Applied Ergonomics
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Lecture – 07

Welcome to this lecture. And we have in the previous class covered the human centered design and as far as the summary of this basically this previous lecture, we have covered introduction to human centered design. And we have sort of illustrated anthropometry and description of various dimensions of the body. So, this is the lecture in continuation with the previous lecture.

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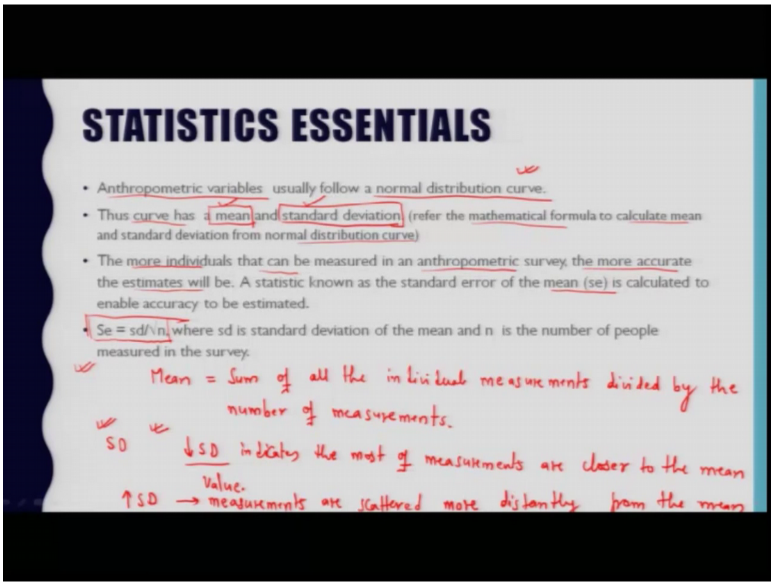

So, just have a recall of our previous lecture that we have discussed about Anthropometry. So, this anthropometry is a word which is derived from 2 Greek words Anthropos and Metrons. It means that measurement of human body. So, these anthropometric data which means that data which we have obtained from the measurement of human body is used in ergonomics to specify, the physical dimensions of the work spaces, equipments, vehicle, any system design, just to ensure that these products physically fit their users.

In most of the cases we have to perform analysis and we require some statistical analysis. So, in that first before designing for the population of the users, we have to take care of the kind of majority of the people in that population. So, first we have to specify the user population and then design to accommodate as wide as range as possible.

So, normally 90 percent of the users, why this particular 90 percent we have taken, we will discuss these things in detail. So, as far as statistical measurements are concerned, these anthropometric variables usually follow a normal distribution curve. So, these anthropometric variables follow a normal distribution curve.

Now, we will understand what this normal distribution curve is all about; what is the importance of this normal distribution curve in order to analyze any anthropometric data which we have captured with the help of measurements of various parts of the body as per the requirement. So, this particular curve has a mean and a standard deviation I will speak about the formula with which we can calculate this mean and standard deviation. So, there is a mathematical formula to calculate mean and standard deviation from normal distribution curve, I will discuss about that and the fact is the more individuals that can be measured in an anthropometric survey the more accurate the estimates will be.

So, as statics statistics known as standard of error of the mean that we denote as se in this lecture is calculated to enable accuracy to be estimated. So, that standard error is calculated with the help of this formula that is SESD stands for standard deviation and n stands for the number of people measured in the survey. So, this standard error and it is related applications I will tell you in the forth coming slides. So, this is majorly we will be covering here in this lecture. So, these anthropometric variables in a healthy population usually follow normal distribution curve. So, here in order to understand normal distribution curve in a much better way. So, there are 2 key parameters of the normal distributions which are mean and standard deviation; what this mean is all about this mean is the is the sum of all the individuals. In fact, all the individual measurements divided by the number of measurements.

It is a measure of central tendency and now how you will calculate the standard deviation. So, that standard deviation is calculated using the difference between each individual measurement and the mean. So, I will give you the formula of the same also.

So, it is basically calculated with the help of difference between each individual measurements and the mean. So, basically the value of this standard deviation determines the shape of the normal distribution. This small value of standard deviation indicates the small value of standard deviation indicates the most of the measurement are closer to the mean value and a large value of standard deviation means that measurements are scattered more distantly we can say from the mean. So, the distribution will be having a flatter shape.

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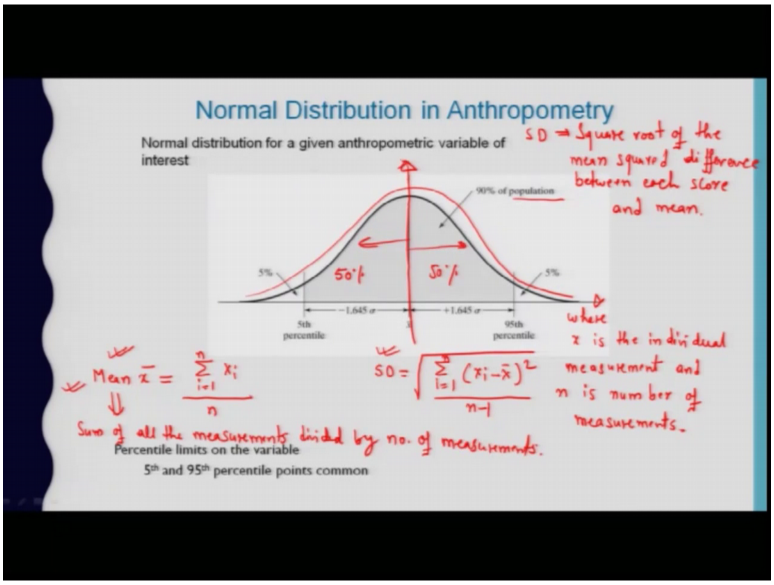

Now, this is the normal distribution representation where you can see this particular nature of the curve and the formula with which we can calculate this mean and standard deviation which I am writing here. So, in order to estimate the parameter of several dimensions or stature in a population it is necessary to measure a random sample of people who are representative of that particular population. So, the formula that we can use to calculate the estimates of the mean and standard deviation are as follows. So, if we have to calculate mean.

So, the formula to calculate mean we are denoting as x bar is sigma from I equals to 1 to n x i in the denominators n. And the formula to calculate standard deviation is if we are denoting standard deviation as SD. So, these are the equations which we use to calculate mean and standard deviation from the measurement sample from a population where x is where x is the individual measurement and n is number of measurements.

So, the mean and the definition wise we can state that the mean is the sum of all measurements. So, mean is the sum of all the measurements divided by number of measurements.

And as far as the definition of standard deviation is concerned so standard deviation can be defined as the square root of the mean squared difference between let us say each score and mean. So, here in this normal distribution curve a important characteristic of this particular curve is that it is symmetric as many observations lie above the mean as below it. So, the right of the mean is equally is equal to the left of the mean. So, if a distribution is normally distributed. So, the 50 percent of the score will lie on either side of this particular axis. So, in this way we plot this normal distribution curve and nature of the variation of the number of the populations or number of users.

So, this is in more detail these properties of normal distribution curves are. So, just have a brief idea of this particular curve is.

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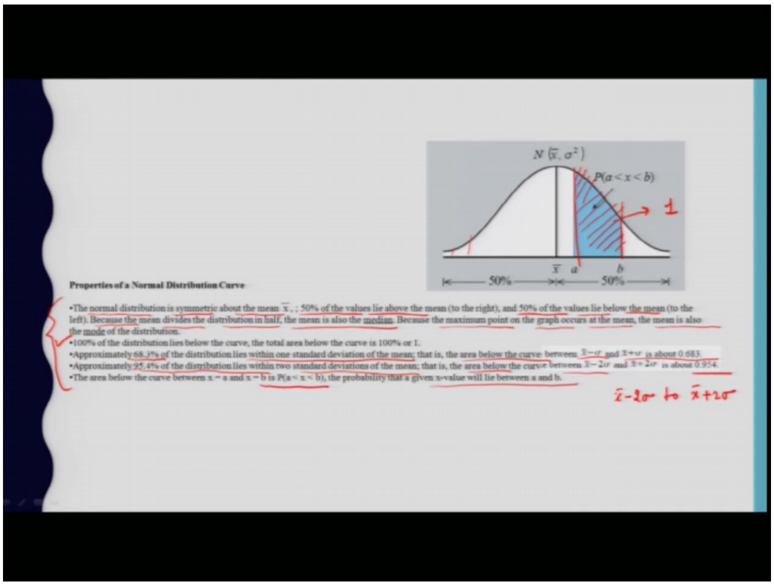

So, the properties of normal distribution curve. So, the normal distribution curve is symmetric above the mean that I have told in the previous slide that is 50 percent of the value lie above the mean and 50 percent of the values lie below the mean. Because the mean divides the distribution in half the mean is also the median, because the maximum point on the graph occurs at the mean. The mean is also the mode of distribution. So, the one more interesting point is that 100 percent of the distribution lies below the curve the total area below the curve is 1. So, the area that is covered by this particular curve is 100 percent means all the datas are lying in beneath this curve. So, the total area is assumed as a it is 100 percent. So, the total area below the curve we can take it as a 1.

And approximately 68.3 percent of the distribution lies within 1 standard deviation of the mean, that is the area below the curve between x minus sigma and x plus sigma is about 0.683 that is 68.3 percent and about 95 95.4 percent of the distribution lies within 2 standard deviation of the mean. So, that is the area below the curve that is x bar minus 2 sigma to x bar plus 2 sigma so about 0.954.

So, the area below the curve between x is equal to a and b if you take any area of the particular curve, which lies between the point a and point b the probability that a given x value will lie between a and b. So, this particular P is the probability. So, now, this is all about the rough idea of normal distribution curve and these things will be more clear when we solve numerical.

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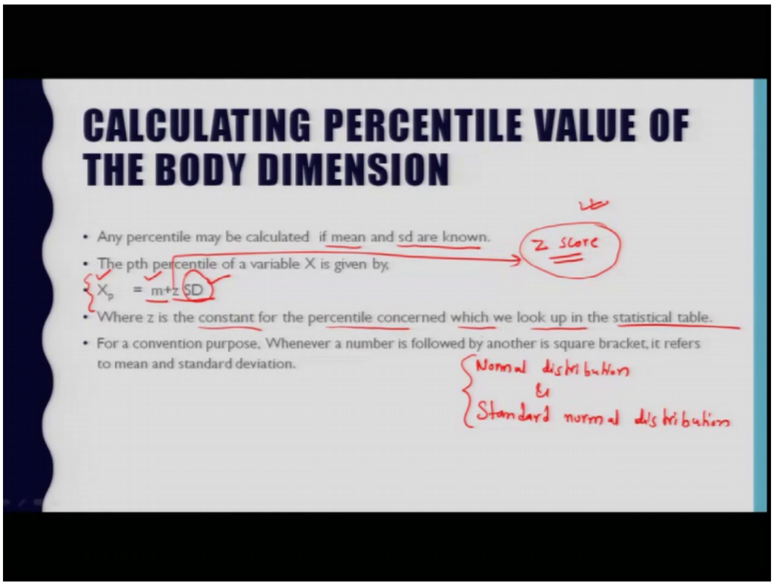

Now the next thing that we need to learn in this anthropometric analysis is the calculation of percentile. So, we will learn how to calculate percentile value of the body dimension. So, the any percentile may be calculated if mean and standard deviations are known. So, there is a formula through which you can calculate percentile of a variable let us say X. So, Xp p-th percentile of a particular variable x can be calculated with the help of and the sum of mean plus standard deviation. So, SD is the standard deviation m is the mean and Xp is the p-th percentile.

Now, if we have known that how to calculate this mean and how to calculate this standard deviation, now the question is how can we calculate this particular z what is this z and how we can calculate this value in order to evaluate the percentile. So, z is the basically z is the constant for the percentile concern which will look up in the statistical table. So, generally this z score we calculate with the help of a table. So, before that we have to know that there is a difference between a Normal distribution curve and Standard normal distribution curve. If we will be able to know the difference these 2 we will be able to calculate this z score because for different values of z under the curve of a normal distribution we have separate values.

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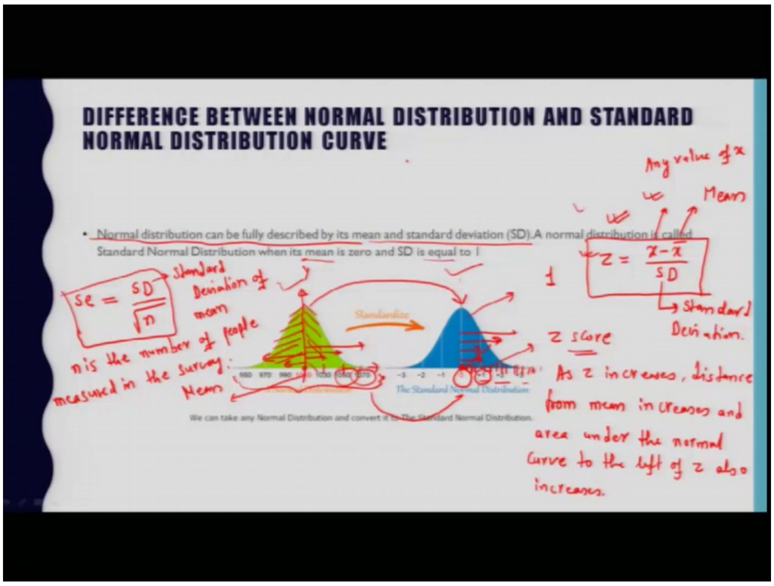

So, now we will try to understand the difference between normal distribution curve and standard normal distribution curve. So, this normal distribution curve as we have learned in the previous slides that it can be described by the mean and standard deviation. So, the value that is calculated as a mean we plot in the in the middle of the curve, that is let us say if it is y axis and it is x axis. So, then the middle of the curve were half of the portion is lying on the left side and half of the portion remaining half of the portion is lying on the right side. So, here we plot it as a mean and as per the standard deviation we calculate. So, we go beyond this particular y axis. So, these are the standard deviation values through which we deviate from the mean of the particular curve.

So, now the difference between this normal and standard distribution curve. So, we have to standardize and bring this curve to this particular status, where this the status is like instead of plotting a particular mean value we plot it in the mid of the particular curve as 0 and with that 0 with respect to this particular point we calculate the standard deviation and that we known in a normal distribution curve as a z score. So, these are the instead of so if a heavier datas are there. So, it is not for complex situations it is not mathematically convenient to have a record of these huge numbers. So, rather than these we convert these particular normal distribution curve as this. So, we as a median we in the mid of the point of the curve, we take it as a 0 and the deviation that has been occurring we plot it as a 1 2 3 or in a lesser numbers that number is known as z score. Now the question is how can we calculate this z score and how can we brought this values as a lesser numbers.

So, here just a so the difference between this normal distribution and standard deviation is that the total area, under the curve, under the basically, under the whole, standard normal distribution has a value of one, that is obvious for both kind of curve. So, by definition as z increases distance from mean increases and the area under the normal curve in fact, to the left of z also increases.

So, how we how we how we will calculate this z score. So, there is a formula through which we can calculate this z equals to x minus x bar eq upon this SD. So, this is the formula through which we calculate this z score where x is the normal value as normal value or any value of x this any x bar is the mean and this STA this particular thing is standard deviation as you now have been aware of the fact. So, we have to put in order to calculate these particular values that is z score we have to calculate first we will have to calculate this mean and standard deviation.

Then we can plot the different values of z score which can be plotting somewhere here depending on the particular value of x. So, this is the particular formula through which we calculate the z score this x minus x bar upon SD. So, in any anthropometric survey the more individuals that can be measured in a particular survey the more accurate the estimates will be. So, in that context the statistics known as standard error of the mean is calculated to enable accuracy to be estimated. So, if standard error is se so we that we can calculate with the help of standard deviation and in the denominator square root of n. So, where SD is the standard deviation of the mean and n is the number of peoples measured in a survey that is anthropometric survey.

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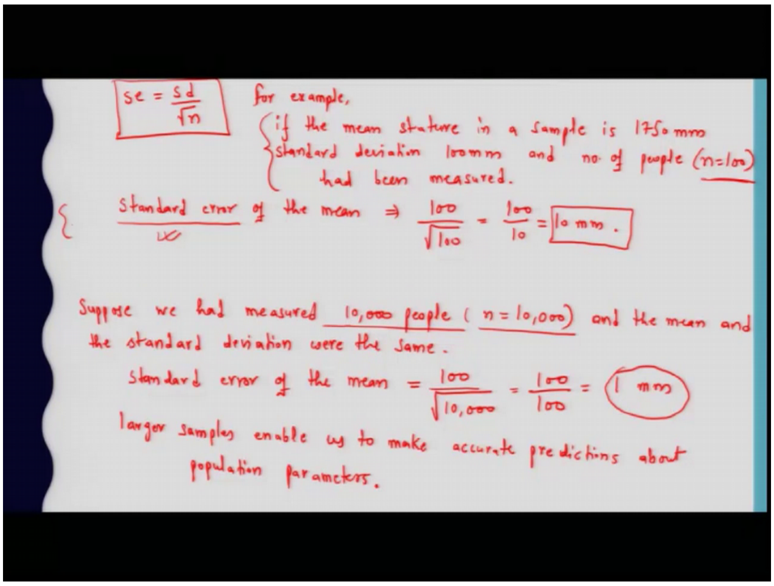

Let us have a one example of this particular formula through which we can estimate something that is really useful to learn. For example, if the mean is stature the stature means any height or any length. So, mean height in a sample is 1750 mm let us say and standard deviation 100 mm and number of people have been measured as a 100. So, the standard error will be in this case standard error will be standard error of the mean. In fact, will be 100 upon square root of 100. So, that will come out as a 100 upon 10 equals to 10 mm. So, let us take another case where suppose we had measured 10,000 people. So, it means the value of n will be 10,000 and the mean and the standard deviation what the same as the previous case.

So, that standard error of the mean will be what it will be standard deviation is 100 and number of people involved in that anthropometric survey are 10,000. So, that data will be coming out as a 100 upon a 100 and it is 1 mm. So, as you can see that here if the number of people involved is 100. So, the standard error that is coming as a 10 mm and if number of people in the survey are involved as many as 10,000 people that is n equals to 10,000. So, error standard error is minimized to 1 mm. So, now, you can see this picture that ks it is you can you can predict particular information from this these 2 examples that more and more individuals if they are involving in a particular survey the lesser will be the standard error.

So, there is a statement that you can make from this particular example that larger samples enable us to make accurate prediction predictions about population parameters. So, that is why in an in any anthropometric survey the number of people should be more. So, for ergonomic work involving the main body segments centimeter accuracy is sufficient because of the uncontrolled variability due to let us say clothing and circadian variation in stature and other factors which change the shape and size of the body. So, sometimes the very large samples probably are not needed. So, more important is to ensure that the sample is representative of the population of interest. So, that is the overall estimation of a standard error of the mean and the illustration of the normal distribution curve.

Now, let us have a another example which we will try to solve and the learning that we have obtained from this particular slide that how to calculate z square z score and this mean and standard deviation. So, we will try to solve examples and try to find out how you can calculate the z score with the help of this formula.

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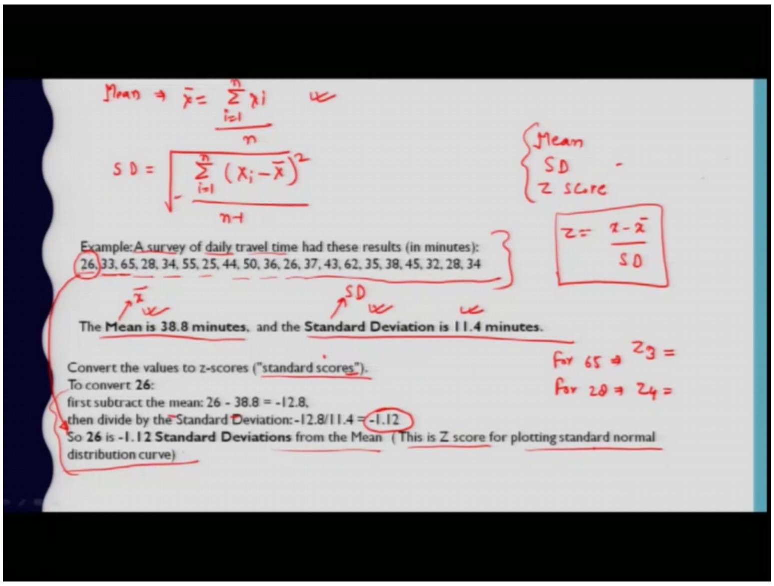

So, now, we will solve one example which says that a survey of daily travel time had these results in minutes; 26, 33, 65, 28, 34, 55, 25, 44, 50, 36, 26, 37, 43, 62, 35 38, 45, 32, 28, 34. So, these are the results that has been obtained by the survey of daily travel time. So, these are the travel time and now we will have to calculate the mean standard deviation and z score. So, that we could have a clear understanding of about the normal distribution curve and which can be drawn with the help of z score.

So, now first how we will calculate the Mean? So, mean is the formula for Mean is clear. So, that is to calculate Mean formula is x bar equals to xi upon n. So, in this way we have to where this i is the number of the travel times; so 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20. So, i equals to 20 and in this way we can calculate this particular mean as a 38.8 minutes and the standard deviation is 11.4 minutes. So, this is the formula to calculate mean and for standard deviation we have another formula summation of i equals to from i equals to 1 to n of number of service or number of terms that have been taken by the mean minus the difference as the mean and upon and minus 1.

So, with the help of these 2 formulas we can calculate this mean and standard deviation. Now, since we have another formula to calculate this z score the we have learned from the so z score is calculated with the help of x minus x bar upon standard deviation. So, for this particular value, so we have to calculate individually for each particular values the z score. So, for let us say 26. So, z will be 26 minus so mean is the x bar and the standard deviation is SD. So, x bar is the 38.8 upon standard deviation has come out as a 11.4 that will be some value. Similarly for 33 you have to calculate z score which will be as a 33 minus 38.8 upon 11.4. So, that will come out as some value. So, in the similar way you will have to calculate for each number let us say for 65 you have you will be having if I am giving as a z 1 z 2. So, it will be z z 3. So, that this will be some value for 28 the value will be something different.

In this way in this way for each particular value you will be having a distinct z score. So, we will have to convert this particular. So, this is the solution that I have already written here. So, that is convert this value to the z score that is known also as a standard score. So, to convert 26 you have to first subtract the mean. In fact, these all the sentences that I have written it is just to calculate the z score with the help of this particular formula. So, again you will divide the standard deviation as minus 12.8 to 11.4 which will come out as a minus 1.12. So, 26 is minus 1.12 standard deviation from the mean. So, this is calculated value which has come out as a for 26, that is for this particular 26 the value is minus 1.12. So, this value you will plot in that particular normal distribution curve as a deviation from the mean. So, this is a z score for plotting standard normal distribution curve.

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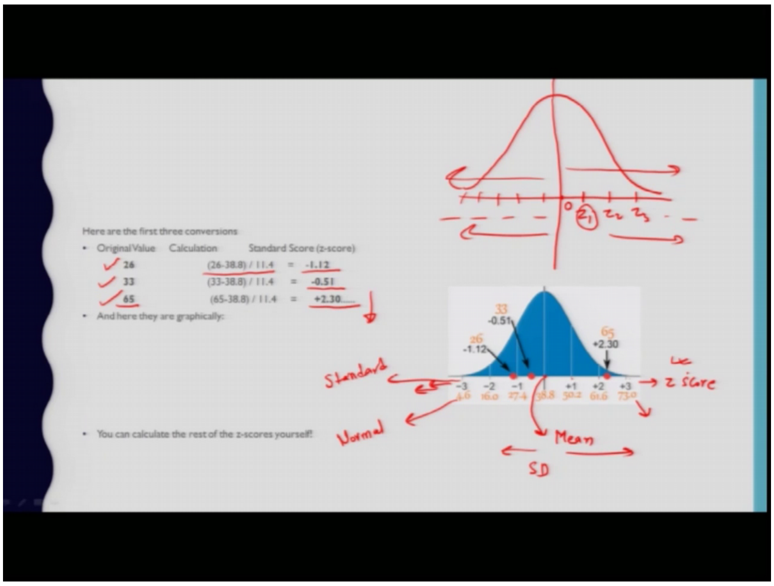

Now let us say for the first 3 value is what 26, 33 and 65. So, I have calculated this value as a original value in it is calculation as this and a standard score has come out as a minus 1.12 for 33 it has come out as a minus 0.51 for 65 it has come out as a plus 2.30 and so and so forth.

So, this will you have to keep on calculating the value for each travel time and up to 20 numbers you will have to calculate the each value of z score. So, then you then after calculating the z score you will have to plot in the normal distribution curve. So, as you as it is clear from the definition itself of standard normal distribution, that you will have to put 0 here and how much deviation let us say if you have to plot in the x axis for each travel time. So, for each travel time there must be 1 z score so that you will plot and in this way. So, let us say if it is lying in the I am not it is not exactly same as the as the score we have predicted that is just notion notation I have used. So, something like that. So, here also the negative values will be plotting here and the positive values will be plotting here.

So, that will be as a as you can see from this figure also that is plus 1 plus 2 plus 3 these are the z score and these are the possible values. So, if you are wanting to plot normal distribution curve. In fact, standard normal distribution curves. So, you will plot it in the form of z score that z score you will calculate with the help of the formula that I have given in the previous slide and as far as normal distribution curve is concerned. So, you will plot in this particular let us say origin here you will plot the mean and the deviation in the left and right side. So, that is the case. So, this is the value for standard normal distribution curve, this is the standard curve and this is the normal curve values. So, this is the difference between the standard and normal distribution curve. So, why we are plotting here because in the later stages of a while solving anything any numerical you will be requiring this particular curves assistance.

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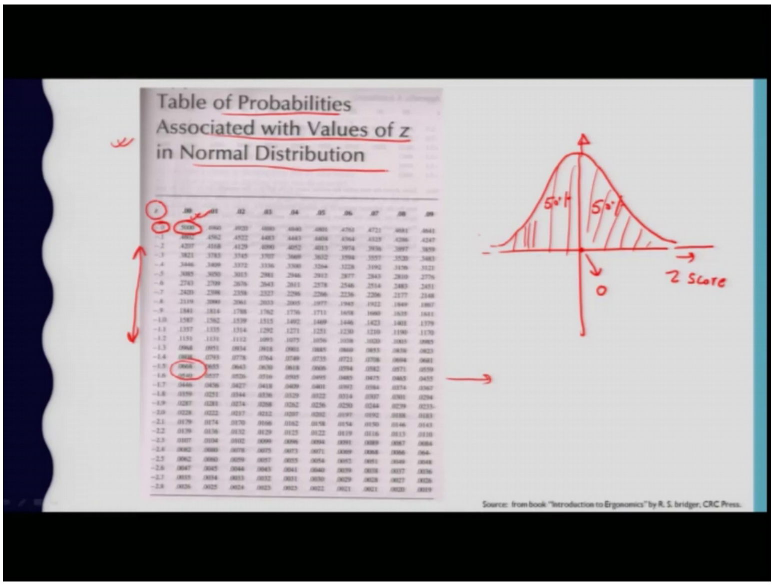

So, I have put a table from book are written by (Refer Time: 36:20) that this is the table of probability associated with the values of z in normal distribution. So, what is indicating it is non-generally while solving numerical this particular table is given to you. So, in order to make your calculation fast and you can choose that particular z score value from this only. So, just I am picking one example in order to understand this particular curve. So, here is a z score if it is coming out as a 0.

So, the area which is going to cover is 0.50 it means that this particular value is indicating that that if z score is 0 this is in the x axis we are plotting as a z score. So, this is 0 so correspondingly the area will be 0.50 it means the 50 percent on the left and 50 percent on the right. So, that is the z score is also used for prediction of the how much area that particular standard normal distribution curve is covering.

So, in this way the these are the z score values that and correspondingly the values are given. So, in this way you can calculate the probabilities of the area covering in this particular curve.

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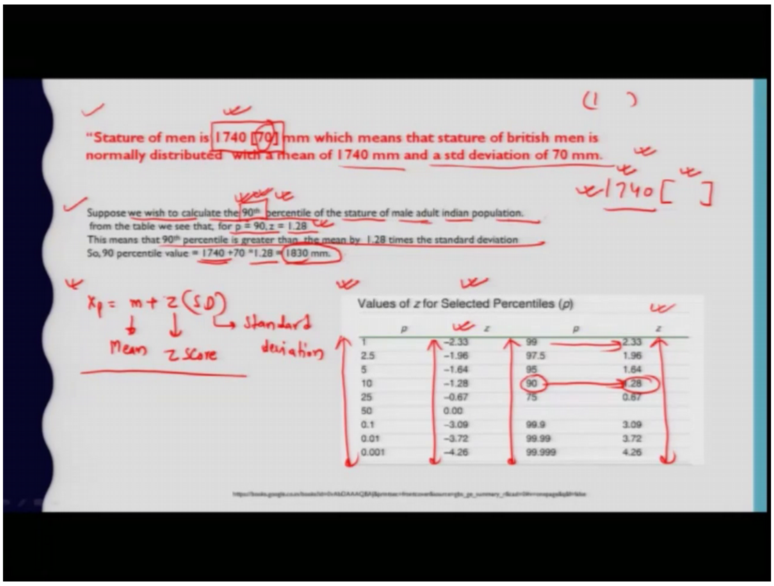

So, now in most often you will read any book and if you find something written as this particular notation like some number let us say some number let us say like 1740 and in the large bracket something is written. So, it means that the digit written outside the bracket will be indicating the mean of that particular user population or measurement and in the bracket that standard deviation is mentioned. So, that is why I have written this statement that stature of men is 1740 in bracket 70 mm which means that stature of British man is normally distributed with the mean of 1740 mm and a standard deviation of 70 mm. So, this particular notation is indicating that the first kind of digit is mean and in bracket that digit mentioned is standard deviation value.

So, now we will take another example and so that the more clear understanding towards the calculation of percentile could be developed. So, suppose we wish to calculate the 90th percentile of this stature of the male adult Indian population. So, there I have put one table for you. So, that immediate z score value can be taken for our kind of calculation. So, from the table we can see that corresponding to p equals to 90 there is a z score value 1.28. So, we have the formula is known so it is very much easy for us to calculate this particular thing. So, as you can recall from the previous slide we have gone with one formula that is this 1. So, x p equals to m plus z times standard deviation so that formula we will we will use in order to calculate the pth percentile.

So, that formula was xp equals to m plus z times S into D. So, that was the pth percentile and m was mean, z was a z score that we have now understood how to calculate this particular z score value and SD is; obviously, standard deviation. So, now, we have to calculate the 90th percentile of this stature of the male adult Indian population. So, first we have to see that here what things are given as p equals to 90. So, this formula is used for calculating the particular value of the percentile. So, now, this table is given this table is the is giving the values of z for selected percentile. So, here is the percentile like these are the percentile values and these are the possible z score values.

Let us say if 90th percentile if you are talking about so it is indicating that it is z score value will be 2.33. So, taking the values corresponding to this table we can evaluate from this so we require the 90th percentile value. So, here we have to find the 90th percentile. So, corresponding to 90th percentile the value of z score is 1.28. So, now, we have we will take this value. So, from the table we can see that p equals to 90 z equals to 1.28. So, this means that 99th percentile is greater than the mean by 1.28 times the standard deviation. So, here we will put these values like mean is given as a 1740 z score is already taken from the table that is 1.28 and a standard deviation is written here in the inside that bracket. So, this is 70. So, 1740 plus 70 into 1.28 which will give you 1830 mm this is the 90th percentile value of the stature of male adult Indian population

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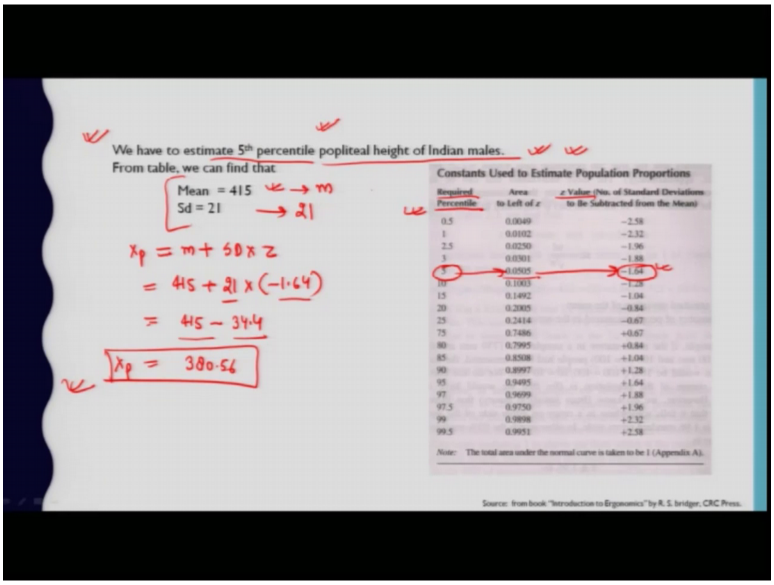

Again we will solve one more example so that the things could be cleared out in a much better way. So, that we can also we could also you learn how to use this table which will give you the probable value of z score. So, now, the question is we have to estimate the 5th percentile popliteal height of the Indian male. So, how you will calculate that the if the table is given so in that. So, how you will calculate the 5th percentile like again you will use the values given the table and dimension and the formula that we have used in the previous slide that for a particular, let us say p-th percentile the value is calculated with the help of mean plus standard deviation times z. So, Mean is 415 standard deviation is 21 and correspondingly the corresponding to p-th percentile the value is value of the z score is what. So, we have to thus required percentile is given in this table.

So, 5th percentile is the area to the left of z is 0.0505 and the corresponding z value is minus 1.64. So, this value is of our use and this value we will pick up from the table and put it here. So, m is the mean. So, it is 415 plus standard deviation is 21 into minus of 1. 64. So, here the value will become coming like when you multiply this 21 and 1.64 it will come out something like 34.4 you check this value and subtract this to this. So, you will be getting tentatively like 380.56. So, this particular value you will be getting. So, in this way the things are clear that how you will calculate the percentile value of any particular user population when the mean and the standard deviations are given and in the table z score will be given to you.

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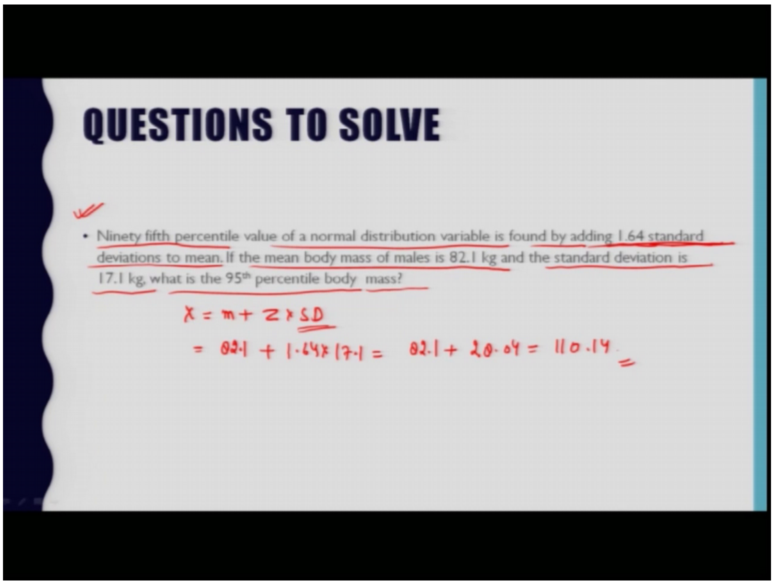

Now the next question is which is again just for the practice. So, the 95th percentile value of a normal distribution variable is found by adding 1.64 standard deviation to the mean. So, if the mean body mass of the males is 82.1 kilo gram and the standard deviation is 17.1 kilo gram what is the 95; 95th percentile body mass?

So, here again we will use the same formula that is so here the things are given like mean body mass is 82.1 plus this particular value is given like it is itself is given. So, you can just have to make a sentence in the mathematical form. So, you can easily convert this particular sentence in the mathematics mathematical equation that is found by adding 1.64 standard deviation to the mean. So, it is something like 1.64 into mean is what, In fact the standard deviation is what 17.1 that will come out as a 82.1 plus 28.04 something and it will come out like a 110.14. So, these are the questions that could be emerged out from this particular theoretical domain.

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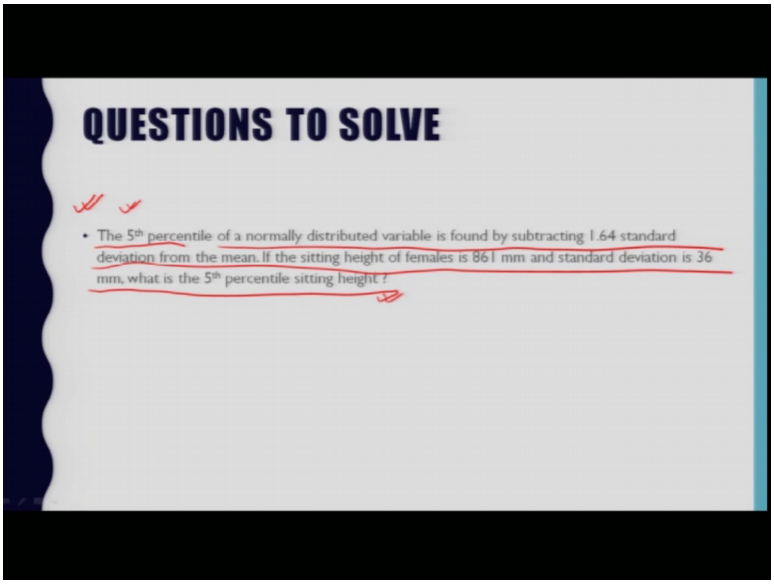

And again there is one more question now I am giving this particular question to you it is much more similar to those what we have solved. So, you can note down this question as well and you solve by your own mind and the answer will be the answer that you have to solve. So, the 5th percentile of a normally distributed variable is found by subtracting 1.64 Standard Deviation from the Mean and if the sitting height of the females is 861 mm and the standard deviation is 36 mm so what is the 5th percentile sitting height. So, that question is I am giving to you just solve it and practice it.

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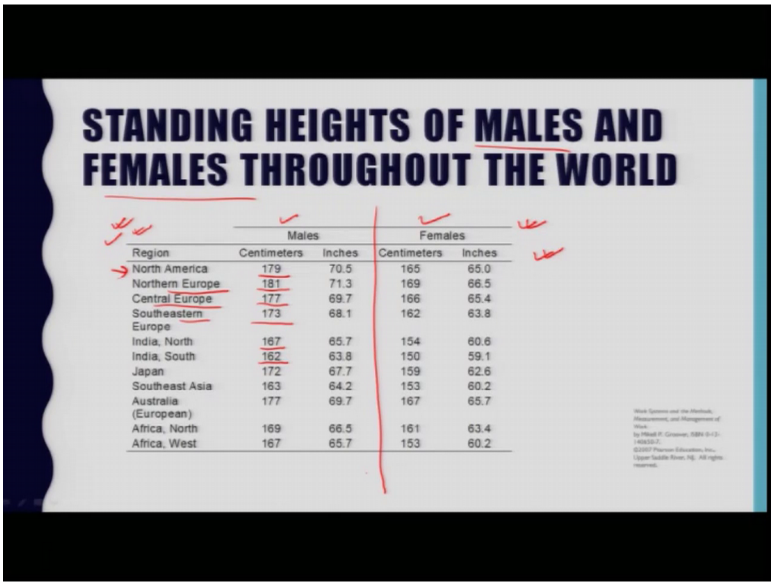

	Males		Females	
Region	Centimeters	Inches	Centimeters	Inches
North America	179	70.5	165	65.0
Northern Europe	181	71.3	169	66.5
Central Europe	177	69.7	166	65.4
Southeastern Europe	173	68.1	162	63.8
India, North	167	65.7	154	60.6
India, South	162	63.8	150	59.1
Japan	172	67.7	159	62.6
Southeast Asia	163	64.2	153	60.2
Australia (European)	177	69.7	167	65.7
Africa, North	169	66.5	161	63.4
Africa, West	167	65.7	153	60.2

So, now, there is a 1 table that I have taken from mp Groover book that will give you the standing heights of the males and females throughout the world. So, that is the very interesting data that you can check here that there is a table of male and female and there is a region discrimination here. So, here you can see that these are the anthropometric data basically which is compiled from the population and this usually this can also usually follow the normal distribution curve. So, this data you can you can see here that north American is having the highest not highest, but it is 179 centimeter north northern Europe is having a height of the male as a as a 181.

So, these are basically these this data’s are usually published not only to list mean values, but also to reveal the dispersion and the distribution. So, the central Europe is 177 and south eastern is 173, India north is 167 is 162 southern part of the India mostly contain so this is the data. So, you can you can have a difference between the standing heights of male and female throughout the world.

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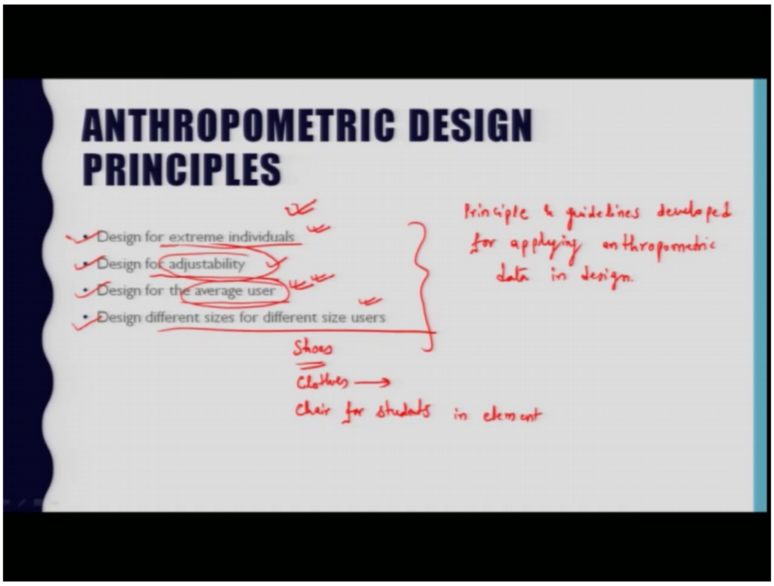

So, now we again go to the next topic that is Anthropometric Design Principles. So, those Design Principles are designed for extreme individuals, Designed for adjustability, Designed for average in user, Designed different sizes for different sized uses. So, basically these are nothing, but the principles and guidelines which have been developed for applying anthropometric data.

So, all the products anthropometric data in design so there are basically variety of designs and that design variation is because of the human size variability and that human size variability we have discussed in the previous slide, which is basically and mostly based on the age and climatic conditions where the people are living and various ethnicity is also one of the major factors and climatic conditions age, sex, health conditions and these are the possible factors of the human size variability.

So, as far as age is concerned so person having age of 20 to 30 as having a difference in it is height or in var in the dimension of various parts of the body, which will be different to the person having older age or the child having less than 5 years of age. So, that is why these 4 principles have been discriminated based on that human sized variability.

So, design for extreme individuals it indicates that the height or the measurement of a tallest person will be surely different from the person who is a is much smallest in height. So, these are the extreme cases I will give you the examples of these distinct principles through which this anthropometric design have been described design for adjustability. So, the products are designed so that certain features can be adjusted in order to accommodate a wide range of users anthropometric dimensions. So, design for adjustability you can think of any example you can take example of automobile driver seat that is adjustable and any chair if you can think if you can visualize in your surrounding so that height is adjustable. So, that is also one of the kind of examples which you can take in the in this category of design of extreme design for adjustability.

So, as far as design for the average user is concerned so average user is. So, average user as an example you can take of the persons who is having age of let us say 25 to 45 where the body posture does not change so much. So, this particular age group you can define in that particular average user and the all sort of if you can take example of cloths and all. So, these cloths are fitting in that particular age group. So, average user is those age group of those age group where design is designing is considered in that design different sizes for different size users.

So, the important examples of these situations may be shoes you can take cloths that can also be considered in the designing of different size for different size users, because cloths designing is different for different age groups. And obviously, chair for students you can take chair for students specially in elementary school.

Thank you.