Research on Ergonomics and Functional Aspects of Health Equipment with a Case Study Including Material and Production

By

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ABSTRACT

This thesis claims that ergonomics and function plays the most important role in the design of health equipments. Every detail is designed according to both ergonomic values of human anthropometry and object's function, of which are the major parts of individual expectations from the object.

As a designed object after a case study, the general purpose hospital bed is a product derived from the dimensional limitations of human body. In the design progress, the spine, pressure points in laying position, have been analised, the functions that a general purpose hospital bed should bring, have been discussed. Also the target market, customer and user differences, are examined.

This analysis have led to a conclusion of a hospital bed as a designed product for a target customer.

Keywords: Ergonomics, Human-machine Interface, Bed, General Purpose Hospital Bed, Spine, Back, Pressure Points, Matress, Function.

ÖZ

Bu tez, fonksiyon ve ergonominin sağlık gereçleri tasarımında en önemli rolü oynadıklarını iddia eder. Üründeki her detay; bireyin üründen beklentilerinin en önemlilerini oluşturan insan antropometrisi ve ürünün getireceği fonksiyona uygun olarak tasarlanır.

Bir etüd sonucunda tasarlanan ürün olan genel amaçlı hastane yatağı, insan vücudunun ölçüsel sınırlarının türetilmesine bağlı olarak bir ürün haline gelmiştir. Tasarımın gelişme sürecinde, omurga ve yatış pozisyonunda vücuttaki basınç noktaları çözümlenmiş; genel amaçlı hastane yatağının taşıması gereken fonksiyonlar tartışılmıştır. Ayrıca, hedef kitle ve tüketici, kullanıcı farkları irdelenmiştir.

Bu çözümleme sonucunda; belirli bir hedef kitle için tasarlanmış bir ürün olan hastane yatağına ulaşılmıştır.

Anahtar Kelimeler: Ergonomi, Insan-makina Arabirimi, Yatak, Genel Amaçlı Hastane Yatağı, Omurga, Sırt, Basınç Noktaları, Yatak Şiltesi, Fonksiyon.

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1. INTRODUCTION

Human beings are born in bed and die in bed. The material which the life span starts and ends in, plays an interesting role to expand it as long as possible. People sleep in it and the "33 percent of their lives is spent in it"[1]. By sleeping people rest and live longer. It is the bed in which they try to give birth to their offspring. When they are sorry, they lay in it and sometimes even cry. When they are ill, people try to get well in their bed. If they don't, they have to spend all their lives in it. And when the end comes almost everybody die in it.

In human lifetime, there is no any other designed product (except the dresses he wears) which is in interaction with the user for a long time, shares the 33 percent of his lifetime. What makes the researches about bed interesting is the fact that it is a designed object that man uses and shares his valuable time with it. But, as a hospital bed is a derivative form of conventional beds and uses more contemporary production techniques; increases the attractiveness of a research on them.

At first this subject was given to me; in the literature search within the comprehensive university libraries in which industrial design and interior design education was given (Middle East Technical University and Bilkent University), I saw that there was not any study focused on the hospital beds. Only in Bilkent University there was a master thesis about interior design of patient rooms. There was also a term project about hospital bed design in Mimar Sinan University, Department of Industrial Design; neverthless, the ergonomic and functional sides were not examined. I couldn't find any references in the libraries of these universities about the human ergonomics in laying positions. In this subject I made a paper research over TUBITAK's Ulakbim but the papers that were next to my subject, included more medical jargon that were not suitable to use in an industrial design thesis.

[1] Raschko B.B., "Housing Interiors for the Disabled and Elderly," (Van Nostrand Reinhold, New York).

Most of the hospital bed manufacturers that I reached on the internet have sent me catalogues of all their products with their best wishes in my thesis study. However, it was so sad that none of the native manufacturers except Reha Saglik Ürünleri Ltd. Sti., had sent me any information about their products. Consequently, a researcher form Helsinki University of Technology Mr. Martti Teikari sent me a booklet of SOTERA project proceeded in his university about rehabilitation room layout for the disabled.

An intention of visiting some of private and university hospitals in my country for examining their hospital beds, especially with a written permission taken from the deanship of my faculty including the contents and purpose of my visit, could not be successful because of some unacceptable behavior of the hospital management. But in a short time stay in Belgium, by just mentioning about my study, the permission for taking photographs by entering the patient rooms and surgery rooms in hygienic dresses in Brugge International Hospital; once again made me see the respect and the attention paid to research and researchers in foreign countries.

In examination of production stages of hospital beds; helpful approach of Reha Saglik Ürünleri Ltdi.Sti by demonstrating the production and by letting me take pictures, helped me to fill a gap in my research.

The data I utilized most in this research and the case study is the information written in the product catalogues of hospital bed manufacturers. The books and the paper indicated as references, the photographs I had taken, and the web sites of the hospital bed manufacturers have also utilized in this work.

Hospital bed customers can be seperated into two, in Turkey. State hospitals with limited allotments and private hospitals which expends relatively more. Most of the state hospitals, prefers cheaper and native products mostly because of their limited allotments. In this case, the bed's aesthetic appeal or functional innovation is not so important. But in the private hospitals, in order to obtain customer (patient) satisfaction and to gain newly customers (patients), they prefer more attractive and multifunctional beds and then tend to buy mostly imported beds.

In order to cover this demand, foreign manufacturers give certain importance to R&D studies. Especially in Great Britain and United States there are companies manufacturing for over 70 years. These companies directs their R&D studies accoridng to the demands received from all over the world.

In our country there are manufacturers in this field for about 30 years. Up till now the quality in design have mostly been ignored, but today native manufacturers must make products matching the world standards in this competitive market.

I wish this study a helpful resource for students and professionals who are interested in ergonomics and health equipment design and be also a resource for native hospital bed manufacturers and hospitals.

2. ERGONOMICS

Ergonomics is the application of scientific principles, methods and data drawn from a variety of disciplines to the development of engineering systems in which people play a significant role. Among the basic disciplines are psychology, cognitive science, physiology, biomechanics, applied physical anthropometry, and industrial systems engineering.

Design begins with an understanding of the user's role in overall system. And the systems exist to serve their users, whoever they are, even workers, system operators, crews or consumers.

Human factors is the term used in the United States and a few other countries. The term *ergonomics*, although used in the United States, is more common in Europe and the rest of the world.

As Kroemer (1994) defines ergonomics as "the discipline to study human characteristics for the suitable design of the living and work environment"[1]. Its fundamental aim is that all man-made tools, devices, equipment, machines and environment should advance, directly or indirectly, the safety, well being, and performance of humans. The emphasis is on human beings and how the design of things influences people. "Human factors, then, seeks to change the things people use and the environments in which they use these things to better match the capabilities, limitation and needs of people"[2].

"Ergonomics has two particular aspects;

1. Study, research and experimentation, in specific human traits and characteristics that were required for engineering design.

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[1] Kroemer et al., "Ergonomics-How to Design for Ease & Efficiency," Edited by W.J.Fabrycky and J.H.Mize (Prentice Hall, New Jersey, 1994).

[2] Sanders M.S., McCormick E.J., "Human Factors in Engineering and Design," (McGraw-Hill, Singapore, 1993).

2. Application and engineering, in which tools, machines, shelter, environment, work tasks, and job procedures were designed to fit and accommodate human."[1]

Scientific investigations are needed to discover information about humans and their responses to things, environments; their capabilities, limitations, characteristics etc. This information serves as the basis for making design recommendations and for predicting the possible effects of various design alternatives. The human factors or ergonomics approach needs evaluations of designed things if they satisfy their engaged objectives.

A number of classic sciences provide the fundamental knowledge about the human. The anthropological basis consists of anatomy, describing the build of the human body; orthopaedics, concerned with the skeletal system; physiology, dealing with the functions and activities of the living body; medicine, interested in illness and their prevention and healing; psychology, the science of mind and behaviour; and sociology, concerned with the development, structure, interaction and behaviour of individuals or groups. Physics, chemistry, mathematics and statistics also supply knowledge, approaches and techniques.

Besides these basic sciences, a group of applied disciplines are involved in ergonomics. Anthropometry, the measuring and description of the physical dimensions of the human body; biomechanics, describing the physical behaviour of the body in mechanical terms; industrial hygiene, interested in the control of occupational health hazards that arise as a result of doing work; industrial psychology, discussing people's attitude and behaviour at work; management; and work physiology.

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[1] Kroemer et al., "Ergonomics-How to Design for Ease & Efficiency," Edited by W.J.Fabrycky and J.H.Mize (Prentice Hall, New Jersey, 1994).

2.1. History of Ergonomics

Ergonomists say that human factors started when early humans first used simple tools and gadgets. Artists, military officers, employers and sportsmen were always interested in body and physical performance. Anatomic and anthropological disciplines began to develop. Over the centuries, information accumulated into special disciplines. "In the 15th to 17th centuries, Leonardo da Vinci and Alfonso Giovanni Borelli were masters of anatomy, physiology and equipment design, although they were artist, scientist and engineer in one."[1]

The development of the human factors had its beginning in the industrial revolution of late 1800s and early 1900s. It was during the early 1900s Frank and Lillian Gilbreth began their work included the study of skilled performance and fatigue and the design of workstations and equipment for the handicapped. In Italy, Mosso constructed dynamometers and ergometers to research fatigue. In Scandinavia, Johannsson and Tigerstedt developed the scientific discipline of *work physiology*. Two distinct approaches to study human characteristics had developed; one was concerned with physiological and physical traits of the human, the other was mainly interested in psychological and social properties. During World War II, the operation of some of the complex equipment, were exceeding the capabilities of the operator. Then it was time to reconsider fitting the equipment to the person.

At the end of the war in 1945, engineering psychology laboratories were established by the U. S. Air Force and Navy. In 1949 the Ergonomics Research Society was formed in Britain.

Until the 1960s, ergonomics in the U.S. was concentrated in the military-industrial complex. With the race for space, human factors became an important part of the space programme. During this period, from 1960s to 80s, human factors in the U.S. expanded beyond military and space applications. Human factors group could be found

[1] Kroemer et al., "Ergonomics-How to Design for Ease & Efficiency," Edited by W.J.Fabrycky and J.H.Mize (Prentice Hall, New Jersey, 1994).

in many companies including pharmaceuticals, computers, automobiles and other consumer products.

The conscious of human ergonomics continued to grow between 1980s and 1990s, with the computer revolution. Discussions about ergonomically designed computer equipment, user-friendly software, and human factors in the office began to take part in the daily press.

In the future plans for building a permanent space station will mean a heavy involvement of human factors. Computers and applications as virtual reality, computer aided design, hyperlinks, etc. will keep a lot of ergonomics staff busy for a long time.

2.2. Human-Machine Systems

A *system* is an entity that exists to manage some purpose. A system is composed of humans, machines (products), and other things that work together (interact) to accomplish some goal which these components could not produce independently.

"A *human-machine system* can be considered as a combination of one or more human beings and one or more physical components interacting to produce, from given inputs to some desired outputs".[2] Simply, a human-machine system can be a person with a hammer or a hair curler. We can also regard the family automobile, an office machine, a lawn mover as human-machine systems, each equipped with its operator. More complex systems such as aircrafts, bottling machines, telephone systems, automated oil refineries can be included.

The typical type of interaction between a person and a machine can be defined as the display of a machine serve as a stimuli for an operator, trigger some type of information processing on the part of the operator, which results in some action that controls the operation of the machine.

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[2] Sanders M.S., McCormick E.J., "Human Factors in Engineering and Design," (McGraw-Hill, Singapore, 1993).

Systems are generally considered in three classes; manual, mechanical, and automatic.

Manual systems; consists of hand tools and other aids which are used by a human operator who controls the operation. Operators of such systems use their own physical energy as the power input.

Mechanical systems; consist of well-integrated physical parts, such as various types of powered machine tools. They are generally designed to perform their functions with little variation. The machine typically provides the power, and the operator's function is one of control, usually by the use of control devices.

Automated systems; performs all operational functions with little or no human action.

Components serve various functions in systems, but they all involve a combination of four more basic functions:

1. Sensing (information receiving)
2. Information storage
3. Information processing and decision
4. Action function.

2.2.1. Ergonomic Factors Influencing Human-Machine Interface

Necessity and importance of ergonomic approach in becoming of human-machine interface can not be denied. In order to realise this ergonomic approach; determination of factors caused by human and designing of certain physical components around these factors, is required.

2.2.1.1. Information Stage: Cognitive Skills

Human identifies his environment and events occurred around himself; by the information gained by his sense organs. Classically five sense channels can be mentioned; visual, auditory, cutaneous, olfactory and tasting. It is obvious that sense organs of human body were used in this classification as in the same sequence of the organs; eyes, ears, skin, nose and tongue.

Stimulation of sense organs is just the first stage of recognition process about outer world. Electrical signs that were produced by sense organs as a result of physical stimulation; must be prepared and expressed in mind. Two definite stages in this process; facts occurring in (1) sense organs, (2) in mind, prove cognitive skills of human. Researches on sense organs are towards the definition of physiology, physiological work and limitations on stimulation of them.

Eye is an organ including a mechanism that helps light reach towards the light sensitive optic nerves in it. Concepts that have to be mentioned in the fact of seeing are as follows;

1. Visual Acuity; is the ability to discriminate fine detail and depends largely on accommodation of the eyes.
2. "Accommodation; is the ability of eye lens to focus the light rays on the retina. Lack of it sometimes causes nearsightedness or farsightedness"[2]
3. Convergence; is the ability of focusing two eyes on the same point at the same time. Lack of it affects person's visual performance especially in the statement of visual tiredness.
4. Stereopsis; depth (three-dimension) perception.
5. Ability of colour separation.

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[2] Sanders M.S., McCormick E.J., "Human Factors in Engineering and Design," (McGraw-Hill, Singapore, 1993).

Ear is another sense organ that functions in realisation of both auditory sense and vestibular perception.

Auditory sense sends information to the brain about the frequency and level of the heard sound. Ergonomic approach focuses on auditory limits about these two and on limit variances that caused by the interaction between them.

"Vestibular sense is related with the perception of direction and position of man in space. Vestibular sense is considered in two;

1. Static sense; in the position of head to the direction of gravity.
2. Kinetic sense; the accelerations of the head in its movements".[3]

Vestibular sense is regarded as a sub-factor of *proprioreceptive system*. This system is known as a co-ordinator of body movements and balance, and some motor skills. Another sub-factor of the system consists of *kinestetic sense*. Kinestetic sense helps to perceive the positional relations of body segments relative to each other.

The clearest of mechanical senses is cutaneous sense. This sense can be defined as, the result perception formed by a group of mechanical nerves inside the skin. Functional differences of these nerves comes from the sense type that they are directed to, such as touch, pressure, pain, hot, cold, etc. Quantitative differences according to types of these nerves in the skin; affect the senses in different parts of the body.

2.2.1.2. Reaction Stage: Motor Skills

Physical action of human in the interaction of human-machine systems; requires his motor skills to be examined, as an ergonomic approach. Motor skills help a person to perform conscious movements with certain parts of the body. These skills are directly related to physical structure of the body (skeleton), to the muscles, to metabolic period and to the nervous system.

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[3] Asatekin M., "Endüstri Tasarımında Ürün Kullanıcı İlişkileri," (Publication of METU Faculty of Architecture, Ankara, 1997)

As some bones participated in the skeleton are formed to protect significant organs (brain, lungs, and heart); however, as a general description, skeleton's work is to provide a structure to help the body stay in a certain position in space and to help it move.

Bones were formed according to the force they are against, and to the type of motion they perform. They came together with joints and again formed various joint types according to the type of motion they involved.

In the human, there are three types of muscles, which together are 40 percent of the body weight. Cardiac muscle makes contractions of the heart. Smooth muscle works on body organs such as by contracting blood vessels.

Another kind of muscle in the muscle system; which are tied to bones with ligaments are called skeletal muscles. These have a fibril structure, which turns chemical energy into mechanical energy, and also have an ability to shorten themselves by contracting. Skeletal muscles and skeleton bones came together and turned the body into a system of levers. With this system, body has its motor skill.

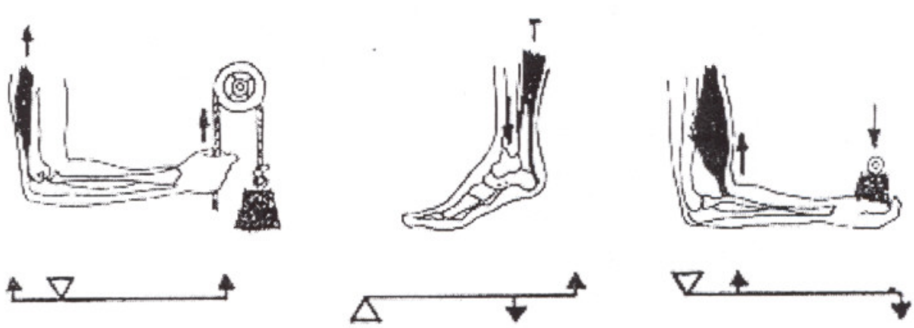

Figure 1: Muscle and lever similarity,(Asatekin, 1997).

"Conscious movements of skeletal muscles are directly related to their control by the motor-neurones. Motor-neurones system (somatic nervous system) serves two purposes. One is to obtain the balance of the body by generating tensile force. The other is to cause local motion of body parts by pulling the bones which the muscles are attached, as to create torque or moments around the joints which serve as pivots".[1]

In ergonomic discipline, discussion of motor skills must not be set apart from biomechanical data. Biomechanics, examines the range, power and acceleration of body movements. "In the muscle functionality; terms like flexion, extension, abduction, adduction, rotation, circumduction, pronation, supination are mentioned. In the operational properties; discrete movements, continuos movements, repetitive movements, sequential movements, static positioning are mentioned".[2]

The range of movement in any joint is dependent on the bone structure of the joint, amount of muscle or other tissues near the joint, and elasticity of the muscles,

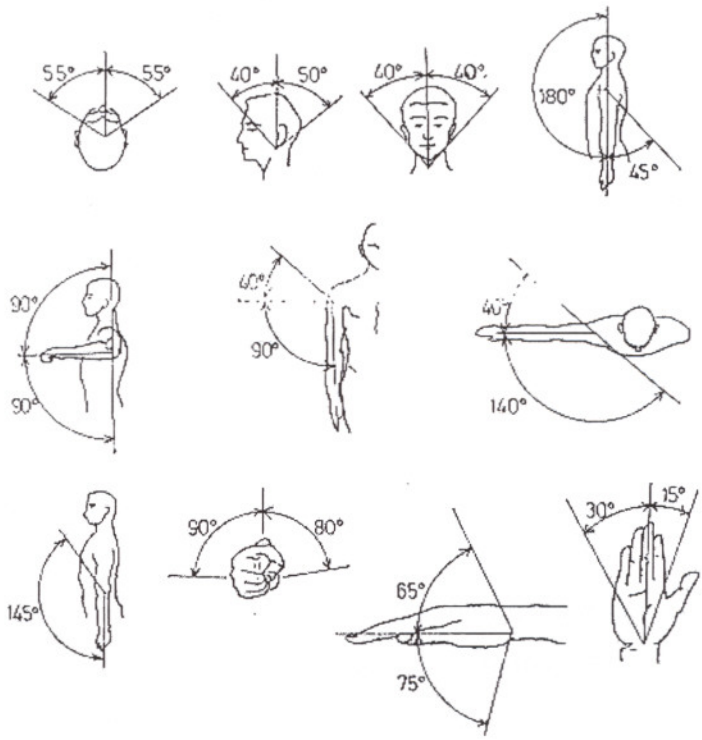

Figure 2: Examples for ranges of joint motion (Asatekin, 1997).

tendons and ligaments around the joint. The range is also affected by age, sex, exercise, tiredness, health and motivation of the person. Consequently; movement of a certain segment may be limited by the positions of the rest of the body. But, as a result of

[1] Kroemer et al., "Ergonomics-How to Design for Ease & Efficiency," Edited by W.J.Fabrycky and J.H.Mize (Prentice Hall, New Jersey, 1994).

[2] Sanders M.S., McCormick E.J., "Human Factors in Engineering and Design," (McGraw-Hill, Singapore, 1993).

ergonomic researches, acceptable ranges of movement for every joint have been resolved.

2.2.1.3. Dimensional Factors

In human-machine interaction; dimensional harmony that must exist between the physical accompany of human and machine, can be established by knowing the generalised dimensional properties of human body. Anthropometry is the discipline searching for dimensional properties of human body.

In ergonomics, anthropometric data is used especially in determination of linear dimensions.

Dimensional anthropometry is considered in two kinds;

1. Static anthropometric dimensions.
2. Dynamic anthropometric dimensions.

Data obtained by measuring between anatomically defined points while keeping the body in standardised certain positions; are called static anthropometric dimensions. Static dimensions have an important limitation; in daily life, human body never stays in the positions that were anthropometrically standardised. Probable biases from these positions offer probable differences.

This kind of limitation creates the concept of dynamic anthropometry. Dynamic anthropometric dimensions are measures between certain points on body in a dynamic posture while it doing a job (motion).

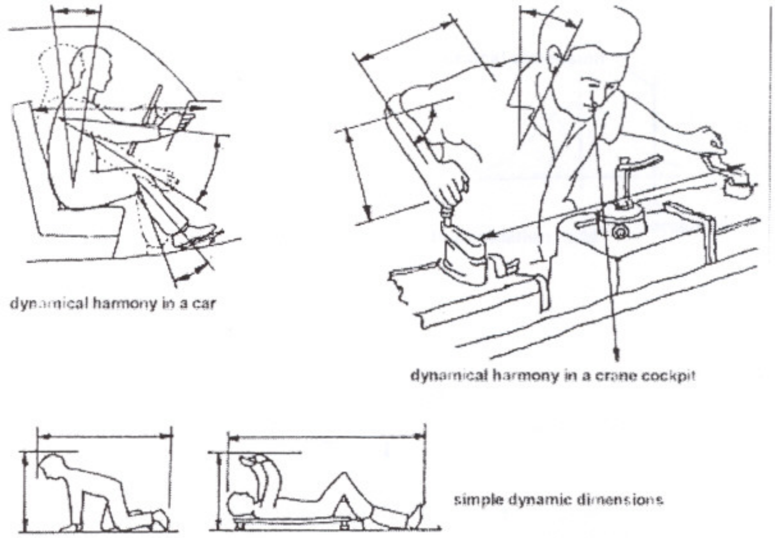

Figure 3: Dynamic anthropometric dimensions and harmony, (Asatekin, 1997)

Dynamic anthropometric dimensions can be either for general purpose, such as reaching distances; or for special purposes directed towards special body positions.

In anthropometry, implementation techniques of dimensional data are as important as data themselves. The purpose is to obtain the dimensional harmony between product and the whole population (or in general 90 percentile of the population). For this reason; anthropometric dimensions are classified in three parts according to their usage;

1. Minimum dimensions.
2. Maximum dimensions.
3. Adjustable dimensions.

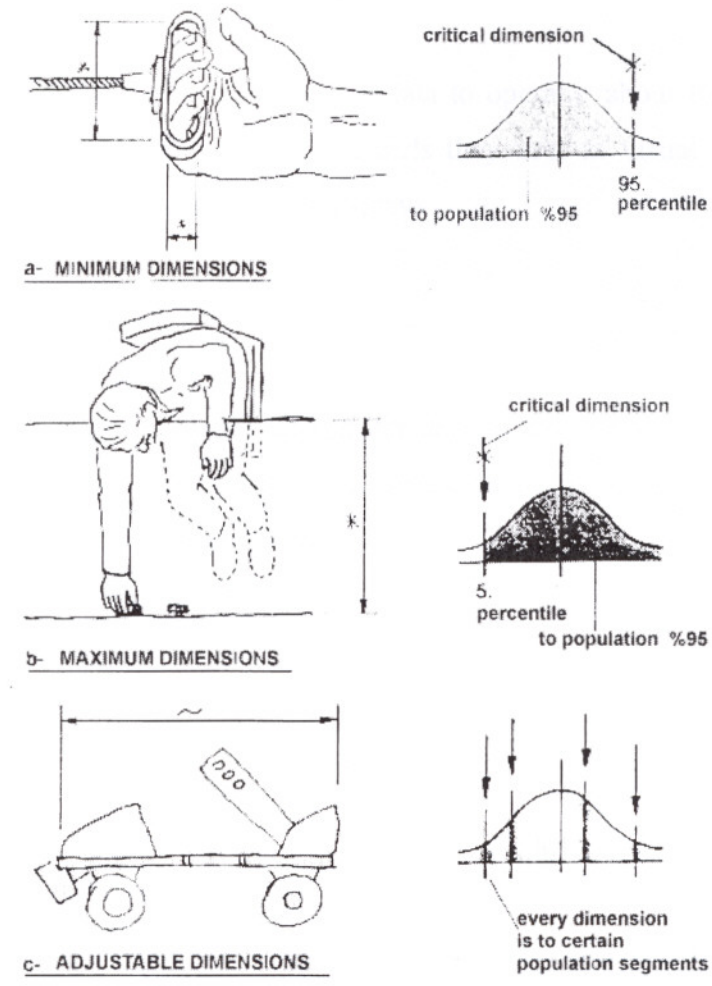

Figure 4: Typology of anthropometric dimensions, (Asatekin, 1997).

2.2.2. Ergonomic Design Components in Human-Machine Interaction

In human-machine interaction, information is exchanged and an output is gained. The information is given by the help of displays attached to the object or the machine. User or consumer can get the data about the conditions of object he used and then gives a response by the help of motor components. This cycle continues until the need is fulfilled.

2.2.2.1. Information Components: Displays

Displays are elements that transfer data to operator about the product's work. They can be classified by the sense channels they use; as visual displays, auditory displays, tactual displays and olfactory displays.

2.2.2.1.1. Visual Display

Visual displays are parts that transfer data to the operator about the product's function by the help of some visual components on the machine. These displays vary according to the way they transfer data.

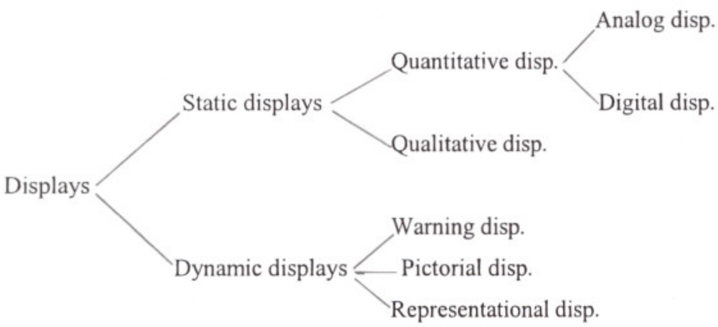

Table 1: Types of displays.

Quantitative displays are used when the operator needs numerical data. It gives the numerical value of the variable. Numerical data can be shown as;

1. Analogue
2. Digital

Analogue displays are more suitable to type of "control reading" at a glance. Digital displays are suitable for the situations requiring a precisious value reading. Factors influencing the readability of analogue displays are;

1. Functional structure of the scale (division system, dividend distances, placement of the smallest value, direction of increasing, etc.)

2. Graphical structure of the scale (length, division form, linetype, line thickness, fonts and sizes of characters, background/foreground colour, background/foreground contrast, colour combinations, etc.)
3. Physical structures of the pointing needle (thickness, colour, distance from the scale, needle form, form relation between other needles, etc.)

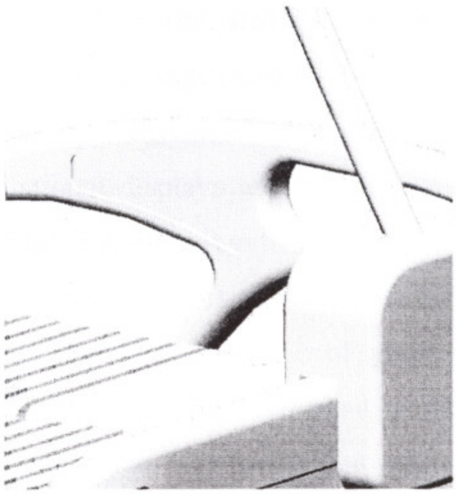

Figure 5: The control panel of the designed bed on the patient side of the siderail.

And also, in general usage, overall dimension is important.

Readability of a digital display is related with visual properties of a graphic component. Characters used, size and font of it, line thickness, background/foreground colour and contrast, interaction with other graphical elements around must be taken into consideration.

Qualitative displays are used in transferring the determinative data about the variable's condition. These displays can be classified in two;

1. Displays in which quantitative data is read as qualitative data. In this example, some parts of the quantitative display are separated as qualitative display.
2. Displays in which coded values are given as qualitative data.

Effective factor in designing qualitative displays is the differentiation of graphic elements such as color, background patterns, symbols, etc. in perceptive state. Warning displays are used to attract attention in situations that operator must react urgent. Usually are arranged by light signs. Design factors in warning displays are;

1. Structure of the display (color of the light, brightness, dynamic properties etc.)
2. Environment (background/foreground contrast, other light sources)

Also graphical elements such as font, size etc. are important design factors; if the warning display is an illuminated message (script).

Pictorial and representational displays are the elements that transfer a visual system. Formal structure of graphic display is related to structure and requirements of the system, which it simulate. Design factors also have differences. Sometimes it is possible to mention about the line thickness, size of grain, scanning density. But according to Asatekin (1997); "display must represent a simplified and a logical graphic. The aim is not a realistic image. It is to obtain a representative graphic which was eliminated from unnecessary details".[3]

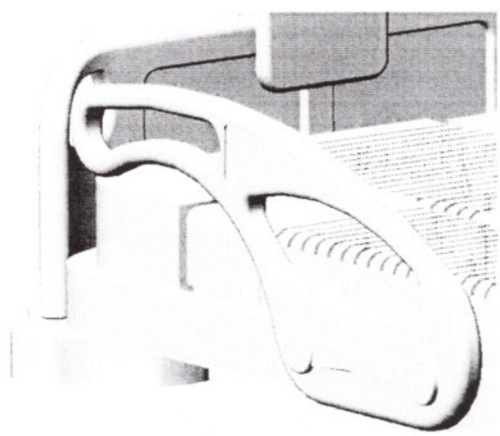

Figure 6: The conrol panel display on the nursery side of the siderail of the designed bed.

[3] Asatekin M., "Endüstri Tasarımında Ürün Kullanıcı İlişkileri," (Publication of METU Faculty of Architecture, Ankara, 1997)

Static displays transfer data, which is not modified by time, as graphic or text. So that, efficient factors in static display design are again line thickness, font, size, colour, background/foreground relation, visual composition etc.

2.2.2.1.2. Auditory Displays

These displays are used either to help visual displays when they are fully loaded or to transfer extra information. Because the hearing is multidirectional against the visuality's monodirection; auditory displays have superiority over visual displays especially in the information of warning. Synthetic speech technology improved by developing electronics provided the usability of auditory displays which can produce more meaningful sounds and have wide variety of information transfer.

Only limitation in this field comes from the temporal structure of sound communication.

As the "sound" is the factor that was designed in auditory displays; its physical characteristics, perceptive properties, description of other sounds around and display interaction, all appear as design factors.

2.2.2.1.3. Tactual Displays

It is for sure that olfactory sense has a certain potential of data transfer. But in current applications olfactory data is only used in description of some controls without visual recognition.

2.2.2.2. Motor Components: Controls

They transfer certain acts that man made to control the machine's work. Either mechanical-dynamical differences of this work system or functional differences required by interaction, cause different types of controls to be used. Functional descriptions can be classified in several topics. Below table shows types of controls interacting with several functions.

Types of Controls	*Operatibility*	*Seperation Adjustment*	*Qualitative Adjustment*	*Continious Control*	*Data Input*
Push-button (by hand)	X				
Push-button (by foot)	X				
Switch	X	X			
Revolve switch		X	X	X	
Thumbwheel		X	X	X	
Lever			X	X	
Crank			X	X	
Pedal			X	X	
Keyboard					X

Table 2: Types of controls interacting with several functions, (Asatekin, 1997)

Functional descriptions in the table are;

1. Operatibility; switch on/off certain systems
2. Separation Adjustment; to adjust the working system into quantitatively separated positions
3. Qualitative Adjustment; to adjust the working system into qualitatively separated positions
4. Continuos Control; to control a certain variable of the working system
5. Data Input; to send alpha-numerical characters to the system

Motor skills of the body are used in operating the controls. In other words; body segments must make a work in operating a control, and must response to the to the force requirement of the mechanical system which the control belongs to. That force requirement is called *the resistance of the control.*

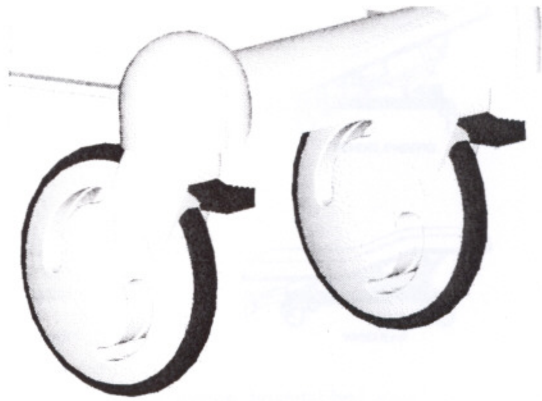

Figure 7: The caster locks are often used by the nursery and the service. The dimensions and the texture on the foot-press should be suitable for the foot.

Formal properties of controls are very important for an effective and right use. End part of a control formed as a knob or handle; affects the grabbing position and so as the performance. As type and amount of resistance in controls affects the performance of the user; it also becomes effective in formation of product's characteristics in human mind.

2.2.2.3. Dimensional Properties

It is an utmost necessity to become in dimensional harmony, for two elements of human-machine interaction; when they make a physical relation with each other. Static anthropometric data is used in the design of elements that are in one to one relation with the user, in conditions when user must contact directly on.

For example, in all kinds of hospital beds, the components should be adjusted for different levels. The must be set both for the type of care, and for the dimensions of the patient. The positions required for the types of care are high-low positions, trandelenburg and reverse trandelenburg positions, cardiac sitting position, fowler, vascular and contour positions. These positions are shown in the figure below.

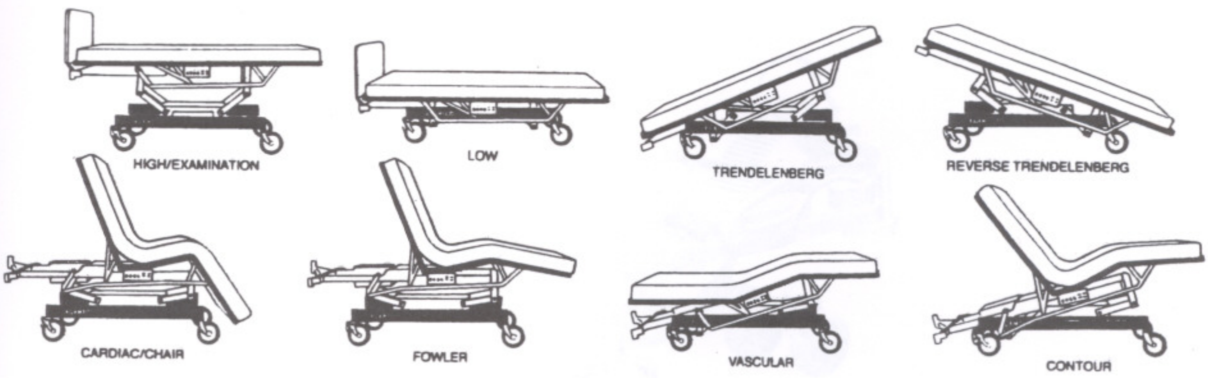

Figure 8: Dynamic positions of general purpose hospital bed according to the care type.

Dynamic anthropometric data affects dimensional design of product; around dimensional properties of certain movements of the body. Here, a series of one to one relations with the operator's body in a certain position, is important.

An example of general dimensions of a general purpose hospital bed are;

- Overall length (including buffers) : 221 cm.
- Overall width (including buffers) : 95 cm.
- Length of mattress support between head and foot boards : 200 cm.
- Mattress : 196x85x12.5 cm.
- Width of mattress support : 86 cm.
- Height variation : 40 cm - 78 cm.
- Under mattress backrest adjustment : 0^{o} to 65^{o}
- Knee and foot elevation : 30 cm.

The dimensions of the bed should be adjusted not only for the patient's anthropometric data but also for the healthcare personnel who will be in interaction with. Because it is the personnel that will adjust the heights and positions for the patients by using the operatible controls of the bed, such as the brakes, some switches and buttons on the control panel of the bed siderails etc.

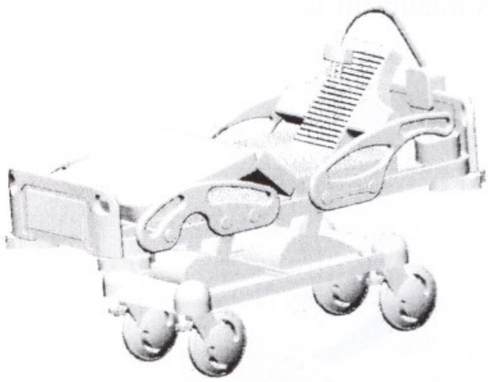

Figure 9:The positions according to the care type can be obtained also in the result designed product.

For the patients the most important interaction with the bed that ergonomics involve, are the body parts that contacts with the mattress. Especially for the supine position, the backsides of the body are in danger of pressure ulcers. The design of the mattress should be in such a form that should eliminate this risk.

Below mattress designed in the end of this thesis, the critical areas are articulated with different sections in order to support the back and spine, to avoid pressure ulcers.

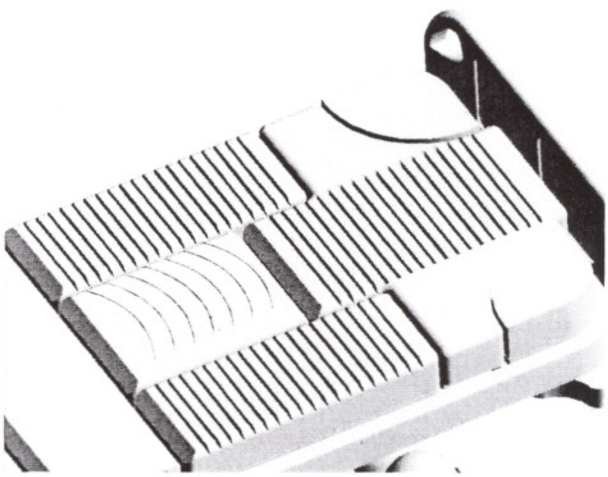

Figure 10: Head, back and arm areas articulated with specialized sections of the designed mattress.

Also another body part is the spine. It flexes through all the suitable or uncomfortable sleeping postures. The design of the bed construction must be in a way that provides the best posture for the body and the spine. The positions of the general purpose hospital bed that were mentioned above are all for obtaining best posture for the spine according to the type of care, and also for minimizing the pressures coming from the mattress surface.

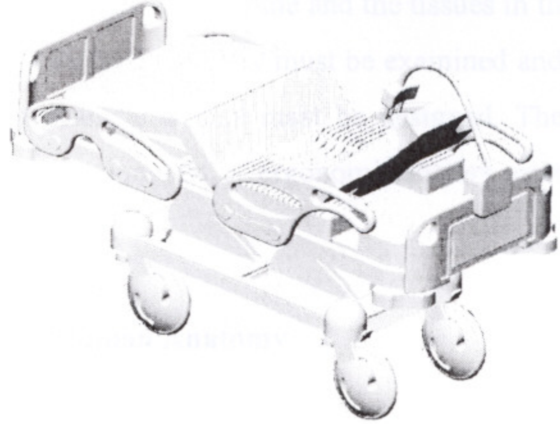

Figure 11:The positions that the designed product had been adjusted, provides best posture for the body and the spine.

2.3. Ergonomic Factors Integrated with the Bed

In the lying posture, some parts of our body is affected by the bed mattress. Mechanical loads are pressurised on the parts of the spine and the tissues in the back. In designing a hospital bed, the affected parts of the body must be examined and then special forms of mattresses and some mechanical details must be designed. These relation of human body parts with the bed, are contents of ergonomic factors related to bed and human anatomy.

2.3.1. Factors Related to Human Anatomy

The skeleton plays the major role in supporting the body. It is like a scaffolding to which all other parts are attached, directly or indirectly. The functions of the skeletal and muscular systems are summarised in table

FUNCTIONS OF THE SKELETAL AND MUSCULAR SYSTEMS

Skeletal system	Muscular system
1. Support	1. Produce movement of the body or body parts
2. Protection (the skull protects the brain and the rib cage protects the heart and lungs)	2. Maintain posture
3. Movement (muscles are attached to bone and when they contract, movement is produced by lever action of bones and joints)	3. Produce heat (muscle cells produce heat as a by-product and are an important mechanism for maintaining body temperature
4. Homopoiesis (certain bones produce rec blood cells in their marrow)	

Table 3: Functions of the skeletal and muscular systems, (Bridger, 1995)

Like any other mechanical system, the body may be stable or unstable and is able to withstand a limited range of physical stresses. Stresses may be imposed either internally or externally and may be acute or chronic.

Mechanical loading of the body may be distinguished between postural stress and task-induced stress. Postural stress is the term used to indicate the mechanical load on the body by integrity of its posture. Posture may be defined as the average orientation of the body parts, with respect to each other and over time. Under the influence of gravity postural stress becomes an important part of the total mechanical stress. In order for the body to be stable, the combined center of gravity of the various body parts must fall within a base of support (the contact area between the body and the supporting surface). When one is laying the weight of the body must be transmitted to the bed mattress through the spine, muscles and tissues under them.

The alignment of the body parts must be maintained to ensure continuing stability, and it is in the maintenance of posture that much stress arises.

The posture, most free of stress is reclining. It was found in 1966, that the pressure inside the intervertebral disks was lowest in this reclining posture compared with others. Most of the muscles of the body, which maintain posture in other body positions, are relaxed in the horizontal position.

For the body to be in static equilibrium:

1. Upward forces (from floor) must equal downward forces (body weight + any objects held).
2. Forward forces (e.g. bending forward) must equal backward forces (extension of back muscles).
3. Clockwise torque (e.g. from asymmetric loads) must equal counterclockwise torque (back and hip muscles).

When a person is leaning forward as shown in the figure( ), a stable posture can be maintained indefinitely, although the posture itself is uncomfortable.

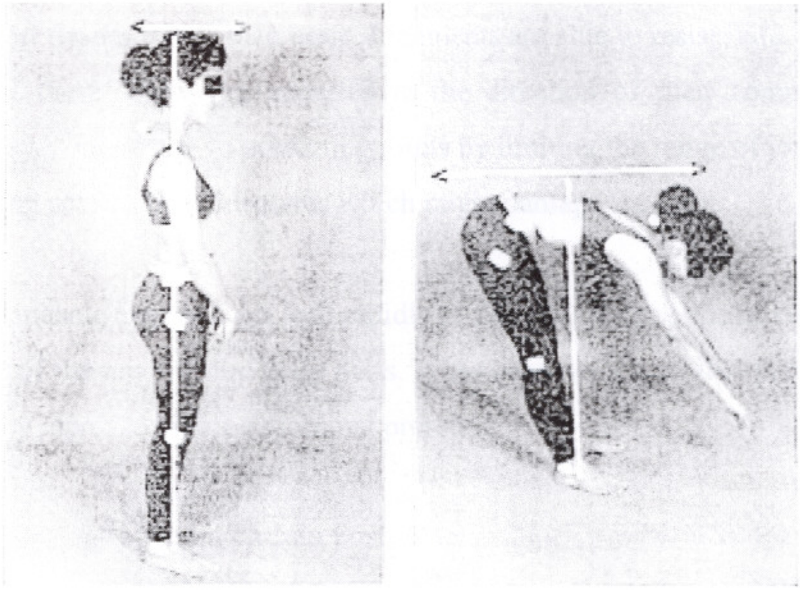

Figure 12: Maintaining stability during movement (Bridger, 1995)

The discomfort is a result of the strain being placed on the posterior spinal ligaments and lumbar intervertebral disks. The upper body load is no longer supported by axial compression of spinal structures but by the tension in ligaments and asymmetric compression "wedging" of the intervertebral disks.

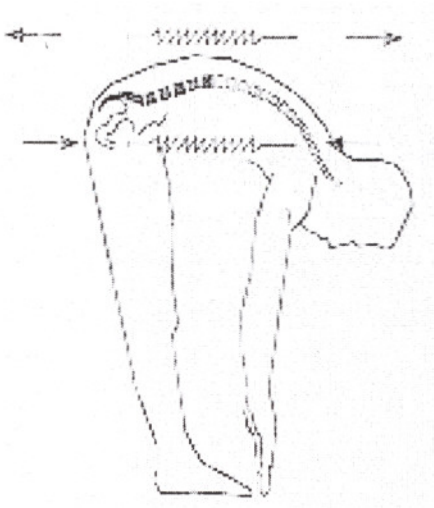

Figure 13: Postural stress occurs in the form of compression of abdominal contents and intervertebral disks and stretching of the posterior spinal ligaments.

This demonstrates that a stable posture can be stressful if support of body mass depends on soft tissues rather than bone. Ligaments are able to resist high tensile forces, particularly if these forces are excerted in the direction of their component fibres. Ligaments play a major role in protecting joints by limiting the range of joint movement and by resisting sudden displacements which might damage the joint.

Static muscle contractions lead rapidly to fatigue. In some cases, soft tissues can support some of the mass of the body parts. It has been suggested that the lumbar spine is supported by increased intra-abdominal pressure.

A major goal of research into posture is to develop principles for the design of environments that impose low postural stress. The use of design principles will reduce the occurrence of fatigue and discomfort. Discomfort is difficult to define because it has both objective and subjective elements. It was suggested that discomfort results in an "urge to move" caused by a number of physical and physiological factors. Pressure on soft tissues can cause ischemia (exhaustion of local blood supply to the tissues), resulting in a shortage of oxygen and a build-up of carbon dioxide and waste products such as lactic acid. This condition is known to lead to pain or discomfort.

2.3.1.1. Anatomy of the Spine and Pelvis Related to Posture

The spine and the pelvis support the weight of the body parts above them and transmit the load to the legs via the hip joints. They are also involved in movement. Almost all movements of the torso and head involve the spine and pelvis in varying degrees. The posture of the trunk may be analysed in terms of the average orientation and alignment of the spinal segments and pelvis. The below figure shows the spine and pelvis viewed frontally and sidely.

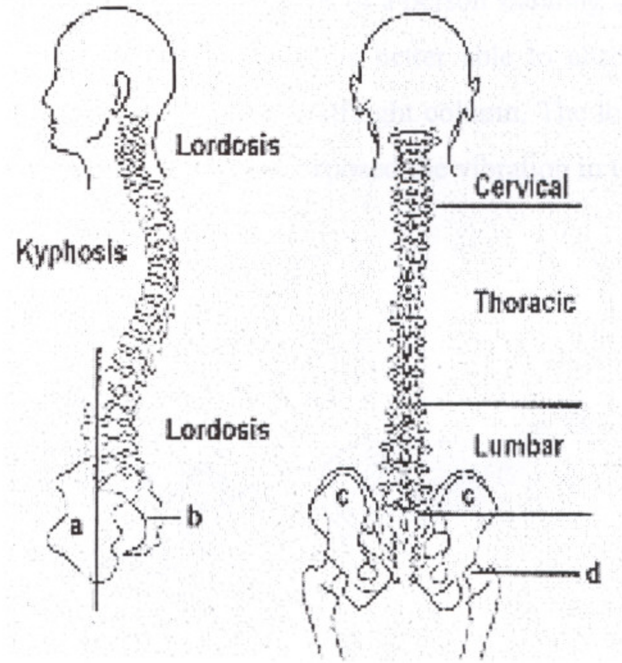

Figure 14: The lumbar, thoracic and cervical spines, and the pelvis (a) and sacrum (b). The weight of the upper body is transmitted through the lumbar spine and the Iliac bones of the pelvis (c) to the hip joints and legs.

2.3.1.1.1. The Spine

The thorax and abdomen hang from the spine and excert tension which is resisted by the spinal ligaments, the apophyseal (facet) joints, and the back muscles. In adult humans the spine is shaped such that it is close to or below the center of gravity of the superincumbent body parts which are supported axially-the effect of weight bearing the standing posture is to compress the spine. This compression is resisted by the vertebral bodies and the intervertebral disks. The cervical and lumbar spines are convex anteriorly-a spinal known as lordosis. It is the presence of these lordotic curves which positions the spine close to or directly below the superincumbent body parts. The effect is to reduce the energy requirements of the maintenance of the erect posture and place the lumbar motion segments in an advantageous posture for resisting compression. The thoracic spine is concave anteriorly and it is strengthened and supported by the ribs and associated muscles.

Spinal spring-the S shape of the spine of a person standing erect gives the entire structure a spring like quality such that it is better able to absorb sudden impacts, transmitted along its axis, than if it were a straight column. The loss of the S shape in sitting may be one reason drivers who are exposed the vibration in the vertical plane are so prone to back trouble.

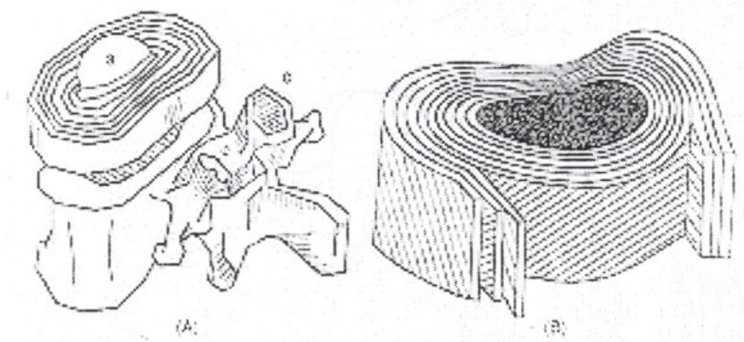

Figure 15: Intervertebral disk and vertebral body. The fibres in the layers run in different directions like the layers of a cross-ply tire. The outer layers run perpendicularly to each other. (Bridger, 1995)

The spine takes part in functional movements of the body-part of the postural adaptation required to carry out many activities takes place in the lumbar and cervical spines.

The spine can be considered simplistically to consist of three anatomically distinct but functionally interrelated columns.

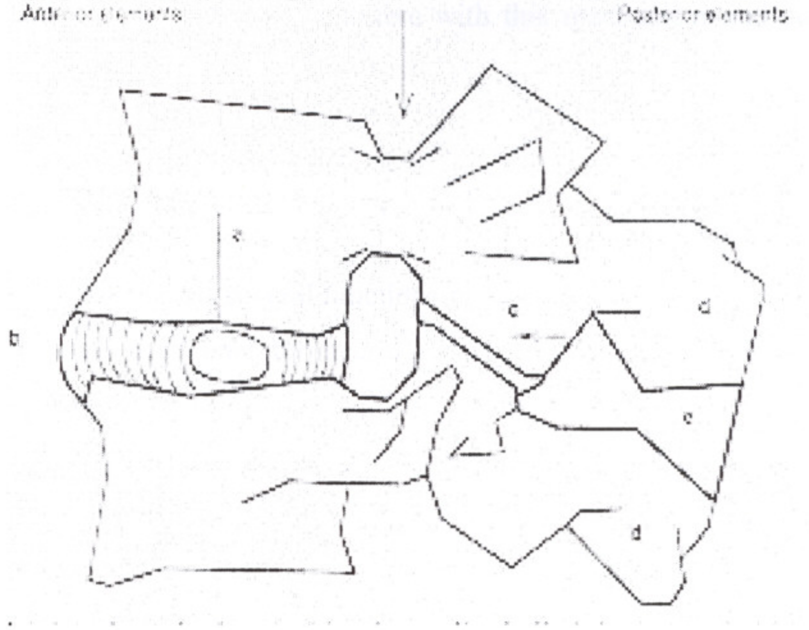

Figure 16: Anterior and posterior elements of the spine. a= Vertebral body; b = intervertebral disc; c = facet joint; d = bony projections; e = ligaments.

The anterior column, consisting of the vertebral bodies, intervertebral disk and anterior and posterior longitudinal ligaments, is the main support structure of the axial skeleton. It resists the compressive stress of the superincumbent body parts.

The posterior elements of the spine act as jointed columns, which control the movement of the complete spine and provide attachment point for the back muscles.

The vertebral bodies and their related structures increase in size from the top of the bottom of the spine in accordance with the increased load that they must bear.

The intervertebral disks act as shock absorbers and limit and stabilise the articulation of the vertebral bodies. The disks are prestressed to withstand loading (analogous to reinforced concrete beams used in the construction of modern buildings). The narrowing and expansion of the disk spaces is natural and occurs as a result of the forces exerted on the spine during everyday activities. Since there are 24 vertebral bodies, all with disks between them, the shrinkage and expansion of disk spaces results in measurable changes in stature-most people are about 1 percent taller when they wake up in the morning than when they go to bed at night for this reason. Postures, which exert static loads on the body, will interfere with this mechanism and accelerate the degeneration of the disks.

2.3.1.1.2. The Cervical Spine

The cervical spine has several functions-principally, to support the weight of the head and to provide a channel for neural structures and attachment points for the muscles, which control the position of the head. It consists of seven vertebrae designed to permit complex movements of the head. The lower five vertebrae of the cervical spine have the same general structure as those in the rest of the spine and are surrounded by anterior and posterior ligaments. The cervical spine consists of vertebral bodies and intervertebral disks, facet joints, bony processes for the attachment of ligaments and muscles, and the intervertebral foramen through which passes the spinal cord.

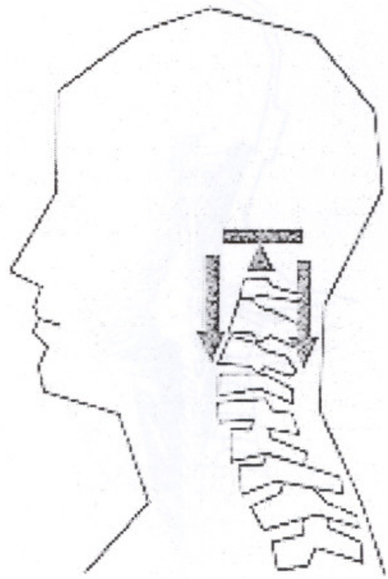

Figure 17: Balancing of the head on the cervical spine

Movements of the head are accomplished by muscles attached to it and to the surrounding parts of the skeleton. The deep short muscles of the neck serve to stabilise the individual vertebrae, whereas the longer, more superficial muscles produce movements of the spine and head as a whole. The posterior muscles, which extend the neck are stronger than the anterior muscles, which flex the neck, because the last are assisted by gravity, whereas the former have to work against gravity.

Static flexion of the cervical spine increases the moment arm of the head according to the sine of the angle flexion. This increases the load on the soft tissues in the cervical region, and the posterior neck muscles are placed under increased static load in order to maintain the forward-flexed head in equilibrium with gravity. The increased static loads on these muscles may cause pressure ischemia and starve the muscle tissues of fuel and oxygen. Pain in the neck and shoulders may result, causing muscle spasm (reflex contraction of the muscle). This condition may increase the pain and lead to a degenerative circle. The forward-flexed position may subject the cervical intervertebral disks to increased compression and the posterior ligaments to increased tension.

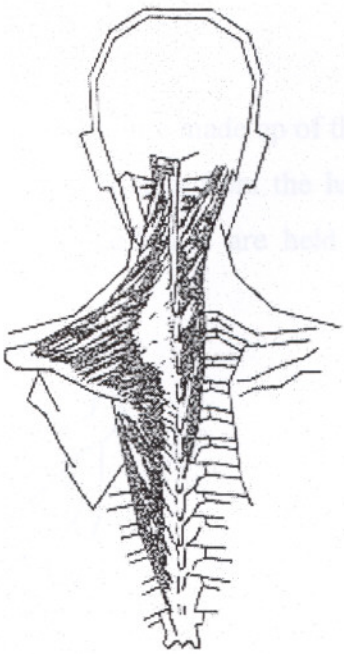

Figure 18: Rear-view of the neck and shoulder musculature.

It is very important to identify the postural factors that increase the mechanical load on the cervical spine through an increase in flexion and to remove these factors by redesigning space.

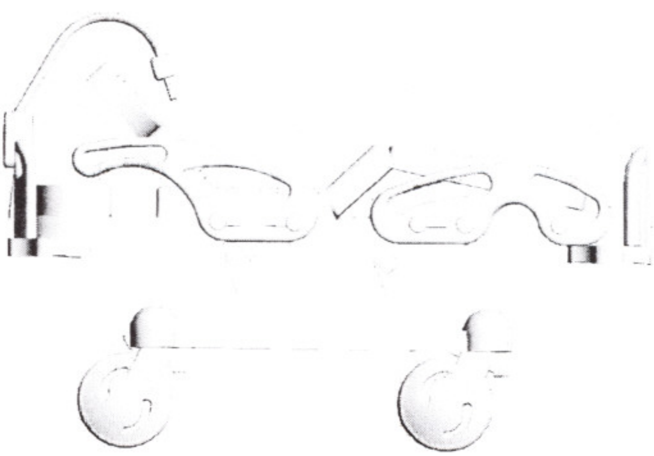

Figure 19: Differentiation in posture in the designed bed, according to the care type, decreases the load on the spine.

2.3.1.1.3. The Pelvis

The pelvis is a ring-shaped structure made up of three bones, the sacrum and the two innominate bones. The sacrum extends from the lumbar spine and consists of a number of fused vertebrae. The three bones are held together in a ring shape by ligaments.

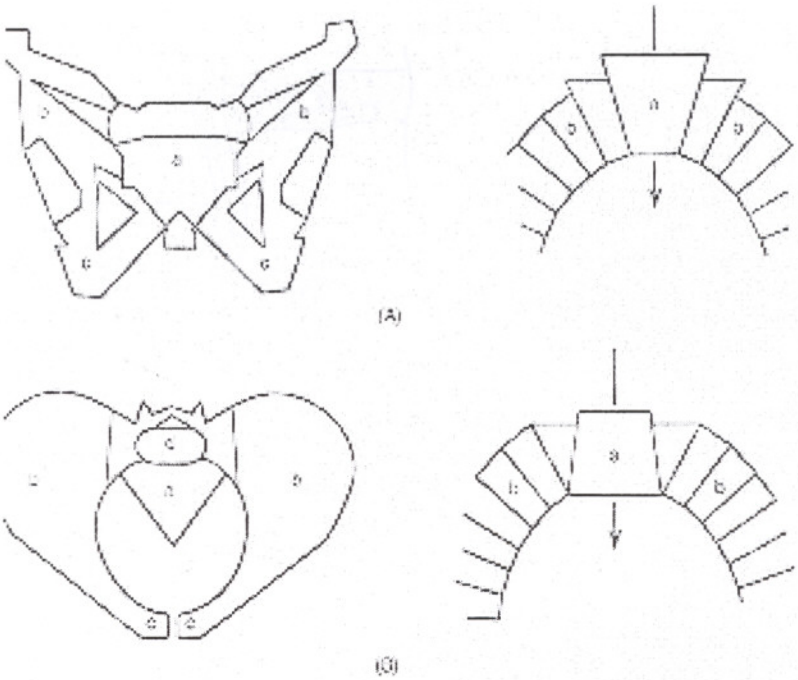

Figure 20: The pelvis as an arch. (A) The pelvis viewed from the rear. a = sacrum; b = illium; c = ischium. The sacrum acts like a true keystone in this plane . (B) The pelvis viewed from above. a = sacrum; b = illium; c = pubis; d = position of the intervertebral disk between the first sacral and fifth lumbar vertebrae. Under load, the sacrum tends to move forward, like an inverted keystone in an arch. It has to be held in place by strong ligaments.

The pelvis is likened to an arch, which transfers the load of superincumbent body parts to the femoral heads in standing and to the ischial tuberosites (part of the two ischia) in sitting. When viewed from the rear (A), the sacrum resembles the keystone of the arch. The load from above is transmitted through the innominates to the femoral heads. However when viewed from above the sacrum has the wrong shape for a keystone-it tends to slide forward, out of the arch (B). Under weight bearing, the tendency of the sacrum to slide forward anteriorly is resisted by the strong ligaments between the sacrum and the ilia.

Relevant to this musculoskeletal construction of the body, it is known that pain can be caused or increased by excessive loading of joints and muscles. This can occur not only as a result of traumatic events but also because of sustained exposure to particular postures. Disk pressure is higher in sitting than in lying down but was reduced when the sitter reclined against a backrest.

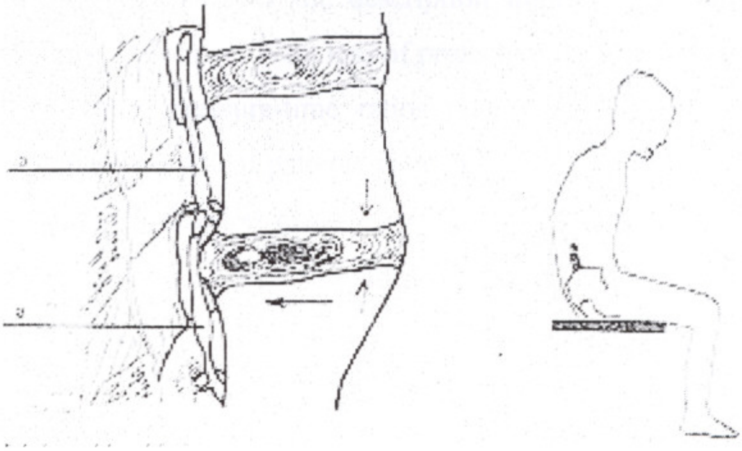

Figure 21: Because of the slumped posture the soft tissues between anterior and posterior elements of the spine may be pressurised, resulting in pain (Bridger, 1995)

2.3.1.2. Pressure Ulcers

Since pressure sores are the most frequently encountered pressure sores and difficult to treat, they present a significant problem in patient care.

"Pressure sores are ulcerated open wounds which are the results of ischemic tissue necrosis invariably formed by long-standing pressure acting on inadequate soft tissue over bony prominence. As the description implies, the major factor in the development of sores is pressure. With loss of protective sensation, most of the times, it is expected that normal pressure-time ratios may be exceeded and induce tissue ischemia. Approximately 3-4% of patients in acute care facilities and 40-50 % of those in chronic care facilities develop pressure sores. The incidence rises to 85% in the presence of a neurologic deficit such as quadriplegia or paraplegia".[4]

In general, the pelvis and lower limbs are the most common sites of pressure sores. The ischial area is the most common region of soft tissue breakdown with 28% frequency, the sacrum and trochanter follows. Ischial sores are caused by pressure above the ischial prominence especially in seated patients. The avoidance of pressure sore is accepted almost impossible in patients with paraplegia. In particular, pressure sores in the ischial region limit the daily activities of patients confined to wheelchairs and prevent their return to society.

One may suppose that the maintenance of structural integrity is a primary nursing responsibility. The acquisition of knowledge relating to the function of the skin, the patophysiology of tissue breakdown and the underlying pathology, is a major nursing objective which offers a foundation for the assessment of patients "at risk" of developing pressure ulcers.

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[4] Akgüner M. et al., "Treatment of Chronic and Wide Ischial Pressure Sores with Gracilis Myoctaneus Flap," (Dokuz Eylül University, Izmir, 1997).

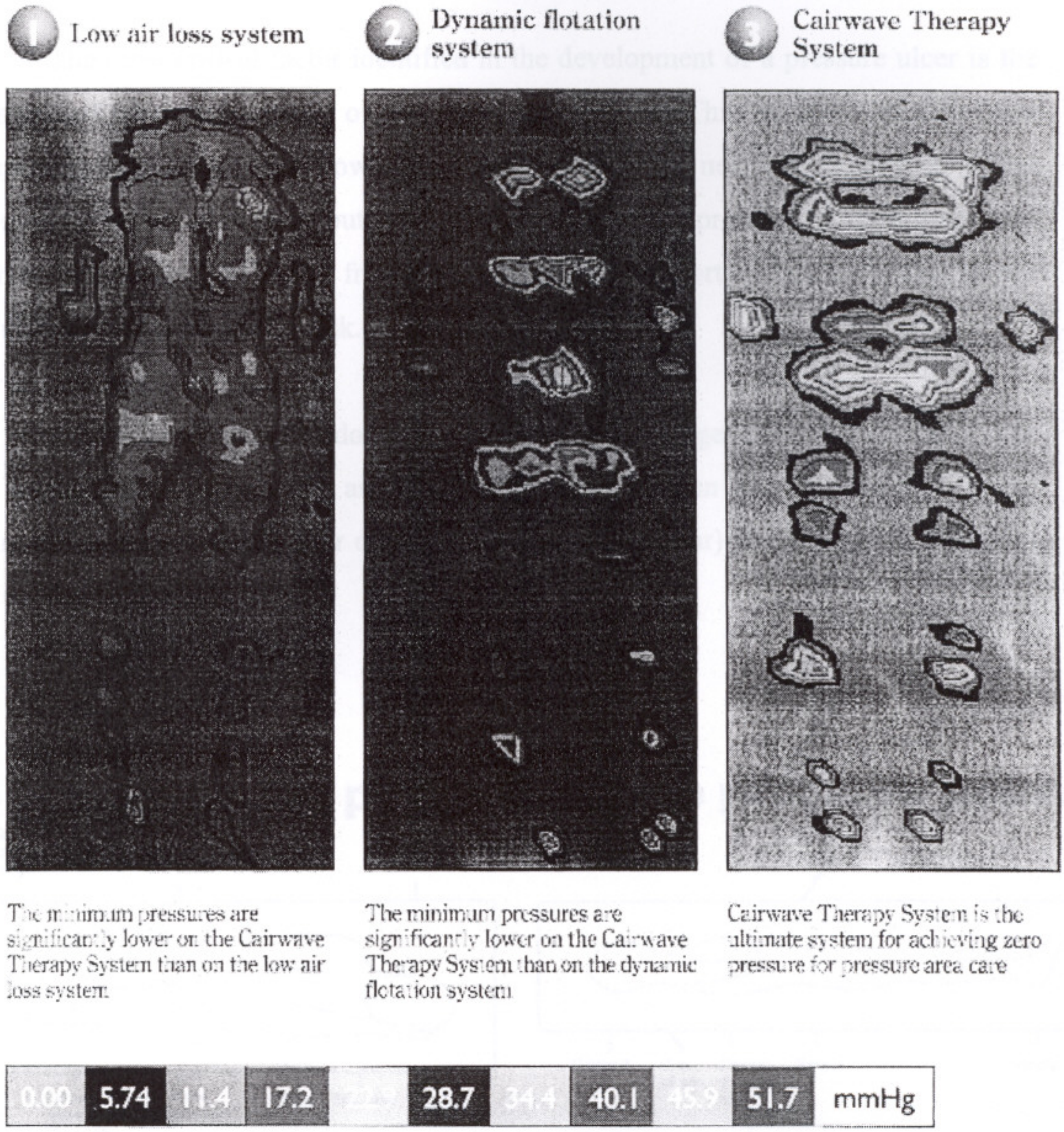

Figure 22: Comparison of interface pressures between various types of mattresses (Pegasus Airwave Ltd,1997)

"Most pressure ulcers can be prevented but if they do develop, intervention can prevent them from worsening. Instead of devoting energies to treating pressure ulcers, the focus should be on their prevention. This is very important because it is a valid goal for nurses to be responsible for the complete care of the patient and this includes care of the skin".[5]

[5] Sharp K., "Asia Pasific Hospital Magazine," (May 1997)

The most critical factor identified in the development of a pressure ulcer is the duration of pressure, usually over a bony prominence. This external pressure will decrease the capillary blood flow to the area causing tissue necrosis. Other factors that have been identified as contributing to the development of pressure ulcers are age and decreased mobility, shear and friction. Therefore it is important that these factors are included on a tool to predict risk.

"Shear and friction undoubtedly cause tissue damage and the different forces that cause this damage require assessment. Shear and friction may respond to different interventions to prevent further damage to deep tissue (shear) and superficial (friction) forces".[5]

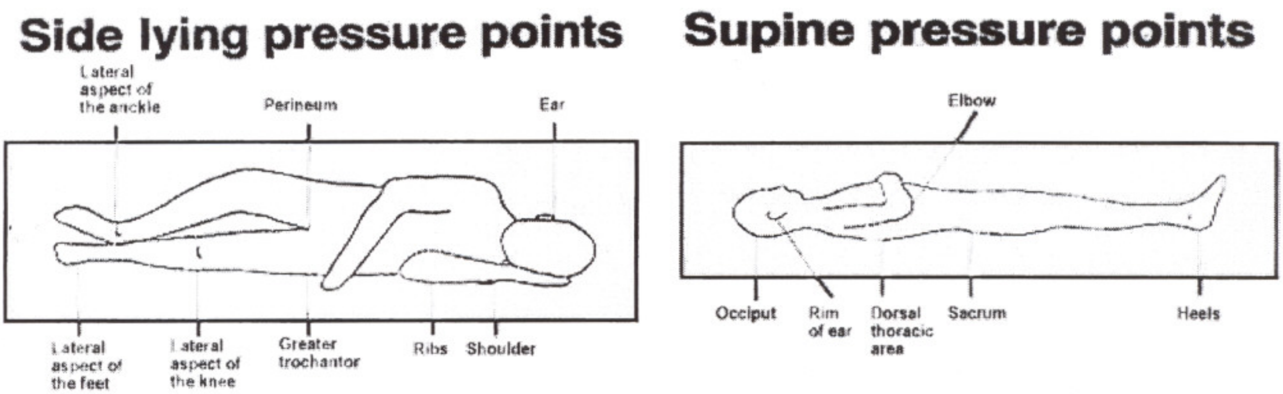

Figure 23: Side lying and supine pressure points, (Sharp, 1997)

[5] Sharp K., "Asia Pasific Hospital Magazine," (May 1997)

In order to establish who is at risk all patients should be assessed on admission to hospital to establish their mobility status. None of the assessment tools clearly identify the primary cause of pressure ulcer development.

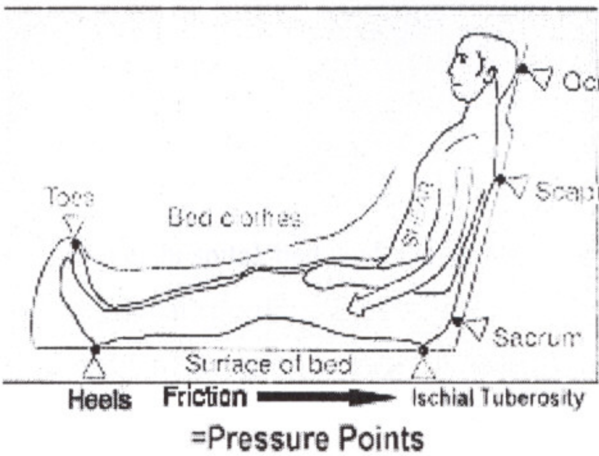

Figure 24: Sitting pressure points, (Sharp, 1997)

A tool, if used, should reflect the progress of pressure ulcer development and have well-defined assessment categories which have a relationship to the development of pressure ulcer.

As the main risk factors have been identified as pressure and reduced mobility, assessment of mobility should be accurately evaluated because there is a strong correlation between decreased mobility and pressure ulcer development.

Variables such as age, shear and friction, that increase the degree of risk, should be included as categories of an assessment tool to identify these factors.

2.3.2. Factors Related to Interior Architecture

Hospital bed and the space in which it stands should not be thought separately. As both the design of the bed and the design of the interior seems to be the job of separate disciplines; in the end the target they would reach is the user, in other words human. Also, the relation of hospital bed with interior space affects its functions to be used more efficiently.

2.3.2.1. The Bedroom

As indicated above, hospital bed and the patient room exist for human as a common aim. The dimensional specifications of both of them is in direct relation with the health of the user. They are designed separately but in designing they are thought of together. They used the only standard, human ergonomics, as a fundamental. Basic dimensions of a patient room was designed while a hospital bed has designed according to human dimensions. It is obvious that in a narrow patient room, the range of movement of a hospital bed also limited. Using a high end hospital bed, can not change the health conditions of a patient so much if it exists in a weakly illuminated and weakly air conditioned patient room. The bedroom description consists of the interior elements of a patient's room.

2.3.2.1.1. The Bed

"It would seem that an ideal bed should have been described and recommended by now, since about %33 of human lifetime is spent in bed. However, this is not the case. There have been many research studies, funded by government, medical institutions, and large bedding manufacturing concerns. Although some general findings have been obtained, no definite conclusions have been reached".[6]

[6] Raschko B.B., "Housing Interiors for the Disabled and Elderly," (Van Nostrand Reinhold, New York).

Even though the "ideal bed" has still not been defined, several pertinent observations and recommendations have been made as follows:

1. Mattress underlayment should be firm, without sag. Examples of good underlayment are; plywood panels, open coil springs with little side play, and pocket coil springs. Flat springs are rejected because of sag that results with prolonged use.

2. Mattress recommendations range from medium to firm, although one study showed little difference in quality of sleep between a firm mattress and a featherbed. The reasons for the advocacy of a relatively firm mattress are as follows:

    a. Motility in bed (i.e. ability to change positions) is important in order to relieve pressure points on the body, to relax different sets of muscles, and to shift weight on the different sets of muscles and on different organs in the body. Too much compression or sag of the mattress will result in entrapment and make shifting too difficult.

    b. An oversoft mattress will not give sufficient support and will not hold the body in good alignment, but will place too much strain on the vertebral column and internal organs, particularly if one is lying in a supine position.

    c. It is ordinarily maintained that a firm mattress is necessary to avoid hallows, sagging and formation of hard lumps or "pockets". Orthopedists for years have advocated firm mattresses for their patients who suffered from back problems and joint ailments such as arthritis and bursitis, chiefly to facilitate motility. Lack of motility increases discomfort and pain.

    d. The narrow width of a twin-size mattress allows the user to grip the edge of the mattress for leverage, to assist in turning over in bed.

3. Other forms of mattresses seem to contradict the general attitude toward the firm mattress, chief among them being the waterbed and the air-fluidized bed. Both of

these beds conform to the shape of the human body and are compressed according to the weight placed on them.

Figure 25: Zero-Pressure Air-Fluidized bed mattress. (Pegasus Airwave Ltd.,1997)

The air-fluidized bed has been particularly beneficial for patients with paraplegia, quadriplegia, decubitus ulcers, burns, hip fractures, and spinal injuries, and for healthy human beings. Waterbeds are usually considered unsatisfactory because of poor ventilation, hygiene and support. There also are hyperbaric and double air mattresses, designed to change support points for patients who are unable to move themselves, and thus to decrease development of decubitus ulcers.

4. The elderly are not a homogeneous group, so their likes and dislikes in relation to beds and sleeping will probably be as broad as those of another age group will. The chief difference will be their greater propensity to aches and pains, which have been individually collected over a lifetime. Thus, mattress selection will be a highly individual undertaking. Whether the choice is a soft, medium or firm mattress, the under-springing should be firm and not allow sagging.

5. The requirements of the disabled will vary according to the disability. The large majority will choose a bed, again, on an individual basis. For those who have severe

motility problems, such as paraplegics and quadriplegics, or who must spend an extended time in bed, special provisions must be made. Decubitus ulcers have been known to develop in a matter of hours in cases in which the individuals were motionless. Since it may be impractical to have someone come in periodically to help the disabled person change position in bed, he/she needs a bed that will help to facilitate this change.

a. The Gatch spring bed or variations of it allow raising and lowering of the head, knees, or feet. This bed can be operated electrically. Many disabled persons have this bed and find it to be valuable assistance. It has also been suggested that an additional asset would be a mechanism that would incline the entire mattress as much as 5°.

b. Many disabled do not like a hospital bed because of its institutional look and go to great lengths to disguise it. However, there are positional beds on the market that are very acceptable in appearance.

c. For those with fair to good upper arm and shoulder strength, shifting or movement in bed can be accomplished if the headboard can be used for leverage. Vertical members such as rods or spindles, incorporated in the design of the headboard, can be used to assist a person in turning over. A trapeze, either attached to the headboard or bolted into the ceiling, can also help materially. (Ceiling attachment should be avoided, since it must withstand a pull of 300 lb. must have special reinforcements placed in the ceiling, and, once installed, prevents moving the bed to a new position.)

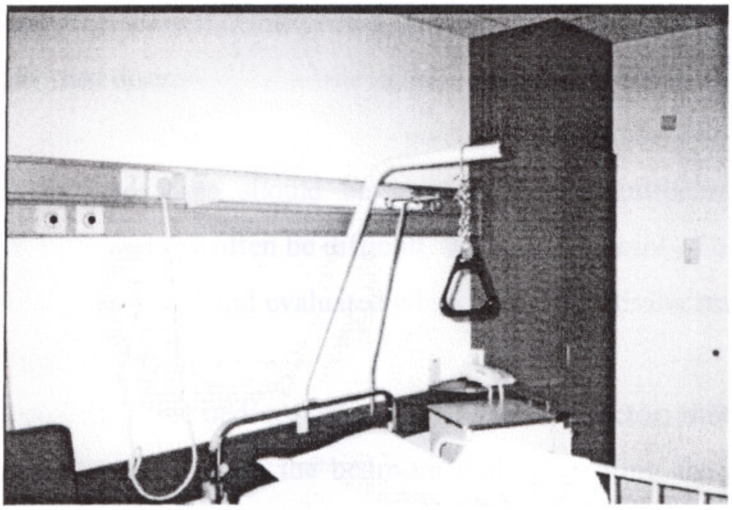

Figure 26: A trapeze attached to the headboard. (Brugge International Hospital, 1997)

d. Ventilation and a high degree of conformity play a large role in comfort while sleeping. To assist this, many disabled have been using sheepskin as a mattress overlayment. The fleece of the sheepskin serves as a soft conforming support for the body. In addition, there is improved ventilation as well as a decrease in perspiration build up because of the high moisture-absorption properties of the fleece of the sheepskin. Mattress pads that allow for air circulation and dissipation of moisture minimize bedsores and skin abrasion; they are available from suppliers.

e. There are sophisticated systems for beds that allow a person to lie motionless while the mattress or underlayment materials undergo changes in order to simulate position changes. These systems include the double air mattress and the hyperbaric (air cushion) and air-fluidized mattresses.

2.3.2.2. Ambient Characteristics

Sound and noise in general should not be obtrusive to the sleeper. This does not mean that there should be absolute silence. There is a multiplicity of sounds around us that only occasionally will rise to a level at which we are conscious of them. Similarly, while we are sleeping, customary sounds are not obtrusive and can even assist sleep (e.g. a breeze rustling tree leaves). Unexpected sounds can be obtrusive, such as the sounds of a loud party next door.

For this reason, bedrooms should be located so that intrusive noises are minimized. Bedroom location may often be difficult, from a standpoint of outside noise, but it should at least be understood and evaluated when selecting a living unit.

Temperature control in the bedroom should be a positive factor; that is, it should be possible to raise the temperature in the bedroom without heating the entire living unit. This can usually be effected with an individual baseboard heater that is thermostatically controlled.

Cooling and ventilation are usually accomplished by opening a window. In warmer climates, a window air conditioner may be desirable. (Note: The bed should not be placed in a draft.)

The elderly and disabled may generally require a warmer bedroom temperature because of several factors, including poorer blood circulation. It should therefore, be possible to raise the temperature to 22°C.

Light in the bedroom takes two forms; general lighting and area lighting. A central ceiling fixture with a diffuser shade often supplies general lighting in the bedroom. Area lighting is usually supplied for reading in bed, occasionally at a dressing table. A bed light, in the case of two sleepers, should be highly directional and should not be overly intense; in order to cut down on reflected light that might disturb the person who is not using it. If only one person uses the bedroom, more light should be used in order to eliminate sharp light and dark areas in the room. A bedside lamp or a valance light above the headboard will generally be satisfactory.

A small continuous-burning night light, which is plugged directly into an outlet, is often advocated as an aid when getting out of bed in the dark, for instance, to go to the bathroom. For those with diminished vision, a disadvantage may be that in-the-plug night light is usually in the wrong location and does not give sufficient light to guide them to their objective. Equally effective is an illuminated light switch by the bedroom door (i.e., a switch with a small light that burns when the switch is in the "off" position). It acts as a beacon to which a person is guided, even for those with diminished vision. The requirements for this arrangement might be as ;the light switch should be visible from the bed; and there should be no obstacles that might cause accidents between the bed and the light switch. One big advantage is that the illuminated switch is not so obtrusive that it will interfere with sleep.

2.3.2.3. Patient Rooms

The design of the acute care patient room is important because for many it's the only room they see during their period of hospitalization. The room must be designed for privacy, comfort and easy interface with both visitors and caregivers. To make this environment enhance healing, the patient should have views of nature (from the bed), be able to control lighting levels, have control over room temperature and privacy, not have to suffer noise of carts or conversation in corridors and be surrounded by a moderately stimulating palette of colors and texture.

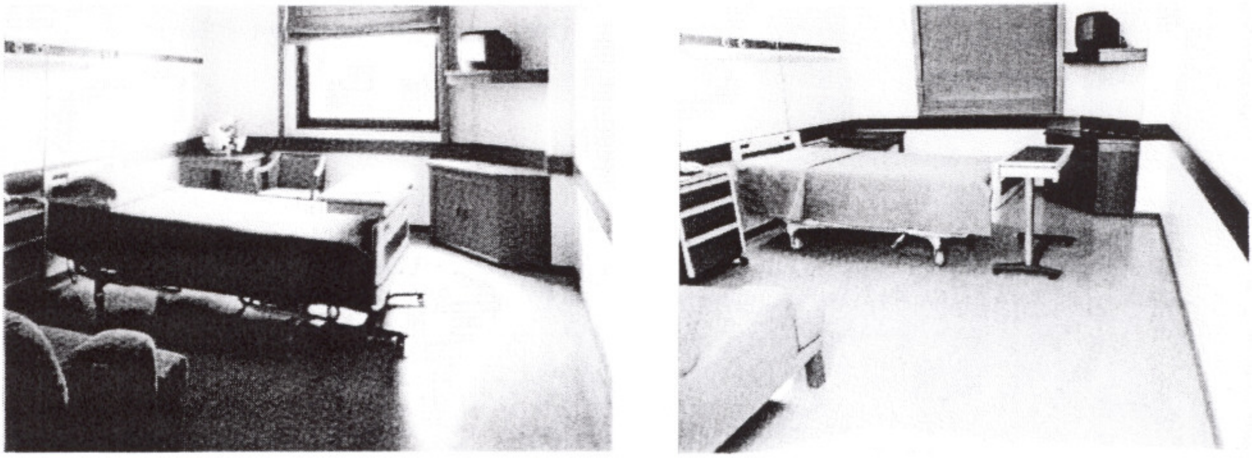

Figure 27: Patient room, daytime and at night.(Archiscope, 1999)

2.3.2.3.1. Privacy and Isolation

Many issues beyond environmental ones cause stress for hospitalized patients. Table represents the results of a survey indicating the chief causes of stress for both medical and surgical patients.

Figure 28: Patient room (Archiscope, 1999)

Factor	Stress Scale Events	Assigned Rank	Mean Rank Score
Unfamiliarity of surroundings	Having strangers sleep in the same room with you	01	13,9
	Having to sleep in a strange bed	03	15,9
	Having strange machines around	05	16,8
	Being awakened in the night by the nurse	06	16,9
	Being aware of unusual smells around you	11	19,4
	Being in a room that is too cold or too hot	16	21,7
	Having to eat cold or tasteless food	21	23,2
	Being cared for by an unfamiliar doctor	23	23,4
Loss of independence	Having to eat at different times than you usually do	02	15,4
	Having to wear a hospital gown	04	16.0
	Having to be assisted with bathing	07	17.0
	Not being able to get newspapers, radio or TV when you want them	08	17,7
	Having a roommate who has too many visitors	09	18,1
	Having to stay in bed or the same room all day	10	19,1
	Having to be assisted with a bedpan	13	21,5
	Not having your call light answered	35	27,3
	Being fed through tubes	39	29,2
	Thinking you may loose your sight	49	40,6
Seperation from spouse	Worrying about your spouse being away from you	20	22,7
	Missing your spouse	38	28,4
Financial problems	Thinking about loosing income because of your illness	27	25,9
	Not having enough insurance to pay for	36	27,4
Isolation from other people	Having a roommate who is seriously ill or cannot talk with you	12	21,2
	Having a roommate who is unfriendly	14	21,6
	Not having friends visit you	15	21,7
	Not being able to call family or friends on the phone	22	23,3
	Having the staff being too much of a hurry	26	24,5
	Thinking you might lose your hearing	45	34,5
Lack of information	Thnking you might have pain because of surgery or test proceedures	19	22,4
	Not knowing when to expect things will be done to you	25	24,2
	Having nurses or doctors talk too fast or use words you can't understand	29	26,4
	Not having your questions answered by the staff	37	27,6
	Not knowing the results or reasons for your treatment	41	31,9
	Not knowing for sure what illness you have	43	34.0
	Not being told what your diagnosis is	44	34,1

Threat of severe illness	Thinking your appearance might be changed after your hospitalization	17	22,1
	Beinmg put in the hospital because of an accident	24	26,9
	Knowing you have to have an operation	32	26,9
	Having a sudden hospitalization you weren't planning to	34	27,2
	Knowing you have a serious illness	46	34,6
	Thinking you might lose a kidney or some other organ	47	35,6
	Thinking you might have cancer	48	39,2
Seperation from family	Being in the hospital during holidays or special family occasions	18	22,3
	Not having family visit you	31	26,5
	Being hospitalized faraway from home	33	27,1
Problems with medications	Having medications cause you discomfort	28	26.0
	Feeling you are getting dependent on medications	30	26,4
	Not getting relief from pain medications	40	31,2
	Not getting pain medication when you need it	42	32,4

Table 4: Hospital Stress Factors, (Raschko, B.B.)

As lack of privacy usually rates high as a source of stress, hospitals have been addressing it by providing a large number of private rooms. A study at the University of Michigan Hospitals found that even if cost were no object, 45 percent of patients would choose a private room, 48 percent would choose a semiprivate room, and 7 percent would prefer a multiple bed room. Many people seem to prefer having someone to talk to.

With respect to visual privacy, the essential point is always the trade off between the patient being able to see into the corridor and yet not be seen by passerby. An interior window provides an opportunity to people-watch and allows nursing staff to monitor the patient without having to walk into the room. The window must have a curtain to provide privacy when needed or else use glass that turn opaque with a click of a switch that is controlled at the patients bedside.

2.3.2.3.2. Layout of the Room

Beds placed toe to toe on opposite headwalls give both patients equal window access and make maneuvering equipment easier. But in this condition may be forced to stare each other unless they pull the privacy curtain.

Beds placed side by side do not afford equal access to window, and visitors to the windowbed are forced to intrude upon the privacy of another patient.

Newer approaches to the design of semiprivate patient rooms include trapezoid or diamond-shaped rooms that allow beds to be positioned at 90° to one another.

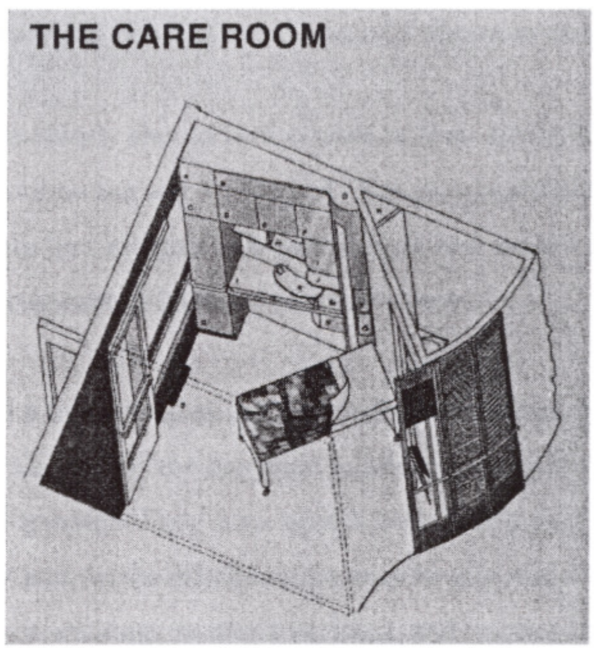

Figure 29: The care room, (SOTERA project catalogue, 1997)

For the disabled, particularly those in wheelchairs, extra space is needed for maneuvering. The room sizes only slightly exceed minimum standards, yet there is still adequate space for elderly and wheelchair requirements.

Figure 30: The accessories for the disabled in the care room,(SOTERA project catalogue, 1997)

Bed heights for the elderly should be the same as their sitting heights, about 40.6 or 43.2 cm., as they often sit on the side of the bed. The elderly should not have too low a bed, in order to facilitate bed making. An overly high bed makes getting into it too difficult and increases anxiety about falls and possible injury.

The disabled need a higher bed if they are wheelchair users; generally it should be about 48.3 cm. High. The top of the mattress should be near the same height as the wheelchair seat to aid in transfer. They also need a bed that is very solid to simplify transfers. Both headboard and footboard should be easy to grip and smooth, as they are often used for support when walking, to assist in rising, and in orientation at night.

The height for the bedside table is about 5.1 to 7.6 cm. above, or at the same level as the mattress height, never lower. At this level orientation is simplified, and objects can be quickly found in the dark.

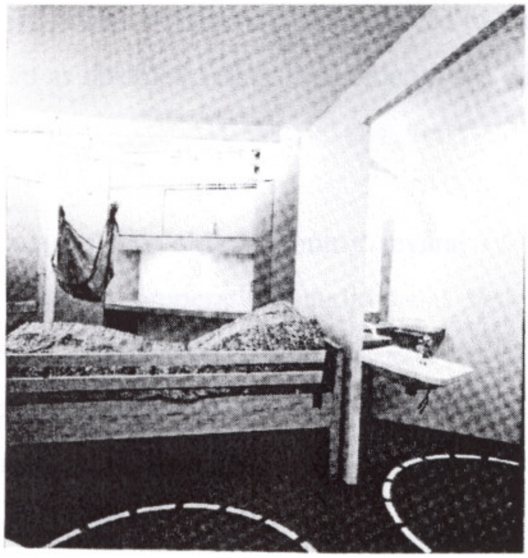

Figure 31: The bed and the toilet in the care room, (SOTERA project catalogue, 1997)

2.3.2.3.3. Amenities

Aesthetic amenities that make the room look less clinical are a plastic laminate, oak-trimmed headwall permanently fixtured to the wall and a cover for medical gas outlets. Often the medical gas cover consists of a framed piece of artwork. Storage of patients' belongings is important, along with shelves for plants and gifts. A private room might include a desk, small dining table and a lounge chair.

"Although patient comfort is very important, it may conflict with circulation of supplies and services to the patient. The same is true for visitor access. The need for quick staff access to patients (generally the patient's right side for examination and treatment) takes priority over the patient's need for control and privacy. In a medical emergency, people and equipment must have easy access to the patient's head".[7]

[7] Malkin J., "Hospital Interior Architecture-Creating Healing Environments for Special Patient Populations," (Van Nostrand Reinhold, New York, 1992).

2.3.2.3.4. Mechanical Systems

Mechanical systems in the bedroom can be very simple, for those who have few needs, or they can be very sophisticated for those who have a multiplicity of needs. Because the elderly may often overlap with the disabled to the extent that some elderly persons should be listed as disabled rather than elderly, we will consider separately the able-bodied and the disabled.

Elderly persons should be able to control several systems within the bedroom. Theses would include lights, temperature, audiovisual systems (e.g. television), and ventilation. The present state of the art is such that some of these systems are controlled before one goes to bed, such as setting a thermostat on either a heater control or an air conditioner, and opening or closing a window. The other controls are handled by a TV remote control and by light switches on lamps by the bed. Controls for a stereo system can also be located by the bed or installed in the headboard of the bed. A bedside telephone is a necessity.

An important mechanical system is an adequate fire alarm system. Whether the occupants are able-bodied or disabled, a smoke alarm is required. When one or more smoke alarms in the unit are recommended, the primary placement is at or near the sleeping area of the living unit. The underlying reason is the frequency of loss of life when fire occurs at night when everyone is asleep. An early warning will assist in alerting sleepers to the fact that an emergency exists and will bring about much earlier restorative measures (i.e. vacating the unit, calling the fire department, and spreading a general alarm).

The deaf/blind must be individually considered here. Since smoke alarms are usually battery-controlled and react to a fire situation by emitting a loud alarm, the deaf may not respond. A secondary system should be installed that will react to fire emergency, either with a bright flashing light or with a vibrator built into the bed that will alert the person to the presence of the emergency.

The disabled may require a much more sophisticated mechanical control system, dependent upon the degree of disability. since their mobility may be severely limited, these bedside controls should be available;

1. A low voltage control system that will turn off or on all lights in the living unit.
2. An alarm system or intercom system in case of need or emergency, that will automatically unlock the entry door. If the door is not electrically controlled, monitoring personnel should have a key to provide entry into the living unit.
3. Remote control of television, radio and stereo systems.
4. Bedside control of ambient temperature.
5. Video and/or audio connection to the front door in case of visitors. A bedside telephone is a necessity.
6. Special bed controls to assist in changing position (may be Gatch spring type, double air mattress, hyperbaric bed, etc.).
7. Outlets and controls for electrically powered aids (e.g. warming pads, respirators, etc.)

Many of these controls can be placed on one consoled boards. Some, such as television and stereo controls, may be embodied in separate systems. A headboard with built-in compartments or shelves could be valuable, for this reason.

"The needs of the disabled often go beyond recourse to mechanical systems. Self-help often dictates a prearrangement of medicines, liquids and other equipment (e.g. a container in which to empty a urine bag). For this reason, adequate table or shelf space is needed".[6]

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[6] Raschko B.B., "Housing Interiors for the Disabled and Elderly," (Van Nostrand Reinhold, New York).

3. FUNCTION of a DESIGNED PRODUCT

In design engineering descriptions some common keywords such as technology, science, functionality, mechanism, planning, efficiency, capability, cost are always mentioned. "Using scientific principles, technical data and imagination in description of a mechanical structure, machine or system which accomplish pre-set functions with the highest efficiency and economy" is a typical portrait of design engineering. The description of designer formulated by ICSID (International Council of Industrial Design Societies) as "... responsibilities of a designer extend from the original description of product's function to formal characteristics of its details. These responsibilities also include the contribution of product's functional, cultural, social and economic properties into the improvement of human environment". It is obviously seen that keywords in this description match partially with the concepts in the description of design engineering. It is natural that, words used in the description of design engineering as mechanism, construction, material, functionality, economy which are directly related to object's work and physical existence; are common as keywords used in the description of a designer.

3.1. Criteria Influencing the Design

Factors effecting the design of human-machine interface by the approach of industrial design; must be identical with the criteria valid in industrial design. Industrial design, in its multidisciplinary structure, must apply various criteria gained from different sources to the design of an object. Variety of effective criteria can be understand from the description of designer above. In this description, it is determined that in designing of an object the designer must involve both with its material, structure, mechanism, form, colour, pattern and with its contribution to the living environment in the meaning of its function, cultural, social and economic values.

More systematic classification of these criteria effecting the design process, can be more helpful because of orderliness. These design criteria were classified into four titles including twelve sub-titles:

1. Functional Criteria
    a. Physiological criteria
    b. Physical environment criteria
    c. Communicational criteria
2. Psychological Criteria
    a. Perceptive criteria
    b. Socio-cultural criteria
    c. Emotional qualities
    d. Expression criteria
3. Technological Criteria
    a. Material criteria
    b. Manufacturing criteria
4. Economical Criteria
    a. Consumer criteria
    b. Manufacturer criteria
    c. Macro level criteria

3.1.1. Functional Criteria

Every object exists as a result of a physical requirement. Main function is to meet that necessity. Criteria which tend to optimise this process are called functional criteria. Functional criteria is examined under three sub-criteria as physiological, environmental and communicational criteria. A designed objects function should express its precision to human physiology, environment and the message given.

3.1.1.1. Physiological Criteria

Human body has certain physical properties. Every object developed for human use; under some circumstances, must interact with certain parts of that body. This interaction may be either a one-to-one physical relation or a visual, auditory contact. During this interaction; compatibility of the objects' physical being to the human's physical existence, is realised along physiological criteria. Human body has a complex structure. In this context, interaction of man with an object comes true according to some ergonomic preferences. So physiological criteria are usually formulated by ergonomical data.

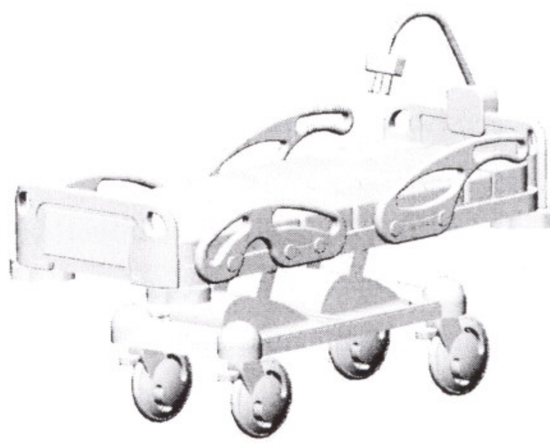

Figure 32: The complete hospital bed design answering the needs of physiological criteria.

3.1.1.2. Environmental Criteria

Objects must be in relation with each other and other elements inside the environment. Suitability of points that establish this relationship is obtained by environmental criteria. Joints, legs, hanging details are results of these criteria. Motion ability of an acrobat lamp or a hospital bed is because of its necessity to fit suitable places and positions in their surroundings.

3.1.1.3. Communicational Criteria

These criteria aim the effective representation of object itself to the user. The information that is given could be even for the utility and its basic structure. In this manner, communicational criteria can be classified in two; functional and communicational.

Functional communication is the act of realising the object's utility by directly looking at it, in other words; expressing its function by its vision. Object must inform about its functionality by the whole form or by its details. In this phenomenon, designer is assisted by natural tendencies, usual predetermining of human and by semiologic symbols. Certain forms of objects remind us certain functions because of natural tendencies. Circular forms remind us a rotating motion.

Rough surfaces remind touching. Convex forms are perceived as bowl. Using semiologic symbols generally helps in complex functions, such as colour codes. The important thing is reading, perceiving, getting the meaning, using and recognising the symbol by the user clearly, especially in diagrams and pictograms. So that the user will get the object's function.

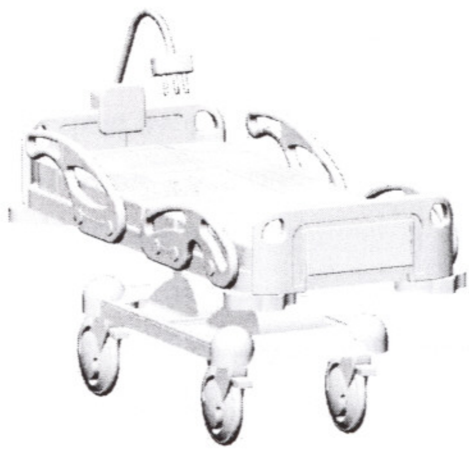

Figure 33:The designed object should express its function by its vision.

"Conceptual communication is involved in the image of form-function relation on human mind. Every object, which was developed for a certain function, reaches towards a formal unity. Formal concept appears on human mind as an image of object itself and form-function relation".[1] New designs for that object usually occur as variations inside this formal unity.

3.1.2. Psychological Criteria

Every individual observes his environment or the products within the environment, and evaluates psychologically; but at the same time it is also the attitude of the designer himself. The needs caused by even the perception period before evaluating and by the state of evaluating, describe the psychological criteria.

3.1.2.1. Perceptual Criteria

Physical and formal properties of an object determine how it is perceived and evaluated. Perceptual criteria have to fulfil the function of clear perception of an object in understanding or evaluating process.

3.1.2.2. Socio-cultural Criteria

Each society create some norms and value systems in order to control and evaluate the attitudes of the individuals. Being an acceptable member of the society depends on the adaptation to these norms. Social safety feeling of the individual occurs with a belief that he was accepted by the society; while choosing the objects around him, thinks about the rate of that social safety which he would gain by owning the object. Therefore; design should take into consideration of the object's formal and functional properties that are available for society's value system. Though this is a little bit conservative approach. Discussion or critics about some cultural norms for the designer by his product is always possible.

Aesthetical criteria or norms also have to be considered inside the Socio-cultural criteria because of their diversity by time and by society.

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[1] Asatekin M., "Endüstri Tasarımında Ürün Kullanıcı İlişkileri," (Publication of METU Faculty of Architecture, Ankara, 1997)

3.1.2.3. Emotional Criteria

There is also an emotional evaluation process while criticising an object. Basically it can be defined as *like* and *dislike*, but indeed the more correct definition would be *to equate the user himself with the object*. In each media and environment that object communicated with the user (visual, tactual, auditory, olfactory, kinesthetic etc.) there are conscious and subconscious values that the user collects as knowledge in his mind during his life. As a result of these criteria, individual communicates with the object or not. As the values that recognised are very personal and in general these can not be explained reasonably, the user evaluates them emotionally. As it is very difficult to generalise the emotional properties; it is hard to make an absolute critics. But this does not mean that we don't have to consider it. The designer, who will ignore the feelings in the object that he designed, will face this responsibility at last.

3.1.2.4. Expressional Criteria

Forming of an object occurs in the frame of a series of objectiveness that a designer determines. Although there are numerous possibilities to state scientific objectives and criteria to have a healthy and right object; there are various ideas and messages besides these that the designer want to express to the user by the help of the designed product.

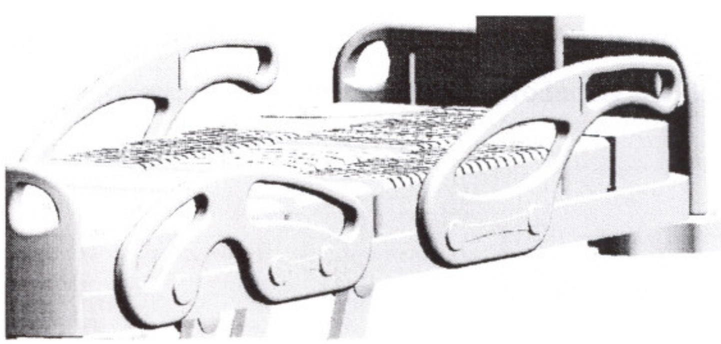


Figure 34: The rounded siderails gives the bed a sympathetic and sheltering look; and also protects the user from possible hazards.

This kind of communication is mainly the aim of fine arts. But when the product starts to involve some functional properties like in architecture and industrial design, aesthetical approach (speech) is began to be pressurised by the functional purpose. It depends on the designer's capability to make the object serve both for the purpose of function and for the expression at the same time. Physical elements of the object must be chosen in a way that they will indicate a message best. This can be described as the object's language. With the object language, a designer proposes a kind of a certain social attitude to the user. So the consumer of this product perceives and accepts these proposals.

Expressional criteria appear in two levels. Design made for every single object, is the result of designer's creative works and it must satisfy the designer psychologically. That exists when the designer believes that he could express himself to the user by the object.

1. The freedom should be provided, but the limits are important.
2. Expressional properties must be arranged in balance.

However, while doing this the designer has to be careful, he must not ignore the user's psychological and physiological comfort for the sake of his own psychological safety.

3.1.3. Technological Criteria

Every object is manufactured within a technological process. Physical requirements of this process, are valid parameters in producing the desired form. These requirements are technological criteria.

3.1.3.1. Materials

These criteria must be considered in direct and indirect way. It is required that the material used must be appropriate to produce the demanded form (criteria for choosing the material) or designed form must be able to be produced from the selected material (criteria for forming the material). Because the selection of material is not only a result of formal properties but also a result of function and usage conditions. Therefore; material criteria must be taken into account in three subtitles:

1. Suitability of selected material to the function and usage conditions.
2. Suitability of selected material to the form.
3. Suitability of form/method compound to manufacturing method.

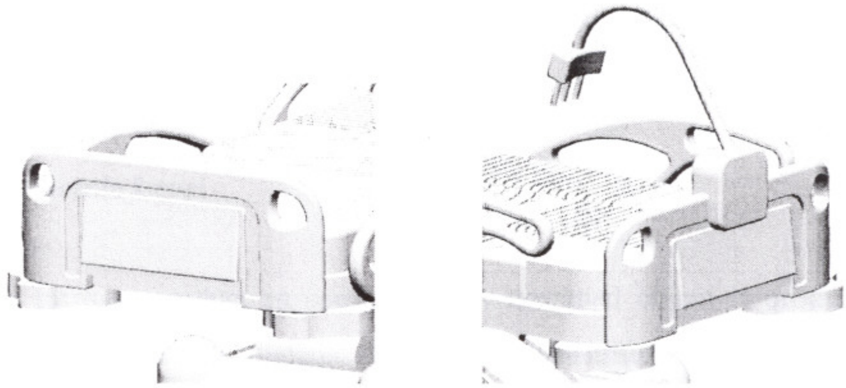


Figure 35: The detachable footboard and headboard, trolley cover, and siderails are made of vacuum formed polystyrene not to consist any bacteria and to be easily cleaned.

3.1.4. Economical Criteria

Both manufacture process and usage stage of products is developed in a certain economic environment. Limitations existed in the phenomenon of fulfilment of needs by the produced object; are economical criteria.

3.1.4.1. Consumer Level

The fact of manufacturing a product is to satisfy certain needs of consumers. Consumer accepts this satisfaction by owning this product. This value exchange must be in optimal level for the consumer. In other words, consumer must find the nominal value of his money in the object he bought. Cost and price analysis of a manufactured object is a complex fact. In this case, the responsibility of designer is to help the object which he designed to reach the consumer as cheaper as possible.

3.1.4.2. Manufacturer Level

Manufacturer has certain possibilities such as production methods, marketing strategies, manpower and time; and certain objectives such as maximisation of profit. True manufacturing of the object depends on the designer's existence in these states and not misunderstanding these objectives.

3.1.4.3. Macro-economic Level

According to mass production concept, every designed object is produced in thousands. Behind these suddenly appeared thousands of consumer products, there are a huge amount of raw material, manpower, energy, natural resources etc. Mistakes appeared in design considerations will cause all of these resources to be wasted. So; designing the right objects, is very important not only for bringing the rightious product to the consumer but also using the resources of all mankind regularly. But the main criteria are the tendency of designer to produce objects in more efficient and positive way of usage of resources mentioned before.

3.2. Industrial Design Approach to Product-User Interaction

It is obvious that there are differences between ergonomic approach and industrial design approach towards the human-machine interface. It will be helpful to determine two points in the formulation of industrial design approach: A widely spreaded functionality, as a combination of physical and emotional functions and a combination of measurements in an ergonomic manner. So, industrial design approach will be considered according to the factors below:

1. Physical functionality factor
    a. Physiological factors.
    b. Communicational factors.
2. Emotional functionality factor
    a. Psychological factors
    b. Socio-economic factors
    c. Expressional factors

3.2.1. Physical Functionality Factor

Physical functionality is related to the primary fact of a product's existence. Every product is manufactured in order to fulfil a certain need.

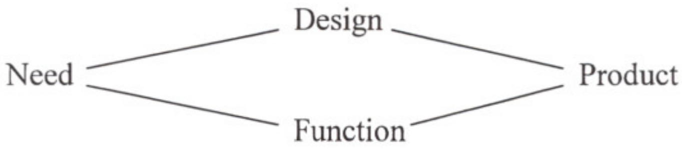


Figure 36: Needs-products cycle.

Today this cycle continues to answer the more complicated needs of a life that grows rapidly and complex. That complexity in identification of the needs, affects the design progress. Functionality can be investigated in two questions according to its relation with the user.

1. Does it work? (Does it satisfy the need?)
2. Is it easy to use? (Does it set up a good relation with the user?)

It can be observed that; a regularly designed product that can answer these questions, was enough for both physiological and communicational criteria.

3.2.1.1. Physiological Factors

Physiological interface, in the same manner, is identical to the human-machine interface. It contains all the physiologic relations of human body with the parts of a machine. The harmony of dimensional properties is focused on motor and cognitive skills of human body with the parts of a machine unit.

3.2.1.2. Communicational Factors

Communicational interface consists of conceptional and functional messages (signs) in the manner of measures between machine and user. *Semiotics* is involved the communicational mechanism of human in the formation of indexes, creating syntax with them and communicating by the help of this syntax.

In every communication case; there must be a sender, a receiver and a message. And also; syntax of components that forms this message and the script related to this must be known by both sender and receiver. The code includes the meanings of indexes and orders from which syntax is created. Every index or display has two elements. Its form and content. These relations can be shown in a figure below.

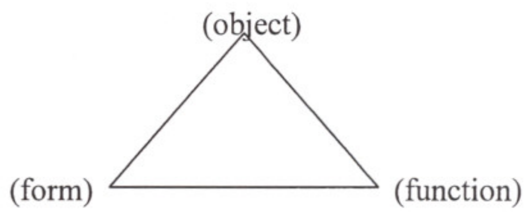


Figure 37: Semiotics approach to form, function, object relation.

A bed can be examined in the manner of this relation.

In the communicational interface, it is obvious that conceptual communication develops at the level of denotation. In this process, an existence of a social encoding must not be ignored. Because, form of the product sends a message to its function by the help of these codes. In other words, by the help of accustomed expectations and familiarities. This type of *functional meaning* can be called as *denotative meaning.*

In another case different designs, and forms may implement the same function. This type of *stylistic meaning* can be called as *connotative meaning.* Connotative meanings result from the fact that every design problem can be solved in many different ways. The result may be socially functional in that this variety prevents uniformity. On the other hand, the variety of solutions to the same problem can be used in a disfunctional way, as is the case where unnecessary distinctions between social classes are fostered by different kinds of designs for objects.

While the index (form) of a product is determined; certain visual combinations that creates the index must be as effective compounds of designed object. Only by giving meanings to these compounds, the user reaches the product's functional concept.

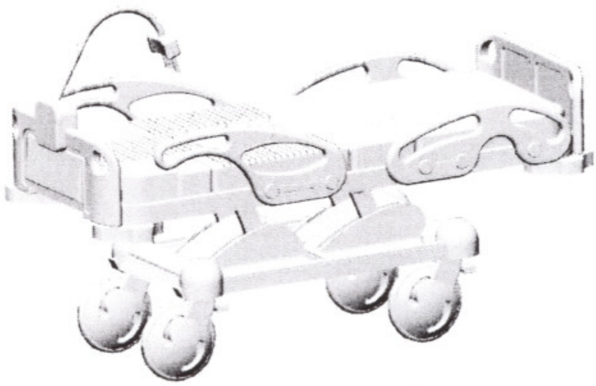


Figure 38: The form of the hospital bed, and its compounds give clues about its functional concept.

In the figure above, the mattress explains the laying function but the bending chamfers on it shows that it can be foldable. The siderails have rounded form. This form gives the user a warm hugging feeling, besides the protection from possible hazards such as falling down. The trolley cover hides the mechanical parts and motors, so that the user doesn't think it is a machine.

The casters are big, they give an impression of dynamism and not to be stuck in obstacles. The blow control unit is optional for the paralytic patients whom may control the positions of the bed by only blowing.

Another factor that impresses the designer is the relation between codes and social or technological dynamics. In the development progress of technology; some elements, which describe the senders of most of the objects, may be changed, disappeared, or new elements may exist.

The principles of functional communication process can be examined in semiotics. But in this case the important thing is; the transfer of data about how an object is used, not its function. Therefore giving meanings to some components of the object becomes more important rather than the object itself.

4. CASE STUDY

In this chapter, evolution of bed will be examined because, the hospitals bed comes from a long evolutionary stage of classic beds. Types of hospital beds, the type of designed bed, its target market determination and the production stages of a hospital bed will also be written in order to conclude the knowledge given in former chapters.

4.1. Evolution of bed

In the most primitive stages of culture, the need for something to separate men from the ground led to the use of beds of matting, animal skins or dry vegetation such as moss or heather. In warmer climates the mat-bed remained the only type used in far more advanced stages of culture, as with the Aztecs; and this is also true of some modern societies such as the Japanese.

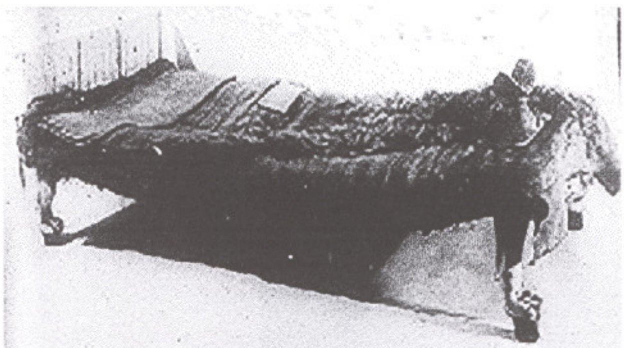


Figure 39: Egypt. Bed of Meryt. Kha's wife, 8th dynasty,(METU,1999)

In colder climates, however, the need for more adequate support and protection led, by the Neolithic period, to the construction of beds in wood or stone. Where wood was used, remains are clearly very few; but where stone was used, as in the Neolithic dwellings in Skara Brae in Orkney, a fair reconstruction was possible.

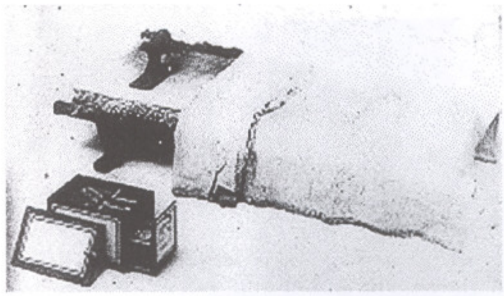


Figure 40: Egypt. Plain bed with linen coverings. 11th dynasty, (METU,1999)

The beds there were framed by stone slabs, which had apparently once contained a mattress of heather; and stone posts at the corners suggest the possibility of a canopy for extra warmth. Structures similar to these must have been made in wood for other Neolithic people. By the European Bronze Age carpentry was certainly sufficiently advanced to provide efficient wooden bedsteads.

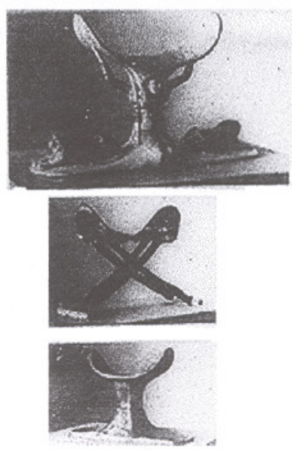


Figure 41: Egypt. Head rests. 18th dynasty,(METU, 1999)

In Egypt far more complicated wooden beds were being made at least by the 4th Dynasty; and owing to the dry sands and climate, a good deal of woodwork has been preserved. A bed in the tomb of Queen Hetepheres, about 2690 BC, was of carved ebony and cedar, with an overlay of moulded gold, and was an example of skilful joinery. It had a detachable footboard, and a base frame threaded with thongs. Floor-beams carried corner posts to support a cornice for curtains and canopy; this could be disconnected for portability.

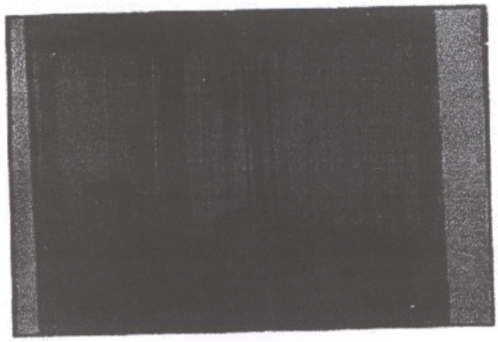


Figure 42:Egypt. Bed of Queen Hetepheres, 4th dynasty,(METU, 1999)

There was an inlaid headrest to the bed. Other and later Egyptian beds included a type of folding camp-bed in which the legs folded down when the bed was extended; such a bed was found in the tomb of Tutankhamon, dating from about 1340 BC

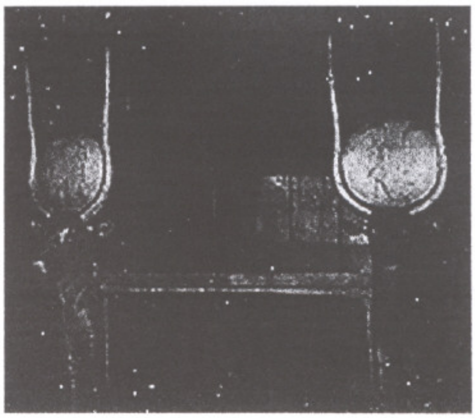


Figure 43: Egypt. Bed of Tuthankamon,(METU,1999)

Some of the features of these Egyptian beds were common to other early cultures, in particular the frame with a lacing of hide or cord, and the carving and inlay. Luxury beds were occasionally made of other materials. In the 9th century BC the Prophet Amos mentioned ivory beds as an example of extreme luxury, and ivory panels from such beds are known from sites in Syria, and Assyrian palaces such as Khorsabad.

Figure 44:Solid ebony bed, with string mesh mattress, 8th dynasty, (METU, 1999)

From the bed of Queen Hetepheres until relatively recent times, there was much variation in design, but very little advance in comfort or efficiency. The Romans often used solid metal for their day and night couches, which were similar in design to previous Greek ones of wood, except for the addition of a back -as well as head- and foot rest. Roman couches were occasionally upholstered. Their beds often had an intervowen base of webbing strips or cord, and a mattress and bolster stuffed with straw, wool, flax or down according to a man's means.

Like the Greeks, they used blankets but not sheets. Both Romans and Greeks developed the habit of keeping the bed in a separate room, though this room might be little more than a curtained alcove.

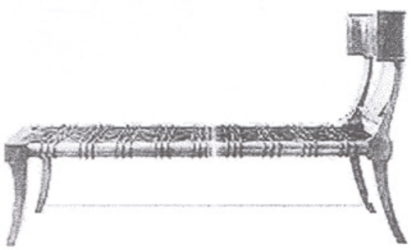


Figure 45:Greek walnut coach (KUNI) with leather thongs, (METU, 1999)

In post-Roman Europe more primitive customs continued again. Beds could be shallow throughs of wood, filled with moss, straw etc. Anglo-Saxon beds were frequently only wooden benches with a straw pallet on top. Pillows were almost unknown.

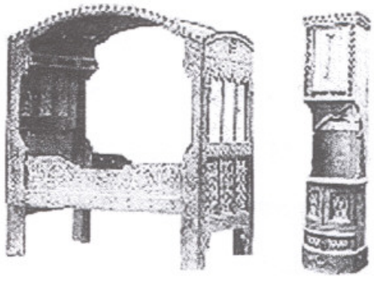


Figure 46:German late Gothic, bedstead and wash cupboard, 16th century. (METU, 1999)

For the rich person, a form of four-poster bed came into favour in the Norman period in England, with the poles supporting a canopy and curtains to keep out draughts. Linen sheets, and pillows began to be used. With the emergence of the merchant class, some standard of comfort also spread beyond the circle of the aristocracy. By the 14th century merchants owned the luxury of two beds, with mattress, feather bedding, quilts and curtains. Even the poorer citizens came to have sheets and woollen blankets, though they generally lacked curtains. Beds themselves, after the 12th century, grew in both size and elegance. By the 13th century they were often decorated once again with inlaid, carved and painted ornament; and the custom grew of hanging a canopy from the ceiling, or from an iron arm projecting from the wall. In the 14th century the woodwork of the bed was often covered by rich hangings.

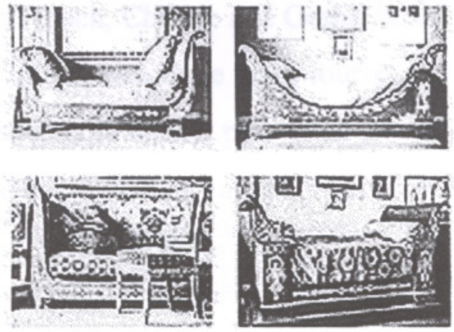


Figure 47: French Empire, Beds and Sofas, 18th century. (METU,1999)

Although the canopy was at first curtaining hung from the ceiling, it developed by about the 16th century into a wooden boarded and corniced canopy with curtaining, and it was part of the bed itself. This was the four-poster bed, which became universally fashionable. The bed-head rose as high as the canopy, and the front end of the canopy rested on foot-posts which were separate from the bed (which had its own front feet). Alternatively the canopy might be a lighter frame, with curtains and valance. The base frame of the bed had wooden side-rails with a network of ropes threaded to them; or later, wooden slats. Underneath the big bed there was often a "truckle" bed for servants, pushed there out of the way in the daytime. The four-poster bed became a huge affair, generally some 7 ft. by 6 ft. The Great Bed of Ware was 11ft. square, and the curtaining turned it into a room within a room. There were also "trussing" beds, which could be folded for travel. Beds were very valuable items of furniture in this period.

In the 17th century the canopy-foot was joined to the bed once again, while in Europe the fashion turned to beds with a canopy, but with curtaining at the head only. Single beds started to look more like present-day ones in design, as they lacked the canopy or four posts, and often had a low head- and foot-board. In France beds generally had voluminous draperies, a fashion which came to England after the restoration in 1660. Beds were often very high, and the woodwork was entirely hidden by fabric. The fashion of the day-bed, with its six legs, also began at this time.

By the 18th century beds had become less massive and more elegant. In England wooden rather than material-covered beds came back into fashion with Chippendale, Adam, Hepplewhite and Sheraton; bed-posts were often painted or gilded. Chippendale's "Directory" shows beds in French, Chinese and Gothic styles, and everywhere there was a great variety in design. In America there were four-poster beds without canopies. In Germany the custom of using large feather pillows as covers instead of blankets began in the 18th century and spread over much of Europe, where it still persists.

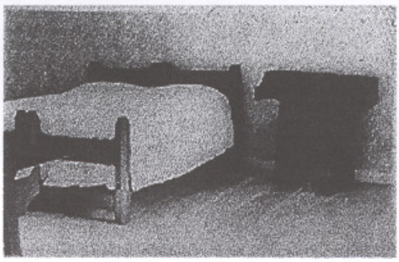


Figure 48: Morris bedroom, at Keimscoft Manor, 19th century, England. (METU, 1999)

It became the custom in France for kings to be on a "bed of justice" when in Parliament; and wherever the king stayed he received ambassadors etc. in honour in his *chambre de parade*, as he lay in bed. For a time at the end of the century four-poster beds went out of fashion, but they returned in the 19th century in even more massive form.

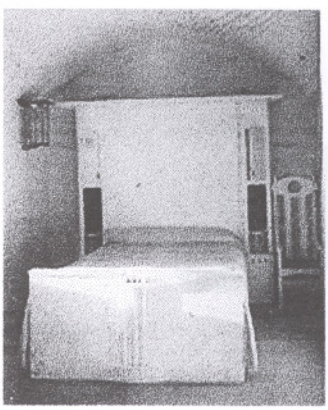


Figure 49: Makintosh bed, 1902, (METU, 1999)

In the early 19th century there was a fashion for copies of Greek and Roman beds, especially in France, which led to the "Empire" style. This fashion also spread to the beds of Regency in England. Meanwhile, however, the iron bedstead had made its appearance; by about 1840 iron and brass-framed beds were being commercially manufactured in the Midlands, and soon became popular. They were generally much decked with frills. At first they were very heavy, and of cast iron; later welded parts made lighter frames possible. The bases were of webbing of linen or jute bands, and the introduction of coiled-spring upholstery in France in the 18th century had by now led to the manufacture of the spring mattress. From this time on, there was continual progress in comfort and efficiency, especially by designers such as Ambrose Heal in England.

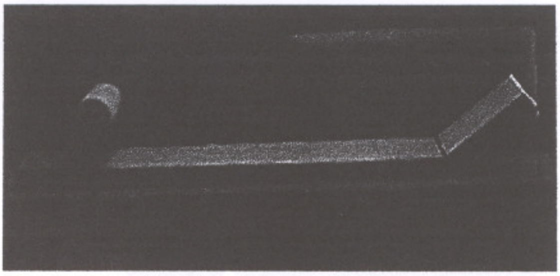


Figure 50: Andrea Branzi, "Century Sofa",1982. (METU,1999)

The 20th century saw the return to popularity of wooden beds in the western world, though of much lighter construction than before, and often with simple low head- and foot-boards. In the more recent "divan" bed there is generally a sprung base, over which a sprung or foam rubber mattress is used. Inner spring mattresses normally have the springs surrounded by layers of some soft filling. Although many countries, especially where there is a hot climate, keep traditional types of bedding, the western design of bed is becoming increasingly common.[1]

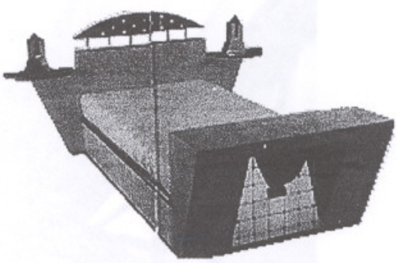


Figure 51: Michael Graves, post-modernist bed design. (METU, 1999)

[1] The New Caxton Encyclopedia, 1966

Although I couldn't find so much clear resources about technical evolution of hospital beds; the time of the addition of head rise function was in the times of World War I, can be observed from the movies reflecting these old times. It possible that the changes in designs and functions had been started after the regions of injuries of war on the body were began to be realized.

Head rise function can be seen from a picture of a hospital bed which I thought it was nearly 40 years old. The undersupport of mattress should be noticed as a simple but insufficient solution. Because of the folding of the mattres, it slides over it.

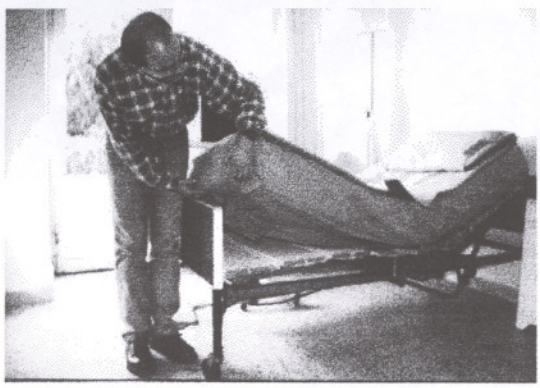


Figure 52: Old type of bed (Alsancak Özel Sağlık Hastanesi, 1998)

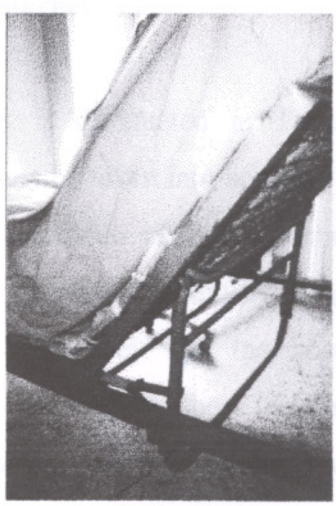


Figure 53: Old type of bed, detail. (Alsancak Özel Sağlık Hastanesi, 1998)

In 1961 a hospital bed of adjustable height and angle was designed to provide the comfort of patients and facilitate nursing, as a project in Royal Collage of Arts.

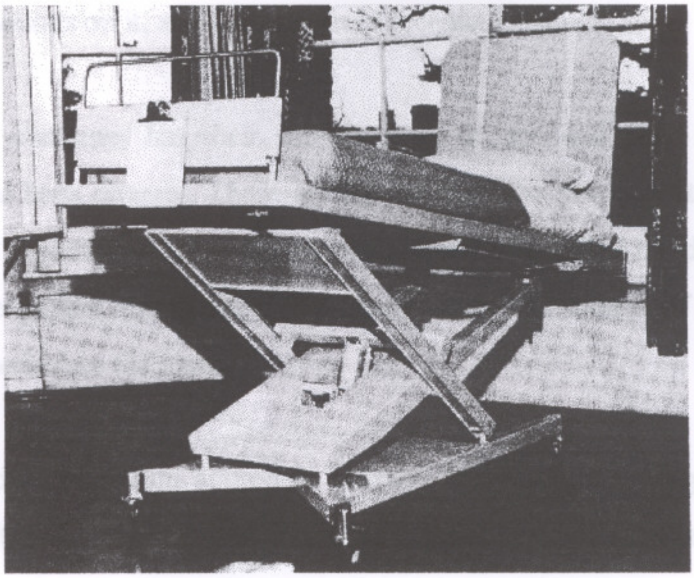


Figure 54:The hospital bed researched by Royal College of Art team in 1961.(Heskett, J., 1993)

Today's manufacturers produce hospital beds full of necessary functions, so that beds are able to be adjusted to desired positions for the care types. Complex and durable materials began to be used for both aesthetical or technological reasons.

4.2. Determination of target market

While a target market is designated in Turkey, technical and economical situations of native hospitals must be taken into account. State hospitals complain about lack of funds, and they don't provide necessary technical hardware. Naturally, this situation force them to tend to cheap equipment by using their low amount of funds in more economic way. In the end, they buy the hospital beds from the cheapest manufacturer. This causes the law quality, short life and not enough warranty of the bought beds. But in the private hospitals, a special importance is given to customer (patient) satisfaction, because this is used as an advertisement and may increase the demand for the hospital. They don't have such a problem like limited funds. So, they don't hesitate to spend money to provide highest customer satisfaction. They should buy the best product they can with an effective service warranty. In these circumstances, it is inevitable for a hospital to buy hospital beds which are aesthetically powerful, containing the necessary functions on it, and pretentious in technical manner.

But each customer has their sub-customer groups and their needs affect the design of hospital beds directly. These are the users of the product. It is either a state hospital or a rich private one, the most important users who affect the design of hospital beds directly, are patient and nursery. The hospitals are consumers of the product, the patients and nurseries are the users.

As an industrial design approach; hospital bed must be in ergonomic integrity with the patient it is directly in interaction in the manner of function. The person who will share most of his time, is the patient who lie on it. Another group of users who will interact with the product, is the nurseries. These are doctors, nurses and service staff. Sometimes, when necessary, these users will also use controls to interfere the basic functions of the bed. So, the components of the hospital bed should also address these users ergonomically.

The general purpose hospital bed that was designed at the end of this study; seems to be more futuristic product than its equivalents in the market; because of the functions implemented on it, the proposed construction materials and components, and its formal expression. The proposed materials to be used in manufacturing construction elements, renewals in materials and in design of the mattress, a communication system made up of electronic hardware; put this product into an expensive category. As a result, its target market becomes the private hospitals which prefer products which have an expensive but functional and a powerful aesthetic appeal.

4.3. Types of Hospital Beds

The name "Hospital Bed" can be given to the family of health equipment which is used for care, treatment, transport and rehabilitation of the patient in a horizontal position. These have different functions with design and detail variations according to the sections of hospitals they used or the medical condition of patient on it, and they have different names. The names and the functions they have according to their usage, are shown below.

1) For transport and treatment; recovery trolley, stretcher trolley, patient treatment trolley.

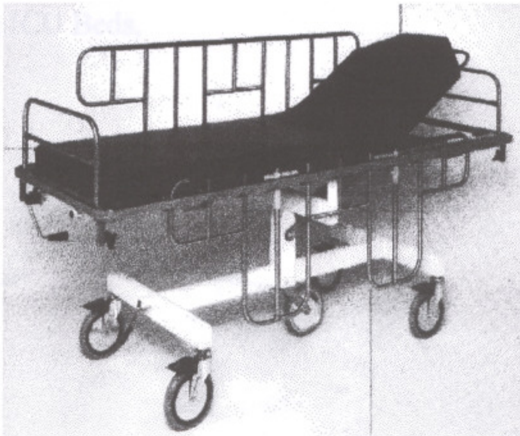


Figure 55: Recovery trolley (Oxford Medical Equipment,1997)

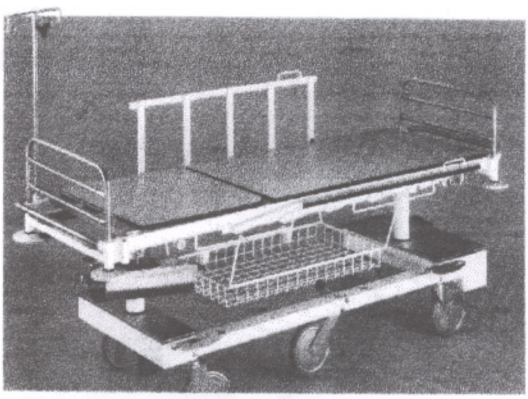


Figure 56: Treatment trolley (Oxford Medical Equipment, 1997)

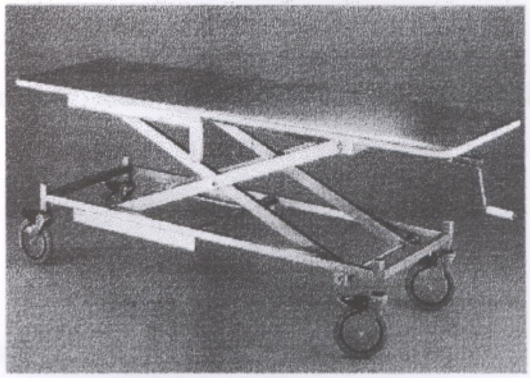


Figure 57: Stretcher trolley (Oxford Medical Equipment, 1997)

2) For Intensive Care Unit; ICU Beds,

Figure 58: ICU Bed, (Joyce Healthcare, 1997)

3) For Home Care; Home Care Bed,

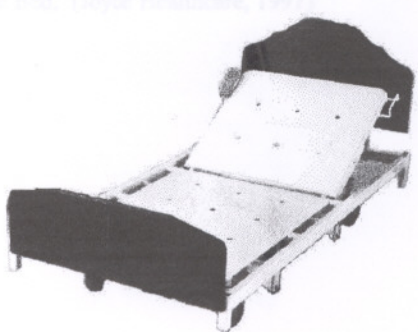


Figure 59: Homecare Bed, (Joyce Healthcare, 1997)

4) For Examination Room; Examination Couch (steady), Examination Couch (variable height)

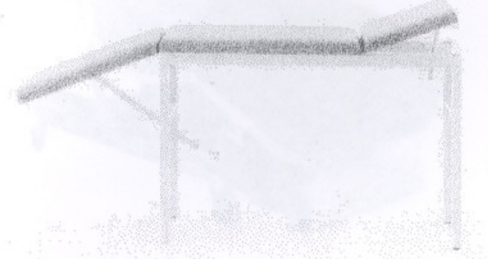


Figure 60: Examination Coach, (Oxford Medical Equipment, 1997)

5) For Patient Rooms and Wards; General Purpose Bed,

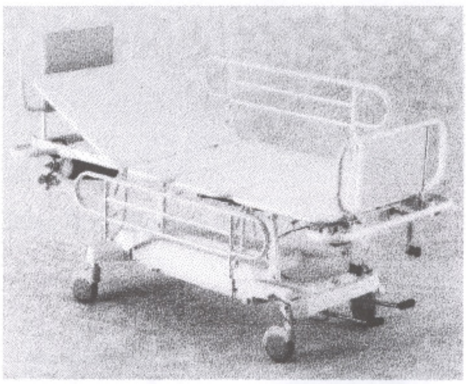


Figure 61:General Purpose Bed, (Joyce Healthcare, 1997)

6) For Special Purpose; Cardiac Bed, Turning Bed, Stand Up Bed, Turning and Tilting Bed

Figure 62: Cardiac Bed, (Egerton, 1997)

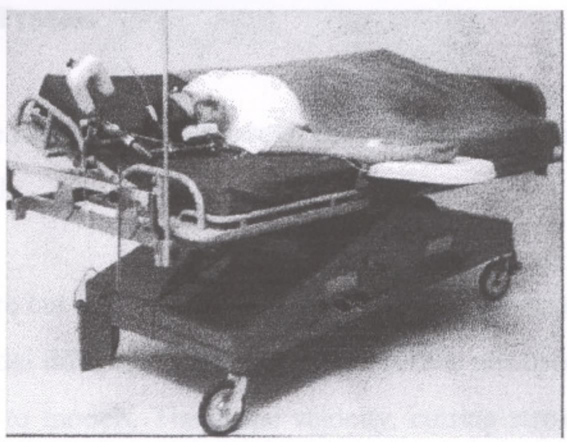


Figure 63: Turning and Tilting Bed, (Egerton, 1997)

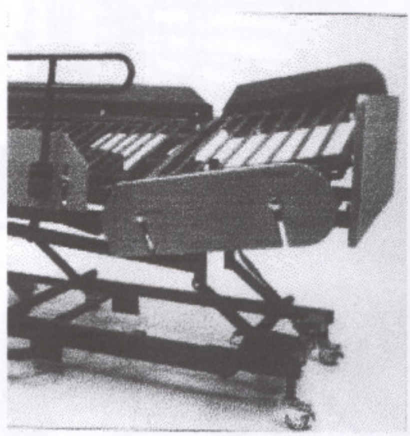


Figure 64: Turning Bed, (Reha Sağlık Ürünleri, 1999)

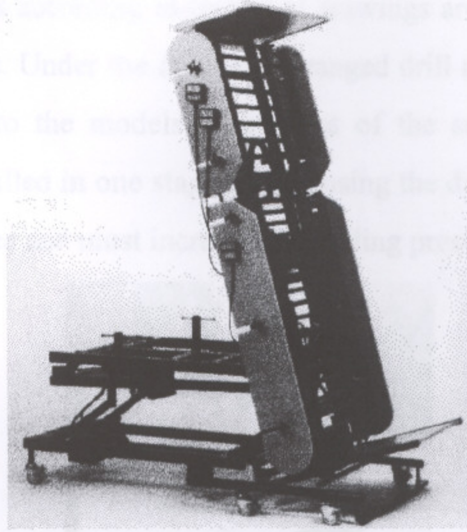


Figure 65: Standing Bed, (Reha Sağlık Ürünleri, 1999)

4.4. Manufacturing Process

As an example manufacturing process, the one that Reha Sağlık Ürünleri Ltd. Şti. uses, will be examined.

The profiles are cut into certain dimensions by the saw according to the model of the bed. In every model different lengths of steel profiles are used. These are classified and stored according to models. The stripe velocity, cutting stroke, tension and type is very important in the saw for a good quality of cutting.

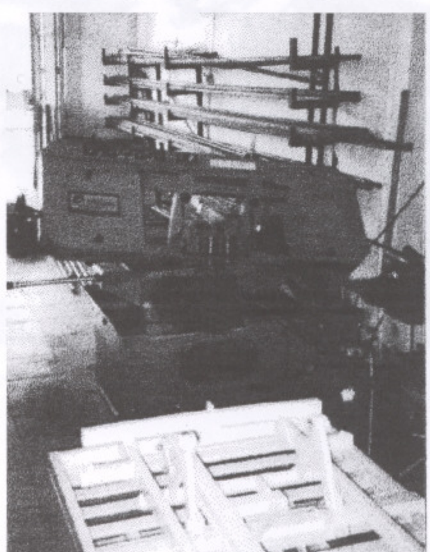


Figure 66: Saw and steel profiles. (Reha, 1999)

Adjusted profiles according to technical drawings are brought to drill station to make holes for the bolts. Under the drill, pre-arranged drill molds are used for required exact holes according to the models. The holes of the sub-parts in the amount of products ordered; are drilled in one stage. While using the drill, operator must use hand gloves, special eyeglasses and must increase the drilling pressure step by step.

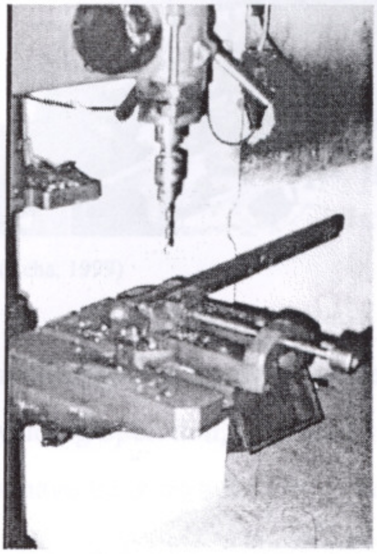


Figure 67: Drilling the profiles. (Reha, 1999)

The drilled profiles are bended, if necessary according to design, in the profile bending machine in desired angles and forms.

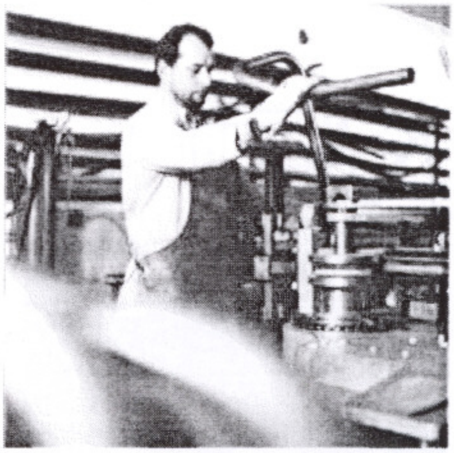


Figure 68: Bending profiles.(Reha, 1999)

Profiles adjusted to desired length, drilled and bended; are then taken to the grinding for burr cleaning. Burr around the profiles or holes are grinded in order to obtain a clean surface for painting.

Figure 69: Grinding station.(Reha, 1999)

After these operations the profiles must be welded in order to create the sub-sections of hospital bed. In welding operation, jig fixtures are used. Every model has its own fixture. All sub-sections have their own fixtures. The profiles which will form the sub-section, are placed on these jig fixtures. Every profile has its own place on the fixture. Any other part couldn't fit this place. This prevents using the wrong profile. After the placement, the profiles are welded on two sides at the same time equally in order to prevent wreckage and shrink while cooling. Because of the strength of the weld, inert gas welding is used.

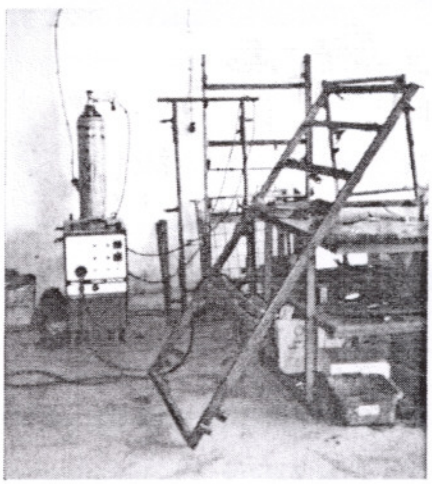


Figure 70: Jig fixture and inert gas weld. (Reha, 1999)

Welded sub-sections are painted with electrostatic dust-paint, and ovened in high temperatures. Non-toxic paint is preferred. That's because not to contain any bacteria.

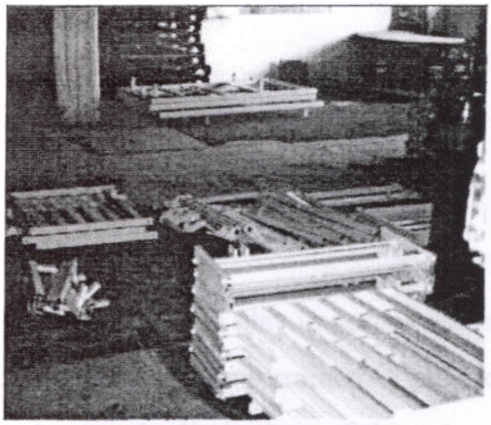


Figure 71: Painted parts grouped together.(Reha,1999)

After the painting, the sub-sections are assembled with special bolts and joints. Bearings and electric motors, casters are assembled on their places. The bolts used in assembly, are fibered bolts, in order not to screwed backwards. Profile openings, heads of bolts are covered with special stoppers in order not to cause any damage by stucking.

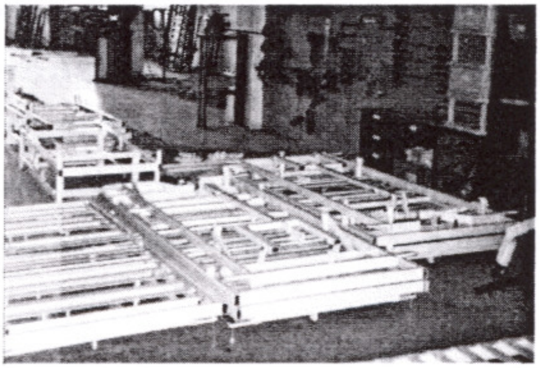


Figure 72: Assembly of sub-sections of hospital bed.(Reha, 1999)

In Reha Sağlık Ürünleri Ltd. Şti., the products are controlled two times after the assembly before selling. The worker makes himself one control himself, second one is made by the marketing manager. After these, the hospital bed enters the market.

4.5. Conclusion

Along this study, two criteria which play important roles in designing a product, ergonomics and functional criteria had been examined. A product should not be put into service of mankind without having the limitations of these two criteria. Every product, must provide a purpose of usage with its function while providing a suitability of usage with its ergonomics, in order to be of help to human. At least two factors needed to consider an object as a consumer product; are its function indicated by its utility and the ergonomics indicated by the harmony of product with the dimensions of user's nature.

The most important reason for me to choose the subject of "Research on Ergonomic and Functional Aspects of Health Equipment With a Case Study Including Material and Production"; is the strict control of these two criteria over the end designed product, in other words its consisting of both of two criteria. Another reason is that, the bed was a product with which human shares 33 percent of his lifetime in direct contact.

As examined in the discipline of ergonomics, a hospital bed is in maximum harmony with the human body. It takes the shape of the body. This helps to stabilise its natural posture. Furthermore, it is also in interaction with other parts of the human body. It is controlled, directed, driven, moved or assemble, disassemble by hands and feet. This necessitates the suitability of hospital bed to ergonomic criteria.

The flexibility of changing into different positions according to the space it is in, or according to the health situation of the patient lays on it, and the usability of its controls by both the patient and the nursery; increases its functionality and attractiveness. These kinds of usage should be appropriate to the functional criteria.

In the end of this study; a general purpose hospital bed, which thought to be suitable for the ergonomic and functional criteria, was designed.

As indicated in the introduction chapter, the data I utilised most in this research and the case study is the information written in the product catalogues of hospital bed manufacturers. The books and the paper indicated as references, the photographs I had taken, and the web sites of the hospital bed manufacturers have also utilised in this work

In our country there are manufacturers in this field for about 30 years. Up till now the quality in design have mostly been ignored, but today native manufacturers must make products matching the world standards in this competitive market.

I wish this study a helpful resource for students and professionals who are interested in ergonomics and health equipment design and be also a resource for native hospital bed manufacturers and hospitals.

REFERENCES

Books:

Kroemer K., Kroemer H., Kroemer-Elbert K., "Ergonomics-How to Design for Ease & Efficiency," Edited by W.J.Fabrycky and J.H.Mize (Prentice Hall, New Jersey, 1994).

Sanders M.S., McCormick E.J., "Human Factors in Engineering and Design," (McGraw-Hill, Singapore, 1993).

Raschko B.B., "Housing Interiors for the Disabled and Elderly," (Van Nostrand Reinhold, New York).

Malkin J., "Hospital Interior Architecture-Creating Healing Environments for Special Patient Populations," (Van Nostrand Reinhold, New York, 1992).

Bridger R.S., "Introduction to Ergonomics," (Mc Graw Hill, 1995).

Asatekin M., "Endüstri Tasarımında Ürün Kullanıcı İlişkileri," (Publication of METU Faculty of Architecture, Ankara, 1997)

Heskett, J., "Industrial Design," (Thames and Hudson, London, 1993)

Papers:

Akgüner M., Karaca C., Atabey A., Menderes A., Top H., "Treatment of Chronic and Wide Ischial Pressure Sores with Gracilis Myoctaneus Flap," (Dokuz Eylül University, Izmir, 1997).

Magazines, Encyclopedia, Archives:

Sharp K., "Asia Pasific Hospital Magazine," (May 1997)

Archiscope Magazine, (July-August, 1999)

The New Caxton Encyclopedia
(Purnell and Sons Ltd., Great Britain, 1966)

METU Library , Slide Archive, (Ankara, 1999)

Product Catalogues:

Pegasus Airwave Ltd. Product Catalogue, (Great Britain, December 1997)

SOTERA Project Catalogue, "The Bed and Its Surroundings," (Helsinki University of Technology, Finland, 1997)

Reha Sağlık Ürünleri Ltd. Sti. Product Catalogue, (Turkey, July 1999)

British Surgical Trades Association, Membership List, (Great Britain, November 1997)

Oxford Medical Equipment Ltd., Product Catalogue, (Australia, October 1997)

Joyce Healthcare, Product Catalogue, (Australia, October 1997)

Egerton Hospital Equipment Ltd., Product Catalogue, (Great Britain, December 1997)

Wietmarscher Ltd., Product Catalogue, (Turkey, March 1999)

Hospitals:

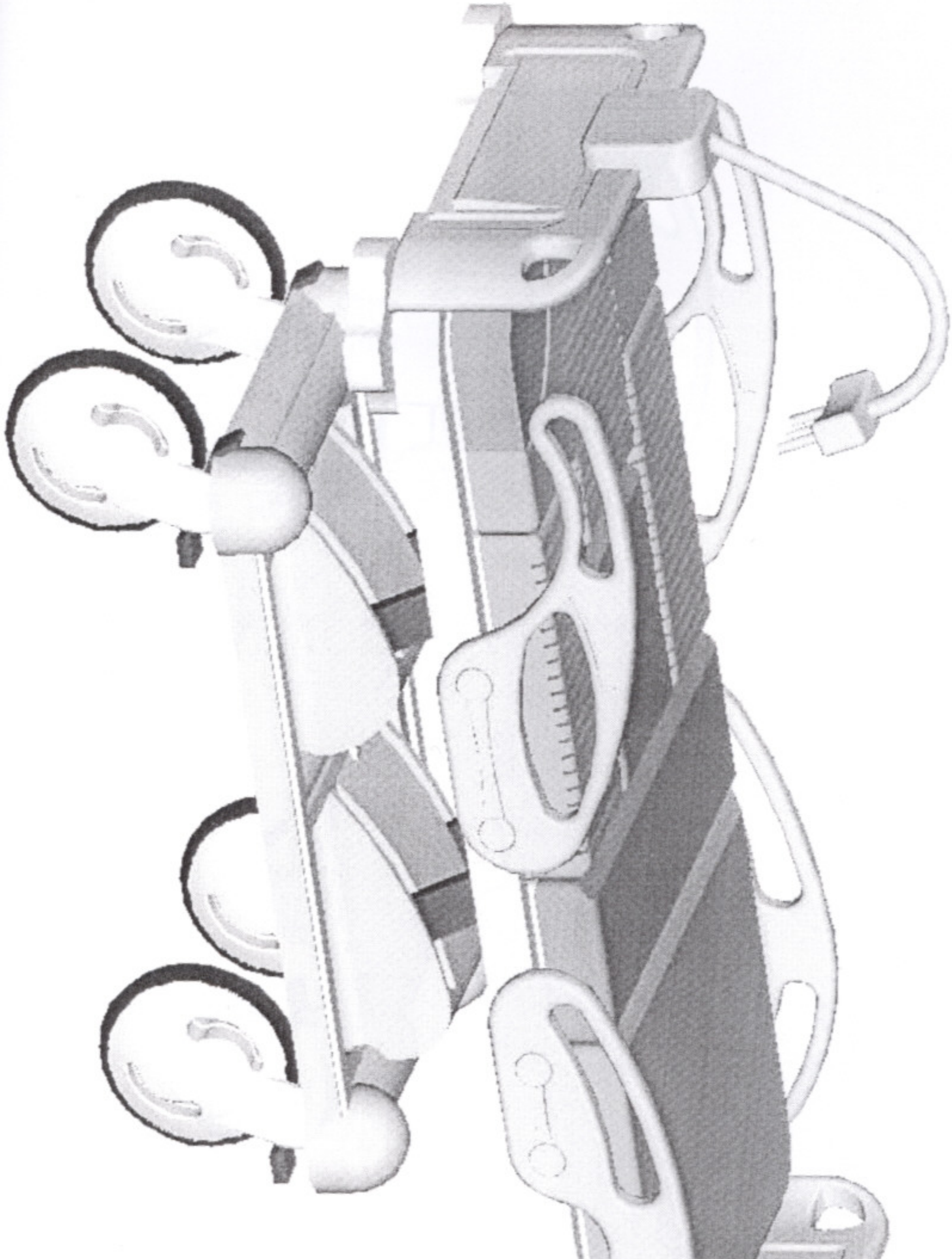
Alsancak Özel Sağlık Hastanesi, (İzmir, 1998)

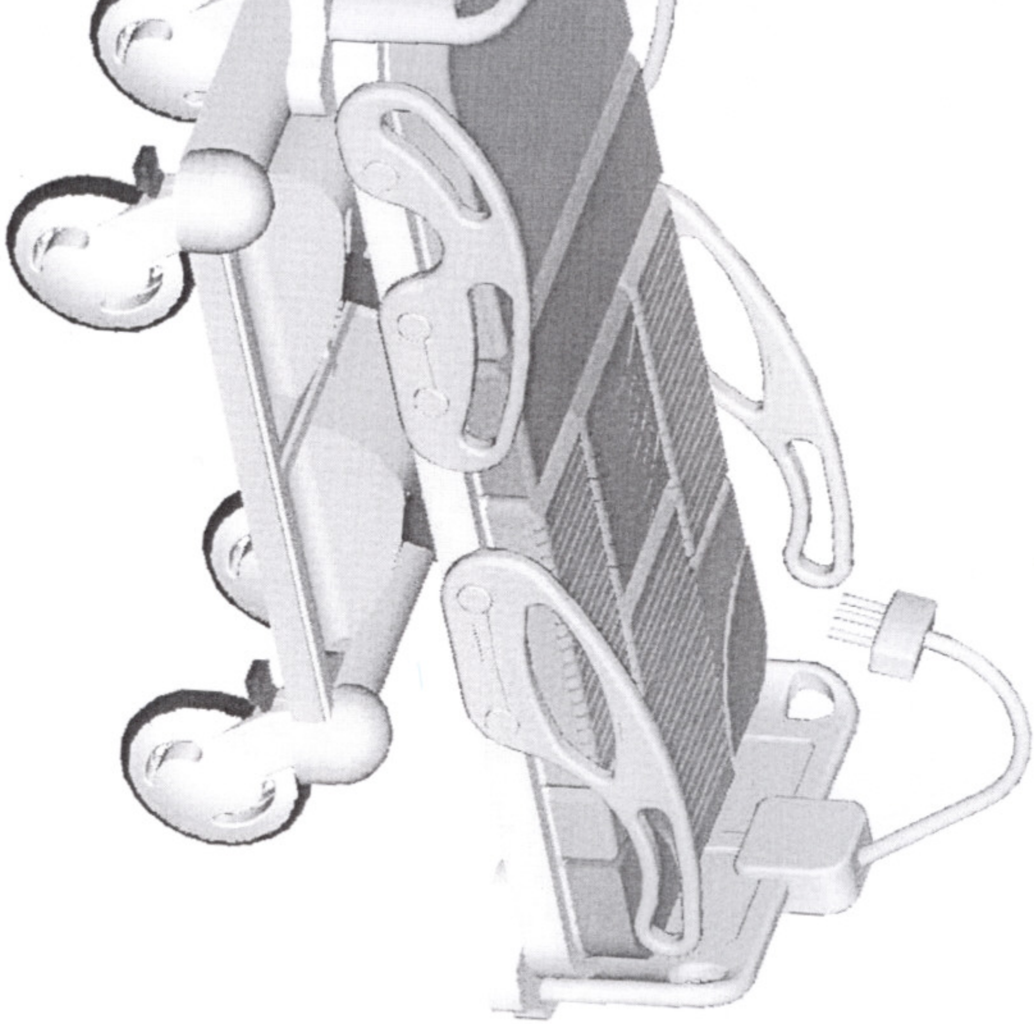
Brugge International Hospital, (Belgium, August 1998)

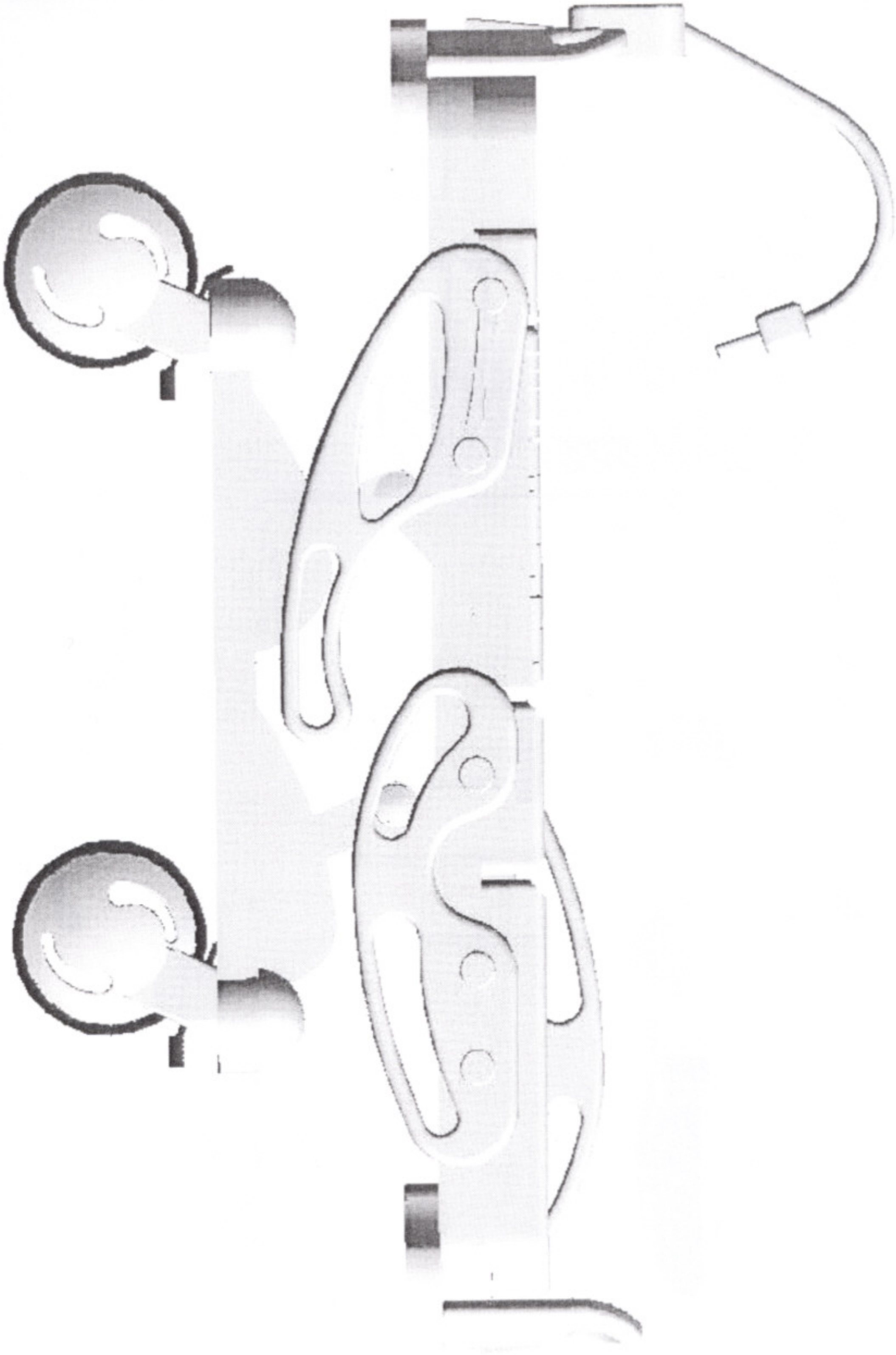
Internet:

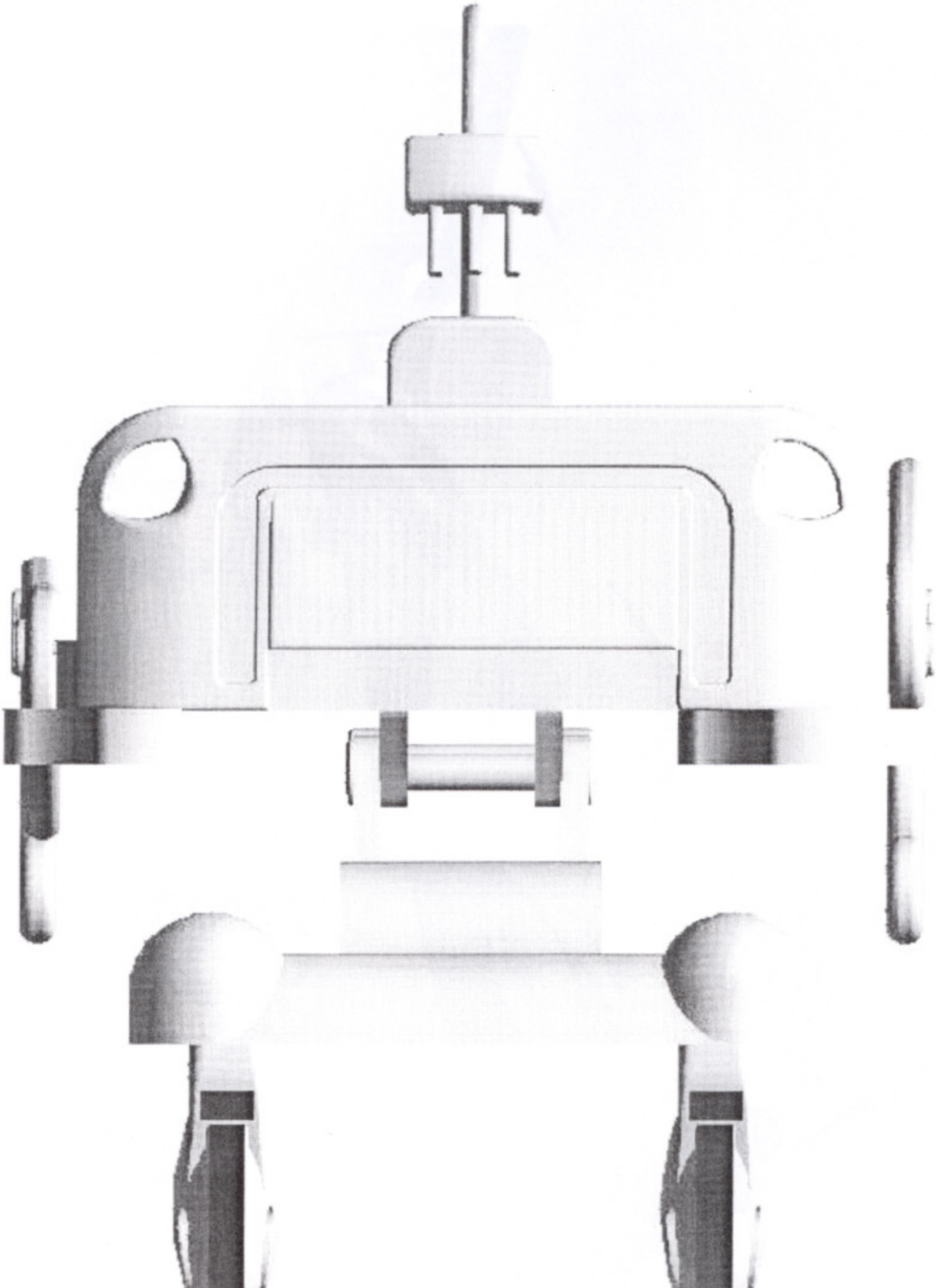
http://www.bertecmedical.com
http://www.adjustabed.com
http://www.ambiencedesign.com.au/
http://www.gelisimmedikal.com/
http://www.specsimple.com
http://www.huntleighhealthcare.com.au
http://www.kur-oz.com.tr
http://limamedical.com
http://med-e-kwik.com
http://www.med-e-quip.com
http://medsupplies.aigworks.com
http://www.konyasanayi.com
http://www.mtx.com.my/PROALLIANCE
http://www.beds.co.il
http://www.sabratek.com
http://manufacture.com.tw/~shiesheng/
http://www.thimedical.com
http://www.valley-med.com
http://www.whcii.com
http://www.computronx.com
http://www.homehealthdepot.com
http://www.turkmed.com
http://www.indeksmedikal.com

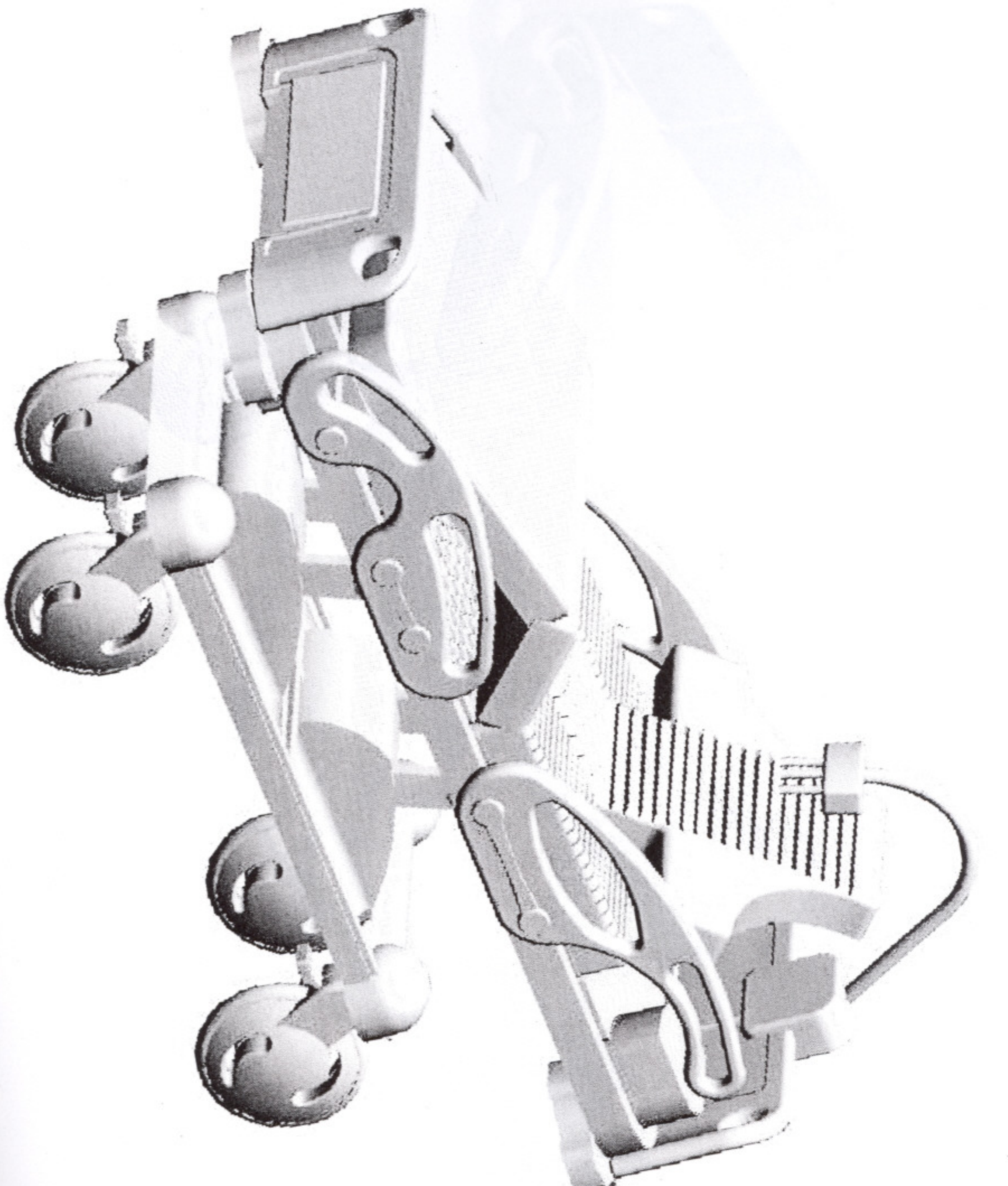
APPENDIX A

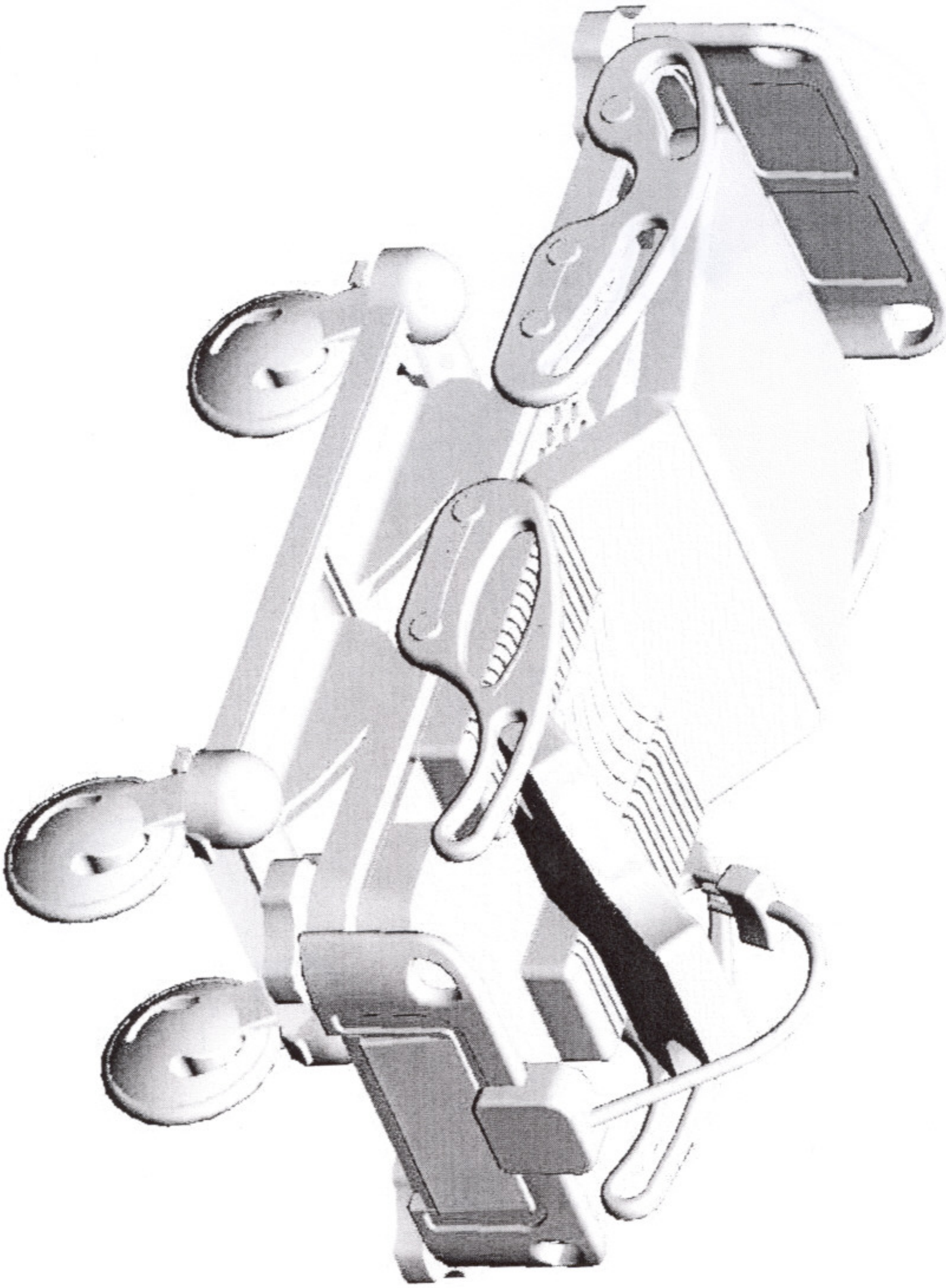


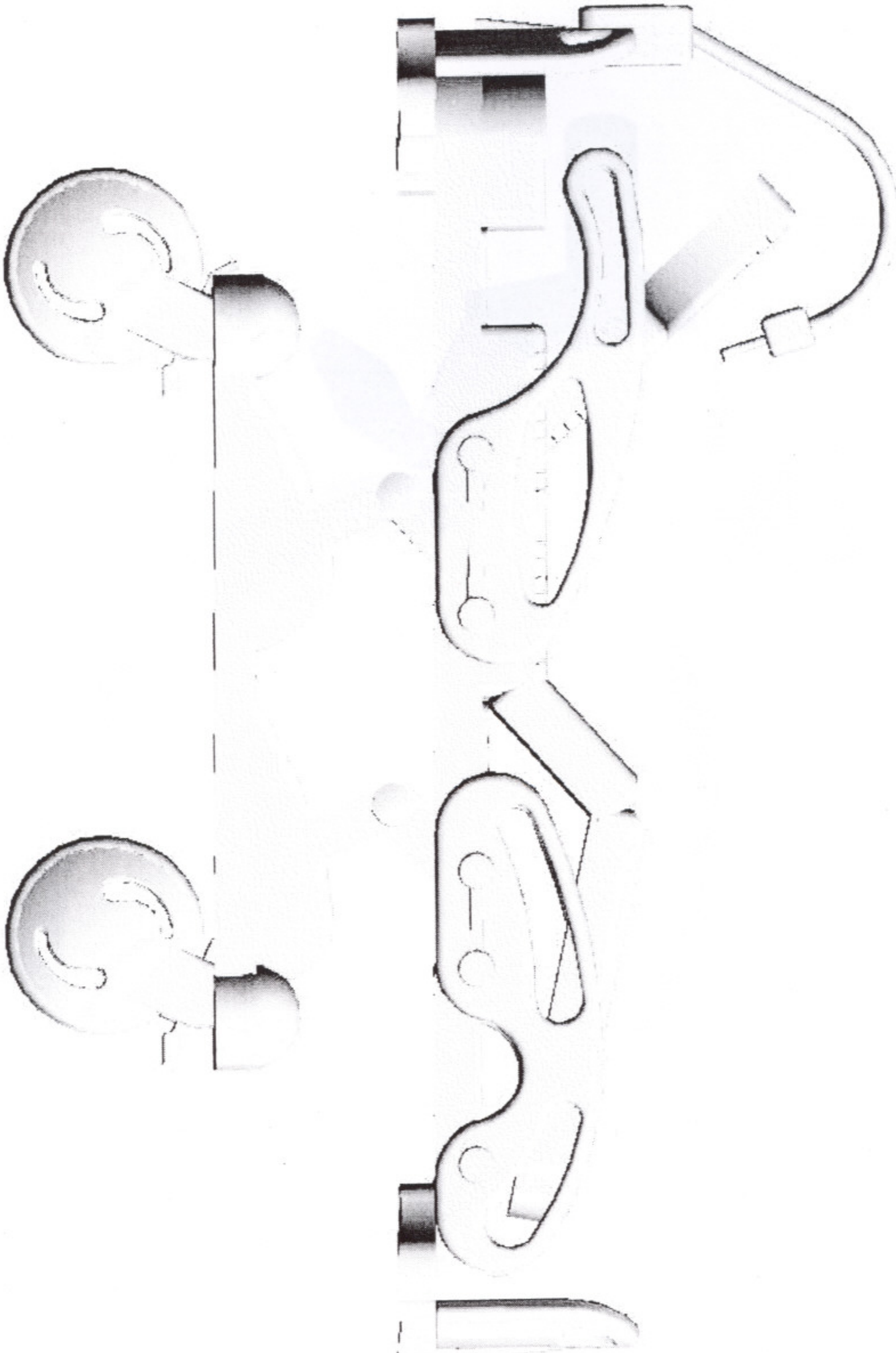


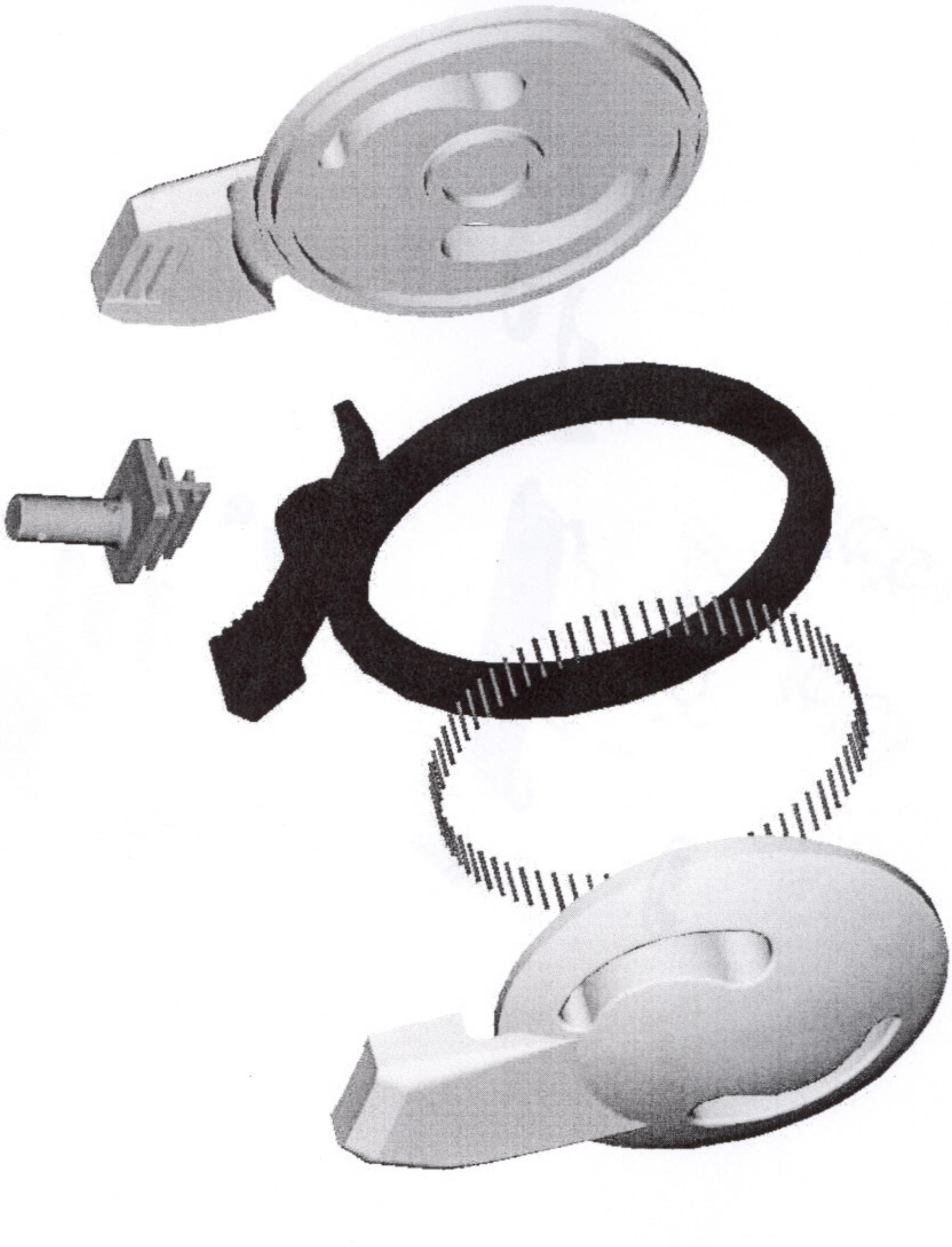


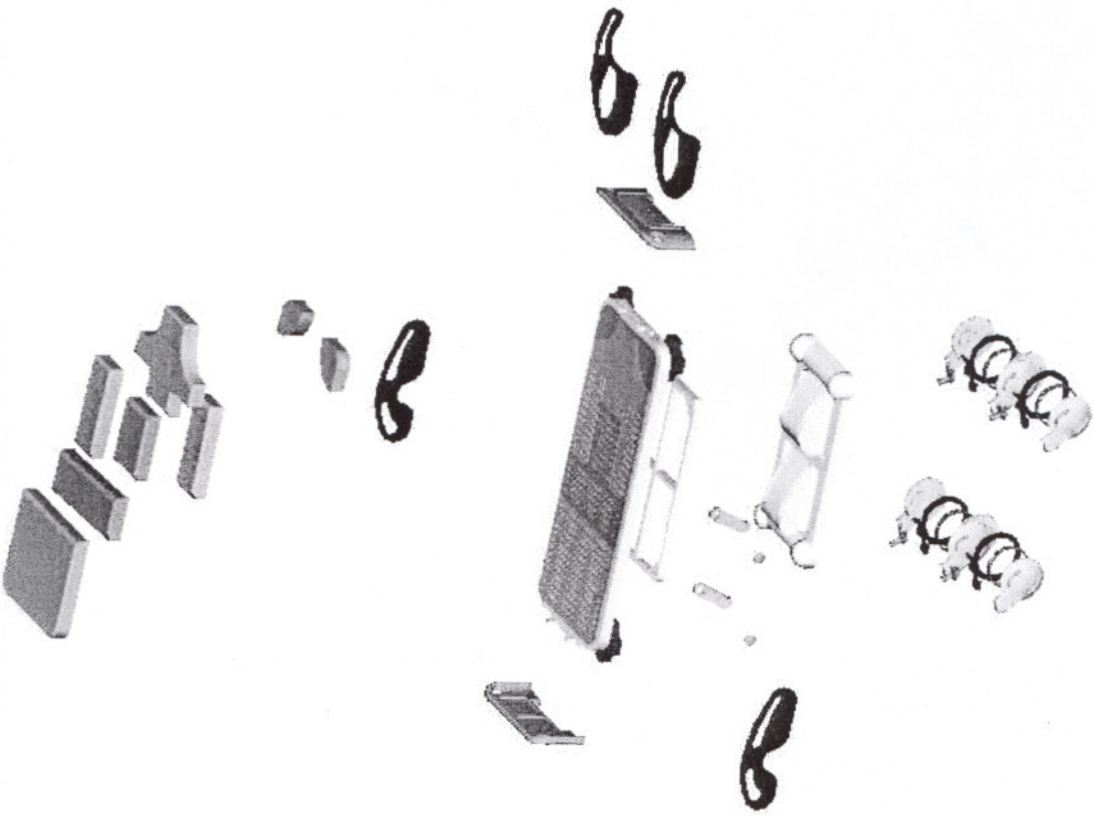












Meanings of some Latin words

Abdomen ... Part of the stomach that includes the stomach and bowels.

... and back of the neck.

... part of the back.

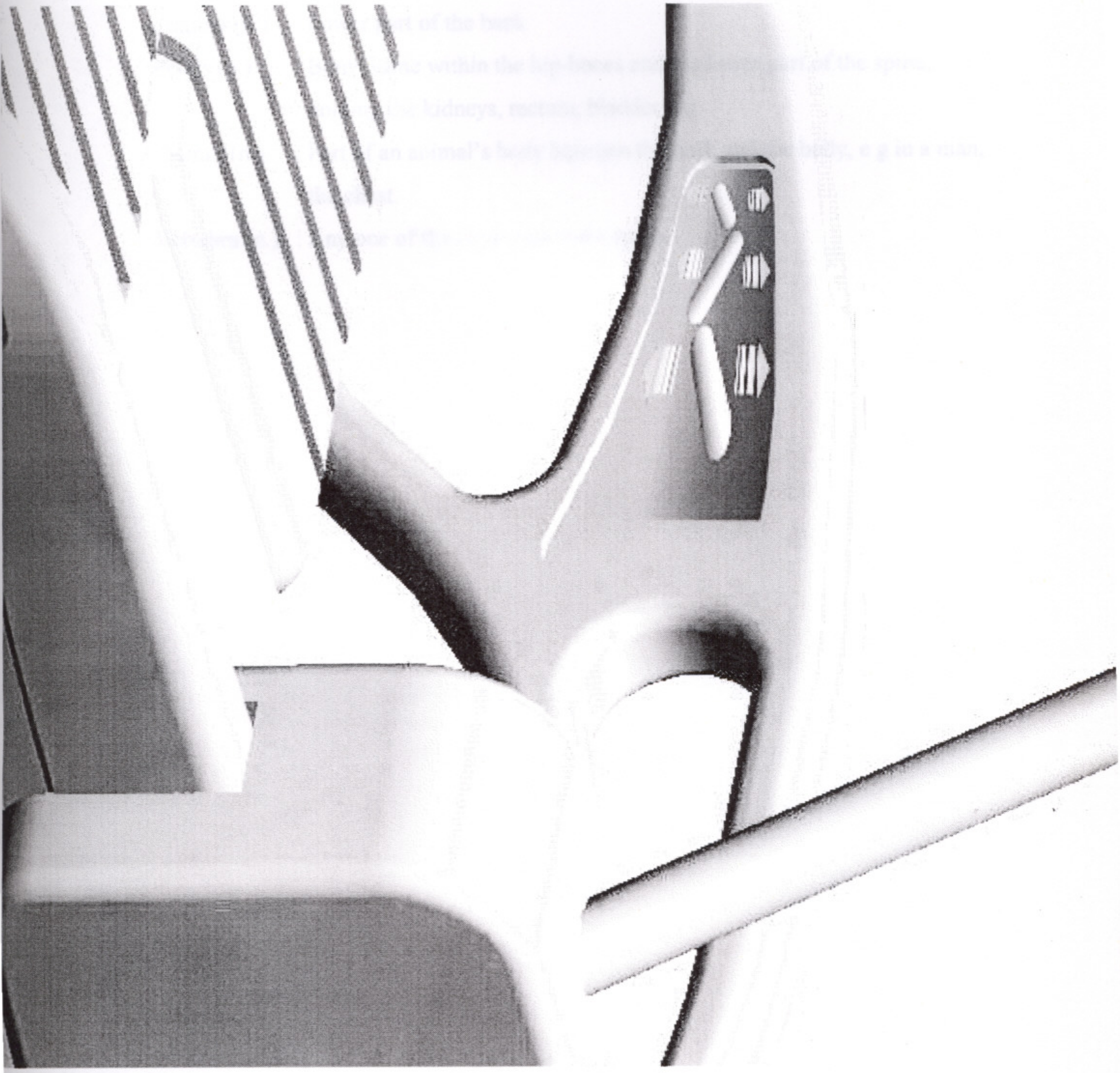
... within the hip-bones and ... part of the spine.

... the kidneys, rectum, bladder ...

... of an animal's body between the ... its body, e g in a man,

... the chest

... one of the ...



Meanings of some Latin words

Abdomen (n.) : (Belly) Part of the stomach that includes the stomach and bowels.

Cervical (adj.): of the neck.

Lumbar (n.) : Lower part of the back.

Pelvis (n.) : Bony frame within the hip-bones and the lower part of the spine, holding the kidneys, rectum, bladder etc.

Thorax (n.) : Part of an animal's body between the neck and the belly, e g in a man, the chest.

Vertebra (n.) : Any one of the segments of the spine.