

# REVIEW OF LITERATURE

## CHAPTER II

### REVIEW OF LITERATURE

In the field of ergonomics much effort has been made to perfect tools and machines for the better use in the industrial area. However, this aspect of research is missing in the field of ergonomics of housing i.e., in the direction of measurements of work areas in the kitchen and storage in relation to 'human-scale'. Knowledge of anthropometric dimensions is an important requisite for the design of equipment, work space and work place layout. Not much data on workers in developing and underdeveloped countries are available. The observations and conclusions already made on ergonomics of housing are presented under the following heads:

- A. Work Place Design
  - 1. Anthropometry in work place
  - 2. Work heights
- B. Posture
  - 1. Work posture
  - 2. Postural effect on health
- C. Anthropometric data
- D. Reaches
- E. Users' studies

## A. WORK PLACE DESIGN

### 1. ANTHROPOMETRY IN WORKPLACE

Block and Gfeller (1951) studied working heights for sinks and gas cookers preferred by 12 female subjects and found that variations of  $\pm 3$  per cent from the optimum were acceptable. Data revealed that a working level of 10cm below the elbow was most convenient when standing. The most favourable height for the sink was 90-95cm (upto the rim of the sink) and for the cooker 80-85cm. However, the authors recommended a height of 93cm for the sink and 83cm for the cooker.

Farely (1955) determined the normal working area as being equal to the volume circumscribed by the horizontal arm pivoting a relaxed vertical arm. The maximum working area was represented by the volume circumscribed during the movement of the fully extended arm pivoting the shoulder pivot point. The results reported by Farely are probably the most widely used by designers at present.

Konz (1960) concluded from the experimental results that the best working height for a standing operator is about 2.5cm below the elbow, nevertheless the

working height can vary several centimetres up or down without any significant effect on performance.

To evaluate storage and counter space, Pickett in 1960 took up an investigation. Based on the results, the storage dimensions and counter space are recommended when planning for the meal preparation activities for a family of four.

- Base cabinet frontage, 12 feet to 13 feet, 6 inches.
- Wall cabinet frontage, 9 feet
- Counter at left of sink, 3 ft to 3 ft, 6 inches
- Counter at right of sink, 3 ft to 3 ft, 6 inches
- Counter on each side of range, 2 feet
- Counter for mixing, 3 to 4 feet.

Further, the study suggested that the straight line arrangement of base cabinet units, or the combination of a 27 inches cabinet and corner unit with revolving shelves, provide adequate counter space but not adequate storage space. But both types of space i.e., counter space and storage space were adequate when 27 inches, 18 inches and 24 inches units were combined in the L-shaped arrangement between sink and refrigerator. The mid-way unit, 6 to 9 inches deep, installed at the back of the counter between wall and base unit allow items to be located within the radius of the elbow-to-grasping-fingertip reach. However, the adequacy of the space

depends upon the quantities and kinds of items to be stored.

Ward and Kirk (1970) worked out the correlation between standing elbow height and preferred work surface heights, seated elbow height and preferred seated work surface height. The findings reveal that, on an average women prefer to have their elbows, higher than the work surface. Also the regression equation data of most of the subjects suggest that majority of the subjects prefer work surfaces for all activities to be below elbow height. There is a positive relationship between elbow height and preferred work surface heights. It was also noticed that, greater the elbow height above the floor, greater is the difference between the elbow and the preferred heights. The authors reported that, their results are similar to the earlier evidence of Ellis, 1951.

( In the opinion of the authors, working situation for seated housewife limits the lower end of the range within which she prefers to perform on a work surface below the level of her elbows. This is due to the necessity of having space in which to fit the thighs below work surface. )

( Nadvi (1971) has suggested the following guides for storage space at cooking and preparation centres :

The height of the wall shelves should be 135 centimeters and for base cabinets it should be 80 centimeters. Dimensions of the base cabinet at cooking centre should be 75x30 cm.

The total linear space needed in the base cabinet at cooking centre is 418.8 centimeters. When arrangement of items is done in two rows 69.65 centimeters are needed in each row.

The total linear space recommended for wall shelf at cooking centre is 138.3 centimeters. When arrangement is done in two rows 69.15 centimeters is required in each row.

The total linear space needed for base cabinet at preparation center is 332.2 centimeters. When two shelves are provided and arrangement is done in two rows, 83.05 centimeters are needed in each row.

For wall shelf at preparation centre the total linear space required is 146.1 centimeters. When items are stored in two rows, 73.50 cm will be required in each row.)

( Gedliczka (1977) listed various ways of formulating the anthropometric data for the use of designers. They are :

- Typical measurements of the static human body.
- The ranges of movement presented within 2 or 3 planes.
- Pictorial form representation of anthropometric data of the operator and the dimensions of device

together.

- Direct recommendations without a picture of man.
- Information on the spatial parameters of the operator without the figure of a man beside a machine.

Further, the author has opined that placing controls outside the maximum reach of the operator necessitates the performance of the task with a difficult movement and in a strained working position.)

In the opinion of Redgrove (1979) the specification of work space dimensions involves compromises between the demands of different job elements and dimensions suitable for operators of different sizes. There are three approaches to such compromises viz., design for extremes, design for the average and design for all through adjustability. Design for the average may mean that no others can cater for it. Design for adjustability gives more scope, but is usually more expensive.

( According to Kazarian (1983), the materials, tools and utensils frequently used for tasks may be located in various places at the work place such as overshelves, undershelves, bins, drawers and cabinets.

The ideal location for storage facilities at work places is between waist and shoulder height. Items that have to be stored below waist level can be put on pull out or swing out shelves. Cabinets with fixed shelves below waist level are not easy to use. For the same reason, it was suggested that shelves and cabinets ought not to be placed more than 6 ft above the floor. Self closing cabinet doors and drawers are desirable. )

Das and Grady (1983) conducted a research on industrial work place layout, with the application of engineering anthropometry. The authors emphasize that, the normal and maximum working areas can be established mathematically by using the existing anthropometric data.

( Reinhold (1983) says, reaches, size, muscle strength and visual capabilities have to be considered when developing a design. Further, he has mentioned the three major categories of work places viz., sitting, standing, and sit/stand. Choice of a suitable work place depends on the task to be performed. ) The most suitable work places under the given circumstances are as follows :

#### Sitting:

- When all items needed in the short term task cycle can be easily supplied and handled within the seated work space.

- When the items being handled do not require the hands to work at an average level of more than 15 cm (6 inches) above the work surface.
- When no large forces are required, such as handling weights greater than 4.5 kg.
- For fine assembly or writing tasks.

#### Standing:

- When the work place or work station does not have knee clearance for a seated operation.
- When objects weighing more than 4.5 kg are handled.
- When high, low or extended reaches, such as those in front of the body, are required frequently.
- When operations are physically separated and require frequent movement between work stations.
- When downward forces have to be exerted, as in wrapping and packing operations.

#### Sit/Stand:

- When repetitive operations are to be done with frequent reaches more than 41 cm forward and or more than 15 cm above the work surface. Operations could have been done at a sitting work place if it were not for the reach requirements.
- When multiple tasks are performed, some may best done sitting and others may best done standing. Provision for both may not be feasible owing to space constraints.

In 1987, an anthropometric investigation was

conducted among several old people's homes in the Hague, Netherlands, by Molenbreck. The author has placed special emphasis on consumer durables in his research.

The guidelines suggested by the author indicate that "the 5th percentile of the reach height standing is approximately 150 cm, and the 5th percentile of the reach height sitting is 74 cm above the seat. Therefore, no controls should be placed higher in work spaces designed for the elderly". This is also suitable for children or wheelchair users.

In his opinion design made for the elderly in accordance with anthropometric guidelines are also easier to use for others who do not have the physical capabilities of young and healthy people. Both for elderly people and for many others, jam-jars are often difficult to open, window handles difficult to reach when they are situated 180 cm above the floor, keys are difficult to manoeuvre into a key hole in the dark.

## 2. Work height :

A convenient kitchen makes the carrying out of tasks pleasant (Agan, 1956). A convenient work surface height to the worker reduces energy cost and prevents fatigue. The right height for a work surface depends upon

the anthropometric measurements and work position. The height upto the elbow is an important parameter for determining the desirable height of work surfaces for household tasks performed in the standing position.

( A desirable working position for either standing or sitting is the one which permits the arm to hang and to swing naturally from the shoulder joint without incurring the static work of lifted shoulders and upper arms. The elbow joint and the arm are usually operated for manipulative motions with the hands. (Steidl and Braton, 1968).

) Further, it was stated that the right angle between forearm and upperarm has been shown to be the starting position of greatest strength and efficiency for exerting force with the hands. Therefore, the height of the work surface should be lower than the height of the elbow of the worker. In their view, working with containers or receptacles necessitates a lower working height. The preferred distance from elbow height to work surface is linked with the height of the elbow from the ground. Increase in elbow height will bring an increase in work surface height and the back becomes increasingly bent. Further, the author has suggested the preferred elbow height above the work surface in the kitchen for

people having different elbow heights above the floor.

Chatterjee and Daftuar (1966), determined the relative height of the stool and the working table with reference to the human height in the job of typewriting. It was concluded that-

- Different bodily dimensions follow a definite pattern of ratio which was 1:1.617.
- The relationship of 1:1.617 is true with other objects also, particularly the working situations of man.
- The best efficiency can be achieved (in term of typing materials) when the stool and the working tables are in the 1:1.617 relationship with human height.

Thiberg (1965-1970) analysed the relationship of preferred working heights to stature and elbow height for women and for men. If standing height increases by about 10 cm, elbow height increases by about 8 cm. The relationship between these two measurements is very similar in men and women, but not quite identical. The increase in elbow height in relation to standing height is rather less among women.

Ward and Kirk (1970), summarized and discussed

the drawbacks of the recommendations offered by the various authors for work surface height in the kitchen.

The recommendations are as follows (Table-1);

TABLE : 1. Recommendations for Working Surface Height in the Kitchen

Sources of recommendation	Works heights	
	Standing (inches)	Sitting (inches)
Bouweentrum, Holland, (1963)	35.5 to 37.0	23.5 to 25.5
Berglund, Sweden, (1960)	35.5	25.5
M.O.H.L.G, England, (1963)	34.0	28.0
Council for Scientific Management in the home, England, (1943)	33.0 to 39.0	-
Walley, England, (1960)	32.0 to 33.0	26.0
Hawkins, U.S.A. (1953)	32.0 to 36.0	26.0

Source : Ward et. al., (1970), Ergonomics. 13(6). 783-797.

Although, these recommendations are exclusively for work surface height in the kitchen, according to the author they suffer one or more number of deficiencies.

These are :

- It is implied that the recommendations should be determined in part by the height of equipment such as cooker knobs and sink rims.
- The recommendations are based solely on static anthropometric dimensions, such as elbow and

hand heights.

- The recommendations are based on out-of-date or unstated or obscure criteria

Ward and Kirk (1970), studied the relation between some anthropometric dimensions and preferred working surface heights in the kitchen for 56 British women. The selected anthropometric measurements were stature, floor to elbow (standing), floor to elbow (seated), seat to elbow (seated). These were all unshod measurements. The following activities were performed at the following preferred working surface heights when the subjects were standing and seated.

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>- A. Peeling vegetables</li> <li>Beating &amp; whipping liquid in a bowl.</li> <li>Slicing bread.</li> </ul> | <ul style="list-style-type: none"> <li>- Working above the work surface.</li> </ul>        |
| <ul style="list-style-type: none"> <li>- B. Spreading butter.</li> <li>Chopping ingredients.</li> </ul>   | <ul style="list-style-type: none"> <li>- Working on the work surface.</li> </ul>           |
| <ul style="list-style-type: none"> <li>- C. Ironing.</li> <li>Rolling pastry.</li> </ul>  | <ul style="list-style-type: none"> <li>- exerting pressure on the work surface.</li> </ul> |

Work surface heights preferred by the 56 women while standing were 34.57 inches for activity A, 35.79 inches for activity B and 34.45 inches for activity C. Also the results revealed considerable standard deviations with regard to the mean values for preferred work heights. The authors recommended adjustment of these unshod work

heights for the purpose of implication. The adjustment could be between 30.34 and 39.33 inches i.e., 2 SDs above and below the highest and lowest preferred mean heights. In their opinion, a wide range of activities from ironing to beating the mixture in a bowl can be performed on this range of work surface heights.

The mean unshod seated work surface heights preferred by these women were 23.68 inches for activity A, 25.28 inches for activity B and 24.23 inches for activity C.

McCormic (1976) has stated that more specific considerations should be given to the design related to horizontal dimensions (counters, height), vertical and sloping work surface dimensions (positions angles etc.). These features of work situation should be determined on the basis of anthropometric considerations of the people who are to use the facilities.

Considering body structure and bio-mechanics, the work surface should be at such a level that the arms can hang in a reasonably natural relaxed position from the shoulder with elbow having satisfactory relationship to the working surface i.e., forearm should be approximately horizontal or sloping down slightly. When the work

surface requires the upperarm to be raised above the relaxed elbow height, the metabolic costs of work tend to increase. Work surface height for standing, should be slightly below the elbow height, namely 2"-4" or 5-10 cm below elbow.

In the opinion of Kazarian (1983), the height of the work surface will vary with the type of task such as small and light weight and larger or heavier weight. Task involving small or light weight materials can be easily done at a surface height of 2 inches below the height of the worker's elbow. In case of larger or heavier task, the height of the work surface can be lowered. The lowest work table surface is at the point where the wrist bends when the arms are extended at the worker's sides. In this case the worker has to use the shoulder and back muscles in handling the heavier materials.

In general, for women the author recommends 37-39 inches height for work surface for light task and 34-36 inches height for heavier work. Further adjustable work surface height was recommended to fit both worker and task.

In 1983 Reinhold, recommended standing work place height. The optimal working height of the hands is

determined by compromise based on analysis of the total work sequence such as :

- For light assembly, writing, packing tasks, the optimal working height of the hands is 107 cm.
- For tasks requiring large downward or sideward forces, such as casing operations and packing, the working height of the hands should be 91 cm. In case of very heavy force exertions, lower heights to about 76 cm may be appropriate.
- For tasks requiring large upward forces like cleaning, removing, the optimal working height of the hands is 81 cm.
- When jobs require handling of articles of different sizes at the same work place, either an adjustable height workbench should be used or the height should be based on the most frequently used items.

According to Hanspal (1985) on the basis of attitudinal scores of the respondents in the field and in the laboratory, suitable height of work surface for persons of 150 cm height was found to be 75 cm for boiling, kneading, rolling, puffing, frying, dishwashing, for peeling and cutting it was found to be 85 cm. The suitable height of the storage was 120 cm in standing.

Magnusson and Ortengren (1987) from Sweden conducted a study on optimal table height and surface angle in meat cutting. The Laboratory tests were conducted

at four different table heights. In the first test the butcher was given a chance to choose a height that he considered to be the most comfortable. For the second and third test, the table was raised and lowered 5 cm respectively. The final test was performed at the best height of the previous tests and with the surface tilted to 8°. The activity of cutting 4 halves of a pig took 25 minutes. The results of the test indicated that for majority of the butchers (4 out of 5) the best height was between 18.22 cm below elbow height. The lowest table height gave the least load on the shoulder. Relatively low load on both shoulders and back was obtained when the table height was in the range of 18 to 22 cm below elbow height. However, all the subjects considered the self chosen height as the most comfortable height.

( Grandjean (1988) stated that, the most favourable working height for handwork while standing is 50-100 mm below elbow level. The average elbow height is 980 mm for women. Author concludes that average working heights of 880-930 mm for women will be convenient. Besides, these anthropometric considerations there must be allowance for the nature of the work.)

Pekkarinen and Anttonen (1988) from Finland,

explored the effect of working height on the loading of the muscular and skeletal systems in the kitchens of work place canteens.

It was reported that, 30 per cent of the respondents had muscular and skeletal systems illnesses. Seventy six per cent suffered from shoulder pain and 58 per cent had pain in the neck and occipital region and in the lumbar region (50 per cent). The reported problems in the neck shoulder region or lumbar region varied according to the worker's stature i.e., shorter workers complained more often about neck-shoulder problems than taller workers. These have been confirmed to be related to a raised position of the upper limbs because of working with the cutting board which was too high. For about 1/3 of the workers the height of the cutting board was too high and for 34.80 per cent, kitchen equipment was also too high.

In the opinion of these authors a suitable working height demands the possibility of adjusting the working surface height between 800-950 mm and the cooker height would be about 650 mm. The rim of working vessels should be 900 mm from floor level.

Varghese et. al., (1989) determined convenient

work heights and corresponding proportionate distance below the elbow for various activities connected with the kitchen. However, the recommendations are for a woman measuring 153 cm height, the recommended measurements is as follows.

Activities	Convenient Height (cm)	Distance below the Elbow (cm)
Chopping	85	11
Cooking	87	9
Kneading dough	87	9
Rolling & roasting	87	9
Dishwashing	78	18

The authors suggest that based on these relationships between elbow heights and work surface heights the actual work surface heights for individuals of other heights could be worked out. Further, it has been stated that the convenient work height differs from elbow height in the range of 10-17 cm.

Further, the authors studied the heart rate and subjective ratings for the above activities at different work heights. Based on heart rate (98 beats per minute) and comfort rating (Rating-1) 85 cm work surface height was preferred for chopping and 89 cm for other activities. (The recorded heart rate was 92, 108, 100, BPM & 1st

rating for cooking, kneading, rolling and roasting respectively).

## B. Posture

### 1. Work posture :

An investigation was carried out by Bratton (1958) in New York, to study the factors affecting the body in standing/sitting posture while working in different postural conditions. Energy cost of the body, rate of work, and angle of arm lift while working in the standing and sitting positions were recorded. The task performed was folding of towels and washing clothes. The various positions studied were :

- Standing at a counter with the height of 36 inches.
- Sitting at the above counter on a stool measuring 26 inches height with the feet on the foot rest and knees under the counter.
- Sitting in the above position but with the knees forced to the side by a cabinet front.
- Sitting on 15 inches height chair at a counter of 23 inches height with the knees under the counter and the feet on the floor.
- Sitting at a counter of 36 inches height, in a perched position on a stool measuring 30 inches height with the feet braced against the floor.

The result of this study indicated that the

difference in average energy cost for standing and sitting to work in the various positions was small. For sitting posture in the different positions the average energy cost ranged from 1.36 to 1.53 calories per minute and for standing 1.45 calories per minute. So these results do not support a general statement that sitting saves energy over standing while at work. The minor variations in postural conditions (stool height) resulted in no changes in oxygen consumption.

Standing positions permitted a smaller (narrow) angle of arm lift when compared to sitting position. In the opinion of the author it is a favourable position for comfortable use of the arms. Finally it was also reported that the rate of work was not affected significantly by the working positions.

Richardson & Macracken (1960) studied the energy expenditure of women performing selected household activities in sitting and standing positions. The energy expenditure is slightly less in standing position than in sitting position for the same work.

Further in 1966, the authors extended their research to study the ironing task at different work heights both in sitting and standing postures. They found

that least energy was expended when the task performed at ironing board was at 36 inches height and energy expenditure increased with every unit decrease in height of the ironing board. The findings revealed that the decrease in the height required considerable body bend which could be the reason for the increased energy expenditure. When ironing was done on a board of 30 inches height in a sitting position least energy was required. However, comparison of this with working on 36 inches height iron board was not reported.

Gray, Hansen and Jones (1966) found that small changes in sitting and standing postures have a significant effect on neck muscle tension. Three postural images viz., most comfortable, best and greatest height were measured in terms of changes in angles between head and trunk and in the differentiated activity in the muscles of sternomastoid and upper trepezius. These postures were distinguished from each other with a high degree of statistical significance. The heart rate as well as neck muscle tension also varied with the postural images.

Lehmann (1966) reported that the metabolic rate is raised by 8.3 per cent in the sitting posture when compared to the lying.

In standing posture metabolic rate was as high as 19.7 per cent. The increased metabolic rate particularly in the standing posture was due to the greater energy expenditure which is connected with the effort of keeping the whole body in balance i.e., in a state of considerable static muscular strain. So, in the opinion of the author, standing for a longer period can affect the condition of the human body and it should be avoided or limited as far as possible.

As stated by Subramanyam and Kutty (1971) posture means the attitude taken by the body in different situations like standing and sitting. A certain amount of muscular activity is necessary for the maintenance of these postures. However, it is different from ordinary muscular contraction and relaxation characteristic of voluntary muscular movements. Since the posture has to be maintained for longer period of time, it should be achieved by a minimum expenditure of energy. The main basis of this phenomenon is the stretch or myotic reflex.

The energy expenditure of the body differs according to the posture. (Chakraborty, 1974). The energy cost of various postures reported by the author is:

Lying - 1.14 cal per minute

Sitting - 1.19 cal per minute

Standing :

Relaxed - 1.25 cal per minute

Attention - 1.30 cal per minute

Standing Relaxed :

After light

meal - 1.45 cal per minute

After heavy

meal - 1.56 cal per minute

On an average 9 per cent extra energy is required to keep the body in standing position than reclining.

Tanasescu, Chiriae, Dobre and Birescu (1974) investigated the influence of a few working positions viz., erect, bent at  $90^{\circ}$  and crouched, on heart rate, respiratory volume and oxygen consumption. These were recorded for polishing activity. The heart rate increased by 4.6 per cent in erect position, by 10.1 per cent in the bent position at  $90^{\circ}$  and by 12.7 per cent in the crouched

position, after the completion of the task. For the same positions respiratory volume increased by 11.5 per cent, 11.6 per cent and 16.7 per cent and oxygen consumption by 6.7 per cent, 17 per cent and 19.5 per cent respectively. Therefore, the authors conclude that the position bent at 90° and crouched positions impose a greater strain on the physical effort than in the erect position.

Jindal (1974) studied the human energy cost while ironing during sitting and standing positions in terms of energy expenditure. Three different positions during ironing viz., sitting at ground level, standing while using tables with 82 cm and 69 cm height were investigated. It was reported that the maximum amount of energy was required while working at 69 cm table height. However, marked differences were found between the heights.

Dhesi and Chahal (1975) studied the effects of stages of chapati making and angles of body bend on heart rate during sitting and standing postures. The variation in the heart rate was significant in the sitting and standing body positions, as well as between the stages of the task. The heart rates were less at all the standing positions than at the sitting positions.

In the standing position, slump and back bend were the main angles that caused changes in the heart rate. While in the sitting position, the angles of knee bend and ankle bend were the significant sources of variation in the heart rates.

Dhesi and Devadas (1976) opined that the design of the house can not be blindly transferred from one region to another, also from culture to culture. This is because people differ in postural styles due to anatomical, physiological, psychological, cultural and technological factors. Therefore, the authors have suggested that postural habits need to be considered as important factor in planning the design of the house. Otherwise improper or inappropriate design of the house can produce degenerative changes in the body through a poor posture.

In relation to posture, Corlett and Richardson (1981) answer the question of what can be described as satisfactory and what is unsatisfactory by saying that the difference between the two cases is not necessarily the level of 'fitness'. Physically, each may be equally fit for the work performed. But, the major difference is the

variability in posture which is possible in each job. When the same muscle groups are used every few seconds and if the work place design is poor then the attempt to use other muscle groups will inhibit the ability to do the task because the individual will have adopted a position from which he/she can not do it.

The effect of work place at the wrong height, a seat too high or low, poor visual situations or any other of the many common mismatches between people and their work places is to restrict their choice of working positions and movements. With this it is evident that people will adapt to bad work places but it is also true that this is done at personal cost and results in lower productivity. Further the authors have reported that many of the diseases of middle age are contributed in a major way by postural inadequacies. Low back pain, varicose veins, and tenosynovitis, affect large segments of the population and make their lives and leisure uncomfortable. In their opinion, we can not afford to ignore posture, because it creates widespread misery and incurs the social costs of unnecessary disease and the direct costs in lost productivity.

Bala, Miglani and Bakshi (1982) conducted a

research on comparative physiological cost of chapati making in different postures. It was reported that average energy expenditure while at rest, kneading the dough and chapati making was 0.636, 1.50 and 1.074 cal/sq.m/min respectively in squatting position and 0.666, 1.268 and 0.980 cal/sq.m/min respectively in standing position. Hence, energy expenditure was significantly higher ( $p < 0.01$ ) when activity was carried out in squatting position than in standing. The authors have justified that, working in squatting position requires head and trunk to bend forward. As a result, ligaments and tendons undergo strain and increase the energy expenditure.

Eklund and Corlett (1984) studied the changes in stature resulting from sitting on a stool without back support, sitting on an office chair with a support and sitting in an easy chair for a period of 1 and 1/2 hours. The results indicate that the stool produced 4.6 mm of shrinkage in the stature whereas the two chairs caused negligible changes. In other words, the normal progress of diurnal shrinkage appeared to be halted. They also studied the effects of sitting and applying a horizontal pushing force of 25N alternatively with the right and left hand for 30 minutes, with and without a backrest. This also indicated the regaining of stature with backrest and

shrinkage of stature without backrest.

In 1985, they further studied and compared shrinkage from sitting in a chair with 38 cm high back rest and another with a lumbar support of 18 cms high. Each subject performed a pushing task, exerting 25N, using both hands. The high back rest caused significantly less shrinkage during the 45 minute task (ie 0.66 mm for high back rest and 1.37 mm for the lumbar support).

Nag, Chintharia, Saiyed and Nag (1986) carried out the EMG (Electro Myo Grams) analysis of sitting work posture on women. Their findings reveal that sitting on the floor without trunk support as in the positions like sitting on floor with left leg crossed and the right leg bent at knee and resting vertically with foot flat on the ground, sitting on floor with right leg crossed and the left leg bent at knee when the foot rests on the ground, lastly sitting on a plank (10 cm height) with both legs bent at the knee, was more fatiguing than the standing position. This is because, the EMG of the erector spine were certainly greater in the sitting positions. In sitting postures muscles of upper back were more strained.

Yates and Karwowski (1987) from U.S.A., studied the maximum acceptable lifting loads during seated and

standing working positions. The different working positions were four, viz.,

Seated, two handed, symmetrical lift from a table, to a position 38 cm forward of the edge.

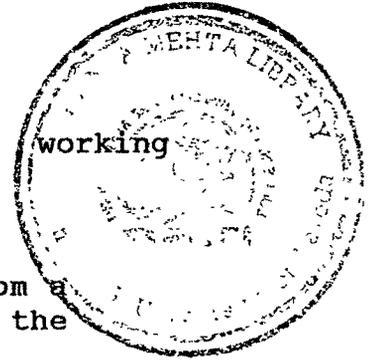
A seated lift from a position at the subject's side (30.5 cm below table height) to table height (85 cm) involving a 90° twist of the torso.

Standing, two handed, symmetrical lift from the table, to a position 38 cm forward of the edge.

Standing, vertical lift from 86 cm to 134.5 cm above the floor.

Each of the four lifting positions were performed at 1 and 4 lifts per minute for a total of eight sessions.

The findings suggest that no significant difference existed between the sitting forward and the sitting twist lifts due to the amount of weight lifted. There was also no significant difference between the standing forward lift and the standing vertical lifts. However, the loads lifted during standing positions (both) were significantly greater than in sitting position. Acceptable weights for standing positions ranged from 8 to 25 per cent greater than those acceptable for sitting positions. Further, the authors opined that 16 per cent



reduction in standing acceptable lifts performed from table height to shoulder height would provide reasonable adjustment.

(Varghese et. al., (1989) studied the postures adopted while performing cooking activities. All the homemakers preferred to do cooking activities such as food preparation, chopping vegetables, grinding spices, frying and cooking, kneading dough, rolling and roasting chapaties in standing position while, dishwashing was mainly done in the squatting position.)

According to Astrand (1971), Varghese et. al., (1989) a good working posture reduces the physiological cost of work and fatigue to the minimum. Static muscular efforts and incorrect postures for long periods during household activities can damage the intervertebral discs.

Further, Varghese et.al., (1989) carried out an experimental study and ergonomically evaluated the selected household activities in the various postures. Food preparation was one of the selected activities under the study. Mainly two postures viz., standing position and sitting/squatting position were adopted during the experiments. The findings demonstrate that the cooking activity done in sitting position is less tiring than in standing position. Since the standing type of kitchens

are common in urban homes the authors recommend the combination of sitting/squatting and standing postures for kitchen work.

## 2. Postural effect on health :

A systematic study on sitting postures and somatic troubles in office workers was carried out by Grandjean and Buarant (1962). The results of the study revealed that the comparison of the behavioural results with the body sizes showed that small people mainly sat on the front edge of the chair, tall people more often sat to the back of the chair. The detailed analysis indicated that people with pains in neck and shoulders (24 per cent) were mainly those whose work table was too high. This caused them to lift their shoulders while working. In the opinion of the authors, adjustment in the posture is the reason for frequent complaints about pains in neck and shoulders. Further the group which reported pains in knees and feet consisted of mainly smaller people who had the practice of sitting on the front edge of the chair. According to the authors, this sitting posture is the reason for causing excessive pressure in the thighs with resulting venous congestions in the lower legs.

Grandjean and Collaborators (1968) studied postures and behaviour of shop girls in a departmental

store. The result discloses that the shop girls are exposed to a considerable static work load to the extent of 5 hours per day. Because of this higher percentage (26 per cent) of shop girls suffered from somatic trouble in the leg and feet. The author assumed these troubles are related to the static postures.

Vanwely (1968) and Grandjean and Hunting (1977) have listed the following postures and probable site of pain.

TABLE : 2. Bad Postures Versus Probable Site of Pain

Bad Postures	Probable site of pain
<b>VANWELY (1968) :</b>	
Standing (particularly a pigeon footed)	- feet, lumbar region
Sitting without lumbar support	- Lumbar region
Sitting without support for the back	- Erector spinal muscles
Sitting without good footrests of the correct height	- Knee, legs and lumbar
Sitting with elbows rested on a working surface which is too high	- Trapezius, rhomboideus, and levator scapulae muscles
Upperarm hanging unsupported out of vertical	- Shoulders, upperarms
Arms reaching upwards	- Shoulders, upperarms
Head bent back	- Cervical region

Trunk bent forward; stooping	- Lumbar region position
Lifting heavy weights with back bent forward	- Lumbar region
Any cramped position	- The muscles involved
Maintenance of any joint in extreme position	- The joint involved

**GRANDJEAN AND HUNTING (1977) :**

Standing	- Feet and legs (possibly varicos)
Sitting without back support	- Extensor muscles of the back
Seat too high	- Knees, lower legs and feet
Seat too low	- Shoulders and neck
Extended arms	- Shoulders and upperarms (possibly periartthritis of the shoulders)
Inadequate grips on tools	- Lowerarms (possibly peritendinitis)

Recent results of orthopaedic research on sitting posture reveal the valuable information of possible relations between frequent complaint of pains and pathological degeneration of the discs in the spine. Nachemson and Elfstrom (1970), Anderson and Ortengren (1974), and Nachemson (1974) gave a new insight into the problem. The authors found that the pressure on the discs is considerably increased when the trunk is bent

forward when compared with standing in an upright position. Further, it was noted that the intradiscal pressure is higher in the sitting than in the standing posture. In their opinion this is certainly due to the turning mechanism of the hips in the sitting position, which produces a kyphosis in the lumbar region of the spine. Therefore, the increase in intradiscal pressure must be considered as an unnecessary load and strain on the discs promoting pathological changes when the knees are straight and the back bent. The intradiscal pressure is about three times as high when compared with the correct way of lifting a load i.e., by keeping knees bent and the spine straight. The pressure in the discs in various sitting postures is low in a relaxed position. Also, in the writing position, with the arms lying on the table, pressure is lower than in the typing position where the arms have no support. The highest disc pressure is recorded when a load is held with outstretched arm.

Ronquist and Hansson 1979, Jonson and Jonson 1980, Viikari Juntura 1983, reported that butchers who are cutting meat have a high frequency of occupational disorders. Further Magnusson, Ortengren, Anderson, Peterson and Sabal 1981 and 1987 stated that, the disorders are mainly localised to their low back,

shoulders and neck. These body parts are also subjected to high loadings during work which are mainly caused by factors like inappropriate working postures, handling of heavy materials, forceful cutting due to the cutting resistance of the meat.

A survey on sitting posture in a blouse factory was conducted by Safoluwe and Young (1974). Their findings are very interesting, particularly regarding the situation in developing countries. The findings reveal that 16 per cent of the workers complained aches in the knee, 12.5 per cent in the ankle and 30 per cent in the lumbosacral joints. All these workers were working in this job for 3-4 or more years. No complaint was made by the workers who worked for less than three years. According to the workers these disorders and discomfort was due to unsuitable heights of seats and cushions.

Further, the authors studied the tailoring section of a towel manufacturing company. Similar kind of complaints were reported. Two workers complained that the machine was too low. Chest pain was reported by five employees, eight people suffered from backache (lumbosacral) and six from shoulder pain. Bending of spinal column (Kyphotic) was reported by one worker.

If the arm is held above the head when mending an electrical fitting on the ceiling the contraction of muscles prevents the blood from flowing into the muscle. The lactic acid resulting from the work must be oxidised by oxygen from reserve. When this is exhausted, lactic acid starts to build up and before very long the muscle becomes so painful that the work has to be stopped to allow the muscle to relax and permit the blood to flow through it.

Life and Pheasant (1984) conducted an experiment to study the posture in keyboard operation. As per the results of the survey, increase in the keyboard height gives rise to discomfort due to the greater amount of work that must be performed by the shoulder to keep the hands on the keyboard. Keeping the copy script flat on the desk beside the keyboard resulted in the need for increased muscular activity to support the head while reading. This could give rise to discomfort in the neck, shoulders and upper back because of too high keyboards and not using script holders.

Green, Briggs and Wrigley (1991) reported that elevation of the shoulders in occupational tasks is sure to cause pain in the neck and shoulder. So, the authors

have opined that the position of the upper limbs is also important in any analysis of the working posture.

### C. Anthropometric data

The findings of O'Brien (1941) reveal that, the vertical and horizontal measurements are correlated within themselves. Correlation between vertical and horizontal measurements were negligible. Weight has little correlation with many of the vertical measurements. The lower girths of the body are closely related to the legs and the upper girths with the arms.

Further, her research findings reveal that, single women (unmarried) were thin and weighed the least. Women married and not having children are the tallest of the groups. Women having a number of children are the shortest and heaviest with the largest girth measurement. Thus, when all adult women are considered irrespective of their marital status, the correlations between heights and girths are lower than for women in any particular age group.

In the opinion of the author, to predict relationship of all the measurements, combination of vertical and horizontal measurements must be used. Although weight showed considerable correlation with many

of the vertical measurements, it was much more highly correlated with girth. It was also seen that girths below waist were closely related with legs and girths above waist with arms.

Corbusier (1951) says that the golden mean ratio can also be obtained for various dimensions of the body and their interrelationships. Further it has been pointed out that the man's total height with arm raised is double the height of the man's navel (solar plexus). The dimensions of man's height up to his head is 1.617 times the height of the solar plexus. Both the measurements are from the ground. The relationship of 1:1.617 is the same golden mean ratio.

Rasch (1954) recorded the speed of voluntary movements of the hand, forearm and arm, then recorded strength and linear measurements of these segments and the weight of the arm. He found no significant correlations between the anthropometric measurements and speed of movement.

The findings of Clarke, Henry and Whitley, (1960) further substantiated the above fact by revealing little or no relationship between anthropometric measurements of the arm and reaction time or movement

time. However, they have opined that the obesity might interfere with the movement time of the body.

The sizing of the rooms and objects for human use has not always received the attention it deserves. There is a common assumption that what looks right is right (Page, 1960). As stated by the author many research findings and reviews of the anatomical physiological principles in design of furniture and building reveals certain draw-backs. The heights normally adopted as standards in many countries are unsuitable for the majority of the population. In practice many people face problems like drawers and cupboards are too deep, working surfaces are too high or too low. This is because of involvement of anthropometric problems. It is linked with the deviation from the mean. Therefore, it is not to be designed to the average size but to a range of sizes, it should be designed to the actual size distribution of the population who will have to use it. So, anthropometric data required for a general population and for a special population should be the distribution of actual sizes and not the mean.

A study by Bhavnani (1965) on reaches of homemakers of Keymore Cement Works Colony, reveals the following anthropometric measurements of the homemakers.

Anthropometric Measurements	Range	Mean (in inches)	Median
Height	58-65	62.5	62.30
Arm length	25-29	27.2	27.30
Distance from elbow to floor	34-39	35.26	35.27

Further the findings of the study disclose the positive relationship between arm length and height which was  $0.66 \pm 0.15$ .

Barkla (1961), Lewin (1969), Thompson et. al., (1973), contributed an interesting anthropometric data. Barkla made an attempt to derive detailed anthropometric data from stature alone. He adopted the assumption that the dimensions of the body are a constant proportion of stature for different individuals. He estimated body measurements relevant to seat design for a British population, using data from American and European sources. While Lewin, by studying 77 Swedish women aged 25 to 49 published an extensive range of anthropometric measurements. Based on measurements of 7187 British women aged 18-76, Thompson et. al., rendered height, weight, forward and upward reach and elbow height. Some of the selected measurements from Lewin's (1969) data viz.,

average stature (164.2 cm) with elbow height (102.5 cm) were found to be similar in Tompson et. al., (1973) study also. In their study almost same results i.e., 164.5 cm (height), 102.5 cm (elbow height) were observed for 60th percentile. This supports the argument of Barkla i.e., the dimensions of body are a constant proportion of stature for different individuals.

The following data for anthropometric dimensions as proportion of stature from Lewin and Barkla's study also revealed a similar trend.

TABLE : 3. Comparative Data on Anthropometric Dimensions as Proportion of Stature

Characteristics	Lewin	Burkla
Shoulder to elbow (Standing)	0.202	0.210
Sitting:		
Height of seat	0.238	0.245
Crown to seat	0.523	0.525
Shoulder to rest	0.350	0.335
Elbow to seat	0.132	0.125
Top of knee to floor	0.303	0.310
Buttock to front knee	0.350	0.350
Buttock to angle of knee	0.295	0.290

The variation in the dimensions as proportion of stature between the above data ranged from 0.002 to 0.015.

In a study conducted by Gupta (1968), she grouped her entire sample (500 women students, Baroda) into various body sizes on the basis of height. The average ranges of body measurements for each height group is as follows.

Body Measurements (in cm)	Heights groups		
	Short (N=60)	Medium (N=353)	Tall (N=87)
Height	142.5 to 146.8	148.5 to 155.7	160.6 to 164.2
Bust	73.4 to 93.8	71.6 to 94.5	67.3 to 94.6
Waist	58.5 to 75.8	56.1 to 84.5	56.0 to 67.8
Hip	78.5 to 100.5	79.8 to 118.0	79.0 to 104.2

Anthropometry of standing and sitting positions was studied for men and women aged 25-49 years by Lewin (1969). In this study important ergonomic body dimensions were investigated. As revealed by the findings, the men had significantly higher means than the women throughout, with the differences varying between 0.7 and 1.6 SDs. Correlation and regression analyses indicated highly significant positive correlations with no sex differences i.e.,  $r > 0.90$ , between stature and other body dimensions

which include the lengths in the lower extremities and the trunk skeleton. The regression line for men and women are found to be parallel and high positive correlations were found between height measurements and radiale but only for men.

Further, the relationships between body measurements standing and sitting with particular reference to dimensions of ergonomic importance were also investigated. Significant positive correlations with values between 0.60 and 0.90 were found for height of shoulder, elbow and knee-joint in standing and height of shoulder and elbow as well as the distance sacrale-tibial tuberosity in sitting. The women have a significantly higher positive correlation for the relationship between shoulder height standing and height of seat. The correlation for women was  $r = 0.80$  and men  $r = 0.67$  and  $t=2.8$ . Correlation between elbow height standing and height of sitting was also significantly positive. The regression analyses indicated that seat height for women increases significantly with increasing shoulder height. The relationship between the floor-to-elbow distance sitting and shoulder height standing gives a significantly higher correlation for the women ( $r=0.76$ ), than men ( $r=0.35$ ). In his opinion since women have a relatively

higher elbow height in standing than men, work tables should therefore be higher for women than for men of the same stature. Also, sex differences for height measurements when sitting reflect a greater amount of soft tissues in women when compared to men in relation to skeletal size.

As cited by Johnson and Buskirk (1974) linear and circumferential measurements provide useful information concerning both physical growth and development. They also provide basis for many useful indices.

Shahnawaz and Davies (1977) have felt, knowledge of anthropometric dimensions is an important requisite for the design of equipment, work space and work place layout.

The lack of comprehensive anthropometric data for designers in the western world is documented. Also in developing and under developed countries data on workers are even less available.

Redgrove (1979), stated that as individuals mature they increase in size, but adults steadily decline in stature. However, the author failed to reason it out whether this is due to a decrease in stature with age or to a steady increase in the average height of the general population. This implies that more younger people come from taller populations than older people.

Cronev (1980), Pheasant (1982) and Boussena and Davies (1987) have expressed that the design of the work place needs to be based on the anthropometry of the users. The anthropometric characteristics of any population are dependent upon a large number of biological, social and demographic variables. The authors have commented on the effects of such variables on body measurements. Therefore it is important to emphasize the differences between designing for a specific group and for the general population.

Hanspal's data (1985) revealed the height of the person at 5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentile and values were

found to be 150 cm, 154.2 cm and 160 cm respectively. The readings of elbow height were 88.6 cm, 94.4 cm and 100.0 cm for 5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentile respectively, in standing posture.

Varghese et. al., (1989) studied the anthropometric measurements pertaining to work place organization and product design.

The mean, coefficient of variation and percentile values for various anthropometric parameters are presented in Table-4.

The authors also compared their findings on anthropometric data with the data reported by Nag (1986), Ray et. al., (1983) and Eyeleth and Tanner (1976). It is presented in the Table-5.

The authors have justified that the wide variation in the ranges for each dimension could be attributed to the ethnic bias as well as to the nutritional status.

#### D. REACHES

Hemelrijk and Sitting (1966) investigated the relationship between upward maximum reach and body length. They have suggested the following formula:

$$\text{Maximum upward reach} = 1.24 \times \text{Body length}$$

TABLE : 4. Anthropometric Measurements of Indian House wives.

Body dimensions	Mean	SD	CV	Percentile values 5 <sup>th</sup>	95 <sup>th</sup>
<u>Height</u>					
Stature	153.2	5.7	3.7	143.5	162.6
Eye level	142.1	5.3	3.7	133.1	150.9
Elbow	96.1	3.9	4.0	89.4	102.8
Tibiale (Lower leg)	43.9	4.7	10.7	38.3	50.4
Functional reach	71.9	4.1	5.7	65.1	79.2
Total arm span	156.5	7.6	4.9	144.3	169.3
<u>Sitting measurements</u>					
Height	78.1	3.7	4.7	71.3	84.0
Eye	67.4	3.7	5.5	60.5	73.9
<u>Breadth</u>					
Elbow to elbow	39.4	3.6	9.1	34.9	44.9
Waist	26.2	4.0	15.2	19.2	32.4
Hip	31.6	2.9	9.1	27.3	36.1
<u>Circumferences</u>					
Bust	86.7	8.5	9.8	73.8	101.0
Waist	80.1	9.8	12.3	63.8	98.4
Hip	92.2	7.8	8.5	78.8	105.0
Forearm (relaxed)	22.5	2.6	11.4	18.2	26.3

Source : Varghese, et. al., (1989) U.G.C. Project Report (1).

TABLE : 5. Comparative Analysis of Anthropometric Measurements.

Body dimensions	Varghese et.al., (1989)		Nag et.al., (1986)		t-value	Ray et.al., (1983)		t-value	Eyeleth & Tanner (1976)		t-value	
	Mean	SD	Mean	SD		Mean	SD		Mean	SD		
<u>Height</u>												
Stature	153.2	5.7	149.8	6.2	0.40	155.1	5.8	0.24	151.5	6.1	0.19	
Eye height	142.1	5.3	-	-	-	144.2	6.0	0.02	142.0	6.0	0.06	
<u>Sitting height</u>												
Sitting	78.1	3.7	78.1	3.9	0.005	79.0	3.0	0.20	79.0	3.5	0.18	
Eye	67.4	3.7	-	-	-	68.6	3.2	0.25	69.0	3.3	0.33	
Elbow	20.9	2.9	20.3	3.2	0.15	18.7	2.4	0.54	22.0	2.8	0.26	
<u>Breadths</u>												
Waist	26.2	4.0	-	-	-	20.7	2.2	1.24*	-	-	-	
Hip	31.6	2.9	31.7	2.8	0.19	30.2	2.4	0.36	33.0	2.4	0.36	
<u>Circumferences</u>												
Chest	86.7	8.5	72.7	5.7	1.35*	-	-	-	-	-	-	
Waist	80.1	9.8	63.4	9.2	1.24	-	-	-	-	-	-	
Forearm	22.5	2.6	-	-	-	20.9	1.4	0.75*	-	-	-	

\* P < 0.5% when compared with findings of Varghese et al.

Source : Varghese et. al., (1989) U.G.C. Project Report (1)

On the basis of this analysis they have obtained the curves of accessibility for cupboard space. Their findings indicate that a woman of average body length (162 cm) can reach a cupboard with her hand at the following heights and depths:

Height of shelf	Depth of shelf
200 cm	15 cm
160 cm	50 cm
120 cm	60 cm
80 cm	53 cm
40 cm	45 cm

Bhavnani (1965) was interested in finding out the vertical and horizontal reaches of homemakers of Kymore having the mean height of 62.5 inches and mean elbow height of 35.26 inches. The findings related to the reaches are as follows :

Reaches	Average reaches (in inches)		
	Range	Mean	Median
Max.upward vertical reach	65-73	68.2	68.2
Normal upward vertical reach	35-40	38.36	38.35
Max.downward vertical reach (12" away from wall)	29-33	30.25	30.28
Max.downward vertical reach (close to wall)	23-27	25.42	25.43

Upward vertical reach over  
the counter at the height of:

29"	59-67	62.0	62.2
30"	58-68	62.28	62.29
32"	57-65	51.41	51.45
Max. horizontal reach	16-24	21.4	21.5
Normal horizontal reach	6-11	9.0	9.2

In the opinion of the author, the shelves in the kitchen should not be built higher than 68.2 inches, beyond this will cause unnecessary strain and stretching of the body. At normal vertical upward reach (38.36 inches) one can handle the materials with ease and without dropping the things. The articles stored at 25.42 inches height i.e., maximum downward reach will minimize bending and stretching. This will serve as a guide for storage under the counters. The maximum upward vertical reach over the counter indicates that at the height of 30 inches homemakers can reach the distance more comfortably than at the height of 29 inches and 32 inches from the floor. Therefore top most shelf should not be built above a height of 62.28 inches from the floor over the counter. The maximum horizontal reach indicates a range of 16-24 inches when the range of arm length was 25-29 inches. This reach determines the work surface area or depth of the work counters, to work without straining.

Berg, Boalt, Holm and Leander (1966) investigated the height of reach of 45 female subjects (155- 182 cm in height) in relation to their stature and under various conditions. The results are as follows.

Reach height under different circumstances (in cm) in relation to stature :

Body length	A	B	C	D	E	F
155	171	170	157	177	175	164
160	178	177	164	183	181	170
165	185	184	172	190	187	176
170	193	191	179	194	194	183
175	200	198	186	202	199	189

The different circumstances are viz., :

- A - Height of a shelf 30 cm deep on which the flat of one hand can be laid without standing on tip toe when there is a lower cupboard 60 cm deep and 90 cm high.
- B - Height of a shelf 30 cm deep, on which both hands can be laid flat, under the same conditions as in 'A'.
- C - Height of a shelf 30 cm deep where the back wall can be touched with the tips of the fingers of one hand, under the same conditions as in 'A'.
- D - As in 'A', but without the lower cupboard
- E - As in 'B', but without the lower cupboard
- F - As in 'C', but without the lower cupboard

Tyagi (1976) determined the spatial requirements for economically weaker section dwellings. Based on anthropometric measurements of postures for various household activities, such as squatting and cooking, squatting and eating and using storage facilities were determined. Similarly horizontal and vertical reaches were established with regard to handling of storage items by female adults and children (less than 12 years age). It was noted that adults can reach maximum vertical reach of 1.70 mt and horizontal reach of not more than 45 cm and children not more than 1.4 mt and 30 cm respectively.

In 1977, Gedliczka from Poland, made an attempt to construct a model for recording the data in relation to the range of arm reaches. His model suggests a system of three co-ordinates namely, the position of a particular element within a frontal projection, the degree of the change brought due to the change in the position of the elements and value of the distance. In testing spatial ranges, the front edge of the working table has to be considered as the extreme front position. This kind of concise system of recording data makes possible the projection of the work place in relation to the range of arm reaches both in horizontal and vertical planes.

Reach area of the arms for work place design was determined by Nowak (1978), from Poland. Results of the study indicate that, mean values of the reach areas of men and women demonstrated considerable differences in all measuring planes. Men's reach areas have a far bigger linear range as well as angular range especially, when centripetal movements are concerned. According to the somatic measurements of arms it was determined that the right arm is better developed and has bigger dimensions in respect of length and circumference but smaller in respect of acromial height.

The differences of statistical significance (t-test) in the reach ranges of both extremities indicate the zone where differences take place. It was noticed that, the differences between right and left arm take place in the zone of polar system from  $30^{\circ}$  to  $120^{\circ}$  on the '0' measuring plane i.e., two acromial points. According to the author the differences between the reach areas of left and right arm constitute critical information for design purposes. For instance, location of control accessories and any hand manipulators within the asymmetric field ( $30^{\circ}$ - $120^{\circ}$ ), when the work plane is at the level of the shoulders, should be adjusted to the values of the reach areas for both arms separately.

Reinhold (1983) reported that the left arm reach can be considered a mirror image of the right arm. According to him without stretching or leaning forward, most people can reach about 46 cm in front of the body as long as the object is 110 to 165 cm above the floor and not more than 46 cm to the side of the body's centerline. Further he has stated that if the distance to the side or height is less than or greater than the above mentioned range, forward reach capability alters.

Also, he has mentioned that, for two handed tasks for instance, steadying and controlling an object etc. the acceptable forward reaches are somewhat less than those for one handed tasks. The most extensive forward reaches i.e., about 51 cm are within 15 cm of either side of the body's centerline. The farthest two handed reaches to the side are only about 46 cm from the body's centerline; at this point only 36 cm of forward reach is possible without bending forward.

For occasional standing tasks forward reach can be extended by bending forward over a work surface. If the bend can be made at the hips, an additional 36 cm of forward reach can be obtained. If the bend has to be made at the waist, as in leaning over a 89 cm high barrier,

forward reach can be extended only 20 cm. Forward reach is only marginally shorter for two handed tasks than it is for one handed tasks within 46 cm lateral limit, except at the lowest and highest points above the floor.

In the opinion of Kazarian (1983), requirements for work surface space are dependent upon the materials used and the types of hand and arm actions needed to work on the materials. Further, the author has stated that the hand and arm movements should be confined to the normal and maximum work areas.

The normal work areas on the working surface will have radius of 14-16 inches for most of the people. Also, locations outside the maximum work area require bending of the body to reach them. Therefore, movements to these locations should be kept to a minimum. So, he concludes that, normal and maximum work areas, the work surface for most tasks performed specially concerned with food handling, can be within a space of 2 feet deep and 4 feet width.

#### **E. USER'S STUDIES**

Bhavnani (1965), attempted to develop guide lines for designing of kitchen storage and working counters by taking body reaches of homemakers from the

Kymore Cement Works Colony. While interviewing the homemakers the investigator made some observations viz., the shelves for kitchen storage were too high for homemakers to reach. The counters for working were built at a very low height which caused stooping and straining. In some houses depth of the counters was too narrow or too wide. In general there was dissatisfaction among the respondents.

Ward (1974) recorded a list of complaints from housewives of England. In the list, the items relating to thermal comfort were prominent. However, the following features were also considered unsatisfactory in the kitchen by the housewives of public and private sectors :

**Public Sector Households :**

45% lack of adequate ventilation.

45% noise in kitchen.

43% Condensation.

33% difficulty in opening windows.

31% volume of storage

25% Position of doors

19% area of work surfaces.

**Private Sector Households :**

- 44% Volume of storage
- 33% difficulty in opening windows
- 32% area of work surface
- 31% lack of ventilation
- 30% poor lighting
- 30% difficult access
- 28% noise
- 25% condensation
- 23% poor layout

With the findings of the study the author has expressed the need of further research in the area of this problem.

Wilson (1984) expressed that, the accident reduction can be achieved through improved standards of product design and associated safety performance standards. He is of the opinion that, data and criteria are required to measure and assess the product, equipment and architectural features. According to him ergonomic data of the relevant population can be taken as the criteria and information about people's behaviour, abilities and limitations can serve as the guidelines or standards for judging the safety performance of equipment

and architectural features. Further, he has stated that, body sizes and structure can be used for dimensional standards.

National commission on product safety (1970) have felt there is requirement for dimensional standards. Human factors particularly those which can be reported quantitatively can be fitted into the specifications of safety performance criteria.

The findings of Hanspal (1985) on existing work surface, storage space and kitchen size revealed that the range of width and length of the kitchen was 200-260 cm and 250-300 cm respectively.

The information on the existing work surface and storage space in the kitchen, indicated that the minimum height and depth of work surface was 75 cm and 40 cm respectively. In majority of the urban households the range of work surface height was found to be 75-80 cm (54 per cent) and depth, 50-55 cm, (70 per cent). Also, other existing work surface heights were 80-85 cm, depths were 40-45 and 45- 50 cm. In many urban (50 per cent) and rural (46 per cent) households the height of the storage ranged from 110 to 120 cm and depth 40 to 45 cm. The data also revealed that 100 per cent rural and 92 per cent

urban households reported open shelves and only 8 per cent urban households had built-in-cupboards.

Varghese et al. (1989) studied the existing kitchen design in Bombay city. From the survey of 120 houses, the following conditions were observed and reported.

Kitchen space as a percentage of the total living space (i.e., total area including toilet and bath) needs to be increased in the case of big houses, while it is adequate or excessive in case of smaller flats. (Indian architects specify a kitchen space of 15-20 per cent of the total area)

Due to lack of adequate space and disorganised work centres and storage areas, in a few houses (small kitchen) storage was kept outside the kitchen.

Work counters were unsatisfactory in majority of the cases. It was found to be built to a standard measurement of 70-75 cm which is not convenient to majority of the houses. Maximum storage in small kitchens was found to be at a higher level requiring a stool to reach the supplies. Counter space and the low level storage space increased with the increase in the size of the kitchens.

Very few kitchens had drain board to the sink. All kitchens had adequate ventilation with cross ventilation.

Thermal conditions prevailing in the working environment were found to be comfortable.

The effective temperature of the kitchen was 26.92°C.

The amount of day light available in the kitchen is maximum at sink centre due to its location near the window. Next, is the preparation, cooking and last is the storage. No task light for centres was observed. Most of the houses had one flourascent light in the kitchen. It was inadequate during night time specially at the cooking area (Varghese et al., 1989)

Tyagi (1976) surveyed the houses built by Central Public Works Department for Central Government Class- IV employees at R.K.Puram, Delhi. His data disclose the existing provision of loft was considered to be useful. Along with the provision of open shelves, closed storage facility was considered necessary.

According to Nagarajan (1976) user's requirements vary with climate, manner of life, education, habits and economic level. They differ from country to country. It generally consists of physiological, psychological, sociological requirements and economic circumstances. Further, he has stated that physiological requirements are in many cases considered as absolute requirements from considerations of health hazards. Therefore, they should be taken into account along with the human weight, width and reach. Also the needs and motion patterns of different activities and dimensions of

equipment and furniture should be taken into consideration.

### CONCLUSIONS

From the review of existing literature on various topics namely use of anthropometric measurements for work place design and work height, work posture and postural effect on health, anthropometric data, reaches and user's studies, the following conclusions were drawn.

Research studies in the field of ergonomics of housing under Indian condition are few and in piece meal. However, in abroad much effort has been made to implement ergonomic principles in the industrial area i.e., designing of tools and machines in relation to human scale.

Research on postural effect on health is scanty and what ever is available it is among the industrial workers. Also from the existing literature, it is clear that no effort has been made to observe and study the posture adopted by the housewives while carrying out the kitchen activities.

Although few studies have been carried out in India to suggest the suitable work counter or surface

height, it is based on the type of cooking activities for a particular stature/elbow height. In the opinion of the researcher work counter height based on cooking activities found to be not practical in reality. None of the studies have suggested designs for work counter or for the storage shelves (wall shelves, or shelves above the work counter or under the work counter) for the suggested measurements.)