CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents a critical review of the available literature related to the problems of research being undertaken such as studies on eye strain, noise and lifting. The literature is presented under three heads, one each for the problems considered for study.

2.2 LITERATURE REVIEW ON EYE STRAIN OF VDT USERS


In meeting the eye care needs of VDT operators, it is important to consider the factors such as VDT design, its placement, lighting, glare control and task breaks. Assessment of visual performance has been made considering the factors such as contrast luminance and exposure time. Among these factors exposure time has been suggested to be the most important factor (Mark A. Bullimore et al 1991, Stephen C Miller 1984 and David J Oborne 1983).

A method has been devised to determine whether lighting levels are adverse and to determine the ambient illumination level for VDT task based on the nature of work. Studies have been conducted on viewing distance of VDT
screen, based on accommodation and convergence of eyes. Studies have also
been conducted on lighting and visual performance (David C Breeding 1997,
Mitchell Schieman 1996, Dennis R Ankrum 1996, Boyce 1981 and Bennett

Many investigations have been carried out on problems experienced
by VDT users such as eye strain, double vision, glare, eye irritation, neck pain,
shoulder pain, back pain, eye fatigue, focussing difficulty, muscle spasms,
binocular vision disorders and myopia. As a solution they suggest, proper
diagnosis and treatment along with proper workstation design (Donald O. Mutti
1973).

A number of medical experts have dealt with in detail the different
methods of measurement of visual fatigue based on functioning of various
oculomotor systems. The system includes accommodation control, vision
control (eye movements), pupil control, blink control, changes in version
control, Eletro oculography, Cornea reflection, limbus tracking etc. (Theodore
Grossvenor 1996, Haschang Shahmawaz and Laif Hedman 1984, Wright and
Rea 1984 and Safir 1980).

Many technical papers have been published on evaluation of visual
tasks, user adjusted VDT, lighting and difficult visual tasks (Grandjean 1986,
Kokoschka and Haubner 1985, Brown and Schaum 1980, Faulkner and Murphy

Stephan C. Miller (1984) in his paper on eye care needs of VDT
operators has said that introduction of VDT into the work place has brought
about increased visual complaints and concern for user's health and safety. He
has also explained about the visual, ergonomic and environmental factors to be considered at VDT work. He stressed the importance of ergonomic factors like VDT design and its placement, lighting, glare control and task breaks. The placement of VDT refers to the correct angle and distance from screen to eyes.

Haschang Shahmawaz and Leif Hedman (1984) made an attempt to investigate possible relations between (i) Change in operator’s accommodation after six hours of work at display unit and (ii) work-station lighting and screen characteristics. The study revealed a significant relationship between lighting conditions and change in accommodation. The influence of screen characteristics, such as screen illuminance, luminance and irradiance upon visual accommodation were evident during the night shift.

In 1991, James E. Sheedy studied the problems experienced by the VDT users. It is found that the most commonly reported systems among VDT users are related to vision. He mentioned that the problems like eye strain, double vision, glare, eye irritation, neck pain, shoulder pain and back pain were the most frequent visually related symptoms. As a solution to this, he suggested that proper visual diagnosis and treatment along with proper design should be undertaken to resolve most of these problems.

Mark A. Bullimore et al (1991) made an assessment of visual performance considering the factors such as contrast, luminance and exposure time. Along with the assessment, they also discussed the aspects of human visual systems, viewed objects and task, which are relevant to visual performance. They surveyed about 1000 optometrists and found that about one of seven patients required eye examination for symptoms primarily related to
VDT use. According to their survey, the number of eye exams given annually is about 10 million for computer related problems in U.S alone.

In 1992, Dr. E. Vaithilingam, Principal, Elite School of Optometry studied around 115 VDT users regarding the problems experienced in their profession. He classified the nature of complaints from the study under ocular, visual and systemic problems. He noted that persons who work with VDTs have more visual than ocular and general problems. He also noted that VDT users experience the eye strain, one of the ocular problems, most frequently. Reasonable task breaks and improvement in screen contrast will be the remedy to minimize the eye strain.

In the same year (1992), U.S. Department of labour prepared a fact sheet highlighting safety with VDTs.

Morgan (1993) in his paper titled 'The Definition and measurement of visual fatigue' has discussed the origin of visual fatigue and the methods of measuring it. He mentioned that the measurement of visual fatigue is based on changes in the functioning of various oculomotor systems. The system includes accommodation control, vergence control, pupil control and blink control. He has also explained the methods of measuring visual fatigue by changes in version control. Electro-oculography, Corneal reflection and Limbus tracking are the main methods to measure the visual fatigue in terms of eye movement.

In 1996, Dennis R. Ankrum conducted studies about the viewing distance of VDT screen from the operator, based on accommodation and convergence of the eyes. In 1997, American academy of ophthalmology discussed about the special needs of VDT users. Notice of a variety of
symptoms including eye irritation, eye fatigue and focussing difficulty indicated that VDTs are associated with eye strain.

In 1996, Donald O. Mutti and Karla Zadnik reviewed the literature on relationship between VDTs and asthenopia, fatigue, accommodation and vergence. He concluded that transient, fatigue-induced changes in accommodation and vergence may occur after work with VDTs.

Mitchell Schieman (1996) had conducted research, which demonstrated a high prevalence of accommodative and binocular disorders in VDT users. He indicated the importance of the assessment and management of accommodation and binocular vision for patients working with computers.

Theodore Grosvenor (1996) discussed about the merits of VDT placement below the eyesight and explained the benefits in terms of visual and biomechanical factors.

David C. Breeding (1997) has suggested that a survey has to be done to determine whether lighting levels are adequate to the employees and to the tasks being performed. He has devised a method to determine whether lighting levels are adequate and to determine the ambient illumination level for VDT tasks based on the nature of the task. He has also stated that factors such as contrast, glare, reflections and colour are also relevant.

The optics of accommodation are relatively straightforward, and most visual problems which are due to optical causes can be successfully corrected using appropriate lenses. When one is viewing a distant object, the incident light rays can be considered to be parallel (which they would be if the viewed object were at infinity). The light is then refracted by the cornea and lens to
produce an image on the retina. In practice any object more than 6 m away can be considered to be at infinity. When one is viewing close objects, the incident light rays are divergent and greater refractive power is required to produce a sharp image on the retina. In young people, the refractive power of the lens can increase from 15 to about 29 diopters to bring close objects into focus, the lens has about 14 diopters of accommodation in these individuals (Dennis R Ankrum 1996). Although this is quite a small portion of the eye’s total refractive power, it is necessary for seeing clearly both near and middle-distance objects (such as a VDT on a desk and a bulletin on a wall across a room).

When stationary objects are being viewed, acuity is least if blue. Mark A Bullimore et al (1991) investigated colour and dynamic visual acuity. When moving targets are being viewed under photopic conditions, their colour does not seem to influence visual acuity. However, dynamic visual acuity under scotopic or mesopic conditions is affected by target colour and blue targets are much more easily resolved than other colours, probably because of the differential sensitivity.

Glare may be direct or indirect. White walls on the inside of a room may reflect sunlight in to an operator’s eye and would be classed as a diffuse source. Chrome plated controls or components such as bevels on dials and gauges may cause specular reflections (Howrath 1990)

For visual comfort and to meet visual demands, the following should be considered. (Grandjean 1986)

1. A suitable level of illumination
2. A balance of surface luminances
3. Avoidance of glare
4. Temporal uniformity of lighting.

The colour rendering properties of light sources might also be taken into account.

Selection of light sources for good colour rendering should be based on objective data about the emission spectrums of the source. In practice, an index, the colour-rendering index has been devised to describe the colour rendering properties of light sources. Daylight is used as a standard and given a value of 100. The colour-rendering properties of other sources are expressed with respect to that standard (Boyce 1981). A high value of colour-rendering index usually indicated that a light source has good colour-rendering ability. Unfortunately there is an approximate negative relationship between colour rendering and luminous efficacy. In other words, good colour rendering costs more.

The apparent colour of an object depends very strongly on the properties of incident light. Winkel et al (1993) summarizes some of the effects of using coloured light. Under red light, for example, white appears pink, red colours are greatly strengthened and blue appears purple.

Work with display units may be visually demanding, because of the quality of the image on the screen, the design of the workstation, or the design of the operator's job. Although screen design has improved over the years, the characters on a CRT always have blurred edges, because the boundary between the excited and non-excited regions of the CRT phosphor is not sharp. Since the blur is one of the stimuli for accommodation, unresolvable blur may make accommodation unstable. There is evidence for a temporary recession in the
near point of vision after prolonged performance of close tasks. This unresolvable blur has also been reported in microscope operators (Soderberg et al 1983). Recession of the near point is suggestive of a loss of refractive power and is sometimes referred to as accommodation strain. It has been reported in VDT workers (as has the time to refocus between near and far points) and is exacerbated by organizational factors such as the rigidity of work routines and the duration of the work periods (Gunnarson and Soderberg 1983).

The visual problems associated with VDT operation are not unique to it. They can occur in many other tasks, where close visual work is required (Grandjean 1986). It appears that stressing of the accommodation and vergence systems by requiring users to carry out close visual task for long periods increase the tension in the muscles of the upper body (Lie and Watton 1987). This connection between the ocular muscles and those which control the position of the head is not surprising, when it is remembered how the eyes and head move together to locate a stimulus in space. In fact, the two systems share common neural pathways.

It is usually recommended that dedicated VDT workers take periodic rest periods throughout the day (5 minutes per hour). Jobs can be designed to provide natural rest periods if some non-VDT work is included. Even short breaks (2 to 60 seconds) for every 10 minutes may help prevent fatigue (Pheasant 1991). More detailed technical discussion on visual factors in VDT operation can be found in the report of the panel on impact of video viewing on vision of workers (National Research Council 1983 and Cakir et al 1980). A broad review of health issues in VDT operation can be found in Marriot and Stuchley (1986).
The introduction of visual display terminals (VDTs) to the workplace has given rise to much discussion about potential ergonomics problems including: visual problems, effect of sitting posture, exposure to radiation, and effect of computer usage on job satisfaction. Although much of the knowledge on VDT ergonomics has come from research work done in office environments, VDTs are now commonly used in manufacturing (Grandjean 1986). Since the introduction of VDTs in the workplace, there have been tremendous developments in technology and the ergonomics of design (Winkel et al 1993).

The centre of the screen should be depressed at a viewing angle of about 25°-35° below the horizontal. People who sit in an upright posture prefer to look down rather than look up or look straight ahead. In particular, looking up with the head bent back is common cause of muscle fatigue in the neck (Howrath 1990).

In modern office chairs many design features are adjustable. This is the most important adjustability feature and the only one that is mandatory in ANSI standard. The second most important factor is adjustability of the seat back angle. A seat back angle of grater than 110° reduces the pressure on the spine (Helander et al 1984).

The third most important adjustability factor is the lumbar support. Lumbar supports are often not used since chair users do not sit straight and usually do not press their back all the way in to the back rest. In fact, many chair users prefer a more relaxed sitting posture (Grandjean 1986). The lumbar support can become very uncomfortable if it puts pressure on the wrong spot in the back, and lumbar supports must therefore be adjustable (Boyce 1981). Wrist rests are optional. Because, typing habits are different, some operators prefer wrist rests and some do not. Soft wrist rests (rather than hard) are supposed to
put less pressure on the wrist and reduce the risk of developing carpal tunnel syndrome. However research has not been able to prove that there are any significant benefits of wrist rests, and whether soft wrist rests really make a difference. Footrests, arm rests and wrist rests are inexpensive and it is a good practice to make them available to operators who ask for them (Sauter et al 1985).

Some researchers claim that the viewing distances to the screen, to the documents on the document holder, and to the keyboard should be identical so that it is not necessary to refocus the eyes. Refocussing takes time and is unproductive (Cakir et al 1980). In addition, for older operators with presbyopia, the uniform distance is helpful since it is easier to focus. Another school of researchers claim that it is important to keep exercising the focussing mechanism of the eye, thereby visual fatigue and temporary myopia can be avoided (National Research Council 1983). The term 'temporary myopia' implies that the accommodation or focussing of the eyes adjusts to somewhat closer viewing distance, which is imposed by a close working task (Ostberg 1980), thereby the range of clear vision is moved closer to the eye, and it is difficult to focus on distant objects. This phenomenon is not unique to VDT work. Every close work task may cause temporary myopia, which typically goes away an hour after work. Nonetheless, many individuals notice these effects and are overtly concerned. For example, when driving home after work during darkness, temporary myopia combined with dilated eye pupils makes it difficult to read traffic signs. Some individuals may misinterpret this and obtain glasses to correct on condition, which hardly needs any correction.
Many VDT operators complain about visual fatigue. However, there are indications that the visual fatigue does not have anything to do with VDT as such (Helander et al 1984). Rather, working with VDTs is sometimes a very intense and fatiguing task. For example, a data input operator may input as many as 20,000 characters per hour for 8 hours a day.

Typically they look at the source document and glance at the screen only occasionally to check the formatting of the data. After such an intense workday it should not be surprising that operators are fatigued in their entire body, and visual fatigue is just another aspect of general fatigue. Several studies have indeed confirmed that data input operators complain the most about visual fatigue, although this type of work involves comparatively little screen viewing (Helander et al 1984).

Several investigators have addressed the long-term effect on vision of VDT viewing. Researchers generally agree that there are no adverse effects (Cakir et al 1980). The eyes do not become more myopic, hyperopic or presbyopic nor do these conditions develop more rapidly. Most of the changes in eyesight experienced by VDT operators are normal due to ageing, and they would have happened with any close work. Nonetheless VDT viewing is visually more exacting than other viewing tasks. Compared with printed characters on a paper, VDT characters are more blurred and there is less luminance contrast between the characters and the screen background. This has been shown to decrease the speed of VDT screens as compared with papers (Gunnarson et al 1983).
Another more severe aspect of VDT viewing, is that many individuals lack eyeglasses with appropriate correction (Santer et al 1985). This is particularly true for older operators who use bifocal lenses. The lower part of the bifocal lens is typically ground for a viewing distance of about 30 cm and the upper part for a far viewing distance of about 400 cm. The distance from the eyes to the VDT monitor may be around 40-50 cm and the most clear image is obtained if the operator bends his head back to read the screen through the lower part of the lens and at the same time moves the head closer. This causes neck pain and shoulder pain (Sauter et al 1985). Many companies now supply special glasses known as terminal glasses. An optometrist can measure the viewing distance at the workstation and prescribe lenses, which are ground for the exact viewing distance.

2.2.1 Summary

Literature review reported on eye strain of VDT users can be summarised as follows:

Many researchers have studied problems related to VDT, its design, location etc. Some of the research work carried out includes the various factors that affect the eye strain of VDT users. Some of the factors identified as important from the literature in affecting eye strain are viewing distance, illumination level, glare control and task breaks.

Many investigations done on problems experienced by VDT users indicate the various vision related problems such as double vision, eye irritation and neck pain.
A systematic investigation on the factors affecting eye strain using design of experiments is not reported in literature.

2.3 LITERATURE REVIEW ON EFFECTS OF NOISE


Environment noise pollution is another subject that has attracted many investigators and their work includes effect of noise and vibration on drivers of commercial vehicles. (Lazarus and Hoge 1986, Broadbent 1978 and Mackie et al 1974).

Weinstein (1977) reported that a 68-70 dB(A) noise level significantly impaired the detection of grammatical errors in a proof-reading task, but the same amount of noise did not have any adverse effects on the ability to detect spelling errors.

Sperry (1978) noted that there are many acoustic, as well as non-acoustic factors, which influence the reaction of traffic. Among the non-acoustic factors are: the time of the day, the source of noise and the attitude of the exposed person. Noise from aircraft is perceived as more annoying than the noise from automobile trucks.

Questionnaire investigations in industrial plants show that workers usually single out noise as the most important problem. (Poulton 1978).

Through engineering change, noise energy can be sometimes be moved in frequency to solve a noise problem as has been shown by the U.S Department of labour (1980).

Gawron (1982) reviewed 58 noise experiments and found that 29 showed a reduction in performance, 22 showed no effect and 7 showed that noise improved task performance.

A person with auditory nerve damage first loses hearing of the higher frequencies at around 4000 Hz. (Loeb 1996).
Earplugs made out of rubber, neoprene, glass and plastics offer good protection to the ears. Custom moulded earplugs are also available which are individually made to fit the ear canal and can offer excellent ear protection for a long time. (Casali and Park 1990).

There are two main methods of measuring noise: use of dosimeters and sound level meters. Worker’s exposure to noise can be quantified using a noise dosimeter. (ANSI 1991).

Conductive hearing loss can be caused by mechanical rupture and/or dislocation of the eardrum and bones in the middle ear. As a result there may be physical damage to the middle ear, for example by dislocation of the stirrup. The hearing loss may be partial or total, temporary or permanent. (Karl D. Kryter 1993).

Prolonged noise exposure can cause hearing loss due to auditory nerve damage, also called neural hearing loss. If the noise exposure time is short there may be only temporary swelling in the middle ear, which being reversible causes only temporary hearing impairment, called Temporary Threshold Shift. (TTS). (Ward 1996).

An example of a noise survey which was carried out in a colliery, can be found in Broadbent (1982). All areas where noise levels exceeded 90dB(A) were identified and the duration of exposure of persons working therein was determined. Special attention was paid in areas with noise levels greater than 105dB(A). Within the previously determined 90dB(A) contour, attenuation of noise was measured by taking repeated measurements up to 1m from the source (Intensity halved approximately as distance from the source doubled) maximum and minimum noise levels were also measured at the operator’s ear level at all
fixed workstations. Operators suspected of being exposed to noise over 105dB(A) were issued dosimeters so that more information on their, could be obtained. Noise exposure when travelling to and from working areas was also measured. In this way, both high-risk areas and high-risk jobs were identified.

Casali and Park (1990) investigated ear protection attenuation performance under different fitting conditions and physical activities. When users fitted the ear protectors using only the manufacturers instruction, protection was 4 to 14dB less at 1000 Hz than when they were trained in correct fitting techniques. Muffs were less susceptible to fitting effects than plugs. When subjects carried out tasks involving much upper torso movement and acceleration of the head, losses in protection up to 6 dB occurred. Premolded plugs, muffs, and muff-plug combinations were most susceptible to these losses and foam earplugs were least susceptible. It seems that workers should be trained in correct fitting techniques if proper protection is to be obtained. This finding applies to all kinds of ear protection, particularly foam plugs. For tasks requiring a great deal of movement, foam plugs may offer the best protection over the workday if workers are trained to fit them properly. If workers cannot be trained or for occasional users, muffs may be the best choice.

Lhude (1980) investigated earmuff acceptance among workers in a sawmill. He developed an index for rating earmuffs whereby earmuff attenuation (in decibels) was divided by the product of muff clamping force and weight (in newtons). Out of a sample of commercial earmuffs, the two most highly rated were also found to be the most acceptable to workers. However it was concluded that the concept of an index for evaluating earmuff acceptability required further investigation. Weight was not regarded as an important determinant of comfort by many workers, although the hotness of the muffs in
warm conditions was found to be extremely important. It can be seen that ergonomic factors are important determinants of operator compliance in the use of hearing protection. However, because noise-induced hearing loss is a long-term phenomenon, many workers may be unaware or unconvinced of the potential threat to their hearing. Ear protection in the workplace should be part of a wider industrial hearing conservation program containing appropriate educational and safety information.

Woods et al (1988) has compiled the findings of many studies of the effects of noise on human performance. Although noise levels below 90dB(A) are not a serious threat to hearing, they can degrade task performance and cause annoyance.

Many machines have both primary noise sources (such as the power unit) and secondary noise sources (part of the machines, which resonate). In tractors for example, the primary sources are the air intake, fan, engine walls, injector pump, and transmission. The fuel tank, cab structure, panelling and fenders are examples of secondary sources (Tomlinson 1971).

The relative contribution of the primary and secondary sources to the total noise depends on the particular machine. For example, pneumatic machines are inherently noisy because of the exhaust gases. The energy loss, due to noise of machines such as pneumatic jackhammers is only about 0.08 percent (Howrath et al 1990), because 87.5 percent of the noise is due to exhaust gases rather than to the impact of the drill steel against the stock or to the piston and gears of the machines (Weinstein 1977). Hydraulic pumps can be very quiet, yet the hydraulic system itself can be a source of considerable noise
due to resonance if the pump is not securely mounted and mechanically isolated from fluid lines and other structures.

Noise from the primary sources is often periodic and below 1000 Hz, whereas secondary noise is often of a higher frequency. For example, velocity gradients in the exhaustion to atmosphere of compressed air create random vortexes, which move and are dissipated in a chaotic manner, giving rise to wide-band random noise (Beiers 1966). Frequency analysis with the machine operating under representative conditions of loading is an important first step in machine redesign. The most intense frequencies can be identified and redesign can proceed in a systematic manner. Beranek et al (1950) provide an interesting case study of the redesign of a pneumatic rotary-percussive jackhammer. These machines emit noise of 115 to 120 dB(A) at the operators ear level. By muffling the exhaust, redesigning the drilling mechanisms using nylon instead of metal components, and acoustically treating the drill steel, noise was reduced to 95 dB(A).

Most human work depends on verbal communication and concentration. Noise can interfere with communication in a manner, which is analogous to the way glare interferes with vision. According to the place-pitch theory of cochlear function, it would seem that registration of target sounds such as speech will be disrupted by back ground noise and that the disruption will be grater if the background noise shares frequencies that are similar to those of the target signal. Such disruption is known as masking, and there is evidence that masking is greater when the signal and the noise frequencies are similar (Davies et al 1982).
It would seem obvious that noise can affect the performance of auditory tasks by masking important sounds, making the task more difficult to perform. How much more difficult would depend on factors such as the intensity and nature of the noise and the contextual importance of the information conveyed acoustically. In addition, the magnitude of decrements in task performance depends on non-auditory factors such as difficulty of the task without noise and the motivation of person doing the task. It has been hypothesized (Poulton 1978) that noise may improve task performance under some circumstances of increasing arousal.

Whether sound is perceived as noise depends as much on the listener and the context as it does on the sound itself. Sound levels of 100 dB(A) are commonly found in factories and are rightly termed as noise. Fisher (1973) measured sound levels of over 100 dB(A) in a busy hotel bar—whether this level was perceived as noise and by whom is much more debatable.

2.3.1 Summary

Research work carried out on noise includes studies on various methods of noise measurement, its evaluation and effect on noise on human performance. Many researchers have investigated about methods of noise prevention, hearing protectors and other devices. Also studies have been carried out on noise pollution and noise control.

Studies on effects of noise on transport employees have not been reported in the literature.
2.4 LITERATURE REVIEW ON LIFTING

Many research papers have been published on different methods of manual lifting such as sagittal plane lifting and squat lifting. (Bernard et al 1999, Lin et al 1999, Granata 1996, Sen and Gangopadhyay 1988, Davies 1972 and Datta and Ramanathan 1971).

Various aspects of lifting loads have been dealt with by many investigators, which include weight perception of workers, measurement of angle of joints and evaluation of human work (Joseph M Deeb 1999, Chaffin and Baker 1997).


Many researchers have worked on biomechanical models and have come out with different types of biomechanical models and their study includes motor control of human movement, biomechanical, musculoskeletal models etc. (Maurel 1996, Kumar 1990 and Roy et al 1989).

Many investigations have been carried out by researchers on spine and its modelling and these studies include finite element analysis of lumbar region of spine, functional anatomy of spine, spinal stability, mathematical
modelling of spine and construction of spine, analysis of spine under aircraft
ejection loading. (Lian and Amrouche 2000, Antonious Rohlmann et al 1999,
and White and Panjabi 1978).

A number of Technical papers have been published on postural study.
These papers include studies on anatomy of upper, lower body limbs, motor
control of human movement and ankle joint stiffness. (Carlos et al 2000,

National Institute of Occupational Safety and Health (NIOSH) (1981)
recognised the problem of work related back injuries and published the Work
Practices Guide (WPG) for manual lifting.

The material properties of the lumbar region were studied by Shirazi-
Adal (1986). Work on FEM analysis of segmental level lumbar L2/L3 and
cervical spine were found during the survey. (Carlos et al 2000 and Lian et al
2000). But FEM analysis of the combined L1/L2/L3/L4/L5/S1 of FSU, has not
been reported in the literature.

In order to analyse the biomechanical models, the data such as
segment mass/total mass and centre of mass/segment length are needed. This is
given by Dempster’s body segment parameter data (Winter 1990).

Techniques in human motion synthesis can be used to generate
motions using a computer. These techniques thus provide the means for
ergonomists to perform dynamic biomechanical analysis without actually
collecting time-displacement data. It is reported that, in lordotic spine during
prolonged standing and the impacted joints at each segment level bear an average of 16% of the axial load. (Oliver and Middleditch 1991).

Hutchinson and Littlefield tried to simplify FEM of vertebral body by modelling it as a cylinder. (Cantu 1997). In general, a lifting action, which starts at a distance and moves towards a person’s body is likely to be easier to control than one, which starts close to the body and moves away. (Pheasant and Stubbs 1992).

The geometry, material properties and loading conditions of the lumbar spine are very complex. Though FEM is a well established method, various simplifications have to be used and assumptions are to be made. (Jenna Bowling et al 1995). Estimation of stresses imposed on the body musculoskeletal system based on biomechanical models was found to be successful. (Maurel 1996).

Accurate measures of the trunk kinetic data are difficult to achieve from dynamic exertions without significant approximation, cost or motion constraints. It calls for experimental set up proposed by Granata (1996). Annual cost associated with back pain in U.S alone ranged from 20 billion US $ to 50 Billion US $. These statistics justify studies on lifting. (Miller et al 1997).

A group of research students in the Department of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin, Texas, USA attempted to analyse spinal finite-element modelling. Because of the inability to achieve the initial objectives of this project, the group created a new objective of generating an extensive literature review of the aircraft ejection and the spine. This literature review work formed the basis of the present work (Cantu 1997).
Practical reasons for studying MMH are to identify factors causing risk and to recommend and implement conditions for safe lifting (Bernard et al 1999). Predicted motion pattern by computer motion simulation resembles the observed motion pattern (Lin et al 1999). Thus prediction of stresses is also viable. Lin et al (1999) have proposed a five segment biomechanical model for the human body. Biomechanical analysis treats the human body as a system of links and connecting joints.

Antonious Rohlmann (1999) conducted experimental studies on cadaveric spines and estimated the stresses on FSU. In occupational settings, determining the risk of low back pain through posture and hand load sampling approach is found to be yielding desired results (Neumann 2001).

Although epidemiological studies have suggested possible causes, the actual mechanisms by which the lumbar spine is injured during load cycle resulting in low back pain remains unknown. The response of the disc to loading conditions that occur during lifting is difficult to measure in vivo and in vitro and has not been investigated using any model so far (Williams et al 2002). Therefore, the purpose of this research is to construct a FEM that predicts the loading behaviour of FSU. Low back injuries associated with manual lifting activities are frequent in industry. According to a US Department of Labour Report (1982), back injuries accounted for nearly 20% of all injuries and illnesses in the workplace, and nearly 25% of annual worker compensation payments. In the USA for the year, 1989, Wakers et al (1993) estimated the cost of worker compensation for low back pain to be $11.4 billion. Similar figures are obtained from other countries. In the UK, for 1988-1989, 27% of all reported accidents involved manual handling. The annual cost of sickness...
absence due to back pain and back injuries in the UK is estimated to be of the order of $6000 million (Pheasant and Stubbs 1992).

Manual handling and lifting are the major causes of work related back pain. (Keyserling et al 1988). However, back pain and in particular low back pain, is also common in other work environments such as seated work, where there is no lifting or manual handling (Lazarus et al 1986). In fact, back pain is extremely common. During a lifetime, there is 70% chance of developing low back pain, and there is a 1:7 chance that any individual will presently be suffering from back pain. (Pheasant and Stubbs 1992). Many low back injuries seem to happen spontaneously. Magora (1974) indicated that lifting and bending were related to only about one-third of back injuries.

In 1982, the US Department of Labour published a report of 906 back injuries associated with lifting. The interesting aspect about this study was that only accidents due to manual materials handling were analysed. From the data, it was observed that 42% of all back injuries due to lifting occurred in manufacturing. This was three times as much as for any other industry. Back injuries are therefore frequent in manufacturing and it is important to analyse their causes.

The basic problem in lifting is that the force from a lifted load is multiplied by about 10 times in the spine. The human spine is a flexible column of 24 vertebrae and a large wedge-shaped bone at the bottom, which is called the sacrum. Between each pair of vertebrae there are discs which act as shock absorbers. On top of the sacrum, are five lumbar vertebrae referred to as L1 to L5. The bottom disc L4/L5 incurs most of the back injuries. A disc has a fibrous outer layer and is filled with fluid. With increasing age, and also with
increasing exposure to manual materials handling, cracks develop in the disc, and if there is a great amount of pressure, there is a risk of disc herniation (Helander et al 1984).

The fluid of the disc will press through the fibrous outer layer and put pressure on the nerves adjacent to the spine. Most medical experts, now believe that only about 5% of back injuries involve damage to the discs. However, when they occur, these injuries tend to be more serious and long lasting. Fracture of the vertebrae is very rare in lifting accidents, unless the bones have become softened, such as in osteoporosis. Since disc injuries occur in either the L4/L5 disc or L5/S1 disc, the biomechanical calculations are done for these discs (Lindh 1980).

In many organizations, training courses are given to instruct employees in correct lifting techniques. This entails lifting with straight back and bent knees, which can reduce the disc compressive forces (Magora 1974). The guidelines for correct lifting techniques 'straight back-bent knees' have become quite controversial in the recent years. The first observation is that this technique only applies to small compact objects that can be held between the legs while lifting. Larger boxes, for example, are too larger to lift with the straight back-bent knees technique. To clear the knees it will be necessary to hold the box at some distance. In addition, there is much more load on the leg muscles. For many lifts, the technique is simply difficult and awkward and it will not be used by workers. Further more, Garg and Owen (1992) calculated disc compressive forces and concluded that stoop lifting (bent back-straight knees) is sometimes superior to squat lifting (Straight back-bent knees).
Scholey and Hair (1989) investigated the incidence of back pain among 212 physical therapists who were involved in back-care education. Their incidence rate was compared with that in a carefully matched group consisting of individuals who were not physical therapists. There was no difference in the incidence rate reported in the two groups.

In developing training programme, one must consider what to train. There are many problems with training programmes (McGill et al 1986).

1. There is usually a limited time effect of training. During the immediate time following training, trainees have a sense of enthusiasm and relevance. After a few weeks, the information sinks back and is perceived as secondary to many other problems. People tend to revert to previous habits if training is not reinforced.

2. One of the problems in teaching correct lifting techniques is the lack of feedback from the body itself while lifting. There are no nerve endings in the discs, which means that the lifter is not aware of differences in disc pressure due to lifting technique. The trainee must then relay on feedback from the training instructors and managers.

3. Emergency situations, which lead to back injury, are difficult for an individual to control. As with other accidents, several different things occur simultaneously. Therefore, if job requirements are basically stressful, behaviour modification through training may not be successful. It is better to design safe jobs, where manual handling is less frequent.
In many countries, there are guidelines and standards which limit lifting in the workplace. The purpose of these guidelines is to reduce the amount of low back pain as well as work injuries. The rationale is that manual lifting poses a risk of low back pain, and low back pain is more likely to occur if the load exceeds the worker's physical capability. In addition, the physical capabilities of workers vary extensively and in designing work places and tasks one must consider that some workers are less capable than others (Waters et al 1993).

In developing guidelines for lifting, three criteria for lifting are considered: biomechanical, physiological and psychophysical (Waters et al 1993). The biomechanical criterion is based on calculating the compressive forces in the L5/S1 disc. Several studies have indicated that, during lifting, the largest moments are created in the trunk area and the L5/S1 disc is at greatest risk. Based on the studies of human cadavers, it was concluded that a maximum disc compressive force is 3.4 KN, although for some individuals, it may be twice as much.

The lifting index provides a simple estimate of hazard of an overexertion injury for a manual lifting job. Lifting index is defined as the ratio of load of weight lifted to the recommended weight limit. Several experts agree that the lifting index should not exceed 3, because many individuals will be at great risk (Waters et al 1993).

The types of posture that people assume at work can often lead to pain in specific part of the body. Webb (1982) reported that there are certain common complaints for different work postures. For example one were to observe an operator who sits with his or her elbows on a high surface, it is a
reasonable hypothesis that if the operator has any problems they would be in the upper back or lower neck. If the operator indeed voices such complaints, then our hypothesis has been confirmed and one would reasonably take measures to improve the work posture by lowering the work height.

Professor R S Sen from the University of Calcutta explained that industrial workers in India often sit hunched directly on the floor without a chair or they may sometimes sit on a brick (Sen et al 1988). They develop motion patterns that can be very different from industrial workers in western countries. Sometimes they swing their knees back and forth to manipulate items, at the same time as they work with their hands. Although their knees flexed in extreme position, professor Sen asserted that these workers do not have any problems with their knee joints. The reason may be that they have been hunch sitting for their entire lives, and this is a common lifting posture at home or in social gatherings. Professor Sen’s statement was surprising, since hunch sitting violates the principle of keeping the joints in a mid-range position. It seems obvious that more basic research is necessary to analyse this controversy.

According to Pheasant (1982), postural stress is the term used to denote the mechanical load on the body by virtue of its posture. Posture may be defined as the average orientation of the body parts, with respect to each other, over time. Task induced stress is that which results from the performance of the task itself. An astronaut in space under conditions of zero gravity is weightless and experiences minimal postural stress. When using a wrench to tighten a nut, the astronaut would be subjected to task-related stress caused by gripping the wrench and generating a torque to tighten the nut while stabilizing the body.
parts (wrist, elbow, shoulder, etc) to counteract the force reaction at the wrench-nut interface.

The posture most free of stress is reclining. Nachemson (1966) found that the pressure inside the intervertebral discs was lowest in this posture compared with others. Most of the muscles of the body positions are relaxed in the reclining position. It has been suggested that the lumbar spine is supported by increased intra-abdominal pressure during manual materials handling. The working of this abdominal mechanism and the manner in which it supports the spine, however, are still under debate (Aspden 1989).

A close relationship exists between the length of a muscle and the tension it can exert. If a muscle is removed from the body, it assumes a resting length which depends on its own internal properties. If the muscle is placed in an apparatus suitable for manipulating its length and for measuring the tension required to maintain the muscle at a given length, a length-tension curve may be plotted. As the muscle is artificially lengthened, increased tension is required to overcome the elastic resistance of the connective tissue, which surrounds the individual muscle cells and holds the muscle together (Pheasant 1982).

A major goal of research into posture is to develop principles for the design of working environments which impose low postural stress on workers. The use of those design principles, it is hoped, will reduce the incidence of fatigue and discomfort is difficult to define because it has both objective and subjective elements (Bennett et al 1977).

In adult humans, the spine is shaped such that it is close to or below the centre of gravity of the superincumbent body parts, which are supported axially and the effect of weight bearing in the standing posture is to compress
the spine (Adams and Hutton 1985). This compression is resisted by the vertebral bodies and the intervertebral discs. The cervical and lumbar spines are convex anteriorly, a spinal posture known as lordosis. It is the presence of these lordotic curves, which positions the spine close to or directly below the super incumbent body parts. The effect is to reduce the energy requirements of the maintenance of the erect posture for resisting compression (Klausen 1965). The thoracic spine is concave anteriorly and is strengthened and supported by the ribs and associated muscles.

The intervertebral discs act as shock absorbers and limit and stabilise the articulation of the vertebral bodies. Each disc consists of concentric layers of cartilage, whose fibres are arranged obliquely in a manner similar to a cross-ply tyre. The layers of cartilage enclose a central cavity, which contains a protein-mineral solution. Positive osmotic pressure ensures that water is always tending to enter the disc. Thus the discs are prestressed to withstand loading (in a manner analogous to reinforced concrete beams used in the construction of modern buildings). According to Kapandji (1974), the nucleus pulposus functions as a swivel joint.

Intervertebral discs exhibit viscoelastic behaviour. Forces of rapid onset are resisted in an elastic manner, the disc deforms initially and then returns rapidly to its original shape when the force is removed. Under continuous loading however, the disc exhibits a type of viscous deformation known as creep. Creep occurs as a loading above or below a threshold level. Under compressive loading, the disc narrows, as fluid is expelled and the superior and inferior vertebral bodies move close together. Under traction (stretching or pulling forces), fluid moves into the disc and the disc space becomes wider (Bridger 1995).
According to Kapandji (1974), prolapse of the intervertebral discs of the cervical spine is rare. However, the discs can certainly degenerate, as can the intervertebral joints and the degeneration can cause irritation of the nerve roots in the cervical spine. Pain in the neck and shoulder may result. Degeneration of the cervical spine, sometimes known as cervical spondylosis can have serious consequences. Compression of the spinal cord at the level of the cervical spine can take place, resulting in weakness of the upper limbs, which may then spread to the lower limbs.

As is the case with the lumbar spine, some of the degeneration of the cervical spine is part of the natural process of aging. According to Bendix and Hangberg (1984), by the age of 65, 90 percent of the population has radiological evidence of cervical spondylosis. Cervical spine degeneration is a potential cause of neck pain, because of the mechanical changes, which occur as a result of age-related degenerative process.

2.4.1 Summary

Many studies have been carried out on manual lifting methods such as sagittal plane lifting and squat lifting. Many investigators have conducted research on various kinds of backpain problems associated with lifting. Investigators for analysing lifting activities have developed a number of biomechanical models. A number of technical papers have dealt with study on spine related problems associated with lifting posture. Use of finite element method for analysing stress distribution on L5/S1 disc is not reported in the literature.
2.5 NEED FOR THIS RESEARCH WORK

Eye strain is one of the major problems reported by millions of people world over working with VDT. Eye strain is defined as a kind of visual discomfort that occurs due to the prolonged attention of visual detail with reduced eye movement. Considering the above, it is obvious that study on eye strain due to continuous exposure to VDT gains importance.

Technology has created many environmental pollutants of which noise is an immediate and identifiable example. Many industrial processes have generated noise of sufficient sound level to cause deafness. Thus occupational hearing loss is not a new phenomenon. Even though it has long been recognized, occupational hearing loss has generally been accepted until recent times as part of the price to be paid for employment and technology.

Manual Material Handling (MMH), especially lifting poses a risk to many and is considered the prime cause of back pains and various other joint impairments. This in turn leads to increased worker compensation and loss of productive man-hours. Approximately one third of all jobs in industry involve MMH. Low back pain is one of the most prevalent and costly work related injuries. Spine disorders are found second only to natural childbirth in accounting for hospital stays of patient under age of 65.

In developing countries like India, where labour intensive operations are common, not much effort has been made to study the occupation related problems.
In this research an attempt has been made to study the effect on eye strain due to VDT work, effect on hearing ability due to continuous exposure to noise and loading behaviour of the spine during lifting.