of time.

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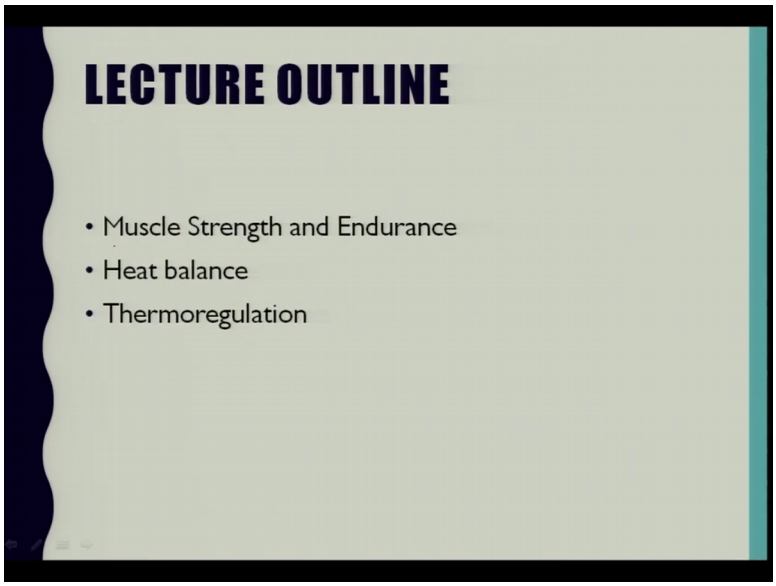

Now as for as today's lectures topic is concerned we will be discussing about the Muscle Strength and Endurance the heat balance done automatically by our body and thermoregulation. So, the first kind of topic that we need to discuss today is Muscle Strength and Endurance. So, as you all know that in addition to energy consideration in the operation of any physical effort which is made by human muscles there are various essential factors.

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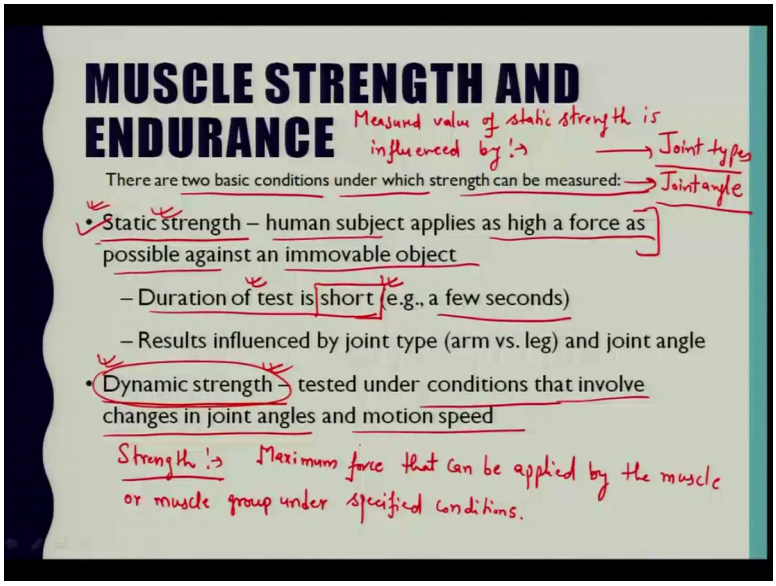

So, that factor is strength you need some strength some power in order to perform work and in that strength is a very unnecessary part.

Any kind of manual work which you are performing it needs strength to perform that particular task. In context with the muscle capacity we have to be define that particular word strength. So, we need to define a strength, all of us knows about the strength. So, strength can be defined as the maximum force that is required or that is applied in order to perform any task in a fullest way and basically this particular a strength. The maximum force that can be applied by the muscle all muscle group under specified or specified conditions.

So, in that context basically a force is usually more convenient to measure it a talk. So, there are basically a 2 basic conditions under which is strength can be measured, first is Static strength and the second is Dynamic strength, in the Static strength the measured a basically this is static strength is measured by the human subject applying as higher force as possible against an immovable object to avoid muscle fatigue the duration of the applied force is short.

This particular period to apply a particular force is short and the tendency of body is to remove that particular force because of the fatigue avoidance or to avoid a stress. So, that is it is clear from the a definition itself that for a few second that particular forces are applied and that 2 is the force is not in variable condition on the force is the moral less constant. So, in that in that period of time the particular force is measured and that is it is strategic strength which is fits by human muscles. Now, this measured value is influenced by various join types, it may be Joint types, Joint angles, the measured value of static is strength of this static, is strength, is influenced, by joint types joint angle as well as motivation of human subject and the other factors also.

Now if you have to define Dynamic strength that it is generally this dynamic strength is tested under the conditions that involve changes in joint angles and motion is speed. So, this particular dynamic strength is a mostly affected by the speed of the motion pattern with higher strength values being associated with slower speeds. If we have to compare this static muscular activity and dynamic muscular activity so I have put one table which is shown here in which the comparison between the static muscular activity and dynamic muscular activity is shown.

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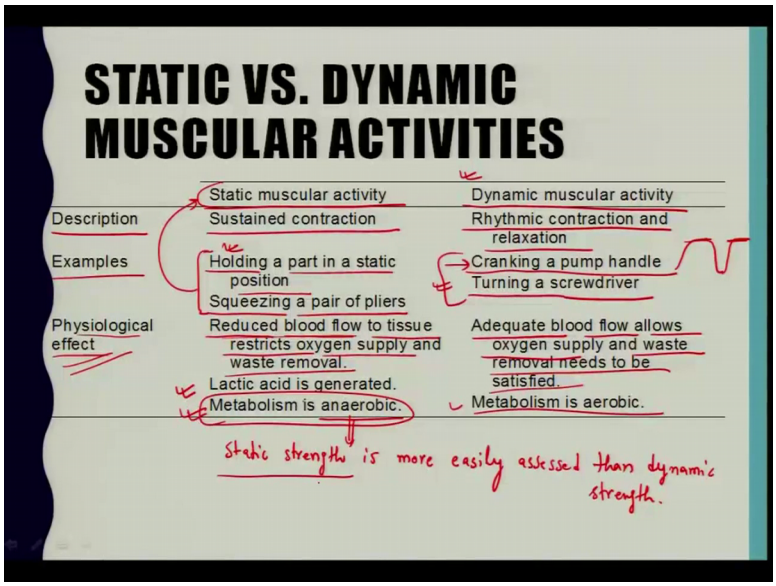

So, this particular table is follow up examples and in this way the difference between these 2 will be cleared to the large extent. So, the description is that into in context with a static muscular activity it is a sustained contraction, but in dynamic muscular activity rhythmic contraction and relaxation takes place.

As an example then you hold a part in static position or squeezing a pair of pliers. So, those force of actions that are involved in this activity comes in this static muscular activity as well as dynamic muscular activity is concerned cranking up pump handle is one of the kind of example where the load is continuously varying and turning as screwdriver in which the force that we are applying is dynamic in nature. So, to the it is sums at some point of time it is going to it is maximum off it is force and then it is again going to 0 then it is going to peak of it is magnitude. In this way the dynamism of the movement is taking place in the movement taking place and these are the examples that you can put to describe dynamic muscular activity.

As far as physiological effect is concerned so this is particular static muscular activity it will reduce it produces basically blood flow to tissue and this particular reduced blood flow to tissue restricts oxygen supply and waste removal, in that particular case electric acid is generated and metabolic activity is an anaerobic. So, whole metabolism is anaerobic. So, anaerobic is absence of oxygen or very less amount of oxygen is involved, in the dynamic muscular activity the adequate blood flow allows oxygen supply and

waste removal needs to be satisfied and metabolism is aerobic. Basically this these all difference so only 2 differences in the required measurement apparatus static strength is more is more easily accessed then dynamic strength and most of the available data on the human strength are in terms of static strength at in real activities are most the work includes dynamic muscular efforts and dynamic effort is physiologically less costly to the muscle than static effort.

So, this was all about the comparison of static and dynamic muscular activity.

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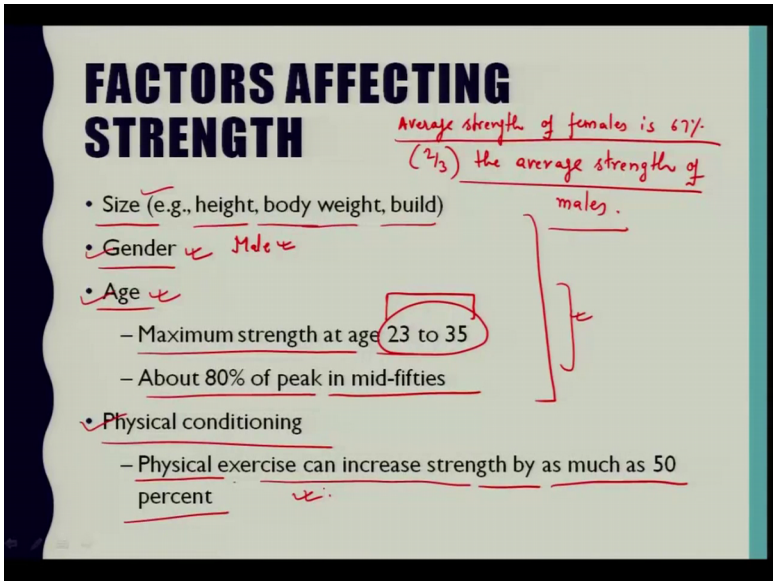

So, now we come to the next thing that is one of the most important thing that is to know or to become aware of the factors that affecting strength. So, as a general activity performer we know that what are the rough parameters which affects strength. So, these has been these criterias have been categorized in several factors. So, basically this as you are aware that there are significant variation in the strength among us or among each and every individuals. So, the differences in measured static strength between the strongest and weakest worker is all can be identified. So, that identification can be done on the basis of size, gender, age, physical conditioning. So, these are all the factors which affect the strength.

These are the possible factors that explain each wide range in human physical strength. So, these are the following personal characteristics like size in which height, body, weight, build physical conditioning, gender, age these are the some of the factors. And

certainly the size and physical conditioning of the workers are key factors size does matter. So, if you we will see that you can you can achieve maximum strength at the age of nearly 23 to 35. So, age is also factor in strength capability, this particular a strength achieves a maximum level in human when they are in between let us say year a 23 to is 35 years. It decreases slowly until the mid forties and then decreases more rapidly thereafter. So, in mid 50 is average is strength is about 80 percent of the peak and in the mid 70 it is about 60 percent of it is peak.

This data has been taken from the original source of this rule of thumb seems to be so 1 writer Ja Roebuck and Kroemer in his book engineering anthropometry methods. So, they have described it is factors affecting strength, I have taken this data from that book and as well as in comparing the strength between the male and female workers. So, it comes as no surprise that male workers are stronger and the rule of thumb that is frequently cited in ergonomic literature is that that average strength of females is 67 percent it means 2 by third two-third sorry the average strength of males over the various muscle groups that are normally tested in the body. So, this was all about the factors and that another factor that remained the untouched. So, that is physical exercise cause increase can increase a strength by as much as 50 percent.

So, this was all about the factors that affect a strength and the again the next topic is your Endurance.

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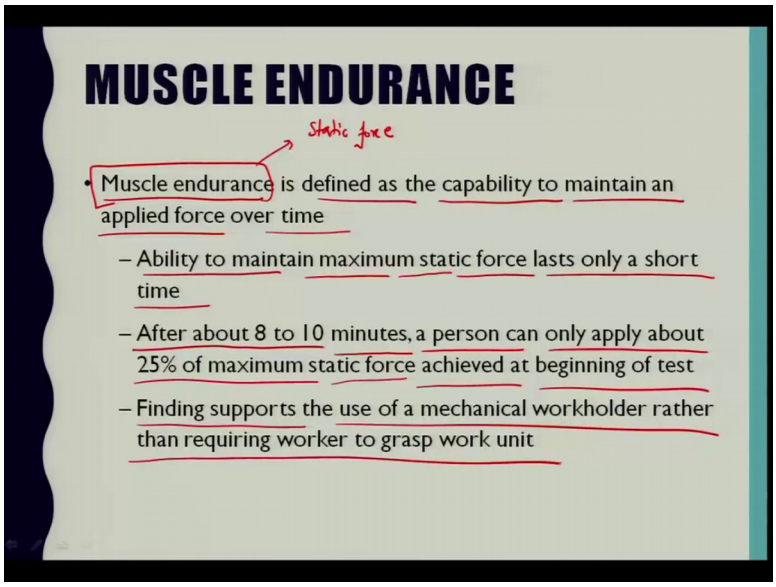

Basically we are talking about Muscle Endurance. So, this Muscle Endurance is defined as the capability to maintain and applied force over the time. So, this particular tern is mostly explained in the context of static force, the ability to maintain his or her maximum static force last only a short time. So, the gender relationship between force capability and time, I have put in the next figure that I am going to show you. So, before that let us have a some facts about that that after about 8 to 10 minutes a person can only apply about the 25 percent of the maximum static force achieved at the beginning of test, and Finding supports the use of a mechanical work holder rather than requiring worker to grasp work unit.

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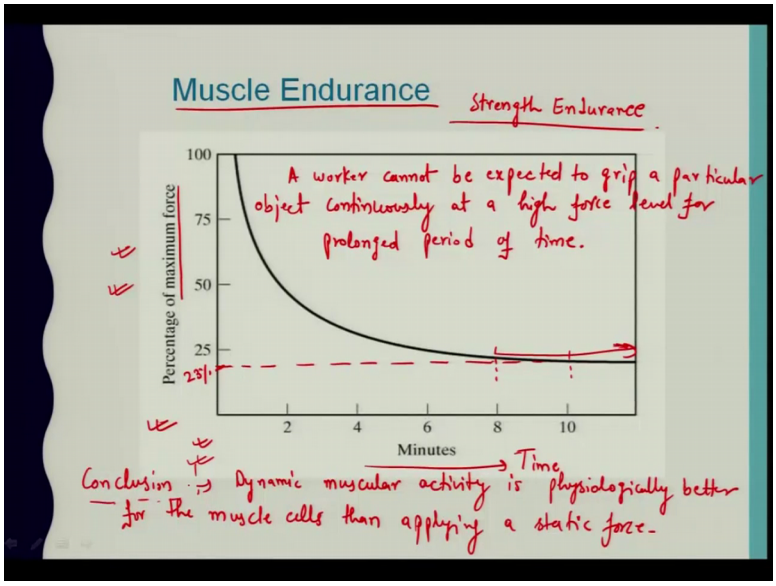

So, this is the particular figure which is showing that the strength endurance. So, this is a general relationship between the maximum force capability that can be applied by a person as a function of time. So, this particular figure is showing the strength endurance. So, this is particular showing the force capability and time as indicated in this figure. So, this plot is suggesting that let us say about after 8 to 10 minutes a person can apply only, a person can apply only about 23 percent of the maximum static force that could be achieved at the start of the rest start of the test sorry and due to the onset of muscle fatigue. So, this finding is important in the design of a work methods because worker cannot be expected to grip a particular object continuously at high magnitude of force or high force level for an for let us say prolong period of time.

So, the general rule is to use a mechanical work holder rather than required the worker to perform that function. So, a somewhat similar relationship occurs in the dynamic muscle activity in which individual is applied to apply forces during a repetitive portion cycle. So, a muscle fatigue gradually causes the applied dynamic force to decline over time, but this decline is slower than in the case of an applied static force and a sustainable bottom level is reached that is higher than 23 percent as observed for static force. So, the differences are that dynamic muscular activity is, In fact physiologically better for the muscle cells then applying static force.

So, this was all about factors affecting strength and the phenomena about muscle endurance.

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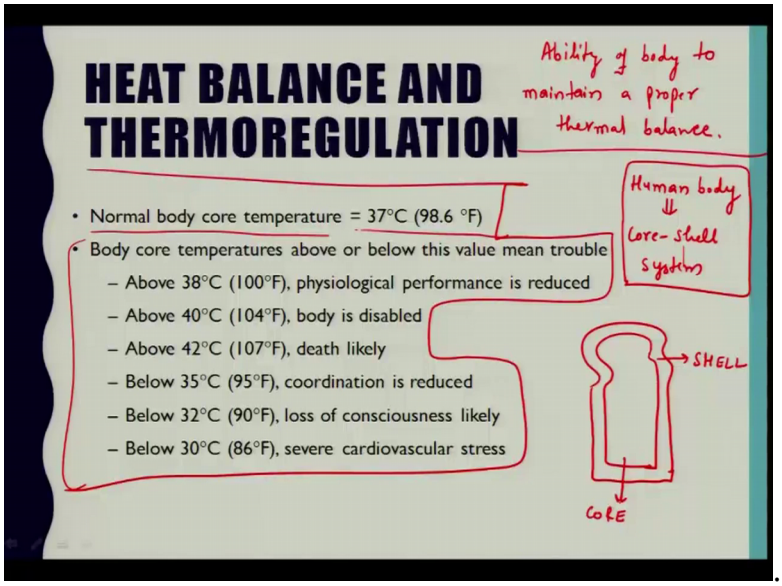

Now, the next topic which we are going to understand as the Heat Balance and Thermo regulation; so as we all know that our body converse or our body adjust himself according to the temperature of the surrounding. If temperature is exceeded then the required temperature of the human body it regulates that internal temperature and it and if it is low then accordingly it also reacts and maintain the body temperature. So, here that is why some facts and some fundamentals regarding to the thermo regulation, we are going to discuss in these a slide. So, the topic is thermo regulation and heat balance. So, apart from since we have studied in the previous lecture that the there are 3 factors which are affecting the capacity of the human body.

First is less Oxygen consumption, second is Heart Rate, and third is that Perspiration or maintaining the proper thermal balance. So, inside the third factor that we are going to discuss here is the ability of a body to maintain a proper thermal balance. If the body temperature rises too far above it is normal level or false too far below that particularly level the body function is entered. Now, forward discussion of thermal balance we need to know some of the facts that a normal body co temperature is 37 degree Celsius. In fact, before going to explain these things let us develop a model of our human being as an, this suppose our human body is consisting of a core surrounded by a shell.

So, human body as a core shell system. So, particularly what is happening here like suppose this is particular human being and there is a outer covering that is protecting human body. So, this particular is shell and this region is core. So, to understand this thermo regulation in a better way let us consider our human body as a core shell system.

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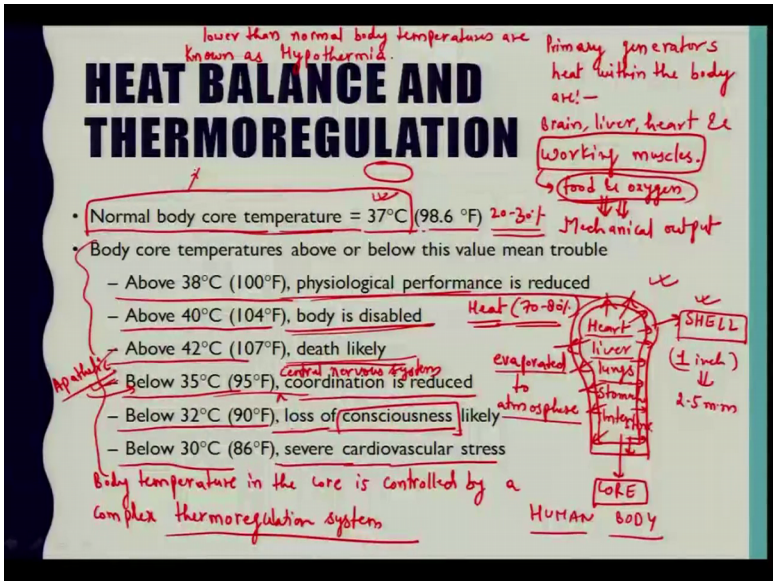

Suppose this is the core and this is so this particular is assumed as a shell and this is core and this whole sys is our human body. For our discussion for thermal balance we have assume that this human body is consisting of a core, which is surrounded by shell; this shell is perhaps one inch thick 1 inch or let us say 2.5 mm thick and it basically it consists of this particular shell consists of a skin and flesh immediately beneath it.

So, the core consists of organs in the body this particular core. So, this core contains the various components inside that, such as heart, liver, lungs, stomach, intestine, and In fact

then should also be included although it compounds the core in shell model somewhat. So, the brain, liver, heart and working muscles are the primary generators of the heat within the body. So, the Primary generators of a heat within the body are and main is working muscles. So, the muscles function to convert this particular working muscle function to convert food and oxygen into mechanical output, but the conversion process from food and oxygen to mechanical output is only let us say 20 to 30 percent efficient and remaining energy is in the form of heat.

So, here we can see that basically it is nothing, but the second law of thermodynamics that each the kind of input that we are providing cannot directly converted and 100 percent cannot be converted into output some other part will go into sink that sink here is as a heat. So, heat is containing the comp remaining portion is as a 70 to 80 percent after all the energy that has been obtained from the food and oxygen. So, here heat is transferred from the core to the shell by blood flowing in the cardiovascular system. So, blood is mostly water which has ideal thermal properties for this purpose.

Ideal thermal properties is like high volumetric specific heat and thermal conductivity as well, at the now when heat goes from core to shell perspiration is produced and the skin and then it is evaporated to the atmosphere, evaporation extracts heat from the body and convection and radiation also contribute to the heat loss if the surrounding temperature is lower than the skin temperature. So, body temperature in the core is controlled by complex thermoregulation system, this body temperature in the core is controlled by a complex thermo regulation system basically that attempts this complex thermoregulation system attempts to maintain a set point of value for our body and that is approximately 37 degree Celsius.

So, that is why the first line of this particular slide is mentioning that normal body core temperature is 37 degree Celsius, that in Fahrenheit 98.6 Fahrenheit. So, this is our normal body core temperature and core is made up of what core is made up of various organs inside our body. Those organs I have listed down the major organs I have listed down and those have the major responsibility to take care of this thermoregulation system within the body. So, the body core temperature that increase or decrease significantly from this particular value mean trouble. So, core temperature above 38 degree Celsius tend to reduce the physiological performance, temperature when

temperature of the bodies above 40 degree Celsius. So, a here the dead body gets disabled if temperature above 42 degree Celsius Fahrenheit 107.6 Fahrenheit.

So, this particular temperature is likely to cause that, now in the following regime if we talk about the temperature below 35 degree Celsius. Basically if the lower than the normal body temperature are called hypothermia. In fact, that 1 more point which needs to be a known that lower than normal body temperatures are known as hypothermia and can also have severe consequences if the deviation becomes too large. So, below about 35 degree Celsius the central nervous system coordination is reduced. So, the coordination in the among the various part of the central nervous system is reduced and the person becomes apathetic and person becomes apathetic.

Below 32 degree Celsius muscles become very rigid and the person loses his consciousness. So, loss of consciousness likely to happen and when the temperature is below 30 degree Celsius the muscles become a very rigid and In fact, there is a severe cardiovascular a stresses and In fact, the death occurs when body temperature drops to around 27 degree Celsius. These are the very serious facts that person must be aware because these are the limitations of our body and these are the temperature domain and certain domain certain. Say up to certain temperature our body is performing a function and if it is below certain temperature, these kind of things are happening if the our normal body co temperature is above 37 degree Celsius.

So, these shorts of happening are making our body in at our some situations and the person will not be in position to make a recovery out of that particular situation. So, this was all about the thermoregulation and the conditions where the body can survive and body cannot survive.

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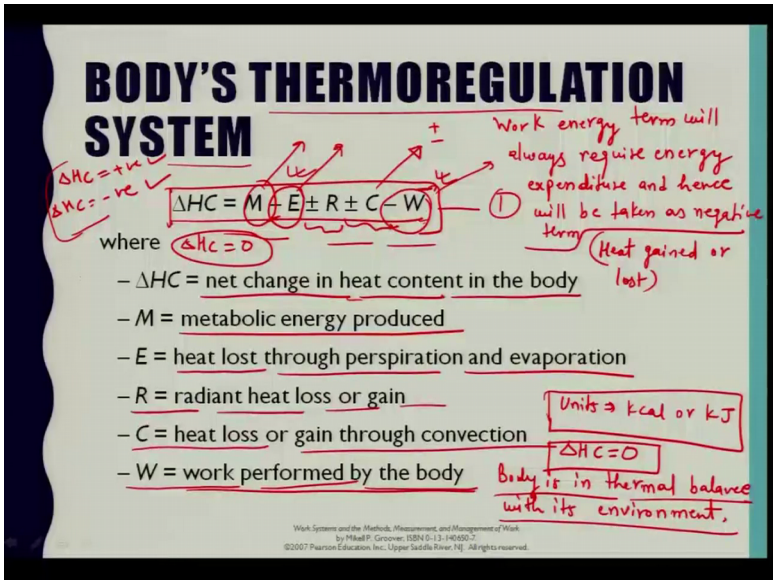

As for as Body is Thermoregulation System and some sort of calculation is concerned, this is a particular equation through which we can speculate the thermo regulation and thermal balance as well. So, the body is thermoregulation system maintenance this particular body temperatures within the narrow range about normal my achieving a thermal balance with the environment. So, the environmental temperature is should be well should be in well range in order for a human performance.

This particular thermal balance involves heat exchange between the body and environment and that can be expressed in the form of equation the equation is given here. So, delta H C equals to M minus E plus or minus R plus or minus C minus W. So, this particular equation is used to evaluate the thermoregulation of our body. So, where this particular delta H C is the net change in heat content in the body, that net change in the heat content means Heat gained or lost. M is the metabolic energy produced E is the heat lost through perspiration and evaporation, where R is the radiant heat loss or gain, C is the heat loss or gain by convection, and W is the work performed by the body.

So, appropriate units in the equations are Kilo Calorie or Kilo Joule. All though this particular equation is not practical for actual calculation, but it is a useful conceptual model in order to have an approximate evaluation of or in order to have a complete discussion of how body temperature can be regulated and how much particular energy is required in order to regulate that particular temperature of the human body.

So, accessing the terms on the right hand side of the equation the metabolism is always a positive term, because of the heat generation that accompanies the biochemical reaction associated with it. So, it will always be taken as a positive, since here the evaporation is taking as the negative term. So, it will always be a negative term as it is indicated by the minus sign. So, the minus sign is appearing because the heat of vaporization required to convert perspiration that is mostly water to vapor.

So, much of the heat is extracted from the body, that is why this negative sign is appearing here in the equation radiation are can be positive or negative. So, this particle radiation is positive or negative depending on the weather the bodies cooler or warmer it is cooler or warmer than it is surrounding basically here the next term is convection. So, convection involves the transfer of heat by the flow of fluid past the surface of an object. So, convection can be positive or negative. So, here W is also taking as a negative so, W is work performed by the body. Since work energy term will always required energy expenditure and hence it will be taken as negative term.

Now things are clear that why we are taking these things at the positive or negative or plus or minus. So, the condition is like when delta H C equals to 0 in the heat exchange equation. So, what is the meaning of being 0 this as a right hand side of the equation? So, it means that body is in thermal balance with it is environment, this delta H C as the ideal condition where body is in thermal balance with it is environment, when delta at C is positive or negative it means there is a net heat gain or heat loss that translates into an increase or decrease in body core temperature. So, thermal regulation system this particular thermal regulation system of our body tries to compensate for the deviation from the normal temperature by increasing heat generation one body temperature drops below normal and by expelling heat from the body when it is temperature is above normal.

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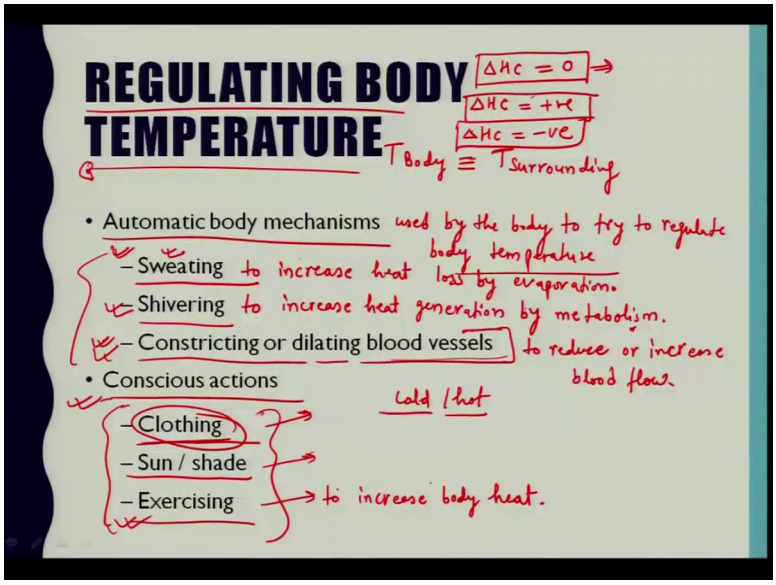

In this way the regulation of body temperature is carried out. So, what we have discussed here I am going to write it here for retaining in your memory that delta H C can be positive, it can be 0 and it can be negative. This is the thermal balance condition where body is in thermal balance with the surrounding if the temperature is in this condition when delta H C is positive. So, this particular thermoregulation system tries to compensate for that deviation from normal temperature. So, that the temperature of the body could be nearly approximately equal to the temperature of the surrounding, that is why those control strategy are guiding by the equation that I have mentioned in the previous slide.

So, here there are 3 automatic mechanism used by the body to try to regulate body temperature. So, there are basically these are well known facts, but we need to become aware of these facts also because to in order to make our body fully functional we need to learn this aspects as these aspects are very much important in order to understand the physical ergonomics in a in a better way. So, this automatic body mechanism used by the body to try to regulate the body temperature, the first kind of metal is mist Sweating, Shivering and Constructing or dilute dilating blood vessels. So, why sweating has occurred this particular mechanisms has a generally occurs in the body to increase heat losses by evaporation shivering to increase heat generation that heat generation is performed by metabolism within the body.

After sweating shivering the next automatic body mechanism constricting and deleting blood vessels, this particular mechanism happens because of the reason that a human

body has to reduce or increase blood flow. In this way these particular main a 3 mechanism through which has been used by the body itself. So, that the temperature of the body can be regulated to it is normal level and in addition to it a person experiencing net heat or loss it likely to take a variety of conscious actions to mitigate that affect the some of the conscious actions I also have listed down those things are to wear clothes sun and shade on exercising.

These are the external what you can say external remedies that you can take in order to regulate your body temperature. In that wearing clothes, depending on the weather whether it is a cold session, you have to wear formal clothes and if there is a excessive heat outside the body. So, you have to wear light clothes second is in coder season moving out moving into the sun light that is option or moving out of the sunlight and into the shade in hot weather and like if you face the cold or a windy weather. So, you have to add more and more layers of clothe in that particular season and the third kind of conscious action is including the exercising the body in cold weather to increase body heat. So, exercising the body to increase blood circulation as well as body heat, these are the main conscious actions depending on the whether the weather is cold or hot you will perform you perform the action and in this way that discussion of the regulation of body temperature is ending here.

So, I am going to close this lecture, but before that let us have a some interesting fact that did you know that bodys machinery adopts to cope with heat.

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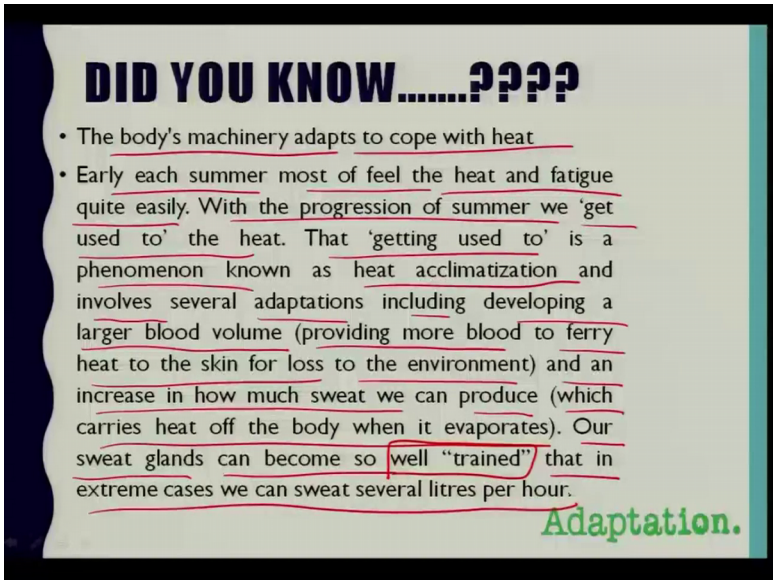

So, early eat summer most the feel the heat and fatigue quite easily. With the progression of summer we 'get used to' the heat. That 'getting used to' is a phenomenon known as heat acclimatization and involves several adaptation including developing a large blood volume providing more blood to ferry heat to the skin for loss to the environment and an increase in how much sweat we can produce; obviously, which carries heat off the body when it evaporates. So, our sweat glands can become so well "trained" that in extreme cases we can sweat several litres per hour.

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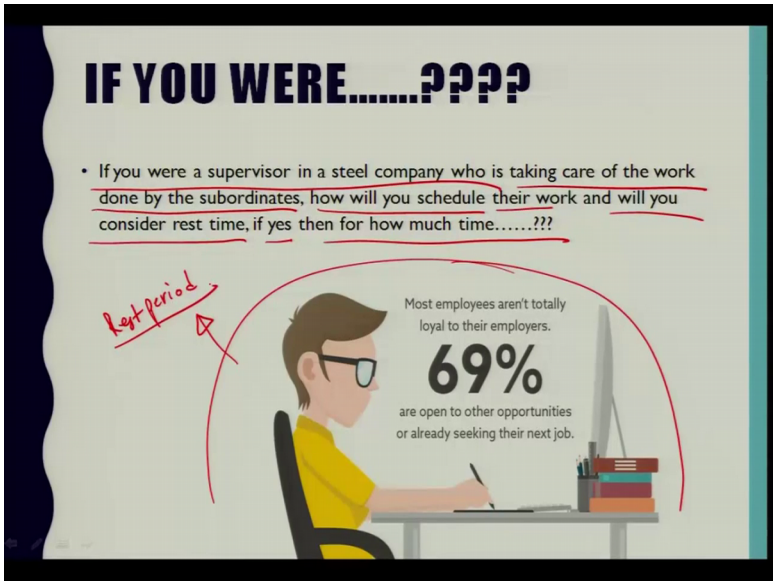

Just one thing that I have added for you just to create humor that If you were a supervisor in a steel company who is taking care of the work done by the subordinates how will you

schedule their work and will you consider rest time, if yes then for how much time? So, that particular the cartoon avoided just to have a recall about the rest period that we learn in the previous lecture.

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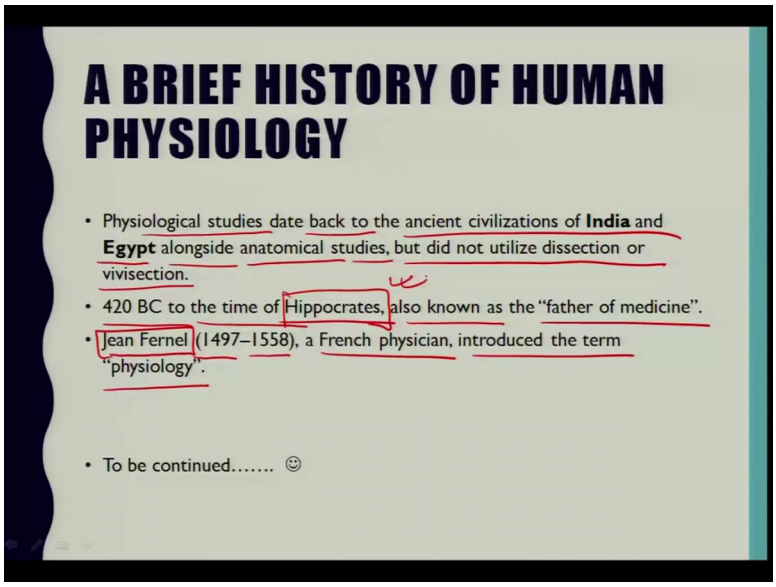

So, before ending let us have a brief history of human physiology because we have to as a tribute we have to recall those researchers and the persons who have contributed largely to the ergonomics. So, the Physiological studies date back to the ancient civilization of India and Egypt alongside anatomical studies, but did not utilize dissection or vivisection. So, in 420 B C to the time of Hippocrates, also known as "father of medicine" and Jean Fernel in 1497 to 1558 French physician; introduced the term "physiology". So, in Jean Fernel and hippocrates have contributed largely to the ergonomics.

Thank you very much.