Textile Product Design and Development
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Lecture - 14
Ergonomics

Today's topic is ergonomics. We will explore the role of ergonomics in the design of textile products and examine its significant influence on the design of various textile products.

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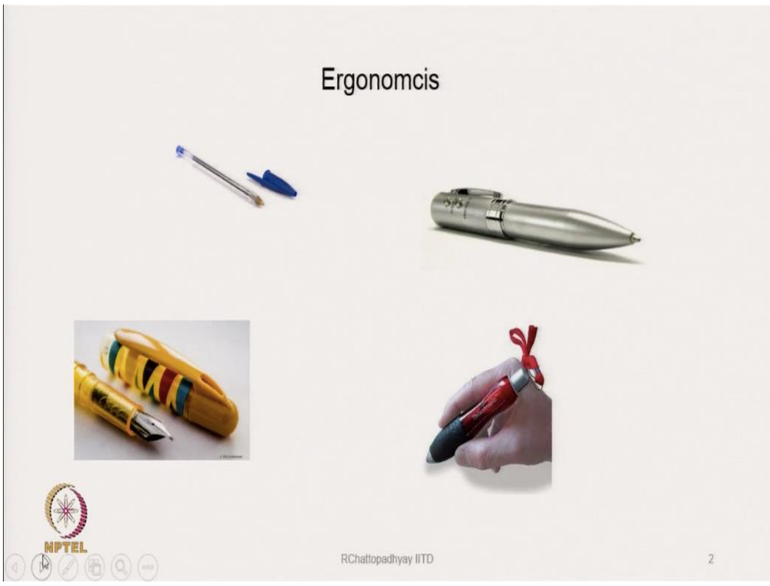

In this slide, different designs of pens are displayed. While all the pens function as writing instruments, the differences are that one is colour, and the other one is size. In terms of size, some pens are quite thick, and certain pens are quite thin. There are reasons for these differences in their size. The colour differences are attributed to the aesthetic aspects as they enhance visual appeal. There is a reason behind the thick and thin size of the gripping area of the pens. Similarly, buttons come in different sizes and are often used in uniforms or dresses.

Some buttons have a large diameter, while others are quite small. These differences are all aspects of ergonomics. Another example is the placement of buttons and buttonholes in a shirt. It is observed that the buttonholes are typically on the left-hand side, and the buttons are on the right-hand side. It is not the case where buttonholes are on the right-hand side and buttons on the left. These design considerations are all connected to ergonomics. We will discuss how ergonomics plays a key role in the design of textile products.

Ergonomics is a vast subject, and we will learn a few principles of ergonomics so that we can make use of these principles in the design activity. If we consider the question of varying size of the gripping area of the pen, i.e., thick and thin, the answer lies in the age of the person using the pen. When giving a pen to a toddler just learning to write, a thin pen will be difficult for the child to grip. The gripping part needs to be made slightly thicker to improve the gripping of the pen.

Similarly, for elderly individuals, particularly those over the age of 70 whose fingers may tremble or have stiff joints, a thicker gripping area is also necessary. Hence, pens tend to have larger diameters, making them easier to hold and use. For adults and school-going children, a thinner pen works just fine. However, even these pens are not too thin, as the user needs to grip the pen comfortably and control its movement on paper. Pen designers pay careful attention to this gripping aspect and address it in various ways.

In some cases, to improve grip, the gripping area of the pen is not smooth but slightly made rough, preventing it from slipping easily. Alternatively, some pens have a simple rubber grip, providing softness and improved grip. These are all examples of ergonomic design. Similarly, when it comes to buttons, those designed for older people are generally larger in size. This makes it easier for them to grip the button and push it through the buttonhole. Hence, buttons on clothing designed for older people are often made a bit larger.

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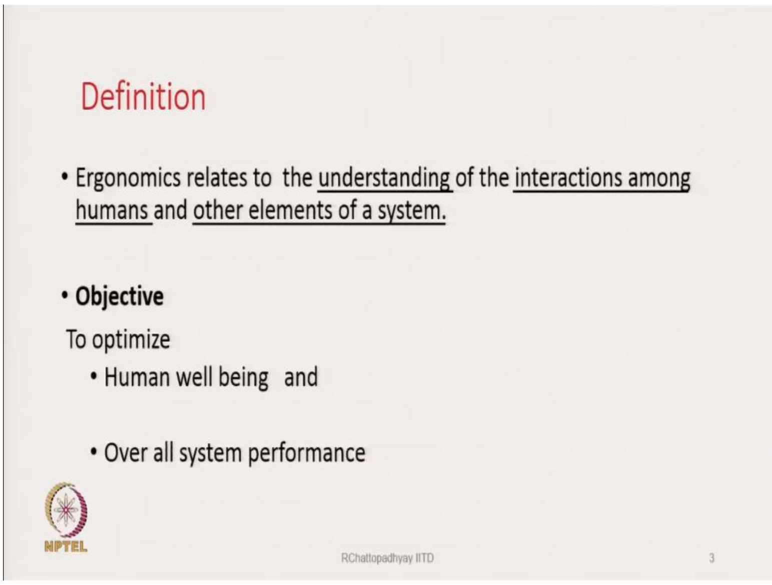

What is the definition of ergonomics? Ergonomics involves understanding the interaction between humans and other elements within a system. To define it precisely, ergonomics focuses on this relationship. The main objective is to optimize human well-being. Whenever there is an interaction between a human and the external environment or the external objects they use, it is essential to prioritize the individual's well-being. Another key objective of ergonomics is to enhance overall system performance, aiming to optimize or improve the whole performance of the system. These are the two important aspects of design in which ergonomics plays an important role.

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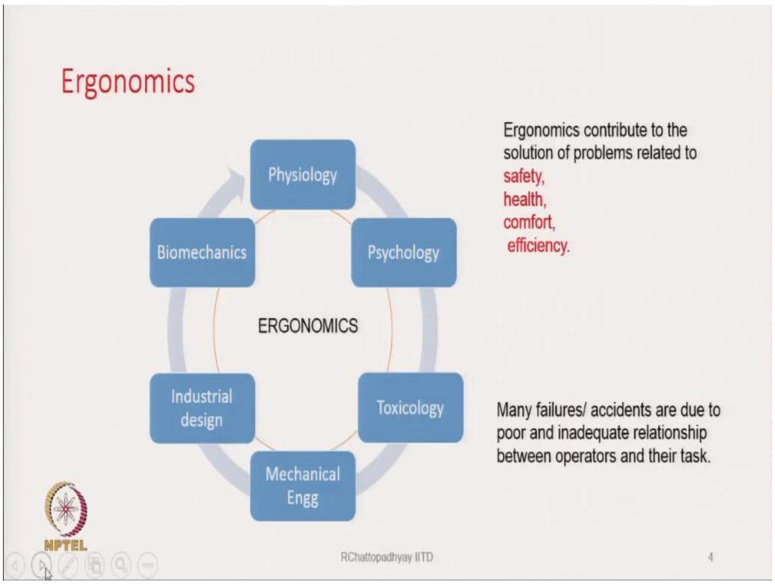

In this slide, we see that ergonomics draws knowledge from various fields. These include physiology, psychology, toxicology, mechanical engineering, industrial design, and biomechanics. Ergonomics contributes to solving problems related to safety. When designing products or systems, it is crucial to consider the user's safety to prevent injuries during their work. Health aspects also must be considered because the person's health may deteriorate due to their working environment or the machines and tools they use.

It is essential to prioritize comfort and efficiency in design, ensuring that the final product enhances the user's overall performance and well-being. Many failures and accidents are often caused by a poor or inadequate relationship between operators and their tasks. It has been observed that accidents in industries or workplaces frequently result from this mismatch. Upon investigation, it often becomes clear that the way the task was designed or set up contributed to the injury or accident, making it almost inevitable.

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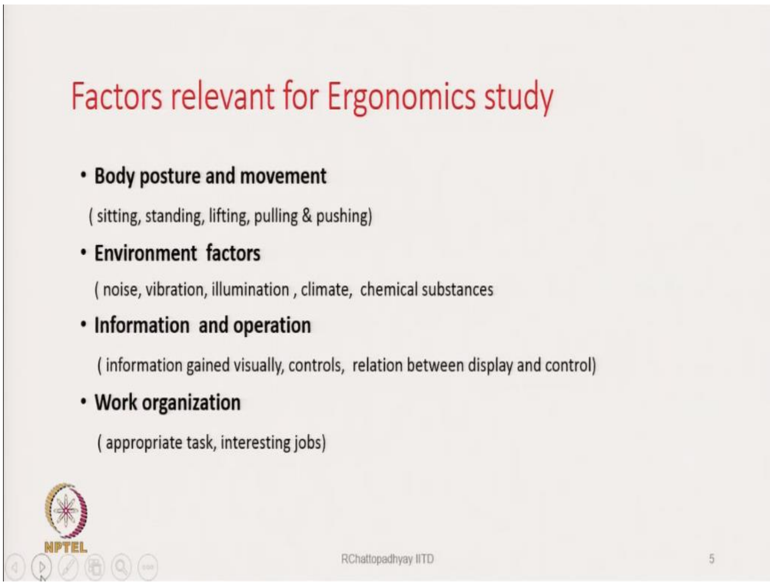

The first factor relevant to ergonomic study is body posture and movement. This includes actions like sitting, standing, lifting, pulling, and pushing, which are essentially all the physical activities a person engages in while working. Understanding how the body is positioned and moves during these tasks is a crucial aspect of the ergonomic study.

The next factor is the environment in which a person works. Some may work in quiet rooms, others in open outdoor spaces, and some in industrial settings. Each environment presents different conditions, and the type of stress experienced by the individual will vary accordingly.

Environmental factors must be carefully considered, including noise, vibration, lighting, climatic conditions, and exposure to chemical substances. Next is the factor of information and operations, which refers to how information is received visually and the relationship between displays and controls. Work organization is another important factor, involving the nature of tasks assigned and whether they are appropriate or engaging for the worker.

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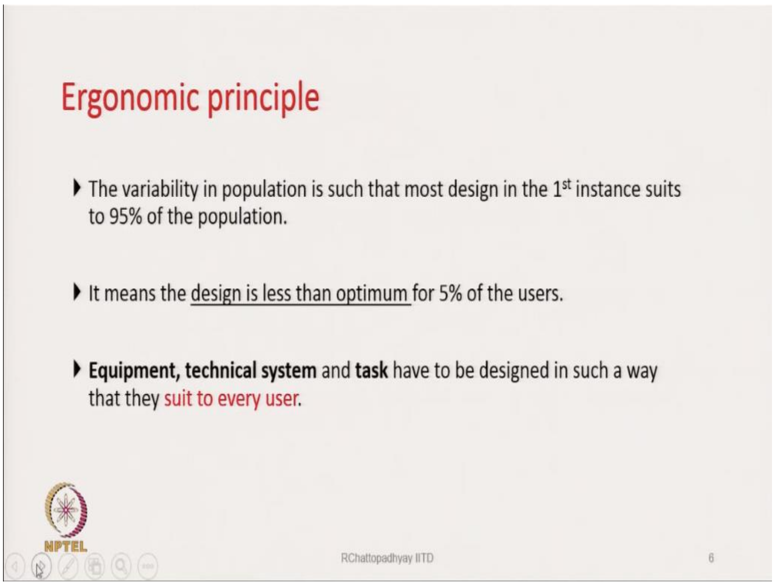

These are the various factors that come into play when considering the ergonomic design of any product. Now, regarding ergonomic principles, one key point to remember is the inherent variability in the population. Humans come in different sizes, shapes, weights, heights, and volumes. Due to this diversity, most designs are initially tailored to suit approximately 95% of the population. This means the design is less than optimal for about 5% of users. Therefore, equipment, technical systems, and tasks must be designed to suit every user.

When designing, the designer often does not see the specific end-user but must remember that the design should work for all types of people, as they are potential customers. So flexibility has to be present in the design.

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People who require special attention from an ergonomics perspective include a diverse range of individuals. These people have varying physical attributes, such as those who are short or tall, overweight, or have disabilities. Additionally, elderly individuals, young children, toddlers, babies and pregnant women also need careful consideration. So, all types of people must be considered when designing products as they are the potential customers. The design should ideally suit every individual, regardless of their unique characteristics. While this scenario is ideal, its success depends on the specific product type. Sometimes, it may not be possible to create a product that suits everyone perfectly, but modifications and adjustments can often be made to make the product more suitable for a broader range of users.

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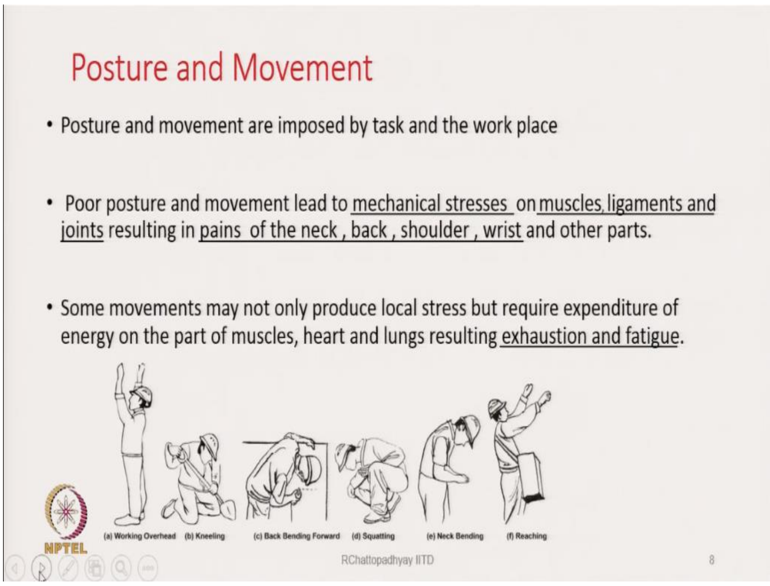

Next is the posture and movement. The tasks performed, and the specific workplace environment influences posture and movement. Poor postures and movement lead to mechanical stresses on muscles, ligaments and joints, resulting in pains in the neck, back, shoulder, wrist and other parts. For example, in the garment industry, where workers operate various sewing machines, their posture and movements are crucial.

To avoid long-term physical strain, how they sit and move their hands, necks, and eyes while working must be carefully studied. It is essential to harmonise their movements to reduce stress on workers while performing tasks, ensuring that stress levels are minimized. However, some movements cause localized stress and require extra energy from the body's muscles, heart, and lungs, potentially leading to exhaustion and fatigue.

Various working postures are shown in the image at the bottom of the slide, highlighting the diversity of positions people may adopt while working. In the image, a variety of postures is observed. some individuals are bending, others are twisting, and some have raised hands. These different postures arise from the specific activities the individuals are engaged in, particularly those involved in physical work.

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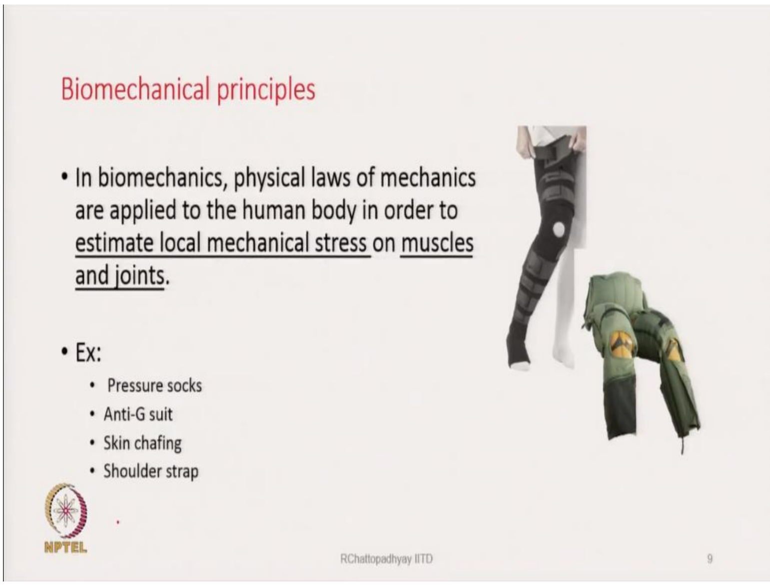

The biomechanical principle is essential in understanding how the physical laws of mechanics apply to the human body to estimate the local mechanical stress on muscles and joints. In the textile industry, for example, when designing products like pressure socks and anti-gravity suits for pilots, particularly fighter jet pilots, to ensure comfort and effectiveness during high-stress conditions. Additionally, considerations around skin chafing are important, as improper design can lead to discomfort and injury.

Minimizing the stress and pressure on the shoulders is essential when designing shoulder straps. In various scenarios, pressures and abrasions can impact our muscles and tissues, sometimes leading to discomfort or skin abrasion. These considerations fall under biomechanics. The implication of design must be done to reduce the mechanical stress on the muscles and joints. The two images illustrate this concept; one shows anti-G suits, and the other is a kind of pressure socks that apply pressure.

There are various designs and types of pressure socks available. It is designed to apply specific pressures on different body parts for various purposes. It is crucial to determine the right amount of pressure required for effectiveness. Additionally, incorporating mechanisms to regulate pressure is another aspect of the design where it can increase or decrease depending on the need. The design should be flexible enough to take care of this aspect. It is also important to ensure the pressure remains consistent over time, maintaining effectiveness without decaying. Ensuring comfort is also another aspect.

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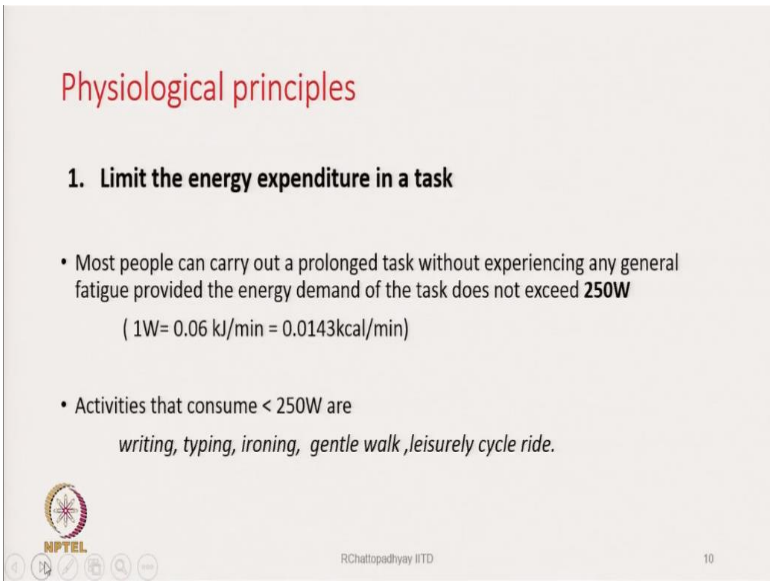

The physiological principle focuses on minimizing energy expenditure during tasks. Most people can carry out a prolonged task without experiencing any general fatigue, provided the energy demand of the task does not exceed 250 watts. There are certain tasks where the energy demand may be 250 watts or less. For example, writing consumes less than 250 watts, and it does not account for fatigue.

When engaging in activities like sitting at a table to write, type, iron, or leisurely cycle, the energy demand for these activities is generally low, making it less likely to experience fatigue. But if it is prolonged sitting or prolonged typing, then some amount of energy may be required. For example, extended periods of typing might cause pain in the fingers or discomfort from maintaining the same posture.

Postures can vary among individuals, and improper alignment can also cause discomfort. Hence, a change in posture is recommended. Office workers, particularly those in the IT industry who spend long hours, often 8 to 12 hours sitting at a desk, are prone to posture-related issues. Therefore, in those cases, prolonged sitting for a long time may lead to some pain in the neck or shoulder.

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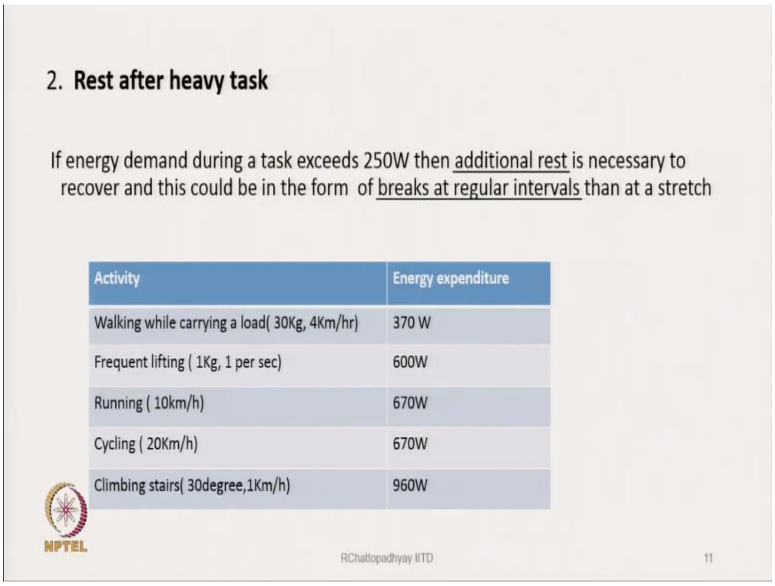

Another thing is rest after heavy tasks. If the energy demand during a task exceeds 250 watts, where a lot of physical activities are involved, then additional rest is necessary to recover, and this could be in the form of breaks at regular intervals rather than at a stretch. There is a mandatory requirement that people must be given rest, especially the workers who are working in the industry. In textile mills, after 4 hours of work, recess is given to reduce fatigue.

There are government regulations that allow breaks after a certain period of time. Some activity and energy expenditure data are provided. Walking while carrying a load of 30 kilograms at a speed of 40 km/hr results in an energy expenditure of 370 watts. Frequent lifting of 1 kg, one per second, results in an energy expenditure of 600 watts. Running at 10 km/h requires 670 watts, while cycling at 20 km/h consumes 670 watts. When climbing stairs at a 30-degree angle and a speed of 1 km/h, the energy expenditure rises to 960 watts.

When climbing the stairs in a high-rise building from the ground to the tenth floor, we will likely feel fatigued due to the significant energy expenditure of almost 1000 watts. After reaching the sixth, seventh, or tenth floor, taking a break and rest is advisable, as this exertion can lead to exhaustion. This consideration is an important aspect of ergonomics.

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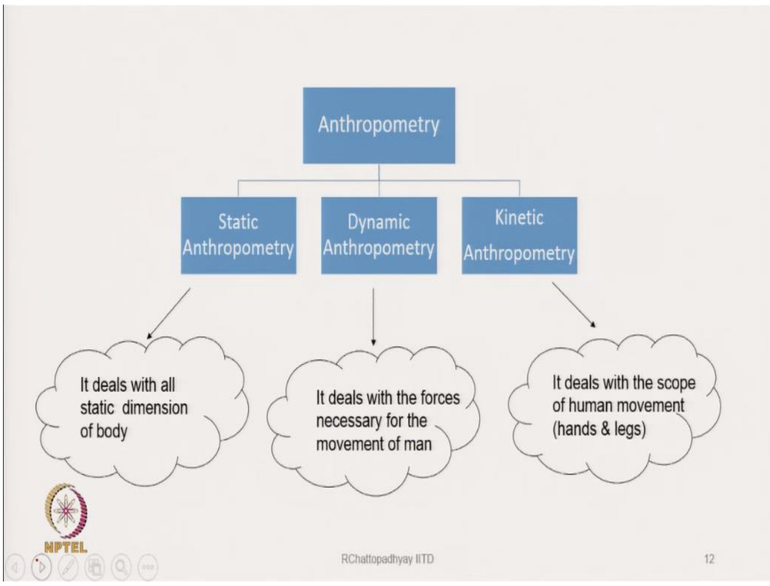

The other aspect of clothing design, especially, is anthropometry. Anthropometry focuses on human dimensions, including the size of various body parts and overall height. These measurements are crucial for designing textile products intended for personal use, particularly clothing. Thus, all types of apparel are based on anthropometric data to ensure proper fit and comfort.

Anthropometric principles are highly relevant for all wearable items, including shoes and gloves. There are three categories in the field of anthropometry. They are static anthropometry, dynamic anthropometry, and kinetic anthropometry. Static anthropometry deals with the dimensions of a body when a person is at rest, whether standing or sitting. Dynamic anthropometry deals with the forces necessary for the movement of a human body, examining how much force is acting on the different parts of the body.

Kinetic anthropometry, on the other hand, focuses on the range of human movements, specifically how far the arms and legs can extend. Accordingly, the designs have to be made. When designing a seating area, it is essential to understand how far a person's arms and legs will move. This consideration falls under kinetic anthropometry. Hence, the three anthropometric aspects are important.

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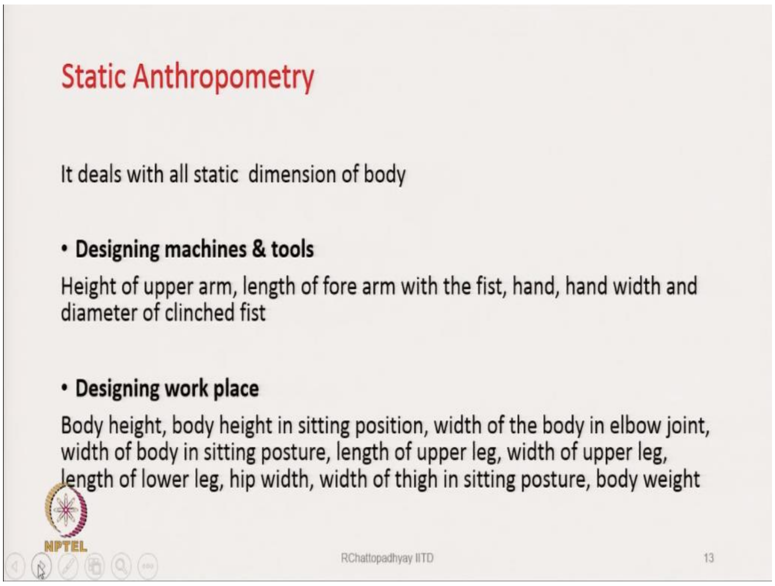

Understanding anthropometry is important when designing machines and tools. For example, when developing a textile machine, such as a spinning machine, it is essential to consider the user's height and arm length. These factors significantly influence usability and ergonomics. Key measurements include the height of the upper arm, the length of the forearm with the fist, hand length, hand width, and the diameter of a clenched fist. Hence, designing the workplace is important in the case of static anthropometry.

Important measurements to consider include body height (both standing and sitting), elbow joint width, sitting posture width, upper leg length, upper leg width, and lower leg length, all of which are essential for accommodating a person in a seated position. These measurements are required for designing the workplace, such as designing the specific chair or the desk or table which will be used by that person.

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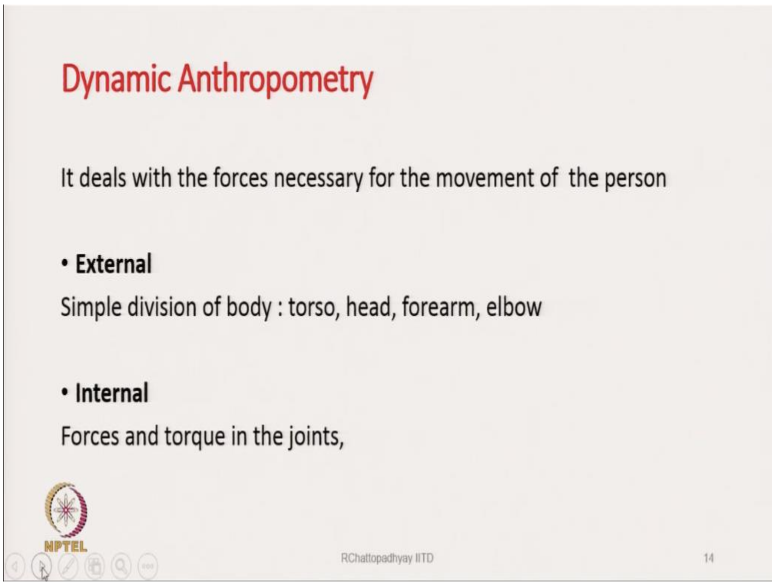

Next is the dynamic anthropometry. It deals with the forces necessary for the movement of the person. The body can be externally divided into sections such as the torso, head, forearm, and elbow, while internally, it involves analysing the forces and torque at the joints. This is important because performing tasks often requires exerting a specific amount of force or torque. Hence, these aspects are relevant to dynamic anthropometry.

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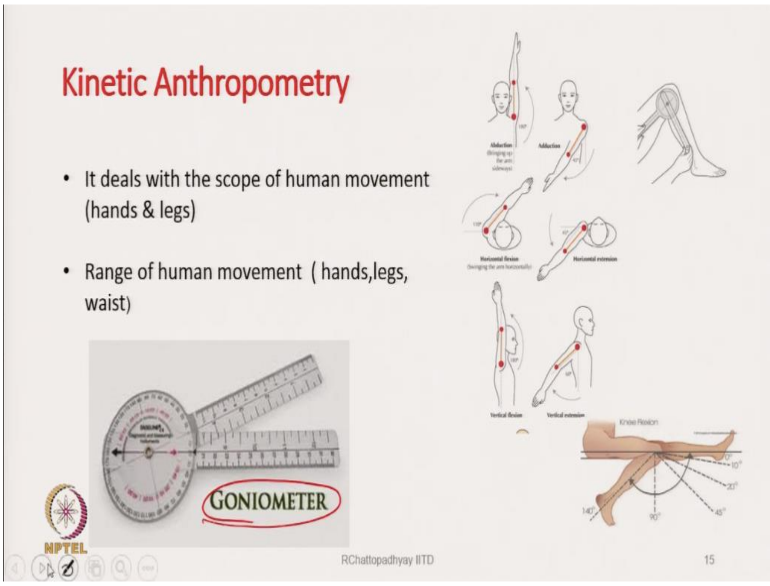

Kinetic anthropometry deals with the scope and range of human movements, such as how far the hands, legs, and waist will move. The design of clothing can restrict movement. For example, when creating uniforms for specific workers, such as firefighters or soldiers, it is essential to ensure that the design does not restrict movement. If the clothing hinders the movement of the limbs, it can negatively affect performance.

These considerations fall under kinetic anthropometry. For example, tools like a goniometer are used to measure the extent of movement, as mentioned in the slide. This device helps to assess the angular movement of various body parts across different planes.

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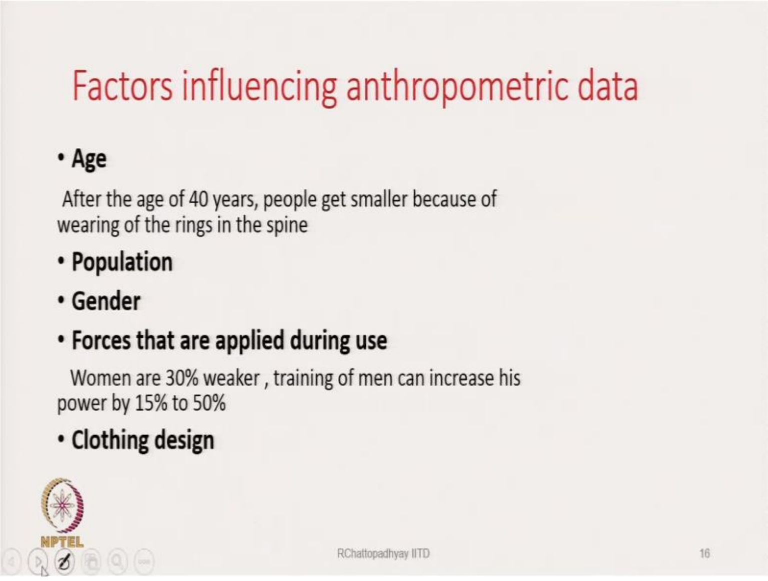

Next are the factors influencing anthropometric data. The first important factor is the age. After reaching 40 years, individuals may experience a decrease in height due to the wear and tear of the rings in the spine. Hence, older adults often appear shorter. Additionally, anthropometric data can vary across different populations. People's body dimensions can vary significantly depending on different regions.

For example, individuals from the western part of India may have larger body dimensions than those from the eastern part. Additionally, there are gender-based differences to consider, as well as the forces applied during use. On average, women may exert about 30% less force than men. Therefore, when designing products for women, it is important to account for this reduced strength. Additionally, training can enhance a man's power by 15 to 50%. Clothing design can affect the scope of the moment.

As mentioned earlier, clothing design can significantly restrict the scope of movement. This is a crucial consideration, especially for specific types of apparel. In critical situations involving safety or emergency response, poor design can have serious consequences, potentially even life-and-death outcomes.

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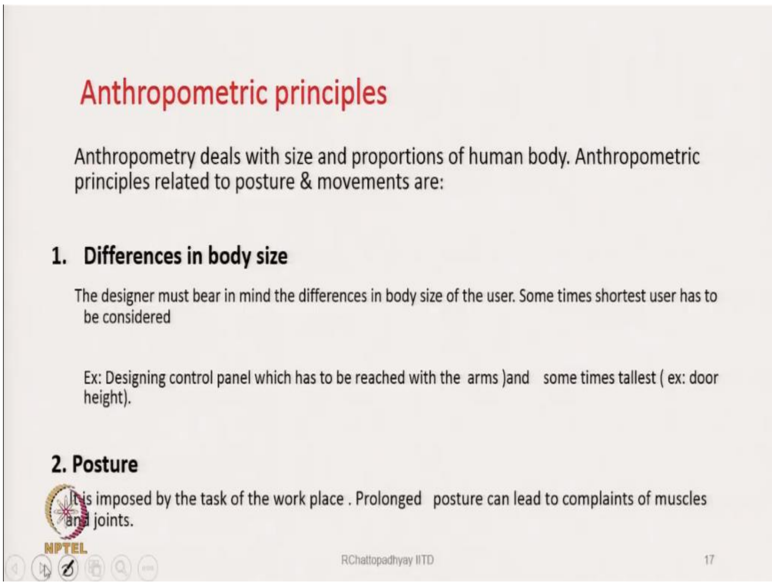

Anthropometry focuses on the size and proportion of the human body. Anthropometric principles related to postures and movements are differences in body size and postures. One key consideration for designers is the variability in body size among users. When creating products, it is important to account for the shortest and tallest users. For example, when designing a control panel, it is important to consider the alignment with the user's wrist and arm.

Similarly, when determining the height of a door in a building, the height of the tallest people must be accounted for. The doorframe height should accommodate even very tall individuals, ensuring they can enter easily. When designing a control panel, whether in a car, it is essential to ensure that even shorter individuals can comfortably operate it. Control panels should be such that the person should be able to look at the control panel and can be able to take control actions.

Another important aspect to consider is posture, which can be influenced by the tasks performed in the workplace. Prolonged postures may lead to discomfort or complaints.

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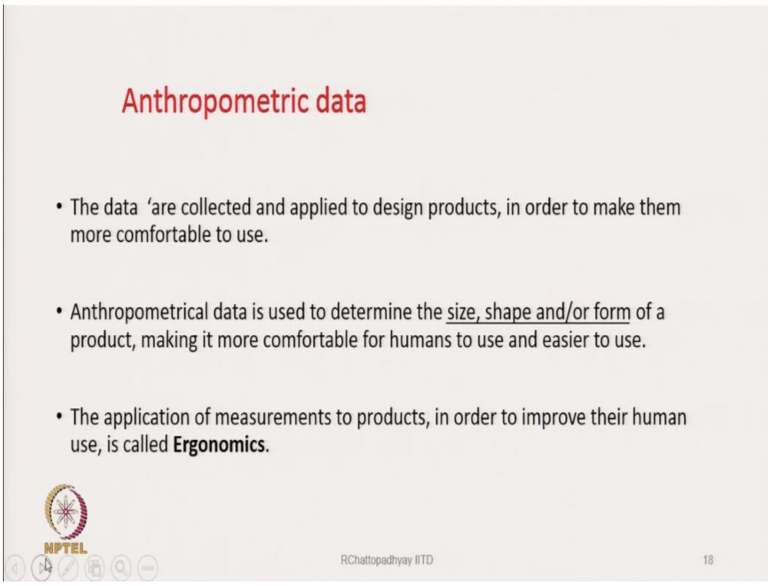

The anthropometric data are collected and applied to design products to make them more comfortable to use. This data is used to determine the size, shape and form of a product, making it more comfortable for humans and easier to use.

Therefore, anthropometric data collection is important. Applying measurements to products to improve their human use is called ergonomics.

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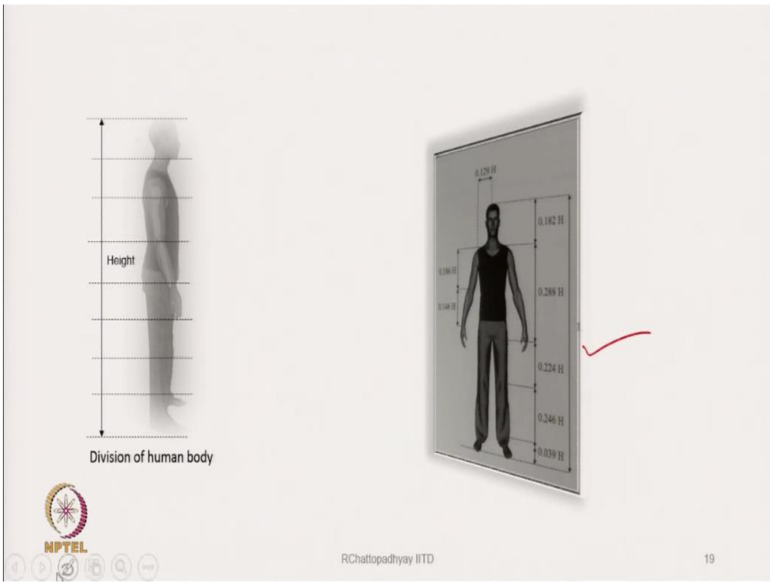

Anthropometry and ergonomics are closely related and interconnected fields. For example, the diagram illustrates the overall height of the human body and the dimensions of various body parts, demonstrating how these measurements are taken.

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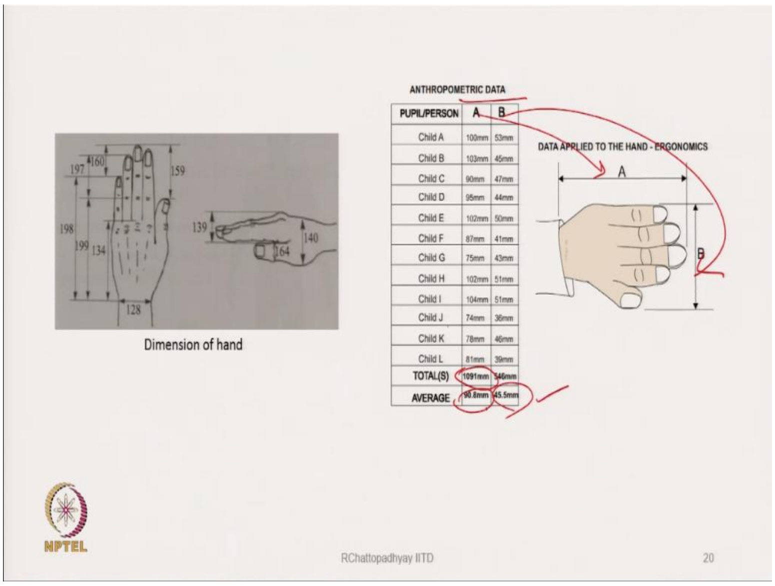

The anthropometric data related to the palm is illustrated here. This example highlights the various types of data we should collect when designing a product. Without complete information, the critical details are not considered, impacting the design. Here are some examples of anthropometric data, specifically for children. There are two measurements: ‘A’ represents one dimension, and ‘B’ indicates the width.

The data is collected for twelve children, allowing us to calculate the total and determine the average values. When designing a product, such as a glove, based on average measurements, we might find that it fits some children well, while it may be too small and loose for others. That means that designing a product based on the average value will not be able to satisfy all the customers.

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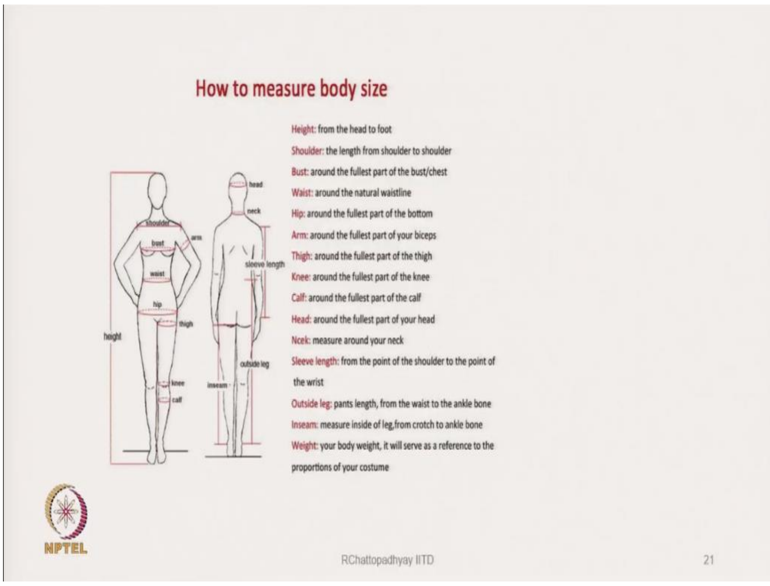

This is another example illustrating how to measure body size. It also highlights the different body parts that are typically measured.

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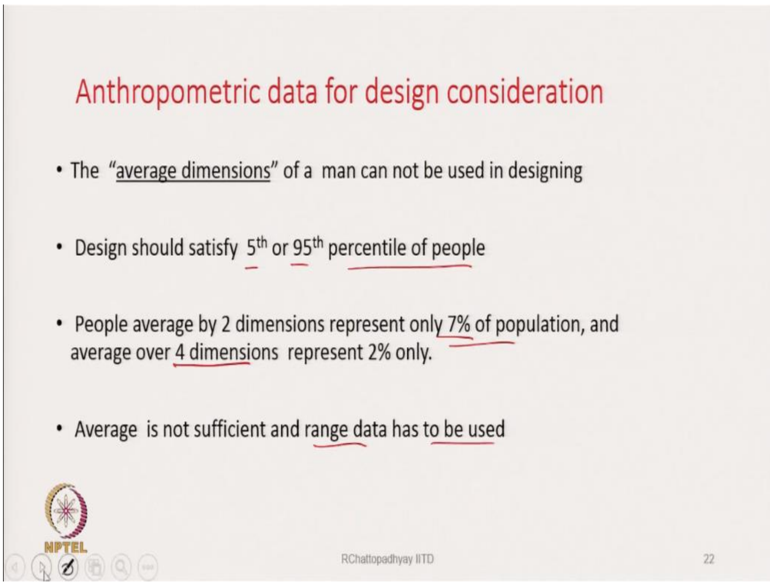

When considering anthropometric data for design, it is important to note that the average dimensions of a man cannot be used in the design because it will not fulfil the needs of the entire population. Design should satisfy the 5^{th} or 95^{th} percentile of people. Since it is impossible to create a design that suits every individual, we must focus on creating products that suit specific groups within the population.

The important aspect of using population data is understanding how to create groups and the logic behind determining the sizes of those groups. People average by 2 dimensions represent only 7% of the population, and average over 4 dimensions represent 2% only. Several variables come into play when thinking about a person's body dimensions. They are total height, leg height, hand height, and shoulder width.

Each of these dimensions contributes to the overall variability in body shapes and sizes. Numerous variables describe a person's overall size, making grouping more complex. The average is insufficient, and the range data must be used.

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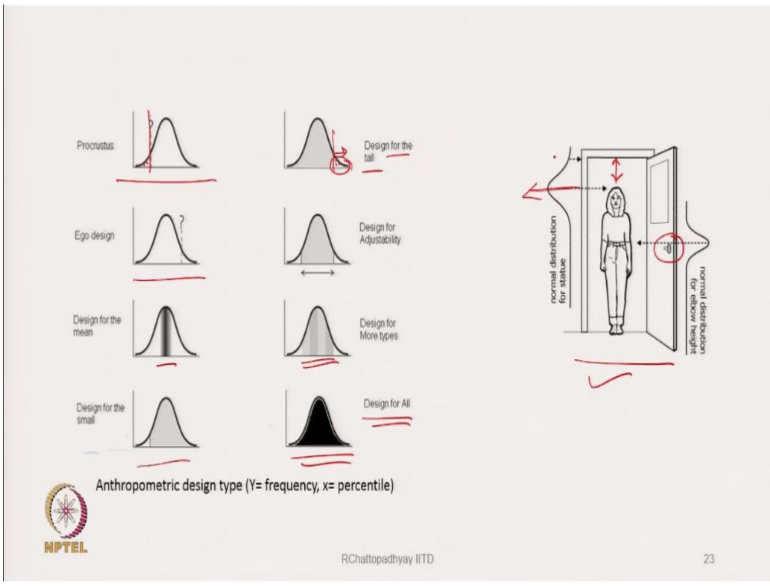

Many people have experience trying on trousers or shirts in a mall, and they might fit some people well but not others. This variability arises because a specific size typically suits only a certain group of individuals. There is ongoing research focused on optimizing the size of the clothing to better meet the diverse needs of the population. Currently, most size charts are derived from European or American standards, while Indian size charts are still in the process of evolving.

For example, the anthropometric design illustrated here shows the distribution of certain parameters. In this case, normal distribution applies to various parameters, reflecting how these measurements are spread within the population. Creating a design that satisfies only a specific part of the population is called procrustes design. This means that the design will suit only those people and not be suitable for the rest of them.

For example, if the design is made exclusive for tall people, it will suit only that population area. This is applied similarly to ego design. Design for adjustability involves creating a product with adjustable features, allowing individuals to adapt it to their specific size. There is a grouping of data observed in the design for more types. Design for all is a design which suits the entire population, and it is often referred to as a fit-for-all design.

Designing a product that fits every individual is generally challenging. For example, consider a door design where the distribution of elbow heights indicates the optimal height for the door handle. This placement accommodates most of the population based on frequency. Additionally, allowances are made in the design to ensure that even taller individuals can comfortably pass through the door.

When designing a door, it's essential to consider dimensions that will accommodate approximately 95% of the population. While exceptionally tall individuals are quite rare, usually, in India, most people will be a maximum of six and a half feet. Therefore, a doorframe height of eight feet would generally suit most people effectively.

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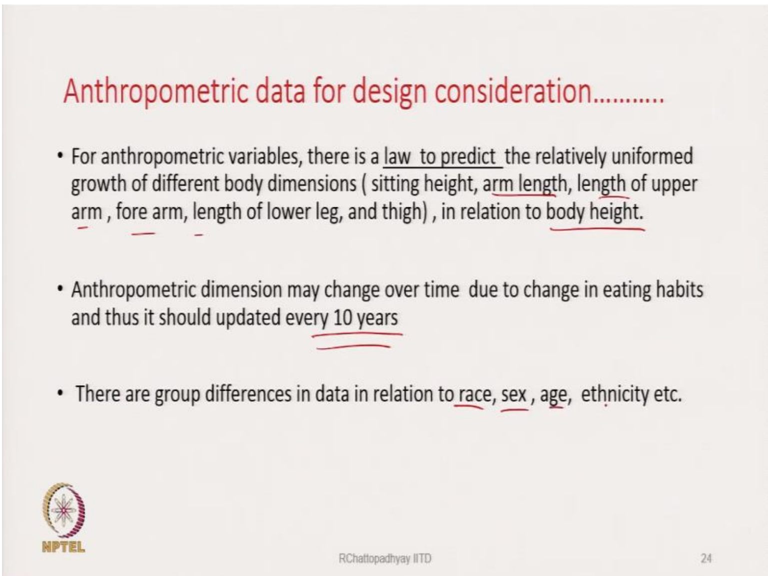

Next is the anthropometric data for design considerations. For anthropometric variables, there is a law to predict the relatively uniform growth of different body dimensions i.e., sitting height, arm length, length of upper arm, forearm, length of lower leg and height, in relation to the body height. if the body height is known, then there are certain rules through which we can predict the length of the upper arm and forearm. The anthropometric dimension may change over time due to changes in eating habits, and it should be updated every 10 years.

Reports indicate that the average height of Chinese and Japanese populations has increased over the last 30 to 40 years. This trend is also observed in India and can largely be attributed to improved nutrition and economic development. Additionally, it is important to consider group differences related to factors such as race, sex, age, and ethnicity when analysing anthropometric data.

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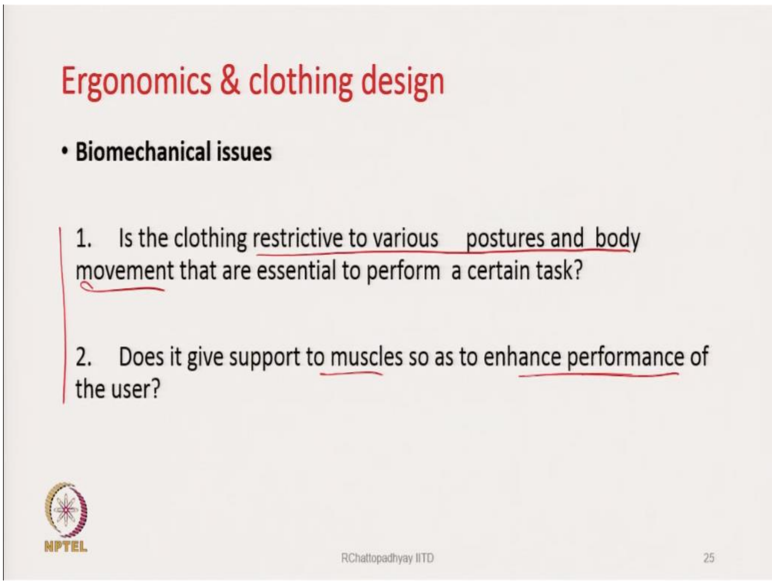

In ergonomics and clothing design, biomechanical issues are present. Key aspects include whether clothing restricts various postures and body movements necessary for specific tasks and whether it supports the muscles to enhance user performance. These two factors are relevant to the design of clothing. For example, muscle support for players playing hockey, football, or even cricket can be enhanced.

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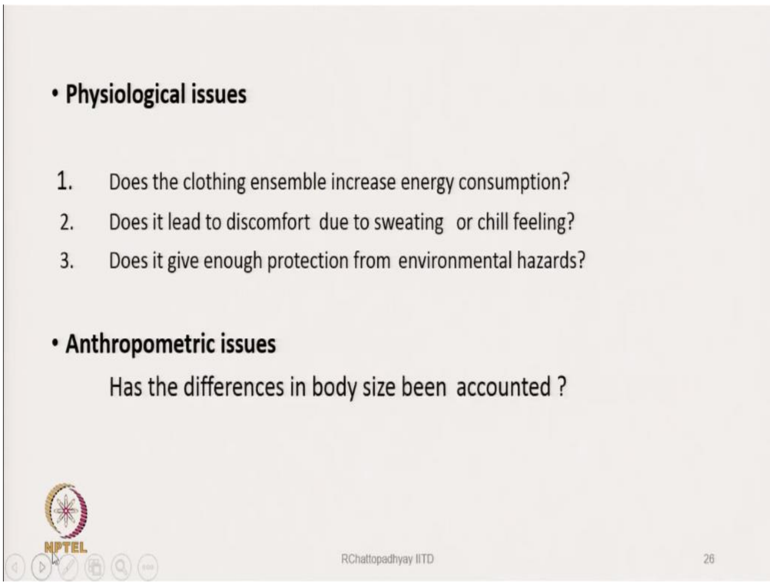

Physiological considerations include whether the clothing ensemble increases energy consumption, causes discomfort due to sweating or chills, and provides adequate protection from environmental hazards. Additionally, anthropometric issues to address include whether differences in body size have been considered.

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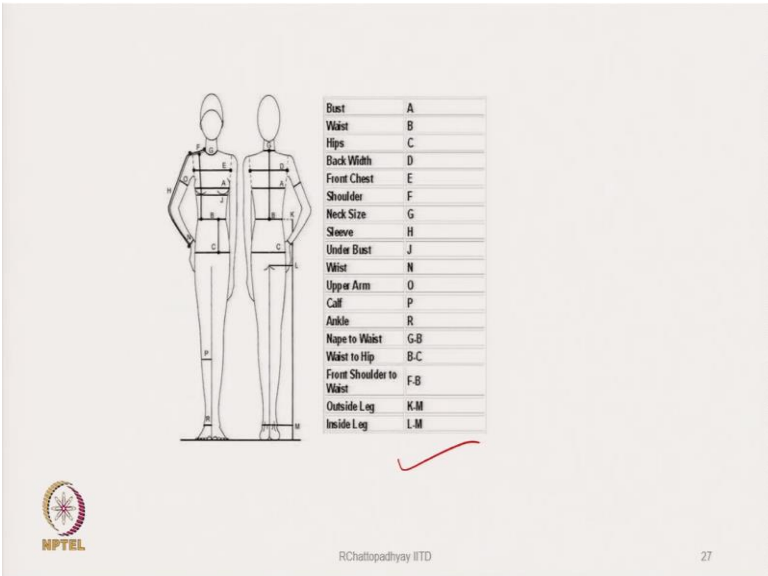

Bust	A
Waist	B
Hips	C
Back Width	D
Front Chest	E
Shoulder	F
Neck Size	G
Sleeve	H
Under Bust	J
Wrist	N
Upper Arm	O
Calf	P
Ankle	R
Nape to Waist	G-B
Waist to Hip	B-C
Front Shoulder to Waist	F-B
Outside Leg	K-M
Inside Leg	L-M

This is another similar figure highlighting the various body dimensions we need to measure from a clothing design perspective.

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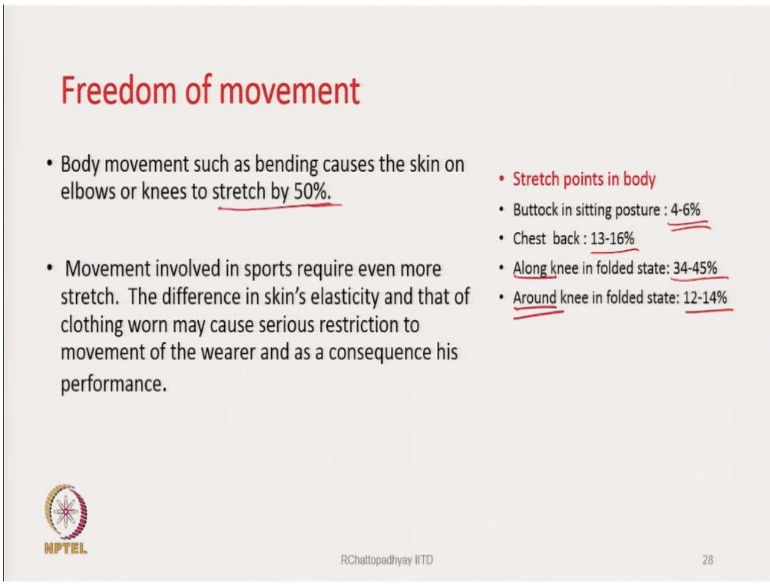

Freedom of movement is essential in clothing design. For example, bending can cause the skin on elbows and knees to stretch by about 50%. The skin is naturally designed to stretch comfortably with movement, allowing us to perform actions without feeling any stress. When designing garments, it is important to account for the skin's ability to stretch by about 50% during movement.

The garment should allow for this stretch to prevent discomfort. However, if the garment restricts this movement, it can lead to relative movement between the skin and the fabric, resulting in abrasion and potential skin irritation. The movement involved in sports requires even more stretch, i.e., the garment has to be designed in such a way, or the fabric that we have to choose should also respond in a similar fashion.

So, in a particular area, if the skin stretches by 50%, whatever fabric component is there, that should also stretch, but at least that percentage, whatever, 50% or 30% or 40%. The differences in skin elasticity and that of clothing may cause serious restrictions on the wearer's movement and, consequently, affect his performance. As mentioned, the skin cannot extend, or skin extends, but the fabric cannot extend, so there is a possibility of restriction in the movement of the person, and therefore, it can affect the performance.

Some data about the stretching of the skin is stated. The skin of the buttock area can stretch by 4 to 6%. Chest back can stretch 13 to 16%. Along the knee in the folded state, the skin stretches a maximum of 34 to 45%. Around the knee in a folded state, it is 12 to 14%. One was around, and the other was along. So, this small amount of stretching is there, and the skin is beautifully designed so that it does not give the feel of stretching.

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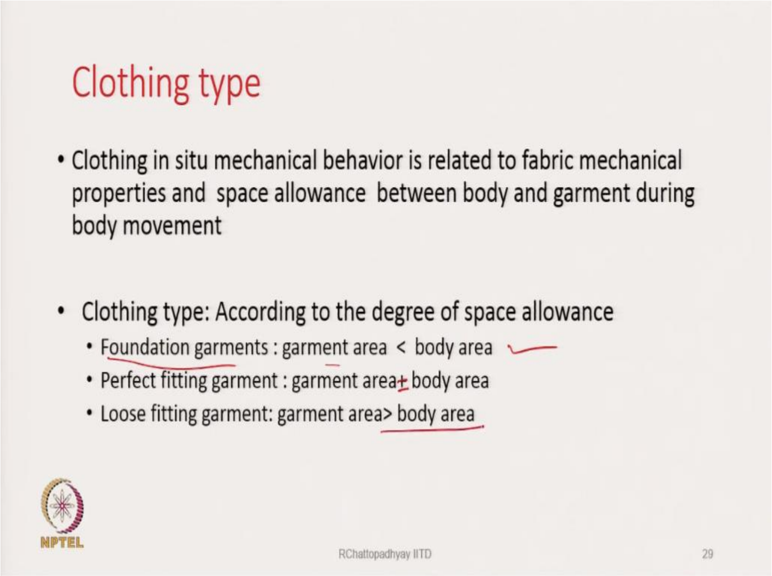

Next is the clothing type. Clothing in situ mechanical behaviour is related to the fabric's mechanical properties and space allowance between the body and the garment during body movement. Thus, clothing can be categorized based on the degree of space or allowance provided; there is always a gap between the body and the garment we wear.

There are three main types of foundation garments based on their fit relative to the body. The first type has a garment area smaller than the body area. The second type consists of perfectly fitting garments, where the garment area equals the body area. The third type includes loose-fitting garments, where the garment area is larger than the body area. All three types of garments serve different purposes and are commonly used.